Erin Herlihy

Attached please find additional documents submitted in support of Association of Washington Business' comment letter.

From: Gildersleeve, Melissa (ECY)
Sent: Friday, May 04, 2012 4:42 PM
To: Niemi, Cheryl (ECY)
Subject: FW: Invitation to Fish Consumption Rate Meeting

fyi

From: Laurie, Tom (ECY)
Sent: Friday, May 04, 2012 4:38 PM
To: Sturdevant, Ted (ECY)
Cc: Pendowski, Jim (ECY); Susewind, Kelly (ECY); Gildersleeve, Melissa (ECY); Hankins, Martha (ECY)
Subject: Re: Invitation to Fish Consumption Rate Meeting

Good set-up

Tom Laurie
(360)407-7017 desk
(360)790-4110 cell

From: Sturdevant, Ted (ECY)
Sent: Friday, May 04, 2012 04:30 PM
To: Gary Chandler <GaryC@AWB.ORG>; Courtney Barnes <courtneyb@AWB.ORG>; chris@nwpulpandpaper.org <chris@nwpulpandpaper.org>; fholmes@wspa.org <fholmes@wspa.org>; Ken Johnson <ken.johnson@weyerhaeuser.com>; Bill Taylor <BillT@taylorshellfish.com>; Dewey, Bill
Cc: Laurie, Tom (ECY)
Subject: RE: Invitation to Fish Consumption Rate Meeting

I've heard from a few of you with the suggestion that I invite municipalities to this meeting as well. I encountered more than slight resistance to that idea when vetting with the tribal leaders, fearing it could dilute the meeting given the time available, though they expressed interest in such a meeting in the future. I won't jam them by forcing the issue right before the meeting, nor would I have done so to you had the situation be reversed.

I understand your interest, and agree with at least part of it – this is not, and should be framed as, a "business vs. Tribes" issue. The reality is that this issue is far bigger than these two (or three) interest groups anyway. However, it is fair to say that business and Tribes have been the most vocal to date. I also strongly believe that a frank discussion with Ecology, business and the Tribes is in our mutual interest. At best, I believe it can help us understand and appreciate each other's real interests and make possible a more collaborative path. More specifically, I hope that the Tribes gain a better understanding of the value of the implementation tools rulemaking, and hope that you hear from them that they're interested in finding a feasible path. At the least, it can provide a frank assessment of what the real lay of the land is.

My intention is to keep this meeting at a high level, to elicit from each party their fundamental goals and concerns, and see if there is common ground to be built upon. I am optimistic that such ground exists. The draft agenda below is a simple one designed to meet that end. I am open to suggested improvements.

Also, you should be receiving today from my staff the response to the questions posed by NWPPA in earlier conversations.

Ted

Business/Ecology/Tribe Meeting
Ecology HQ, Lacey
1:00 – 2:30

Draft Agenda

1. Welcome / Introductions
2. Purpose of Meeting (Ted)
   Key issues and Ecology's approach to date
3. Key Concerns / Issues– Tribal perspective
4. Key Concerns / Issues– Business perspective
5. Discussion
6. If time, more discussion of specific policy choices ahead (Ted)
7. Timing and steps ahead

Ted Sturdevant, Director
Department of Ecology
(360) 407-7001
tstu461@ecy.wa.gov

From: Gary Chandler [mailto:GaryC@AWB.ORG]
Sent: Wednesday, May 02, 2012 8:13 PM
To: Sturdevant, Ted (ECY)
Cc: prigdon@yakama.com; rhepfer@elwha.nsn.us; jpeters@nwifc.org; awhitener@squaxin.nsn.us; dherrera@skokomish.org; syanity@stillaguamish.com; Brian Cladoosby; Courtney Barnes; chris@nwpulpandpaper.org; fholmes@wspa.org; Ken Johnson; Bill Taylor; Fran Wilshusen; Ann seiter; Pendowski, Jim (ECY); Susewind, Kelly (ECY); Laurie, Tom (ECY); North, Teri (ECY)
Subject: Re: Invitation to Fish Consumption Rate Meeting

Thanks Ted

I will be there

Sent from my iPad

On May 2, 2012, at 3:53 PM, "Sturdevant, Ted (ECY)" <TSTU461@ECY.WA.GOV> wrote:

As you may know, I am convening a small table of tribal and business leaders and my lead staff to discuss Ecology's work on updating fish consumption rates and water quality compliance tools.

The purpose of the meeting will be to exchange perspectives on the rule amendments and to discuss concerns that have arisen. Changing and implementing new standards across the clean-up and water quality programs is an important process, and direct dialogue will help us fully understand our respective interests and get to the best possible outcomes.

I want to invite each of you to join me on **May 9 from 1:00 to 2:30 p.m.** at Ecology for this purpose. I understand that some of you may not be available but if your schedule changes, I sincerely hope that you will attend if possible.

Please let me know if you are able to attend this important meeting.

Ted

Ted Sturdevant, Director
Department of Ecology
(360) 407-7001
tstu461@ecy.wa.gov

From: Paul Lumley <plumley@critfc.org>
Sent: Wednesday, October 10, 2012 10:38 AM
To: Dianne Barton; Laurie, Tom (ECY)
Cc: Gildersleeve, Melissa (ECY)
Subject: Re: FW: October 29th--First Water Quality Standards Water QualityPolicy Forum meeting

Tom and Melissa:

Thank you for the invitation. I appreciate the clarification that this meeting is not a government-to-government meeting. The CRITFC tribes met on Monday and directed me to participate on October 29. Dainne Barton will accompany me. Can you please send me more specifics on the time and location of the meeting? I do not see this information in the emails below.

Regards,

Paul Lumley
Columbia River Inter-Tribal Fish Commission
503-238-0667

>>>
From: "Laurie, Tom (ECY)" <tlau461@ECY.WA.GOV>
To: "Paul Lumley (plumley@critfc.org)" <plumley@critfc.org>, "(bard@critfc.org)" <bard@critfc.org>
CC: "Gildersleeve, Melissa (ECY)" <MGIL461@ECY.WA.GOV>
Date: 10/04/12 8:16 AM
Subject: FW: October 29th--First Water Quality Standards Water QualityPolicy Forum meeting

Paul & Dianne, please see the note below from Melissa Gildersleeve who is managing our water quality standards revisions.

We are looking to get more tribal participation in the Policy Forum that we are setting up to work with Ecology as we work to establish Human Health Criteria in our water quality standards which will include a fish consumption rate. This Policy Forum will be open to the public but will revolve around a "Delegates Table" representing key constituencies.

We recognize that this is not a substitute for government to government consultation but hope that tribes will also participate in Delegates Table to provide their expertise and perspective on the important policy choices that lie before us over the next year.

We would welcome direct participation from CRITFC and any help you can offer in helping to identify a few more tribal representatives to this forum.

The letters that went to tribal governments inviting them to this forum are on our website at:
http://www.ecy.wa.gov/programs/wq/swqs/humanhealthcritpolltr.html

Information about the Policy Forum is at:
http://www.ecy.wa.gov/programs/wq/swqs/hhcpolicyforum.html

- Tom

C. Thomas Laurie | Executive Advisor for Tribal & Environmental Affairs | Washington State Dept. of Ecology PO Box 47600, Olympia, WA 98504-7600 http://www.ecy.wa.gov/
email: tom.laurie@ecy.wa.gov phone: 360/407-7017 cell: 360/790-4110

From: Gildersleeve, Melissa (ECY)
Sent: Wednesday, October 03, 2012 3:57 PM
To: Fran Wilshusen (fwilshus@nwifc.org)
Cc: Laurie, Tom (ECY); Ann seiter
Subject: FW: October 29th--First Water Quality Standards Water Quality Policy Forum meeting

Fran---FYI-This just went out today for the first Water Quality Standards Policy Forum. I would sure like to have some staff from NWIF and CRITFC serve as delegates to the table. I think it would help the conversation as well as help you all as you advise others in the tribal community. This is going to be a pretty technical conversation and think your staff will have the capacity and maybe time...to digest all the topics that will be a part of developing human health criteria. That being said I know that you are still determining how to engage. Would you be available to talk with Tom and I and Dianne Barton at CRITFC to see if we can talk you all into participating?--Melissa

From: Gildersleeve, Melissa (ECY)
Sent: Wednesday, October 03, 2012 3:52 PM
To: 'carls@awcnet.org'; 'hkibbey@ci.everett.wa.us'; 'sandra.kilroy@kingcounty.gov'; 'BRawls@spokanecounty.org'; 'nbell@advocates-nwea.org'; 'JStuhlmiller@wsfb.com'; 'JHellman@washingtonports.org'; 'don.hurst@colvilletribes.com'; 'troutt.david@nisqually-nsn.gov'; 'paulm@pgst.nsn.us'; 'rorourke@pgst.nsn.us'; 'slape.james@nisqually-nsn.gov'; 'margaretbarrette@pcsga.org'; 'jstuhlmiller@wsfb.com'; 'jhellman@WASHINGTONPORTS.ORG'; 'dave.steele@centurylink.net'
Cc: Merriman, Scott; 'Williams, Dave'; 'garyc@awb.org'; 'dmparnel@aol.com'; 'jbrimmer@earthjustuce.org'; 'bv@columbiariverkeeper.org'; 'Johnson, Eric'; Conklin, Becca (ECY); Niemi, Cheryl (ECY); Susewind, Kelly (ECY)
Subject: October 29th--First Water Quality Standards Water Quality Policy Forum meeting

Dear Water Quality Standards Policy Forum Delegates-

Welcome. We have picked October 29th as the first Water Policy Forum/Delegates Table meeting. This first Delegate's Table meeting will be held here, in Olympia, at the Ecology Building. We will do the same thing we did with the August 28th workshop and have video participation in each of our regional offices. Right now our plan is to spend the morning with the Delegates Table and then open the afternoon up to the Policy Forum engagement.
Draft Agenda
Our Draft agenda for the morning looks like this-we might rearrange the order but these are the subjects we want to cover:

- Orientation to all that is in motion, and how we want to run the Forums
- Update on Implementation Tool Rulemaking
- Update on Contract for Facilitator
- Introduction to the Delegates Table: each delegate introduces themselves, who they are representing and their interests/concerns related to this process
- Agency Introductions (staff and staff expertise)

* Specific Topics:

-Walk through generic scenario that we will build upon as we discuss implementation and Human Health Criteria and discuss questions we want the scenario to address -Talk about the cost analysis that will be done as part of the rule development

In the afternoon we will open up the discussion to the broader Policy Forum and get ideas and feedback on the agenda items from the morning.

Logistics

We are still working on the best way to set up this forum, so please give us feedback. Our plan for this first meeting is to have the Delegates meet here in Olympia. The morning will be just the Delegates working through the agenda, discussing items, and asking questions. In the afternoon we will open the meeting up to the broader Policy Forum. Several of you have identified alternates and technical support staff . We are going to ask that the alternates and support staff sit in the front row behind you so we can have room for all the designated delegates.

Makeup of the Delegates Table

Below is a list of groups we invited to participate as Delegates in the Policy Forum. We are still working with some organizations to get this list finalized:

* Tribes (Ecology recognizes that this does not replace formal Government to Government consultation.)

o Don Hurst (Delegate) Colville Indian Reservation

o Paul McCollum (Delegate) Port Gamble S'Klallam Tribe

o Rory O'Rourke (Alternate) Port Gamble S'Klallam Tribe

o James Slape, Jr (Delegate) Nisqually Indian Reservation

o David Troutt (Alternate) Nisqually Indian Reservation

* AWB - 4 delegates TBD

* Association of Cities - 2 delegates

o Carl Schroeder (Delegate) Association of Washington Cities

o Heather Kibbey (Delegate) City of Everett

* Association of Counties - 2 delegates

o Sandra Kilroy (Delegate) King County

o Bruce Rawls (Delegate) Spokane County

* Environmental Groups - 2 delegates

o Nina Bell (Delegate) NW Environmental Advocates o TBD Earth Justice and Riverkeepers

* Recreational fishery - 1 delegate TBD

* Commercial Fishery (Association of Shellfish Growers) - 1 delegate

o David Steele (Delegate) Pacific Coast Shellfish Growers

o Margaret Barrette (Alternate) Pacific Coast Shellfish Growers

* Washington Farm Bureau - 1 delegate

o John Stuhmiller

* Washington Ports Association - 1 delegate

o Johan Hellman
As you look at this and have questions or are unclear please give Becca (360)407-6413 or me a call or shoot us an email. The YouTube Videos from the August 28th workshop are up on the website (http://www.ecy.wa.gov/toxics/fish.html bottom of page). I encourage those of you that did not see Cheryl Niemi's presentation on Human Health Criteria 101 to watch that video. She does an excellent job of walking through the development of Human Health Criteria which is a preview for all our discussions.

See you on the 29th and call us if you have questions or need anything. - Melissa

Melissa Gildersleeve, Section Manager, Water Quality, Department of Ecology 360-407-6461 P Please consider the environment before printing this e-mail.

From: Bolster, Todd <tbolster@nwifc.org>
Sent: Monday, October 28, 2013 1:56 PM
To: (Group) Coordinated Tribal Water Quality Program; Ann Seiter; Lauren Rich; Lisa Hainey
Subject: Fwd: Revised agenda and material for FCRWQS call Tues Oct 29 at 1:30
Attachments: EPA WQ stds Comparison-of-Existing-Rule-Language-and-Proposed-Rule-Language.pdf; CTWQP-workshop-OVERVIEW_Oct-16-17_2013_re-FCR-WQS.docx; CTWQP-workshop-notes-TRIBES-ONLY_Oct16-17_2013-2.docx; CTWQP-workshop-notes-WITH-ECOLOGY_Oct17-2013-2.docx; FCR-WQ Update for Tribal Leaders Oct-28-2013_without-attachments.docx

Hi All,
Please find below information regarding tomorrow's coordination conference call on FCR.

---------- Forwarded message ----------
From: **Seiter, Ann** <aseiter@nwifc.org>
Date: Mon, Oct 28, 2013 at 1:44 PM
Subject: Revised agenda and material for FCRWQS call Tues Oct 29 at 1:30
To: "(Group) Tribal Fish Consumption Workgroup" <fishconsumption@nwifc.org>
Cc: Zach Welcker <zwelcker@kalispeltribe.com>

Tribal Fish Consumption Work Group and CTWQP,

This is a reminder that there will be a conference call for the folks interested in the FCR/Water Quality Standards issue on Tuesday October 29th from 1:30 to 3 pm. The call in number is 206-553-1454. There is no pass code. .

Revised Agenda:

- Updates on leadership meetings
- Preparation for November 6th Dept. of Ecology public meeting on rule-making for WQ standards. Please see site at: http://www.ecy.wa.gov/programs/wq/swqs/publicmtgs.html in order to reserve a seat or register for the webinar.
- October 16-17 Workshop follow-up and development of recommendations on implementation options
- Other FCR issues and responses

NEW: EPA Water Quality Standards -- analysis of proposed changes and potential call with EPA

New material attached:

- Notes from the Oct 16-17 Workshop: There are 3 parts, a short overview, the Tribes-only session, and the session with Ecology
- Comparison of existing and proposed EPA water quality standards (thanks, Kalispel)
- An update that is going out to tribal leaders this week. (I did not include their attachments since it is redundant to other material sent to you previously.)

Please call me at 360-683-5725 if you have any questions.

---Ann

This information is confidential and is intended for tribal policy representatives and technical/legal staff only. Please do not forward this message or attachments outside of tribal organizations. Thank you.

--
Ann Seiter
aseiter@nwifc.org
Coordinator: Fish Consumption Rate Project
PO Box 2201; Sequim, WA 98382
Home Office: 360-683-5725

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Todd Bolster
Habitat Policy Analyst
Northwest Indian Fisheries Commission
tbolster@nwifc.org
(360) 528-4347
To unsubscribe from this group and stop receiving emails from it, send an email to CoordinatedTribalWaterQualityProgram+unsubscribe@nwifc.org.

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LAW

Comments to Idaho Department of Environmental Quality
Risk, Human Health, and Water Quality Standards

Please accept these comments, which respond to the Idaho Department of Environmental Quality (IDEQ) *Discussion Paper #7: Risk Management and Human Health* (Dec. 2014)[1] [hereinafter IDEQ Risk Discussion Paper] and follow up on discussion during the public meeting held by IDEQ on December 2, 2014. These comments reflect the views of the author. Although they raise concerns about the impacts of Idaho's water quality standards on tribes, they do not purport to represent the perspective of any tribe; those perspectives must be obtained directly from each tribe.

I. Background

Idaho's deliberations involve risk in the context of its water quality standard-setting efforts. This context is significant, because it constrains the debate in important ways. Among other things, the discussion here must be framed and bounded by the relevant legal provisions, including treaties and other instruments securing tribes' fishing rights, and including statutory directives under the Clean Water Act (CWA). Thus, discussions of risk in other regulatory contexts, or discussions of risk generally, may have more or less relevance for Idaho's deliberations, depending on how far afield they are from the context at hand.

Under the CWA, water quality standards are health-based standards. The touchstone for agencies' efforts is human health. Fish are the primary route of human exposure to PCBs, mercury, dioxins, and a host of toxic chemicals that are harmful to human health. Health-based water quality standards are set to ensure that humans can safely consume fish, without also being exposed to contaminants in harmful amounts. Pursuant to Environmental Protection Agency (EPA) guidance, agencies enlist quantitative risk assessment methods to set standards for both threshold and non-threshold contaminants. For threshold contaminants, standards are set so that contaminants don't exceed levels that are safe for humans. For non-threshold contaminants, including carcinogens, exposure to any non-zero amount has the potential to cause cancer; standards are set so that contaminants don't exceed a risk level

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[1] Idaho Department of Environmental Quality, Idaho Fish Consumption Rate and Human Health Water Quality Criteria – Discussion Paper #7: Risk Management and Protection of Human Health (Dec. 2014)[hereinafter IDEQ, Risk Discussion Paper] *available at* http://www.deq.idaho.gov/media/1118404/58-0102-1201-discussion-paper7.pdf.

determined to be “acceptable.” In either case, agencies then work with the risk assessment equation to “solve” for the concentration of each chemical that will be permitted in the waters that support fish.

Idaho’s water quality standards affect the rights, resources, and well-being of numerous tribes in the region. In fact, when the waters that support fish are allowed to be contaminated, tribes’ interests are profoundly affected and tribal people disproportionately among the most exposed. It is therefore troubling that the IDEQ Risk Discussion Paper contemplates tolerating a greater level of cancer risk than Idaho has in the past – particularly as studies have made clear that tribal people would be the ones who disproportionately would have to bear this risk.

These comments begin in Part II by discussing some historical background specific to EPA’s approach to health-based standards under the CWA’s water quality standards provisions. Part III sketches the various considerations relevant to a risk’s “acceptability,” and distinguishes between assessments of risk in the water quality standard-setting context and assessments of risk in other contexts. Part IV responds to the IDEQ Risk Discussion Paper’s discussion of “voluntary” risks. Parts V and VI raise two issues not discussed in the IDEQ Risk Discussion Paper: risks disproportionately borne by tribal people and risks that impair tribes’ legally protected fishing rights. Part VII considers the direction provided by the relevant EPA guidance for states’ water quality standard-setting efforts.

II. For Carcinogens, the Recommended Concentration to Protect Human Health is Zero

EPA, in a prominent 1984 criteria document for dioxin, made clear that it understood that human health could only be ensured for this contaminant’s non-threshold effects if risk were set at zero.

> For the maximum protection of human health from the potential carcinogenic effects due to 2,3,7,8 - TCDD exposure through Ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero. This criterion is based on the non-threshold assumption for 2,3,7,8 - TCDD.[2]
>
> Under the Consent Decree in NRDC vs. Train, criteria are to state "recommended maximum permissible concentrations (including where appropriate, zero) consistent with the protection aquatic organisms, human health, and recreational activities." 2,3,7,8 -TCDD is suspected of being a human carcinogen. Because there is no recognized safe concentration for a human carcinogen, the recommended concentration of 2,3,7,8 -TCDD in water for maximum protection of human health is zero.[3]

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[2] U.S. Environmental Protection Agency, Ambient Water Quality Criteria for 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin x (Feb. 1984), *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2008_09_10_criteria_dioxincriteria.pdf.

[3] *Id.* at C-180.

While EPA went on to offer calculations based on three risk levels, 10^{-7}, 10^{-6}, and 10^{-5}, it took pains to point out that these were all in the realm of the second best, i.e., that they would not result in a truly health-based standard, because only a standard permitting zero risk could do so.[4]

EPA's statements in this criteria document are notable for three reasons. The first is simply that, for non-threshold contaminants in our waters such as dioxins, PCBs, and other carcinogens, any non-zero concentration is inadequate to protect human health; any non-zero amount will result in quantifiable levels of risk. EPA's statements recognize and preserve the difference between "zero" and "some," between protecting human health and permitting an amount of risk to remain. A risk quantified at 10^{-7}, 10^{-6}, or 10^{-5} can't be converted into zero risk by simply eliding this difference, nor by quoting terms (e.g., "*de minimis*" or "essentially zero") applied in other contexts (a point discussed further below).

The second notable aspect of EPA's statements is that the cancer risk levels EPA deemed relevant to water quality standard-setting at the time ranged from 10^{-7} to 10^{-5}. EPA's 1980 guidance on water quality standard-setting similarly embraced risk levels that range from 10^{-7} to 10^{-5}.[5] And EPA's current 2000 guidance, its *Ambient Water Quality Criteria Methodology* (EPA AWQC Guidance) continues to state that the range of acceptable risk levels runs from 10^{-7} to 10^{-5} – with the caveat that risk levels at the less protective end of this range will be scrutinized for their impact on highly exposed subgroups and may be rendered unacceptable if they result in risks greater than 10^{-4} to members of such subgroups:

> With AWQC derived for carcinogens based on a linear low-dose extrapolation, the Agency will publish recommended criteria values at a 10^{-6} risk level. States and authorized Tribes can always choose a more stringent risk level, such as 10^{-7}. EPA also believes that criteria based on a 10^{-5} risk level are acceptable for the general population as long as States and authorized Tribes ensure that the risk to more highly exposed subgroups (sportfishers or subsistence fishers) does not exceed the 10^{-4} level.[6]

The IDEQ Risk Discussion Paper omits this background and this current EPA language, selectively quoting material from the EPA AWQC Guidance that refers to a range that, at its most protective, reaches only 10^{-6}.[7] As such, it may portray 10^{-6} as an upper limit, whereas EPA offers 10^{-6} as somewhere in the middle.

The third notable feature of EPA's statement in its dioxin criteria document that the "recommended concentration …[for the] protection of human health is zero" is that EPA thus expressed what Douglas

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[4] *Id.* at xi, C-180 to C-181 (explaining that because attaining zero concentration level might not be achievable in some cases and because the criteria document was intended to assist states and the EPA in calculations of water quality standards, EPA was providing concentrations corresponding to a range of risk levels).

[5] U.S. Environmental Protection Agency, Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health 1-8 (2000)[hereinafter EPA, AWQC Guidance], *available at* http://water.epa.gov/scitech/swguidance/standards/upload/2005_05_06_criteria_humanhealth_method_complete.pdf.

[6] *Id.* at 1-12.

[7] IDEQ, Risk Discussion Paper, *supra* note 1, at 5-6.

Kysar has termed a "moral remainder."[8] That is, it registers the "sense of regret" when there remains "a shortfall between statutory command and societal achievement."[9] The lives lost and harms permitted as a result of such shortfalls, however, "are viewed as tragic, lamentable consequences of human fallibility and finitude –a moral remainder that provides enduring motivation for surviving members of society to seek ways of doing better in the future."[10] The Columbia River Inter-Tribal Fish Commission (CRITFC), in comments to then-administrator Browner similarly called attention to this moral remainder.[11] CRITFC reminds us that zero risk is the only level that will actually protect human health, and so, importantly should remain our ultimate goal in enacting health-based standards.[12]

III. "Acceptable" Risk is a Judgment of Value that is Context-Specific

As soon as we move away from zero, there is potential for harm. How much risk (and of what sort, borne by whom) we are willing to tolerate requires a judgment of value. It is a judgment that involves nothing less than deciding, to paraphrase Annette Baier, which harms to notice and on whom we will with good conscience impose "death [or] risk of death."[13]

A. Context is Crucial to the Kind and Amount of Risk Collectively Thought Tolerable

At the individual and collective levels, this judgment of value is context specific. As a general matter, a risk's acceptability can turn on a host of factors respecting the nature of the risk (including, e.g., its familiarity, controllability, etc.); whether the risk is sought out or undertaken voluntarily (please see discussion below); what is at stake/the seriousness of the harm (including, e.g., death, irreversible neurological impairment, cancer); whether the risk is equitably distributed (including, e.g., whether those who bear the risk also benefit from the risk-producing activity); whether subpopulations of particular concern will bear the risk (including, e.g., children); and whether the risk attends the exercise of practices that are important or to which people have rights.[14]

Thus, risks are not fungible (except in the actuarial sense). Judgments of "acceptability" made in one context (e.g., the occupational context) can't simply be transferred to another context (e.g., the environmental context).

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[8] DOUGLAS A. KYSAR, REGULATING FROM NOWHERE: ENVIRONMENTAL LAW AND THE SEARCH FOR OBJECTIVITY 19-20 (2010).

[9] *Id.* at 20.

[10] *Id.*

[11] Columbia River Inter-Tribal Fish Commission, Comments to Administrator Browner on the Draft Revisions to the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (1999).

[12] *Id.* at 3 (arguing that only "zero" risk will actually protect the health of tribal members).

[13] Annette Baier, *Poisoning the Wells,* in VALUES AT RISK 49 (Douglas MacLean, ed., 1986)("When is a public policy that entails death for some and risk of death for more a policy that offends our moral standards? … It is not merely a question of whose lives we should save by what measures with whose money, but whom, among those whose cooperation and whose taxes we use, we will with good conscience kill, cause to die, or let die, and by what measures or neglect.")

[14] See, e.g., Molly J. Walker Wilson, *Cultural Understandings of Risk and the Tyranny of the Experts*, 90 OREGON L. REV. 113 (2011); see generally, VALUES AT RISK (Douglas MacLean, ed., 1986).

Thus, comments at the December 2nd public meeting to the effect that society finds risks as high as 1 in 100 or 1 in 1,000 to be acceptable in the occupational context (with the implication that we should therefore be undaunted by a similar risk level in the environmental context) miss the mark without more. Specifically, their import depends on an inquiry into the similarities in and differences between these two contexts (e.g., risks on the job are undertaken by adults as part of an consensual contractual arrangement for compensation; whereas risks from environmental sources are imposed on all humans whose ordinary practices – e.g., breathing, eating, drinking – leave them exposed to contaminants) and, importantly, why these similarities/differences ought to matter. Consent, in particular, is understood to be among the relevant considerations to evaluations of a risk's acceptability.[15]

Similarly, it is unhelpful to point to figures about the lifetime risk of cancer that we all currently face (i.e., 1 in 3 for women; 1 in 2 for men), as the IDEQ Risk Discussion Paper does.[16] While presumably offered to situate the present risk debate in context, such figures do the opposite: they lump together all cancers, from all causes – devoid of context. This approach doesn't permit inquiry into any of the relevant considerations noted above. Importantly, it doesn't ask *whether* we, as a society, think this is okay. In fact, one of the pioneers of the field of risk perception studies, Paul Slovic, has found that most people believe current risk levels to be too high:

> Another consistent result from psychometric studies of expressed preferences is that people tend to view current risk levels as unacceptably high for most activities. The gap between perceived and desired risk levels suggests that *people are not satisfied with the way that market and other regulatory mechanisms have balanced risks and benefits.*"[17]

In short, the fact *that* we currently face a certain level of risk doesn't tell us whether that level is desirable or, crucially, whether it is ethically defensible.

B. Statutory Context and Constraints

Moreover, as a society, we *have* collectively determined that some risks – such as those from environmental contaminants – should be reduced. And, through democratic processes, we have enacted an array of environmental, health, and safety laws that direct agencies to require risk reduction. These statutes establish various mechanisms for regulating the entities and processes that produce contamination, i.e., for seeking risk reduction from risk-producers. These statutes enlist different approaches and permit different considerations, depending on context (e.g., consumer protection, worker safety, children's health). They reflect our collective judgments regarding the degree of risk reduction to be achieved and the appropriateness of considering relevant tradeoffs for each particular

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[15] See, e.g., Douglas MacLean, *Risk and Consent: Philosophical Issues for Centralized Decisions*, in VALUES AT RISK 17 (Douglas MacLean, ed., 1986)(discussing why the concept of consent must play a crucial role in justifications for governments' decisions to impose risk). As will be discussed, risk in an occupational context is also governed by different statutory commands, namely, the Occupational Health and Safety Act.

[16] IDEQ, Risk Discussion Paper, *supra* note 1, at 2.

[17] Paul Slovic, *Perception of Risk*, 236 SCIENCE 280, 283 (1987) (emphasis added).

statutory program. Notably, these statutory programs sometimes strike different balances regarding risk.

So, the fact that a certain level of risk has been found permissible by a sister agency (e.g., the Food and Drug Administration; the Nuclear Regulatory Commission)[18] or sister program within EPA (e.g., the Superfund program),[19] does not answer the question whether it ought to be viewed as acceptable in the current context, i.e., under the CWA's water quality standards program for Idaho. Yet the IDEQ Risk Discussion Paper presents the results of these agencies' deliberations as if they had equal and obvious precedential force. Again, we would need more information about the context in order to assess whether the reasons offered in support of accepting a particular risk level in a different regulatory context ought to hold sway in the context at hand. In particular, we would need to have more information about the governing statutory instructions, in order to ensure that we were comparing apples to apples. Some environmental statutory provisions permit cost-benefit balancing; some preclude agencies from considering costs. Some direct agencies to set standards based on what is healthful; some direct agencies to set standards that are technologically feasible or achievable. It is not appropriate (and may not be legal) to import results reached under one set of statutory directives (e.g., "as low as reasonably achievable")[20] into a decision making process under another statutory directive.[21]

It is also problematic, as Michael Livermore and Richard Revesz have recently discussed, for agencies to make decisions on the basis of an "unacknowledged factor," such as cost.[22] As noted above, the CWA's water quality standards provisions are health-based; they take human health, not technological feasibility, as their touchstone. Yet the IDEQ Risk Discussion Paper presents a "partial list of potential criteria for considering risk to be acceptable" that includes several entries explicitly or implicitly calling for the weighing of costs. While it adds a note that "[n]ot all of the above are based solely on health risk; some clearly involve cost-benefit analysis," it doesn't make the meaning of this note clear. Members of the public might be misled into believing that weighing the costs of risk reduction is permissible and/or what IDEQ intends to do.

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[18] IDEQ, Risk Discussion Paper, *supra* note 1, at 3-4, 8.

[19] *Id.* at 4-5.

[20] *Id.* at 8.

[21] Thus, the IDEQ Risk Discussion Paper's account of the FDA's attempt to arrive at a defensible risk level under the Food, Drug, and Cosmetics Act's "Delaney Clause" appears to have been given emphasis out of proportion with its relevance to water quality standards under the CWA. *Id*. at 3-4. The FDA was laboring under a particular statutory directive with a unique history; its efforts to determine a "safe" level reflect the language and constraints of the statutory provisions for food additives. The IDEQ Risk Discussion Paper appears to make the leap to a claim that the 10^{-6} risk level ultimately arrived at in that context can be equated with "essentially zero" risk in every other context. Such a claim would require more support. See generally, William Boyd, *Genealogies of Risk: Searching for Safety, 1930s-1970s*, 39 ECOLOGY L. Q. 895 (2012).

[22] Michael A. Livermore & Richard L. Revesz, *Rethinking Health-Based Standards*, 89 NYU L. REV. 1184, 1233 (2014).

IV. “Voluntary” Risks

The IDEQ Risk Discussion Paper delves into one factor understood to be relevant to a risk’s acceptability: whether the risk can be said to have been “voluntarily” undertaken. The assumptions and conclusions embedded in this discussion are troubling and warrant extensive comment. This discussion raises issues discussed in the risk literature as voluntariness, responsibility, and self-relevance.

A. Voluntariness

The IDEQ Risk Discussion Paper accurately states that a risk’s acceptability turns in important part on whether it is considered to be voluntary or involuntary. Researchers from various disciplines have studied this intuition, and it has proven to be stable when tested using a variety of disciplinary methods.[23]

Whether any particular risk is properly viewed as voluntary, however, is not self-evident. In fact, the determination of voluntariness is value-laden and often complex; there may be considerable disagreement in particular cases over whether a particular activity or practice – and the risk it entails – is voluntary. Yet agencies, and other expert or individual evaluators sometimes simply label certain activities as “voluntary” or “involuntary” – without offering justifications for doing so. The act of valuation becomes invisible, as a judgment of voluntariness is presented as a natural, immutable “fact” about the world. The IDEQ Risk Discussion Paper, for example, simply states as fact that: “Examples of voluntary risks are those associated with driving, skiing, and tobacco use. Involuntary risks include exposure to pollutants in air or drinking water.”[24]

Judgments of voluntariness implicate views about whether a particular activity, practice, or lifeway is laudable, important, or essential to living a human life. They rest on particularized understandings of what a practice involves and what, therefore, is at stake. These judgments also implicate perspectives on whether the risks that are entailed when a particular practice brings humans in contact with contamination can be avoided readily or cheaply – or whether risk avoidance would be impossible or would burden fundamental rights or would mean profound loss. The determinations of importance, necessity, ease, and possibility are judgments of value that are recognized to be culturally influenced.[25]

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[23] See, e.g., Walker Wilson, *supra* note 14, at 149-50, 165, 168-69; Cass R. Sunstein, *A Note on “Voluntary” Versus “Involuntary” Risks*, 8 DUKE ENVTL L. & POLICY FORUM 173 (1997). The IDEQ Risk Discussion Paper cites Chauncey Starr; Starr’s early estimates are now viewed as likely overstating the magnitude of this effect, but a significant effect has still been evidenced in more recent studies. *See* Walker Wilson, *supra* note 14, at 168-69.

[24] IDEQ, Risk Discussion Paper, *supra* note 1, at 7.

[25] See, generally, Walker Wilson, *supra* note 14 ; Dan M. Kahan, *Two Conceptions of Emotion in Risk Regulation*, 156 U. PA. L. REV. 721 (2008); Catherine A. O’Neill, *Risk Avoidance, Cultural Discrimination, and Environmental Justice for Indigenous Peoples*, 30 ECOLOGY L. Q. 1 (2003)[hereinafter O’Neill, *Risk Avoidance and Cultural Discrimination*]; Catherine A. O’Neill, *No Mud Pies: Risk Avoidance as Risk Regulation*, 31 VERMONT L. REV. 273 (2007)[hereinafter O’Neill, *No Mud Pies*].

The assignment of a label of voluntariness is thus of particular concern where an agency or other evaluator espouses the perspective of the dominant society, but the risk-bearers are Native people or members of other non-dominant groups. As I have observed elsewhere: "[t]he dominant society's understandings of the value of the practices in question and the ease or anguish with which avoidance would be undertaken will often be different, perhaps profoundly so, from the understandings of the indigenous peoples on whom the burden of risk avoidance will fall."[26]

Yet, a risk may be proclaimed to be voluntary as if everybody, including Native Peoples, agreed it were so, when only (some) members of the dominant society share this perspective. The IDEQ Risk Discussion Paper goes nearly this far. It opines that "given the availability of other healthy food choices, consuming large amounts of fish must be considered a voluntary risk."[27] It allows that, "in some cases, the voluntary nature of fish ingestion risk is tempered by financial need or cultural factors."[28] Its bottom line, however, is firm: "Still, fish consumption is a voluntary behavior."[29] Whereas "we do not have a choice about breathing air and drinking water," fish consumption is deemed a matter of choice.[30]

In an article published in the *Ecology Law Quarterly*, I considered the different understandings typical of dominant society evaluators, on the one hand, and Native Peoples of the Pacific Northwest, on the other, respecting the value of the practices at stake when fish have become contaminated and respecting the possibility of risk avoidance:

> *Value, Necessity of the Pursuit*
>
> For dominant society evaluators, fishing is likely to be viewed primarily as a recreational pursuit and secondarily as an economic activity. Fishing is therefore likely to be understood as a pursuit that is not necessary for most practitioners, but important for recreational or economic reasons for some. Fish are likely to be recognized by those in the dominant society as a palatable, efficient, and relatively inexpensive source of protein and other nutrients for humans, although not the only such source. Fish consumption is therefore likely to be valued, but unlikely to be thought indispensable.
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> For Native peoples of the Pacific Northwest, by contrast, the various aspects of fishing are constitutive of their identity as peoples. Fish, fishing, and fish consumption are understood to be vital for the physical, social, economic, political, spiritual, and cultural health of these peoples and their members. Proper practice includes protecting and tending to fish and shellfish habitat, fishing for or gathering fish and shellfish, preparing, consuming and using fish and shellfish, all attended by appropriate methods, prayers, and ceremonies. Fish, fishing, and fish consumption

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[26] O'Neill, *Risk Avoidance and Cultural Discrimination*, *supra* note 25, at 28.
[27] IDEQ, Risk Discussion Paper, *supra* note 1, at 7.
[28] *Id.*
[29] *Id.*
[30] *Id.*

are understood to be necessary, an indispensable part of what it means to be Nez Perce or Nisqually. Fishing and eating fish are important occasions for the inter-generational transfers of knowledge, including the ecological, historical, social, and spiritual knowledge that is a central part of the inheritance of succeeding generations. Fishing is also important for economic reasons, as fishers can feed their families or sell their catch or harvest for income. The inestimable value that the various Native peoples of the Pacific Northwest attach to fish, fishing and fish consumption is marked in stories and ceremonies, language, treaties negotiated with the invading peoples, past and present fisheries management practices, contemporary leadership in restoration efforts, and the ongoing political and legal struggle for the survival of the salmon, fish, and shellfish and the flourishing of their fishing cultures. Del White, Nez Perce, explains: “People need to understand that the salmon is part of who the Nez Perce people are.
…

Possibility and Costs of Avoiding the Attendant Risk

Dominant society evaluators are likely to believe that there are a host of alternatives to fishing and substitutes for eating fish, each of which might involve some costs, but all of which would be reasonable means of avoiding the risks that fishing and fish consumption have come to entail. To the extent that the dominant society views fishing as a recreational pursuit, fishing in different places, practicing “catch and release” fishing, or taking up alternative pastimes might suit nearly as well. Because the dominant society is less likely to attach any significance to the consumption of particular species or parts of fish and shellfish, risk avoidance measures that advised against consumption of certain species or certain parts would be unproblematic, apart from small compromises in terms of money (perhaps the prohibited species is less expensive to purchase or catch) and predilection (perhaps the prohibited part is a delicacy). Similarly, because the dominant society is less likely to consume fish and shellfish at particular times and frequencies in accordance with seasonal availability or ceremonial requirements, risk avoidance measures that entail consuming at reduced rates or measured frequencies (e.g., “eat no more than one fish meal per week”) would visit little or no hardship on its members, although it might entail some inconvenience (perhaps it is difficult to identify dietary substitutes that provide the nutritional benefits of fish). And, because the dominant society is less likely to employ the particular preparation methods that advisories recommend against, these risk avoidance measures are unlikely to implicate practices that are thought to be culturally important.

From the perspectives of the various Native peoples of the Pacific Northwest, such risk avoidance measures would occasion profound loss. Given that fish, fishing, and fish consumption is part of who these peoples are, it is simply not fathomable for them to avoid the attendant risks by ceasing to fish and eat fish. Indeed, it would be unthinkable….

It would also not be appropriate or possible in most cases to fish “elsewhere.” As the Columbia River Inter-Tribal Fish Commission explains: “Salmon and the rivers they use are part of our sense of place. The Creator put us here where the salmon return. We are obliged to remain and

> to protect this place." Moreover, various tribes' aboriginal and treaty-based claims to the fish and other resources are tied to specific places; the legal protections that flow from these claims cannot simply be re-established somewhere else. In addition, the particularized skills and ecological knowledge that indigenous peoples have developed over centuries are also place-specific and, therefore, are not transferable to other locations.
>
> Similarly, it would be unimaginable from the perspective of these peoples to undertake risk avoidance that required consuming fish and shellfish at reduced rates or frequencies, given that ceremonial observance necessitates consumption of large quantities during certain events timed in accordance with seasonal, traditional or cultural dictates. … In short, the loss occasioned by the potential risk avoidance measures would be profound and felt along cultural, spiritual, social, ecological, economic, and political dimensions.
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> In sum, as these examples help to illustrate, it will often be the case that the practices that have come to entail risk because of environmental contamination are valued differently by the dominant society on the one hand and indigenous peoples on the other. Where this is so, avoidance measures that ask risk-bearers to abandon or alter these practices are unlikely to be understood as particularly burdensome by dominant society evaluators –although they may be understood as impossibly burdensome by indigenous risk-bearers. Because environmental policy is likely nonetheless to reflect the dominant society's understandings of what is at stake, the risk avoidance measures that are adopted will likely be the very ones that encroach most profoundly on the expression of indigenous cultures and the exercise of indigenous rights.[31]

While the discussion excerpted above considers the issue in general, the tribes whose practices and rights are affected are the only ones who can speak properly to the question whether, from their perspectives, the relevant risks ought to be considered "voluntary." Although the IDEQ Risk Discussion Paper appropriately acknowledges that other perspectives exist ("For subsistence fishers, [catching and eating fish] is a way to obtain a high quality protein source inexpensively. Native American cultural identity with fish harvest and consumption also casts the voluntary nature of the risk in a somewhat different light"), it effectively dismisses them in the next breath, delivering its bald conclusion that "fish consumption is a voluntary behavior."[32] Yet the affected tribes have spoken repeatedly to this question as part of public processes and have provided numerous written statements to the rulemaking document.[33] These statements *by the affected tribes* indicate a quite different perspective than that asserted by IDEQ.

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[31] O'Neill, *Risk Avoidance and Cultural Discrimination*, *supra* note 25, at 35-40 (citations omitted; please consult original for supporting authorities).

[32] IDEQ, Risk Discussion Paper, *supra* note 1, at 7.

[33] Idaho Department of Environmental Quality, Water Quality: Docket No. 58-0102-1201-Negotiated Rulemaking (please see tribes' comments regarding their fishing rights, and the importance of fishing and fish to the tribes and their members); see, generally, Affiliated Tribes of Northwest Indians, Resolution #13-44 (2013).

B. Responsibility

An issue related to labeling a risk as “voluntary,” as recognized by the IDEQ Risk Discussion Paper, is that it involves judgments about matters of “responsibility.”[34] The IDEQ Risk Discussion Paper’s discussion here is slippery. After having deemed fish harvest and consumption “voluntary” in the previous paragraph, it states:

> If a risk is voluntary, the question of individual responsibility arises. When voluntary behaviors lead to risk, to what extent is it the responsibility of the government to reduce that risk? When regulatory efforts have reduced the risk associated with fish consumption to the extent possible, individual responsibility still plays a role in managing risk associated with fish consumption.[35]

It purports to raise a question, but buries within it a number of unstated assumptions. First, it portrays the risk as the consequence of the practices themselves (“When voluntary behaviors lead to risk ....”; and, to start off the previous paragraph, “The amount of contaminants in fish to which we are exposed is a function of the amount of fish we consume.”). *But fish, if they aren’t permitted to become contaminated with toxic substances, don’t “lead to risk.”* The source of the risk is not fish or fishing. People’s health is not jeopardized by eating fish – in fact, fish are widely recognized to be a healthful source of protein and other nutrients – people’s health is put in jeopardy when risk-producers are allowed to contaminate the waters in which fish swim. It is true that humans are only exposed to these contaminants when they eat fish. But the IDEQ Risk Discussion Paper presents this discussion in a one-sided fashion, as if the risk results solely from consuming fish. This depiction is unfortunate, as it appears to fault people for eating fish.[36]

Second, this discussion seems to open up to question a matter on which Congress and the Idaho state legislature have already spoken: under the CWA, it *is* “the responsibility of the government to reduce [the] risk” associated with fishing, to the point that the nation’s waters are again “fishable.”[37]

Third, this discussion implicitly rewrites the relevant statutory approach – substituting a feasibility-based standard for the health-based standard under the CWA (“When regulatory efforts have reduced the risk associated with fish consumption to the extent possible ….”). But the CWA doesn’t permit this; water quality standards require that pollution be controlled to the point that it is healthful – feasibility and cost aren’t appropriately part of an agency’s standard-setting efforts. The discussion then summarily answers the question it purported to ask: “individual responsibility still plays a role in managing risk associated with fish consumption.” Here again, the IDEQ Risk Discussion Paper takes the opportunity to

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[34] IDEQ, Risk Discussion Paper, *supra* note 1, at 7-8.

[35] *Id.* at 7-8.

[36] See, O’Neill, *Risk Avoidance and Cultural Discrimination*, *supra* note 25; O’Neill, *No Mud Pies*, *supra* note 25.

[37] Federal Water Pollution Control Act (Clean Water Act), 33 U.S.C. § 1251(a)(2)(2012). The EPA has interpreted this goal to require a baseline “use” of “fishable/swimmable” waters. 40 C.F.R. § 131.2, § 131.4 (2012).

shift responsibility from risk-producers (and the government that is directed to regulate risk production) to risk-bearers.

C. Self-Relevance

The IDEQ Risk Discussion Paper's discussion of voluntariness raises another issue recognized to affect agency and other evaluators' judgments about risk: whether a risk is perceived to be "self-relevant." According to the risk literature, where evaluators are not themselves likely to have to bear a risk, they may view it as less serious or worthy of public response.[38] Conversely, where a risk is self-relevant, i.e., likely to be borne by and of concern to the evaluator, studies have shown that risks will be seen as more serious and worthy of public response.[39] While one can't be sure of the perceptions of particular agency or other evaluators, this effect is worthy of note in a public discussion of risk. There is cause for concern, in any case, where agency statements suggest that agency personnel will be unaffected by relatively greater risk –whether because they don't care to eat fish or because they see ready options for substituting other foods for fish.[40] The IDEQ Risk Discussion Paper, for example, takes it as a "given" that people can easily and healthfully omit fish from their diets and their lives ("given the availability of other healthy food choices, consuming large amounts of fish must be considered a voluntary risk").[41]

On the whole, the IDEQ Risk Discussion Paper's section titled "Voluntary versus Involuntary Risks" contains numerous unstated assumptions and incomplete or one-sided portrayals of the issues. Although it occasionally introduces countervailing considerations, it quickly dismisses these – with the result that the entire section appears to be less a balanced analysis and discussion and more an argument for a position already decided upon.

V. Risks Disproportionately Borne by Tribal People

The IDEQ Risk Discussion Paper is silent on another aspect of risk that is recognized in the risk literature to be important to a risk's acceptability: whether it is shared equally or whether it is borne disproportionately by a few. Such concerns for equity are particularly acute, moreover, if the "few" are members of an identifiable group that has historically been subjected to discrimination or colonization. Where, as here, members of the fishing tribes are among the most highly exposed and will thus disproportionately have to bear the risk, evaluations of risk raise issues of environmental justice.

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[38] See Walker Wilson, *supra* note 14, at 150.
[39] *Id.*
[40] See, e.g., Washington State Department of Ecology, Presentation, Lake Roosevelt Forum Conference, Spokane, WA, Nov. 20, 2013 (Ecology representative in a recent public presentation mentioned that she didn't eat much fish because she "didn't like the taste" and discussed this in contrast to people "who love fish" and therefore eat a lot of it). The existence of people who simply don't eat fish, and so will never be among those exposed to any contaminants permitted to reside in fish, is a feature of exposure via the fish consumption pathway that distinguishes it from some other important exposure pathways.
[41] IDEQ, Risk Discussion Paper, *supra* note 1, at 7.

Yet, public debate about risk is often couched in the abstract, in terms of "statistical lives," i.e., nameless, faceless probabilities. As Douglas MacLean observes, "[r]isk analysts have tended to focus only on the magnitude of the risk, however distributed. … If exactly one person will die each year, the $1(10^{-6})$ magnitude indicates our ignorance in advance about who it will be."[42] This theoretical ignorance allows the discussion about risk to proceed on the premise that everyone is equally likely to be among the unfortunate.

This requisite – that everyone is equally likely to have to bear the risk – is thought to be satisfied in one of two ways. First, everyone can be expected to experience roughly the same level of risk if their circumstances of exposure are roughly the same – that is, the physical, geographical, and other parameters that determine each individual's exposure don't vary that much from person to person. Alternatively, everyone can be thought to experience roughly the same *chance* of experiencing a relatively high or relatively low level of cancer risk if we don't know, in advance, on whom the greater risk will fall – it is a greater chance being taken by all of us, like a lottery.[43] But, as elaborated below, neither of these conditions holds true when we are talking about fish consumption.

As to the first, individuals' circumstances of exposure are emphatically *not* "roughly the same" where the exposure pathway involves fish consumption. In fact, fish intake is highly variable, with differences in people's contemporary intake spanning as many as three orders of magnitude. Some people eat no fish at all; others eat 1453 grams/day.[44] The 90th percentile intake rate for the general population is the source of the EPA's national default of 17.5 grams/day.[45] By contrast, the 90th percentile intake rate documented by recent surveys of the Suquamish and Lummi is 489 grams/day and 800 grams/day, respectively.[46] Note that these are contemporary, suppressed fish consumption rates (FCRs); if historical or "heritage" rates were considered the variability would be even more marked.

As to the second, we cannot pretend that everyone's chances of being subjected to a greater level of risk are roughly the same.[47] Here in the Pacific Northwest, we know *who* it is that depends on fish, *who* it is that is the most exposed. We know, then, *who* will be left to bear the risk if a state such as Idaho shifts to a less protective level: it will be tribal people. This is problematic as an ethical matter, and it changes the terms of the policy debate. We cannot pretend to be debating the appropriate risk level in the abstract, i.e., in terms of statistical lives. In the states of the Pacific Northwest, a determination that

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[42] Douglas MacLean, *Social Values and the Distribution of Risk*, in VALUES AT RISK 75, 78-79 (Douglas MacLean, ed., 1986).

[43] See discussions in Catherine A. O'Neill, *Variable Justice: Environmental Standards, Contaminated Fish, and "Acceptable" Risk to Native Peoples*, 19 STANFORD ENVTL L. J. 73-75 (2000)[hereinafter O'Neill, *Variable Justice*]; Catherine A. O'Neill, *Fishable Waters*, 1 AMERICAN INDIAN LAW JOURNAL 181, 255-260 (2013)[hereinafter O'Neill, *Fishable Waters*], *available at* http://www.law.seattleu.edu/Documents/ailj/Spring%202013/O'Neill-Fishable%20Waters.pdf.

[44] See O'Neill, *Fishable Waters*, *supra* note 43, at Table 1 (The 1453 grams/day figure is the value for intake by the maximum consumer surveyed in the Suquamish tribal study).

[45] EPA's most recent calculations assume a slightly greater fish consumption rate of 22 grams/day.

[46] O'Neill, *Fishable Waters*, *supra* note 43, at Table 1.

[47] Importantly, this fact also renders the use of probabilistic risk assessment techniques, such as Monte Carlo analysis, inappropriate for jurisdictions such as Idaho and Washington.

highly exposed subpopulations may be subjected to risk levels of 10^{-4} is effectively a determination that *tribal people* may be subjected to risk levels of 10^{-4}.

Previously, the state of Idaho had deemed "acceptable" a risk level of 10^{-6}.[48] This is the risk level that Idaho found tolerable *when it assumed that everyone was more or less equally likely to be on the receiving end of the risk of cancer* – when it employed the national general population default rate for fish intake in its calculations. Now, however, Idaho has been required to consider studies that demonstrate both that fish intake is highly variable and that tribal people are among the very highest consumers. Why, now, when EPA has instructed IDEQ to consider this data and to ensure that its standards are "adequately protective of the most highly exposed population"[49] (and when Idaho might be expected to increase its FCR) has IDEQ proposed to reconsider its longstanding cancer risk level? If Idaho now deems acceptable a tenfold increase in its risk level, it cannot deny the implication of this shift: namely, that Idaho believes it to be "okay" for risk-producers to transfer the costs of their processes to identifiable people, tribal people, in the form of increased cancer risk.

If Idaho's decisions regarding the risk level and other aspects of its water quality standards permit tribes to be disproportionately impacted, they may run afoul of commitments to environmental justice. EPA has indicated that it will take seriously its obligations to ensure environmental justice in discharging its duties and in overseeing states' administration of their programs. Executive Order 12,898 commits agencies of the federal government to further environmental justice and specifically mentions to need to protect "subsistence consumption of fish and wildlife."[50] Federal civil rights laws prohibit recipients of federal funds, including state environmental agencies, from administering their programs in a manner that discriminates against American Indians.[51] Moreover, EPA has recently emphasized its particular commitment to ensuring environmental justice for tribes, their members, and indigenous people. EPA's July 2014 *Policy on Environmental Justice for Working with Tribes and Indigenous Peoples* commits in this context to addressing disproportionate risks to human health and the environment.[52] EPA also commits to encouraging states to implement environmental justice principles when states' programs, policies, and activities may affect tribes and their members.[53]

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[48] U.S. Environmental Protection Agency, Region X, Technical Support Document: EPA's Disapproval of the State of Idaho's Revised Human Health Water Quality Criteria for Toxics Submitted on July 7, 2006 10 (May 10, 2012)[hereinafter EPA, Idaho Disapproval TSD].

[49] Letter from Michael A. Bussell, U.S. Environmental Protection Agency, Region X, to Barry Burnell, Idaho Department of Environmental Quality 2 (May 10. 2012)[hereinafter EPA, Idaho Disapproval Letter].

[50] Executive Order 12,898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Feb. 11, 1994) (singling out the issue of "subsistence consumption of fish and wildlife" in section 4-4, the only subject matter issue receiving specific mention in the Executive Order).

[51] Civil Rights Act of 1964 § 106, 42 U.S.C. § 2000d (2012); 40 C.F.R. § 7 (2012).

[52] U.S. Environmental Protection Agency, Policy on Environmental Justice for Working with Tribes and Indigenous Peoples 1 (July 24, 2014), *available at* http://www.epa.gov/oecaerth/environmentaljustice/resources/policy/indigenous/ej-indigenous-policy.pdf.

[53] *Id.* at 4 (Principle 16).

VI. Risks That Impair Legally Protected Rights

The IDEQ Risk Discussion Paper also does not mention the fact that the tribes impacted by Idaho's determination regarding risk have legally protected rights to take fish. As I have discussed at length in an article published by the *American Indian Law Journal*, tribes' fishing rights, which are secured by treaties and other legal protections, can be undermined when the environments that support the salmon and other fish are permitted to be degraded, leading to depletion and contamination of the fish resource.[54] If IDEQ opts for a less protective risk level and thereby derives more lenient water quality standards, it may impair tribes' rights to harvest and consume fish. Presumably, the IDEQ Risk Discussion Paper does not take up this topic because it intends to engage the question fully at another opportunity. My comments, similarly, will not undertake a thorough discussion of the import of tribes' legally protected fishing rights (but will incorporate by reference my *American Indian Law Journal* article, a copy of which will be submitted to the rulemaking docket). Note, however, that courts have repeatedly recognized that if the waters are permitted to be significantly degraded, tribes' legally protected fishing rights can be eviscerated as surely as if tribal members had been barricaded from their fishing places. Idaho, thus, may simply not be free to choose a risk level that undermines or unduly burdens tribes' fishing rights.

VII. EPA Guidance on Risk in the Water Quality Standard Setting Context

States' water quality standard-setting efforts must be framed by tribes' legally protected fishing rights and must comport with the Clean Water Act. EPA has provided guidance for these efforts; EPA has also issued particular direction to Idaho for the effort at hand. The IDEQ Risk Discussion Paper correctly notes that EPA's AWQC Guidance provides some flexibility to states to account for local circumstances and other particularized considerations as they set their water quality standards. Among these circumstances are the presence of highly exposed groups and the applicability of particular legal obligations. In Idaho's case, EPA made clear in its disapproval letter that it understands local tribes to have higher rates of fish intake and so to be among the most highly exposed.[55] EPA also reminded Idaho that it "recommends that priority be given to identifying and adequately protecting the most highly exposed population."[56]

States have cited EPA guidance for the claim that water quality standards premised on less protective risk levels, e.g., 10^{-5}, would be "legitimate and approvable."[57] But EPA has qualified its willingness to entertain a range of risk levels in important ways. First, EPA has recognized – as it must – that its guidance must be considered by states as subsidiary to any applicable sources of law. This would

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[54] O'Neill, *Fishable Waters*, *supra* note 43.

[55] EPA, Idaho Disapproval Letter, *supra* note 49.

[56] *Id.* at 2.

[57] Lee Logan, *Washington Rejects EPA Push To Curb Additional Exposures In CWA Limits*, INSIDE EPA (Nov. 12, 2013)("State officials note that EPA guidance says states can use either risk level, as long as highly exposed populations are protected at least at a 1 x 10^{-4}, or 1 in 10,000, level. 'We were pretty careful that we didn't really show a preference for one or the other today,' [Washington State Department of Ecology Water Quality Program Director, Kelly] Susewind said. 'We think they're both legitimate and approvable.'").

include tribes' legally protected fishing rights; that is, the guidance cannot be read as authority to undermine these rights. Second, EPA has expressed concern for the *actual* risk posed to affected individuals, based on the best information available, when all of the parameters and circumstances are considered.

Additionally, EPA's AWQC Guidance must be interpreted in light of data and developments since it was published, in 2000.[58] Although there was then increasing awareness of the variability in fish consumption as among various subpopulations, EPA's guidance pre-dated the focused analysis of this issue provided by the National Environmental Justice Advisory Council (NEJAC) report in 2002.[59] As a consequence, statements in the guidance must be understood as a product of their time. Importantly, EPA's AWQC Guidance didn't contemplate fully the environmental justice issues raised by the fact that tribal people are among those most highly exposed to toxic contaminants in fish. In particular, the guidance's discussion of "subsistence" and "suppression" warrant comment.

These four issues are taken up in turn:

A. Tribal Fishing Rights

States cannot assume that EPA's AWQC Guidance has accounted for tribes' fishing rights, including rights secured by treaty and other legal agreements. Thus, while EPA's guidance outlines the considerations that will bear generally on EPA's decision whether to approve a state's water quality standards, and while EPA was surely aware at the time it published the guidance that tribes' fishing rights were implicated, EPA cannot be taken to have incorporated an analysis of how these standards intersect with tribal rights to harvest and consume fish. Nor could EPA, in guidance, purport to authorize state actions in contravention of the tribes' treaties and other agreements with the United States.[60] In fact, EPA is careful to make a disclaimer at the outset of its guidance to this effect: "This Methodology does not substitute for the CWA or EPA's regulations; nor is it a regulation itself. Thus, the 2000 Human Health Methodology cannot impose legally-binding requirements on EPA, States, Tribes or the regulated community, and may not apply to a particular situation based upon the circumstances."[61]

B. Actual Risk, When All Parameters are Considered

EPA has indicated that it will consider the actual risk that results to those affected when all of a state's selected parameters are considered, and has stated that its scrutiny will increase as a state's target risk level becomes less protective or less conservative, e.g., if it moves from 10^{-6} to 10^{-5}.[62] EPA has

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[58] EPA, AWQC Guidance, *supra* note 5.

[59] NATIONAL ENVIRONMENTAL JUSTICE ADVISORY COUNCIL, FISH CONSUMPTION AND ENVIRONMENTAL JUSTICE (2002).

[60] O'Neill, *Fishable Waters*, *supra* note 43, at 255-260.

[61] EPA, AWQC Guidance, *supra* note 5, at 1-2.

[62] U.S. Environmental Protection Agency, National Toxics Rule, 57 Fed. Reg. 60848-01 (1992) ("In submitting criteria for the protection of human health, States were not limited to a 1 in 1 million risk level (10^{-6})… If a State

emphasized that it will require “substantial support in the record,” including an analysis of how the state’s selected inputs to its risk assessment equation, when taken together, reasonably estimate the risk actually posed.[63] Among other things, EPA’s statements suggest that states do not have unlimited flexibility to choose the least protective or least conservative values for most or all of the relevant variables, e.g., target risk level, FCR, human bodyweight, human lifespan – at least not, as here, where the result leaves people exposed to significant risk. As the IDEQ Risk Discussion Paper recognizes, moreover, people aren’t actually exposed to one chemical at a time in the real world; rather, they are often exposed to multiple chemicals present in the water and, so, the fish: ”If criteria for carcinogens are based on a risk of 1×10^{-6}, and if an individual is exposed to multiple carcinogens at their criteria concentrations, the total cancer risk experienced by that individual will be greater than 1×10^{-6}.”[64] As IDEQ observes, “[t]his situation presents an argument for conservatism in setting criteria, favoring lower [i.e., more protective] risk levels.”[65] This concern for the risks actually faced by those exposed counsels attention not only to estimates of cumulative impacts experienced by tribal members consuming at contemporary suppressed rates,[66] but also at historical or “heritage” rates, a concept discussed below under “suppression.”

C. “Subsistence”

EPA’s use of the term “subsistence” in its AWQC Guidance does not necessarily track a more particularized understanding of that term as it applies to Native peoples’ lifeways. As set forth above, EPA uses the term “subsistence” both in describing the national default FCR for higher-consuming populations and in discussing the range of risk levels from which states might choose. Specifically, EPA indicates that states must ensure that, whatever risk levels they select, the resulting water quality

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selects a criterion that represents an upper bound risk level less protective than 1 in 100,000 (i.e., 10^{-5}), however, the State needed to have substantial support in the record for this level…. [Among other things,] the record must include an analysis showing that the risk level selected, when combined with other risk assessment variables, is a balanced and reasonable estimate of actual risk posed, based on the best and most representative information available. The importance of the estimated actual risk increases as the degree of conservatism in the selected risk level diminishes. EPA carefully evaluated all assumptions used by a State if the State chose to alter any one of the standard EPA assumption values.”).

[63] *Id.*

[64] IDEQ, Risk Discussion Paper, *supra* note 1, at 7.

[65] *Id.* In a related vein, people aren’t exposed to contaminants solely via the fish consumption pathway. For threshold pollutants, concern for an individual’s total exposure counsels enlisting more protective assumptions for the relative source contribution (RSC). One would expect that a state seeking to depart from EPA’s default assumptions for RSC in the direction of less protection to have to satisfy a heavy burden justifying this move – one that addressed the potential for tribal people’s exposure to exceed threshold levels recognized to be safe.

[66] Studies of cancer risks from the multiple chemicals present in the Columbia River Basin suggest reason for concern. When one considers particular species or sites, the risk levels are sobering. For example, at a site between the John Day and McNary dams, a person consuming fish at contemporary levels documented in the CRITFC survey (389 g/day) has an excess cancer risk between 1 in 100 and 1 in 1000 for all four species surveyed (i.e., steelhead, fall Chinook, largescale sucker, and white sturgeon). EPA and CRITFC, Columbia River Basin Contaminant Survey, app. N, 2-3 and fig. 6-26. (2002), *available at* http://yosemite.epa.gov/r10/oea.nsf/0/C3A9164ED269353788256C09005D36B7?OpenDocument. This estimate of risk is for whole body samples and assumes a 70-year exposure duration.

standards do not pose a risk above 10^{-4} to those more highly exposed, such as “sportfishers” or “subsistence fishers.” However, EPA’s use of these terms here is generic. EPA did not (and arguably cannot) authorize states to impose disproportionately greater risks on tribal fishers by its reference to “subsistence fishers.” In fact, in the Technical Support Document (TSD) for the AWQC guidance, EPA’s use of the term “subsistence” is not consistent.[67] While the term often includes tribal populations alongside other higher-consuming populations, EPA clearly does not mean to refer only to tribal people or other American Indians/Alaska Natives in discussing “subsistence” fishers. Rather, EPA seems to use the word in its more general sense, i.e., to refer to individuals who simply eat a lot of fish, for whatever reason. Thus, for example, among the groups considered in the TSD’s discussion of “subsistence” are “Florida residents receiving food stamps,” and “high-end Caucasian consumers on Lake Michigan.”[68] By contrast, the term “subsistence” is a term of art in some contexts, and is understood by many American Indian and Alaska Native people to refer to a set of interwoven cultural practices and lifeways that includes but is not coterminous with heavy reliance on fish, wildlife, and other natural resources for food and other purposes. Given EPA’s general use of the term “subsistence,” its stated willingness to tolerate a less protective risk level for “subsistence fishers” cannot be taken to suggest that it has explicitly authorized less protective risk levels for tribal people or other American Indians/Alaska Natives. While EPA was clearly aware at the time it issued its guidance that tribal people were among those highly exposed groups and subpopulations consuming fish at the greatest rates, EPA never attempted to delineate precisely who it meant to include in the term “subsistence.”

D. Suppression

EPA’s AWQC guidance also pre-dated widespread recognition of the problem of “suppression,” which was highlighted by the NEJAC report in 2002.

“A ‘suppression effect’ occurs when a fish consumption rate (FCR) for a given population, group, or tribe reflects a current level of consumption that is artificially diminished from an appropriate baseline level of consumption for that population, group, or tribe. The more robust baseline level of consumption is suppressed, inasmuch as it does not get captured by the FCR.[69]

For tribal people in the Pacific Northwest, the forces of suppression, often perpetrated or permitted by federal and state governments, have included inundation of fishing places; depletion and contamination of the fishery resource; and years of prosecution, intimidation, and gear confiscation. By contrast, a baseline reflecting tribes’ historical or “heritage” rates would not be distorted by suppression effects. Scholars of risk assessment have developed methods for deriving quantitative estimates of these historical or “heritage” rates for tribes in the Pacific Northwest. For example, Barbara Harper, et al.

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[67] O’Neill, *Variable Justice*, *supra* note 43, at n.194 (cataloguing different uses of the term “subsistence,” and different groups included among those referred to as “subsistence fishers” in the TSD).

[68] *Id.*

[69] NEJAC, *supra* note 59, at 43-45.

concluded that "[h]istorically, the Spokane Tribe consumed roughly 1,000 to 1,500 grams of salmon and other fish per day."[70]

EPA's recent "Frequently Asked Questions" document remedies the AWQC's silence on this vital point by recognizing the issue of suppression.[71] EPA's recent approval of the Spokane Tribe's water quality standards, moreover, signals its support for addressing suppression by use of a FCR premised on historical or "heritage" fish intake rates.[72] Given that contemporary rates and practices reflect fish consumption at or close to its nadir – a point vividly illustrated by the Nez Perce Tribe's presentation on suppression during the October 2nd public meeting[73] – an FCR selected from the 90th or even the 99th percentile of contemporary consumption surveys will be considerably lower than fish intake consonant with a more robust fish resource and fuller exercise of tribal fishing rights.

In sum, EPA's AWQC Guidance cannot be taken to authorize states to promulgate water quality standards that expose tribal people disproportionately to elevated risk of cancer and that undermine rights to fish that are secured to tribes by treaty and other legal agreements.

Conclusion

Thank you for considering these comments and the document they incorporate by reference.

Respectfully submitted,

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[70] Barbara L. Harper, et al., *The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME*, 22 RISK ANALYSIS 513, 518 (2002).

[71] U.S. Environmental Protection Agency, Human Health Ambient Water Quality Criteria and Fish Consumption Rates Frequently Asked Questions (Jan. 18, 2013), *available at* http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/upload/hhfaqs.pdf.

[72] Letter from Daniel D. Opalski, Director, Office of Water and Watersheds, U.S. Environmental Protection Agency, Region X, to Rudy Peone, Chairman, Spokane Tribe of Indians (Dec. 19, 2013).

[73] Nez Perce Tribe, The Nez Perce Tribe and its Fisheries: "Our Fate and the Fate of the Fish are Linked," Powerpoint Presentation (Oct. 10, 2014) *available at* http://www.deq.idaho.gov/media/1118105/58-0102-1201-nez-perce-tribe-fisheries-presentation-100214.pdf.

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Washington State Department of
Health

PCB Chemical Action Plan

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PCB Chemical Action Plan

by

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Summary of Findings

PBT Rule and Chemical Action Plans

A Chemical Action Plan (CAP) identifies, characterizes, and evaluates uses and releases of specific persistent, bioaccumulative and toxic chemicals (PBT) or a group of chemicals and recommends actions to protect human health and the environment (173-333 WAC). PBTs are considered the "worst of the worst" chemical contaminants because they remain in the environment for a long time, and build up within organisms and/or the food chain.

This Polychlorinated Biphenyls (PCBs) CAP estimates releases of PCBs from various sources to air, land, and water. It also describes the physical and chemical properties of PCBs and why they are considered toxic to humans and other organisms. The recommendations are a set of actions to reduce and phase out uses, releases, and exposures in Washington in consideration of current management approaches. An economic analysis on the cost of recommendations and the most promising options is also included.

PCBs

From 1929 to 1979 about 600,000 metric tons of PCBs were commercially manufactured in the US. The 1976 *Toxics Substances Control Act* (TSCA) prohibited manufacture, processing, and distribution of PCBs. While TSCA is often referred to as a "ban" on PCBs, the law allowed some historical uses to continue, and set allowable levels of inadvertent production of PCBs in other products. PCBs are also regulated under additional state and federal laws, and they are not always consistent. For example, the level of PCBs that is allowed in products under TSCA is millions of times higher than what is allowed in water under the Clean Water Act. This leads to water permit holders being held responsible at the end of their pipe for PCBs that came from other products. Back in the late 70's the total amount seemed small and the amount allowed in each product seemed low, but now we know that it's high compared to levels that impact human health..

PCBs are synthetic compounds that consist of 209 possible arrangements (called congeners) of chlorines around a biphenyl molecule. PCBs were sold commercially as various mixtures of these different arrangements. They are also found in the environment as various mixtures, bioaccumulate as complex mixtures, and have been assessed for toxicity largely as mixtures. They are largely regulated as total PCBs. As a result, Ecology chose to evaluate available information on all PCB compounds.

Major sources

For the purposes of this CAP, sources are considered to be the original material, such as PCBs in transformers. PCBs move through pathways such as stormwater and expose people and wildlife.

Current PCB levels in Washington State represent both historical uses and ongoing manufacturing processes that create PCBs. A large reservoir of past uses of PCBs includes electrical equipment such as transformers and capacitors, and building materials such as caulk and paint. About 75 percent of PCBs produced before 1979 were used in transformers and capacitors, including small capacitors in lamp ballasts and appliances. The second largest pre-1979 use, about 10 percent, was as plasticizers, including in caulk.

PCBs are still unintentionally generated by combustion and by different manufacturing processes, such as for some pigments and dyes. While there is a lot of recent research on the generation of PCBs during production of pigments and dyes, little work has been done to shed light on other processes that are likely to generate and release new PCBs. Non-point releases, such as from consumer products, are becoming increasingly important to control and reduce overall PCB delivery to humans and the environment.

Pathways

Lower chlorinated congeners are more readily emitted to the air from sources such as old caulk and intact lamp ballasts. When lamp ballasts fail or caulk is disturbed, a greater amount of all of the congeners are released. Lower chlorinated congeners travel further in air compared to the higher chlorinated congeners, and eventually all the congeners are deposited onto surfaces. PCBs do not readily dissolve in water and they bind to particles. Particle-bound PCBs can be transported through stormwater and end up in sediment. The relative abundance of PCBs in sediment is seen in Puget Sound where 97 percent of the PCBs are bound to sediment (1440 kg), less than three percent are in organisms (40kg), and less than one percent (10 kg) are dissolved in water. Under certain conditions, such as in the Spokane River, PCBs are found in the water column rather than in sediments.

Stormwater is the largest delivery pathway to surface waters for PCBs statewide. Loadings from water treatment plants and atmospheric deposition are each less than 10 percent of the total, although atmospheric deposition is less well studied. There are smaller pathways, such as from salmon that accumulate PCBs while in the Pacific Ocean and then return to Washington to spawn. While the long-term goal is to prevent PCBs from entering stormwater, it is important to continue work on stormwater management, including piloting new technologies.

Exposure

Levels of PCBs in the environment are mostly declining, but PCBs are still widespread. Wildlife are exposed to PCBs in their diet, along with PCBs in water, soil, and sediments. PCBs accumulate in fatty tissues, including in animals eaten for food. PCBs in food are the most significant source of exposure for most people, and we are particularly concerned with levels of PCBs in fish we eat. People are also exposed to PCBs in air, water, soil, and house dust. Levels of PCBs in people have declined since the 1980s, but everyone in the US has detectable levels of PCBs in their bodies. PCBs remain in people and animals for different numbers of years, varying by type of organism and type of PCB congener. Because PCBs are more readily absorbed than excreted, they accumulate in the body over time.

Toxic effects

PCBs are persistent in the environment, build up in the food chain, and can cause adverse health effects in humans and wildlife including cancer and harm to immune, nervous, and reproductive systems. PCBs disrupt thyroid hormone levels in animals and humans, hindering growth and development.

Priorities for new actions

As shown in Table 1 below, there are a variety of PCB sources with different concerns (each estimate is presented in the order it is discussed in the section on Sources, Uses and Releases and how each is derived is explained in that section). The table divides sources into those that are a legacy of the historic uses before 1979 and those that are currently ongoing.

We are especially concerned about exposure to children in school buildings with old lamp ballasts and other PCB-containing building materials. It is uncertain how many pre-1979 lamp ballasts are still in use, but they should be removed both for their potential to expose people to PCBs when they fail and because newer lights are more energy efficient. A large reservoir of PCBs in old caulk and other building materials is slowly being released into the environment. Releases from building materials can be greatly accelerated during remodeling and demolition. There is an opportunity, through use of best management practices, to prevent releases of PCBs during remodeling and demolition.

Inadvertent generation of PCBs is a potentially large and important source of uncontained PCBs, but little is known about the processes that inadvertently generate PCBs and what products contain them. We do know PCBs are created as a byproduct of pigments and dyes, and this creates a regulatory burden for paper recycling, municipal treatment works, and other dischargers in Washington. Finding alternative pigments and dyes will reduce PCB releases to the environment and alleviate water treatment burdens on business and municipalities.

While about 75 percent of the PCBs produced prior to 1979 were used in electrical equipment, most of the transformers and large capacitors that contain PCBs have been identified and replaced. The remaining equipment is largely monitored for spills that are cleaned up, further reducing the impact to people and the environment.

Table 1. Summary of sources, reservoirs, releases, exposures and priorities.

Source	Legacy reservoir of PCBs	Annual releases of PCBs (kg/yr)	Potential exposure pathways and concerns	Is the release contained?	Priorities
Historic uses					
transformers	100-200 kg	< 2	Accidental spills, which are identified and cleaned up.	Yes	
large capacitors	20 metric tons	10 to 80	Accidental spills, which are identified and cleaned up.	Yes	
lamp ballasts	100-350 metric tons	400 to 1,500	Continual release of lower concentrations, with high concentrations released when the ballast fails.	Yes	**In school buildings as part of energy efficiency improvements.**
small capacitors	1-35 metric tons	3 to150	Disposal in landfills from a variety of old appliances.	Yes	
other closed uses		unknown		Yes	
caulk	87 metric tons	160	Continual release of lower concentrations into the air, with high concentrations released when materials are disturbed.	No	**Remodeling and demolition, especially in schools.**
other open uses		unknown		No	
Current generation					
pigments and dyes	N/A	0.02 to 31[a]	Continual release of lower concentrations, with higher concentrations released during recycling.	No	**Identify and promote safer alternatives.**
other inadvertent generation	N/A	900	Concerns about both continual releases and potential large releases.	No	**Identify processes and products first and then identify and promote safer alternatives.**
residential waste burning	N/A	199	Released to air and already addressed by current regulations.	No	
commercial marine vehicles	N/A	0.4	Released to air and already addressed by current regulations.	No	

a. This estimate is for PCB-11, although additional congeners are present.

Recommendations for New Actions

The goal of a CAP is to recommend actions to protect human health and the environment. Averting toxic exposures and avoiding future costs is the smartest, cheapest, and healthiest approach. The priority recommendations address the largest sources, largest reservoirs, uncontrolled sources, protect the most people, or protect especially vulnerable children, in the context of existing programs, costs, and available technology. Ongoing permitting, cleanup, and other actions are crucial to any efforts on PCBs. The following recommendations are for new actions in addition to our existing efforts to reduce PCBs.

The recommendations are based on an evaluation of the following factors associated with implementing the action: 1) environmental and human health benefits, 2) economic and social impacts, 3) feasibility, 4) availability and effectiveness of safer substitutes, and 5) consistency with existing federal and state regulatory requirements.

Historic PCB-Containing Building Materials

1. Identify PCB-containing lamp ballasts in schools and other public buildings. Encourage replacement with more energy efficient PCB-free fixtures.

Goal: Remove remaining PCBs lamp ballasts from schools and other publically owned buildings.

Before 1979 PCBs were widely used in fluorescent lamp ballasts. PCB-containing lamp ballasts still in use should be identified and replaced with more energy efficient lighting. These ballasts have outlived their useful lives and are at high risk for failing (dripping, smoking, and catching fire). Ballast failures can expose children to concentrated PCB oils and elevated PCBs in air. Low concentrations of lower chlorinated PCB congeners are continually released from lamp ballasts. When ballasts fail, high concentrations of a broader spectrum of congeners are released, so it is important to find and remove the lamp ballasts before they fail.

There is no easily accessible source of information on how many of our approximately 9,000 school buildings are of the age and construction type likely to have PCB-containing lamp ballasts. The first step is to conduct a survey on schools (and other public buildings as time and resources allow) to identify buildings most likely to contain PCBs based on age, type of construction and scope of any past remodeling. This data will be used to identify those buildings where PCB-containing light ballasts are likely still in use. Lamp ballasts with PCBs can then be identified through visual inspection.

Public money should be used to remove PCB-containing lamp ballasts from schools and other public buildings. Since 2009, the legislature has provided money to the Office of the Superintendent of Public Instruction (OSPI) and the Department of Commerce to support energy efficiency measures in schools and other public buildings. It makes sense to combine PCB removal with increasing energy efficiency rather than create a new program just for removal of PCB-containing ballasts. If the grant programs are not funded, the legislature should establish a fund to help offset the costs of replacing PCB-containing lamp ballasts. Schools with PCB-containing lamp ballasts will be provided with information about the importance of removing these ballasts and referred to OSPI (or Washington State Department of Health and other available resources) to replace these fixtures with more energy-efficient lighting. Environmental justice will also be considered in setting priorities for removing PCB-containing lamp ballasts.

2. Develop and promote Best Management Practices (BMPs) to contain of PCBs in building materials currently in use and those slated for remodel or demolition.

Goal: Reduce exposure to people from PCBs in historic building materials and prevent PCBs in building materials from getting into stormwater.

Ecology should work to prevent PCBs currently in building materials from being released into the environment.Historically, PCBs were used at high levels in some caulks and paints. Studies in other areas have shown the widespread occurrence of PCB-containing caulk in buildings from about 1950-1980, especially masonry buildings, and smaller sampling efforts in Washington support this conclusion. There is some information about PCB-containing building materials in the Duwamish basin and other information from source tracing, such as PCBs in sidewalk and building caulk in Tacoma.

Based on available data in Washington, other government programs, and the scientific literature, Ecology would develop BMPs for containing PCBs to prevent exposure during the life of the building and during remodeling or demolition. Lower concentrations of lower chlorinated congeners are continually released from caulk and paint, with higher concentrations of a broader spectrum of congeners released when the materials are disturbed. Ecology should also provide education and outreach on BMPs to local governments and those in the building trades.

While Ecology is working on BMPs, it should also support assembling existing information into a PCB Source Control Guidance Manual that can aid Local Source Control work to identify and control sources of PCBs. PCB source identification work has been performed by a number of urban waters programs around the Northwest. To date, the lessons learned from each of these programs has not been synthesized and summarized for the benefit of future pollution prevention efforts at the state and local level

3. Assess schools and other public buildings for the presence of PCB-containing building materials.

Goal: Reduce children’s exposure to PCB-containing building materials in schools.
Goal: Prevent PCBs in building materials from getting into stormwater.

Many historical building materials, such as caulk and paint, have been found to contain high levels of PCBs. These materials are more common in industrial buildings, including schools, compared to residential buildings. It makes sense to focus on schools for testing and remediating these materials, as children are more sensitive to PCBs and the buildings are usually publically owned. Washington has not tested schools for PCBs, but other states have found high levels of PCB contamination in schools.

The first step in Recommendation #1 is to get information on how many of our approximately 9,000 school buildings are of the age and construction type likely to have PCB-containing materials. The information would be used to prioritize schools for testing, pending the availability of funding to either contain or remediate PCBs that pose a risk for children and teachers. A similar approach should be used to assess other public buildings once the assessment and remediation of schools is complete.

Ecology would initially focus on determining how many schools are likely to contain PCBs in historic building materials, narrow that list with visual inspections and then physical testing to determine the scope of the problem in Washington. This will determine how much time and money will be required for remediation and allow for long term planning, including funding. As Ecology learns more about PCB-containing building materials in Washington schools and other buildings, that information will be used to improve efforts to locate and remediate buildings. Environmental justice will also be considered in setting priorities for removing PCB-containing building materials.

Current Manufacturing Processes

4. Learn more about what products contain PCBs and promote the use of processes that don’t inadvertently generate PCBs.

Goal: Reduce newly generated PCBs in manufacturing processes.

In 1982, the Environmental Protection Agency (EPA) identified 70 manufacturing processes likely to inadvertently generate PCBs. Little is known about most of this potentially large source of uncontained PCBs, including which congeners are produced. More information is known about PCBs in pigments and dyes, which are known to be released into the environment in stormwater, effluents from municipal treatment works, and effluents from pulp mills re-pulping post-consumer paper. Unpermitted non-point releases, such as from consumer products, are becoming increasingly important to control to reduce overall PCB delivery. Ecology should

work with EPA, manufacturers, the Northwest Green Chemistry Center, and other partners to identify products likely to contain PCBs, including a workshop focused on bringing together the supply chain to look for solutions to the current PCBs in products issue.
Ecology should test identified products and give that information to the Department of Enterprise Services (DES) to assist them in implementing new purchasing policies (RCW 39.26.280) that provide a preference for products that do not contain PCBs. Government purchasing of non-PCB-containing products is an effective way to both identify products that don't contain PCBs and encourage suppliers to remove PCBs from their products. Once products are identified that contain fewer PCBs, the information will be available shared with other purchasers, such as by schools, cities and residents. Ecology should support other government and business entities that adopt similar purchasing policies to drive the market-demand for PCB-free products.

Ecology, the Washington State Department of Health (DOH), and DES should work together to educate purchasers and vendors in the state supply chain by developing a focus sheet that concisely outlines the problem and its potential impacts on compliance with water quality standards, as well as impacts on people and the ecosystem.

Ecology should begin with directing an alternatives assessment for pigments and dyes, based on the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide. Businesses and other concerned stakeholders would be asked to participate in the alternatives assessment process. If there are currently no alternatives that do not generate PCBs, Northwest Green Chemistry should work to develop alternative processes.

In addition to investigating which products contain inadvertently generated PCBs and finding safer alternatives, Ecology and DOH should petition the federal government to reform current regulations under the *Toxics Substances Control Act* (TSCA). TSCA generally allow a maximum of 50 ppm of inadvertently generated PCBs in most products, while Washington standards under the *Clean Water Act* (CWA) to protect human health that allow only 0.00000017 ppm (170 ppq or parts per quadrillion) PCBs in water bodies. The TSCA allowance is over 294 million times greater than the CWA criteria for human health and it is suspected that the TSCA allowance is likely a pathway for new PCBs to enter the environment, resulting in a paradox between these regulatory structures that must be resolved. The lower CWA standards are based on protecting human health and what we know about the health effects of PCBs. The higher allowable level of PCBs in products leads to higher levels of PCBs in water, and the responsibility of PCB levels in water are borne by downstream permittees that are not generating PCBs. Allowable levels of newly generated PCBs in products must be lowered by the federal government in order to meet water quality standards to protect human health and the environment.

Historic Electrical Equipment

5. Survey owners of historic electrical equipment, including transformers and large capacitors.

Goal: Confirm estimates of EPA-regulated electrical equipment with more than 500 parts per million (ppm) PCBs, learn what is known about electrical equipment with PCBs greater than 2ppm, and find out when such electrical equipment is estimated to be replaced.

Before 1979, the majority of PCBs were produced for use in electrical equipment. Major industries and electrical utilities indicate that they have either already removed these potential sources or have plans to do so. Ecology should survey the state's 61 utilities and other owners of electrical equipment to confirm that this is the case and provide technical assistance for proper replacement and disposal.

Federal regulations focused on transformers with more than 500 ppm PCBs. According to industry, many of these transformers and other electrical equipment have already been disposed of, but we do not have updated inventories of this equipment to reflect this progress and target technical assistance to remaining equipment. To avoid spills or other unexpected releases, the users should know which pieces of equipment have PCBs and have a plan to remove all such pre-1979 equipment from service or an estimate on when they will be replaced during regular maintenance. This inventory would not include small capacitors. This survey would not require additional testing or disposal of equipment by a certain date. Owners would be asked what they know about detectable levels of PCBs in their equipment, using the industry standard detection level (currently 2 ppm) and when they expect all the equipment to be replaced based on their current maintenance practices. A statewide inventory will allow the state to confirm current inventories and target efforts to prevent releases of PCBs from this equipment. Ecology should also work with EPA to update EPA's 1998 inventory and more accurately reflect the PCB transformers that are no longer in use.

PCB concentrations in many pieces of electrical equipment are high compared to other sources, so relatively rare leaks and spills can release a significant amount of PCBs into the environment. While PCB spills from electrical equipment are cleaned up, there are some spills where PCBs enter the waterways before being cleaned up, such as from transformers that are located close to storm drains or water bodies.

Ecology should also investigate the possibility of providing state financial assistance to businesses, state agencies, cities, municipalities, and schools to accelerate this process of collecting and properly disposing of equipment with concentrated PCBs.

Multi-Source

6. Expand environmental monitoring to identify any new areas requiring cleanup and investigate air deposition.

Goal: Find areas with highly concentrated PCBs and clean them up to prevent the wider release of PCBs.
Goal: Find about more about distribution of PCBs in the state to prioritize future actions.

Ecology should expand environmental monitoring of water, fish tissue, and sediment to identify PCB hot spots. For example levels of PCBs in fish were high enough to prompt Oregon and Washington to issue a joint consumption advisory for select species from Bonneville Dam upstream to McNary Dam. This led to the discovery of an historical landfill of electrical equipment on Bradford Island near Bonneville Dam on the Columbia River. This site is currently a federal Superfund site. A number of fish sampling efforts in the Columbia basin (CRITFC, Hanford Corridor Study and Ecology's Freshwater Fish Contaminant Monitoring Program) found other areas (mid-Columbia and Snake River) with elevated levels of PCBs and a number of hydroelectric facilities. To our knowledge, no work has been done to identify sources of contaminants in these areas. The proposed monitoring would conduct sampling to determine if contaminant sources exist in areas with a focus on hydroelectric facilities. Mapping and prioritization of historical information on the location of potential sites, such as landfills, industrial sites, railroad switching yards, etc., should also be used to find potential sites. Newly identified sites would be prioritized for cleanup using existing procedures.

In addition to identifying new hot spots, Ecology should continue its trend monitoring to show changes in PCBs in the environment and organisms over time.

Air deposition is a potentially significant pathway for PCBs to move into the environment. Ecology should investigate monitoring air deposition to assess the relative importance of this pathway.

7. Conduct a public educational campaign.

Goal: Provide information to residents about ways they can minimize exposure.
Goal: Raise awareness of the problems associated with current and past production of PCBs.
Goal: Educate residents to identify and addresses possible household sources of PCBs.

Ecology and DOH should work together with local entities to help residents, people who fish, schools, local governments, and businesses understand the risks associated with PCB exposure and ways to reduce risks, including the availability of safer alternatives.

The public educational campaign will include perspectives on public health risks and information on where exposures to PCB are most likely. It will also include advice on how individuals can minimize their own exposures to PCBs. The campaign will include where to look for potential sources of PCBs in households, such as in old appliances, electrical equipment, and building materials. It will also teach the public how to safely remove and dispose of these materials to prevent PCB releases.

8. Conduct a study on which PCB congeners are present in Washington residents.

Goal: Learn more about PCB congeners to which Washington residents are exposed.
Goal: Find out more about the distribution of PCBs in Washington to prioritize future actions.

Within available resources, DOH should conduct biomonitoring of Washington residents for PCBs including PCB-11 and other inadvertently produced PCBs associated with dyes, pigments, and printing inks. This would be in tandem with learning more about what other processes produce certain PCB congeners. Use the data to better understand 1) the extent of total human exposure from multiple potential pathways and 2) the relative contribution of these congeners to human body burden of PCBs. In addition, use the data to estimate the statewide distribution of PCBs in Washington residents. This will provide a better baseline than national data, given the elevated levels of PCBs in local fish populations and relatively high fish consumption in a number of Washington communities and regions.

Summary of Recommendations

1. Identify PCB-containing lamp ballasts in schools and other public buildings. Encourage replacement with more energy efficient PCB-free fixtures.

2. Develop and promote Best Management Practices (BMPs) to contain PCBs in building materials currently in use and those slated for remodel or demolition.

3. Assess schools and other public buildings for the presence of PCB-containing building materials.

4. Learn more about what products contain PCBs and promote the use of processes that don’t inadvertently generate PCBs.

5. Survey owners of historic electrical equipment, including transformers and large capacitors.

6. Expand environmental monitoring to identify any new areas requiring cleanup and investigate air deposition.

7. Conduct a public educational campaign.

8. Conduct a study on which PCB congeners are present in Washington residents.

Implementation Steps

The recommendations outline a set of first steps in a long-term plan to reduce PCB releases and exposures. Due to the magnitude and diversity PCB sources, many of the approaches will take significant commitments of time and money to implement effectively. In addition, Ecology and DOH can support other agencies, but it is up to the other agencies to carry out some of the recommendations.

Ecology focuses on prevention, which is the smartest, cheapest, and healthiest approach to reducing PBTs. Our priority is actions that result in the biggest reduction in exposure to the most sensitive receptors. However, sometimes other opportunities to reduce PCBs may arise and it makes sense to reduce all sources of PCBs where possible.

Ecology will continue our existing programs on PCBs to the environment, such as cleanup, stormwater management, and permits. DOH will also continue their existing programs, including fish advisories and working with residents to reduce their exposures. Expanding or increasing programs will require additional funds. Ecology and DOH will work on acquiring additional funds, but cannot predict when we will be able to obtain them.

Ecology and DOH will seek resources to implement the following recommendations in:

FY16-17

Recommendation 1. Survey and assess PCB-containing lamp ballasts in schools and other public buildings. Encourage replacement with more energy efficient PCB-free fixtures.

Recommendation 2. Develop and promote Best Management Practices (BMPs) for containment of PCB-containing materials in buildings currently in use and those slated for demolition.

Recommendation 4. Learn more about what products contain PCBs and promote the use of processes that don’t inadvertently generate PCBs. This will begin with an alternatives assessment on PCBs in pigments. Use this information to continue to request reforms of PCB regulations under TSCA.

Recommendation 5. Survey owners of historic electrical equipment.

Recommendation 6. Expand environmental monitoring to identify any new areas requiring cleanup.

Recommendation 7. Collaborate with DOH to conduct an educational campaign.

FY18 -21

Recommendation 3. Assess schools and other public buildings for the presence of PCB-containing building materials. This work will start once school buildings have been surveyed (Recommendation 1) and the BMPs have been developed (Recommendation 2).

Recommendation 4. Learn more about what products contain PCBs and promote the use of processes that don't inadvertently generate PCBs. Ongoing work will focus on determining other processes that inadvertently generate PCBs and alternatives that do not generate PCBs. Ongoing work to support reforms of PCB regulations under TSCA.

Recommendation 6. Expand environmental monitoring to identify any new areas requiring cleanup. This project is expected to be finished in FY18.

Recommendation 7. Conduct an educational campaign. This education and outreach will be ongoing past FY17.

Recommendation 8: DOH will seek resources to design and conduct biomonitoring.

General Chemical Information

Summary

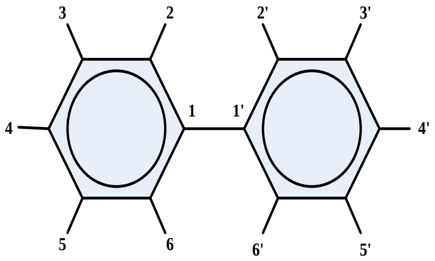

Figure 1. PCB Structure

Polychlorinated biphenyls (PCB) are a family of man-made chemicals consisting of two benzene rings joined together and containing one to 10 chlorine atoms attached to the benzene rings. There are 209 possible combinations of chlorine positions, called congeners. Depending upon the amount of chlorine present, PCBs appear as oily liquids to white crystalline solids and hard non-crystalline resins (HSDB, 2013). PCBs are hydrophobic and bind to particles. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer and hydraulic equipment; as plasticizers in paints, plastics, and rubber products; in pigments, dyes, and carbonless copy paper; and many other industrial applications (EPA 2013a).

From 1929 to 1979, 700,000 tons (or 1.4 billion lbs or 600,000 metric tons) of PCBs were commercially manufactured in the US (EPA 1997a). Most of the PCBs in the US were manufactured by Monsanto, which continued manufacture in the US until 1979 when US production stopped. PCBs were not typically manufactured as individual congeners but as mixtures called Aroclors. Individual Aroclor mixtures were manufactured using specific chemical processes imparting varying chemical characteristics such as vapor pressure, solubility, viscosity, amount of chlorination, etc. that produced a unique distribution of congeners in the different Aroclor mixtures. (HSDB, 2013) Much of the research and discussion on PCBs is centered upon the specific Aroclor mixtures. The 1976 Toxic Substances Control Act (TSCA) prohibited manufacture, processing, and distribution of PCBs. Some legacy uses of PCBs were allowed to continue.

PCBs are identified as persistent, bioaccumulative and toxic (PBT). Because of their persistence, PCBs continue to be found in the environment and contamination from legacy sources remains a problem. In addition, PCBs are not prohibited in some products at concentrations below 50 ppm. PCB concentrations of less than 50 ppm are considered to be “PCB-free.” Recent evidence has also indicated that PCBs may be found as contaminants in a wide range of consumer products because of the presence in several pigments and dyes (Hu *et al.* 2010, Rodenburg *et al.* 2010)

Physical and Chemical Properties of PCBs

A summary of typical characteristics for PCBs can be found in Table 2 (ATSDR 2000).

In general, PCB compounds range from heavy oily liquids to sticky resins, or melting crystalline solids depending upon the amount of chlorine present. These man-made compounds are odorless, colorless to light yellow or amber, and very stable and have relatively low volatility at ambient temperatures. PCBs were attractive in many applications because they resist breakdown at high temperatures or from aging, or oxidation. They persist in the environment since they do not easily biodegrade. PCBs are hydrophobic and thus do not dissolve well in water. As hydrophobic and very stable compounds, PCBs may volatilize from water despite their low vapor pressure. PCBs also easily adsorb onto organic particles in soils, sediments, biological systems, or water. (Panero *et al*. 2005) These organic particles can be transported long distances and has been shown as one of the reasons PCBs are distributed throughout the planet including remote areas.

Washington State's PBT Rule (WAC 173-333) defines persistence, bioaccumulation, and toxicity:

- The criterion for persistence is the half-life (the time it takes for half of the chemical to breakdown) of the chemical in water, soil, or sediment is greater than or equal to 60 days.
- The criterion for bioaccumulation is either:
  - The bioconcentration factor (BCF) or bioaccumulation factor (BAF) in aquatic species for the chemical is greater than 1,000.
  - In the absence of such data, the log-octanol water partition coefficient (log K_{ow}) is greater than five.
- In order for a chemical to be considered toxic, it must meet at least one of the following criteria:
  - Be a carcinogen, a developmental or reproductive toxicant, or a neurotoxicant.
  - Have a reference dose or equivalent toxicity measure less than 0.003 mg/kg/day.
  - Have a chronic no-observed-effect concentration (NOEC) or equivalent toxicity measure less than 0.1 mg/L or an acute NOEC or equivalent toxicity measure less than 1.0 mg/L.

Many but not all PCB congeners are persistent and bioaccumulative as defined in Washington's PBT Rule. Table 2 demonstrates persistence and bioaccumulation for a series of PCBs, one from each of the ten homolog groups as predicted by EPA's PBT Profiler (EPA 2012b). PCBs are often grouped by the total number of chlorine atoms and a group with the same number of chlorines is called a homolog. Washington's PBT characteristics are included in the bottom of the table (WAC 173-333). Table 4 (IPCS 1995) provides ranges of characteristics for congener groups and also includes Washington's PBT characteristics on the bottom of the table.

Although the information in Table 2 is modeled data, which should not be confused with analytical results, the PBT Profiler results do demonstrate some trends. In general, persistence as indicated by the half-lives increases as the number of chlorine atoms increase. The tendency to bioaccumulate increases until the molecular structure of the PCB becomes large enough that the amount of bioaccumulation plateaus and begins to decrease. This plateauing is a direct result of the size of the PCB molecule, which can restrict transport through cell walls. Although all PCBs shown meet Ecology's persistence criterion, some of the mono-substituted may have sufficiently low bioaccumulation factors (BCF) that they may not meet Ecology's PBT criteria.

Table 2. Summary of Typical PCB (Aroclor) Physical Characteristics (from ATSDR 2000)

Property	**Aroclor 1254**	**Aroclor 1260**	**Aroclor 1262**	**Aroclor 1268**
Molecular weight	328	357.7	389	453
Color	Light yellow	Light yellow	No data	Clear
Physical state	Viscous liquid	Sticky resin	No data	Viscous liquid
Melting point, ^oC	No data	No data	No data	No data
Boiling point, ^oC	365 - 390	385 - 420	390 - 425	435 - 450
Density, g/cm^3, 25 ^oC	1.54	1.62	1.64	1.81
Odor	Mild hydrocarbon	No data	No data	No data
Solubility:				
Water, mg/L	0.012, 0.57 (24^oC)	0.0027, 0.08 (24^oC)	0.052 (24^oC)	0.300 (24^oC)
Organic solvent(s)	Very soluble	Very soluble	No data	Soluble
Partition coefficients:				
Log K_{ow}	6.5	6.8	No data	No data
Vapor pressure, mm Hg at 25 ^oC	$7.71x10^{-5}$	$4.05x10^{-5}$	No data	No data
Henry's law constant, atm-m3/mol at 25 ^oC	$2.0x10^{-3}$	$4.6x10^{-3}$	No data	No data
Flashpoint, ^oC (Cleveland open cup)	No data	No data	195 ^oC	195 ^oC
Flammability limits, ^oC	None to boiling pt	None to boiling pt	None to boiling pt	None to boiling pt
Conversion factors				
Air (25 ^oC)	1 mg/m^3= 0.075 ppm	1 mg/m^3= 0.065 ppm	1 mg/m^3= 0.061 ppm	1 mg/m^3=0.052 ppm

Table 3. EPA PBT Profiler Estimates of Persistence and Bioaccumulation for Select PCB congeners

PCB	Congener number	CAS	Half-Life (days)				BCF[1]
			Water	Soil	Sed.	Air	
4-Chlorobiphenyl	PCB-3	2051-62-9	38	75	340	4.2	510
3,3’-Dichlorobiphenyl	PCB-11	2050-67-1	38	75	340	3.9	5,400
2,3,4’-Trichlorobiphenyl	PCB-22	38444-85-8	60	120	540	15	6,700
2,3’,5,5’-Tetrachlorobiphenyl	PCB-72	41464-42-0	180	360	1,600	13	27,000
2,2’,4,4’5-Pentachlorobiphenyl	PCB-99	38380-01-7	180	360	1,600	13	40,000
2,3,3’,4,4’,5-Hexachlorobiphenyl	PCB-156	38380-08-4	180	360	1,600	75	26,000
2,3,3’,4,4’,5,6’-Heptachlorobiphenyl	PCB-190	41411-64-7	180	360	1,600	130	12,000
2,2’,3,3’,4’,5,5’,6’-Octachlorobiphenyl	PCB-199	52663-75-9	180	360	1,600	290	5,900
2,2’,3,3’,4,4’,5,6,6’-Nonachlorobiphenyl	PCB-207	52663-79-3	180	360	1600	370	2,900
Decachlorobiphenyl	PCB-209	2051-24-3	180	360	1,600	880	12,000
WA PBT Characteristics			> 60	> 60	> 60		>1,000

BCF = Bioconcentration Factor; half-life = the amount of time it takes for the concentration of a chemical to diminish to half its original value; N/A = Not Applicable

Table 4. PCB Homolog Chemical properties (IPCS, 1995)

Congener Group	CASRN	Molecular weight (g/molecular)	Vapour Pressure (Pa)	Water Solubility (g/m^3)	log K_{OW}
Monochlorobiphenyl	27323-18-8	188.7	0.9-2.5	1.21-5.5	4.3-4.6
Dichlorobiphenyl	25512-42-9	223.1	0.008-0.60	0.06-2.0	4.9-5.3
Trichlorobiphenyl	25323-68-6	257.5	0.003-0.22	0.015-0.4	5.5-5.9
Tetrachlorobiphenyl	26914-33-0	292.0	0.002	0.0043-0.010	5.6-6.5
Pentachlorobiphenyl	25429-29-2	326.4	0.0023-0.051	0.004-0.02	6.2-6.5
Hexacholorbiphenyl	26601-64-9	360.9	0.0007-0.012	0.0004-0.0007	6.7-7.3
Heptachlorobiphenyl	28655-71-2	395.3	0.00025	0.000045-0.000	6.7-7
Octachlorobiphenyl	55722-26-4	429.8	0.0006	0.0002-0.0003	7.1
Nonachlorobiphenyl	53742-07-7	464.2	-	0.00018-0.0012	7.2-8.16
Decachlorobiphenyl	2051-24-3	498.7	0.00003	0.000001-0.000	8.26
WA PBT Criterion					>5

log K_{ow} = natural log of the octanol/water coefficient

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[1] EPA’s PBT Profiler defines the bioconcentration factor (BCF) as ‘… *a measure of the ability for a water-borne chemical substance to concentrate in fatty tissue of fish and aquatic organisms relative to its surroundings. EPA defines bioconcentration as the net accumulation of a substance by an aquatic organism as a result of uptake directly from the ambient water through gill membranes or other external body surfaces (60 FR 15366).*’

Stability of Ring Structure and Carbon to Halogen Bond

The chemistry and related stability of ring compounds was discussed extensively in the Polycyclic Aromatic Hydrocarbon (PAH) Chemical Action Plan (CAP) (Ecology, 2012a). Benzene (cyclohexa-1,3,5-triene) [2] is cyclohexane with three double bonds equally spaced throughout the molecule. Unlike compounds where the electrons forming the double bonds are localized around specific carbon atoms, the electrons in benzene's double bonds are equally shared among all six-carbon atoms. This is a defining characteristic of aromatic compounds. Benzene is typically represented by chemists as a six-carbon ring with a circle inside to represent the sharing of all electrons equally among the carbon atoms (Figure 2):

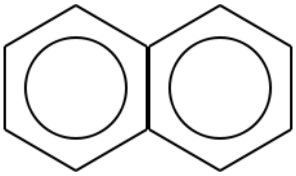

Figure 2. Chemical abbreviation for benzene

The most common theory currently accepted by chemists is that this sharing of electrons accounts for the thermodynamic stability of benzene and other aromatic compounds. Other theories have been promulgated (Cooper *et al.*, 1986) but are not currently widely accepted. Regardless, the increased stability of benzene and benzene-based compounds like PCBs can be attributed to the unique ringed structure and sharing of electrons throughout the molecule.

PCBs have another feature that contributes greatly to their stability. Carbon and chlorine form a very strong bond and the amount of energy needed to break apart the bond is higher than most other covalent bonds. The strength of this bond greatly increases the ability of PCBs to persist in the environment. Persistence is also related to the number of chlorine atoms with increasing degree of persistence with increasing chlorine mass. Comparatively, the mono- and di-chlorobiphenyls are less persistent than the larger congeners; however, all PCBs meet the definition of persistence (see Table 3 for examples).

Naming of PCB congeners

PCBs have a variable structure with two benzene rings joined together. Each benzene ring can have one to five chlorine atoms attached. The number and location of the chlorine atoms attached to the biphenyl ring determine the physical properties and characteristics of the PCB congener.

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[2] The formal name for benzene describes a cyclical compound (cyclo) with six carbons (hexa) and three (tri) double bonds (ene). The '1,3,5' indicates which carbon atoms contain the double bond. Given the structure, the double bonds are represented as between the carbons 1 & 2, 3 & 4 and 5 & 6, although in reality the electrons are equally shared with all of the carbons on the ring.

The position of the chlorine atoms are differentiated by using 2 through 6 for one benzene atom and 2’ (two prime) through 6’ (six prime) for chlorine atoms on the second benzene ring. The naming convention assumes that the two benzene molecules are joined together at the 1 and 1’ position. See Figure 3 for the carbon numbering.

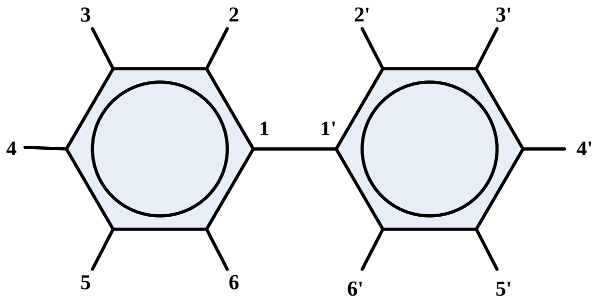

Figure 3. PCB Structure

This naming convention allows chemists to identify the structure of specific PCB congeners. For example, PCB-11 (3,3’-dichloro-1,1’-biphenyl or 3,3’-dichlorobiphenyl) contains two chlorine atoms in the 3 and 3’ position. Unless indicated otherwise, a hydrogen atom is located on the benzene ring in all the unmarked locations.

Because it is possible for the PCB-11 molecule to rotate around the 1-1’ carbon bond, there is no chemical difference between the above structure and 3,5’-dichlorobiphenyl (Figure 4).

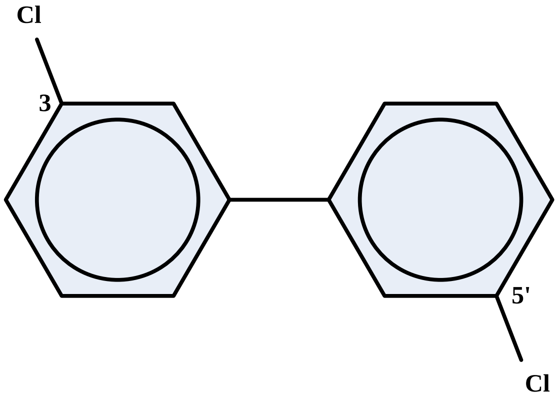

Figure 4. Alternate PCB-11 Structure

Several additional names potentially exist for PCB-11 including 5,3’-dichlorobiphenyl and 5,5’-dichlorobiphenyl. To prevent confusion, the naming convention uses the lowest numbers for these equivalent structures leading to PCB-11 being identified as 3,3’-dichlorobiphenyl. The naming convention can lead to confusion if an incorrect name is used.

Planar and non-planar PCBs

The issue of rotation can also have an impact on the relative toxicity of the PCB congeners. PCB congeners can either exist as planar where the two benzene rings are in the same plane or non-planar where the benzene rings are at 90 degree angle from each other.(ATSDR 2000). Planar and non-planar PCBs can have very different toxicity and this issue will be an important consideration in the relative toxicity of the PCB congeners discussed in subsequent sections.

A further naming convention using the terms ortho, meta and para are also used to identify the position of the chlorine atoms in a PCB molecule. If a chlorine atom is attached to the carbons adjacent to the 1 to 1' bond between the two benzene molecules (positions 2, 2', 6 or 6'), the chlorine atoms are said to be in the meta position. If the chlorine atom is attached to positions 3, 3', 5 or 5', they are in the ortho position. If they are attached to the 4 or 4' position, they are in the para position. Table 5 and Figure 5 indicate the position of the chlorine atoms in a PCB congener using the three naming conventions:

Table 5. Table of location of chlorine atoms

Name	Carbon atom location
Meta	3,3',5,5'
Ortho	2,2,6,6'
Para	4,4'

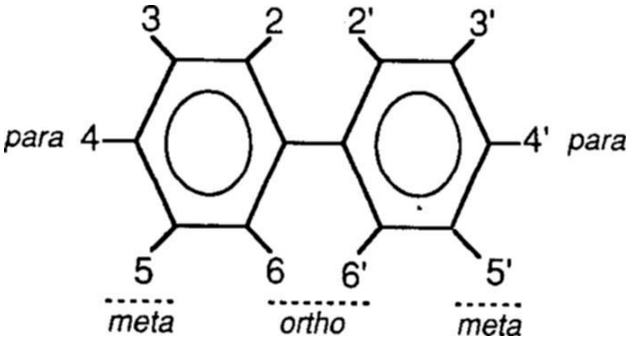

Figure 5. Location of meta, ortho, and para positions

The location of chlorine atoms plays an important role in the decomposition and toxicity of specific PCB congeners. Degradation reactions, for example, may selectively remove chlorine atoms from specific locations while PCB molecules with specific arrangements of chlorine atoms may have greater toxicity than related congeners.

Using the base structure (Figure 3), 209 different and unique PCBs (also known as congeners) can exist depending upon the number and position of chlorines involved. A list of these 209 congeners (EPA 2003) can be found in Appendix A. In addition to specific congeners, PCBs are also often grouped by the total number of chlorine atoms also called homologs (Table 4).

Historic Manufacturing

Historically, PCBs were not manufactured as specific congeners or homologs but as mixtures. Globally there was a wide range of product names for PCB mixtures (Appendix B). There were nine major mixtures in the US called Aroclors (Table 6). Prior to 1971, the Monsanto Chemical Company produced Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268. (ATSDR 2000). Figure 6 shows the amounts and uses of PCBs produced in the US between 1957 and 1971. (EPA 1987). Most Aroclor mixtures are named utilizing a code. Most begin with a 12 and the last two digits indicate the percentage amount of chlorine in the mixture. Therefore Aroclor 1254 contained 54% chlorine by weight, Aroclor 1216 contained 16% chlorine, etc. The only major Aroclor mixture that deviates from this system is 1016.

In 1971, Monsanto voluntarily restricted the uses of PCBs and subsequently produced only Aroclor 1016, 1242, 1254, and small quantities of Aroclor 1221. In 1974, the Monsanto Chemical Company produced slightly more than 40 million pounds (18 million kg) of Aroclor mixtures. Of the total volume of Aroclors sold in the United States for that year, the percentages of the market for each of the Aroclors were: Aroclor 1016, 64%; Aroclor 1242, 17.9%; Aroclor 1254, 17.9%; and Aroclor 1221, 0.1%. The estimated, cumulative production and consumption volumes (in millions of pounds) of PCBs in the United States from 1930 to 1975 were: total production, 1,400 (635 million kg); imports, 3 (1.4 million kg); domestic sales, 1,253 (568 million kg); and exports, 150 (68 million kg) (ATSDR 2000).

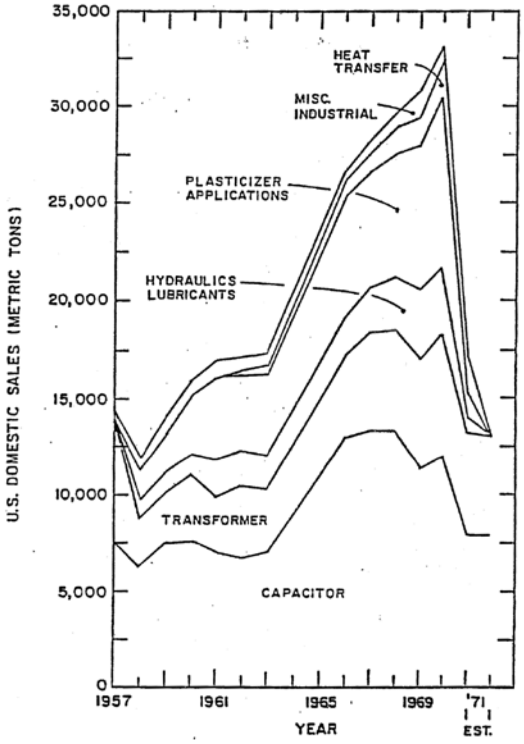

Figure 6. Monsanto Domestic sales of PCBs in the US by use (EPA 1987)

Table 6. Table of Aroclors (EPA 2013a)

CASRN	IUPAC Name
12674-11-2	Aroclor 1016
147601-87-4	Aroclor 1210
151820-27-8	Aroclor 1216
11104-28-2	Aroclor 1221
37234-40-5	Aroclor 1231
11141-16-5	Aroclor 1232
71328-89-7	Aroclor 1240
53469-21-9	Aroclor 1242
12672-29-6	Aroclor 1248
165245-51-2	Aroclor 1250
89577-78-6	Aroclor 1252
11097-69-1	Aroclor 1254
11096-82-5	Aroclor 1260
37324-23-5	Aroclor 1262
11100-14-4	Aroclor 1268
12767-79-2	Aroclor (unspecified)

These Aroclor mixtures can be fingerprinted depending upon the distribution of specific PCB congeners as indicated below (Figure 7) for the Aroclor 1260 mixture.

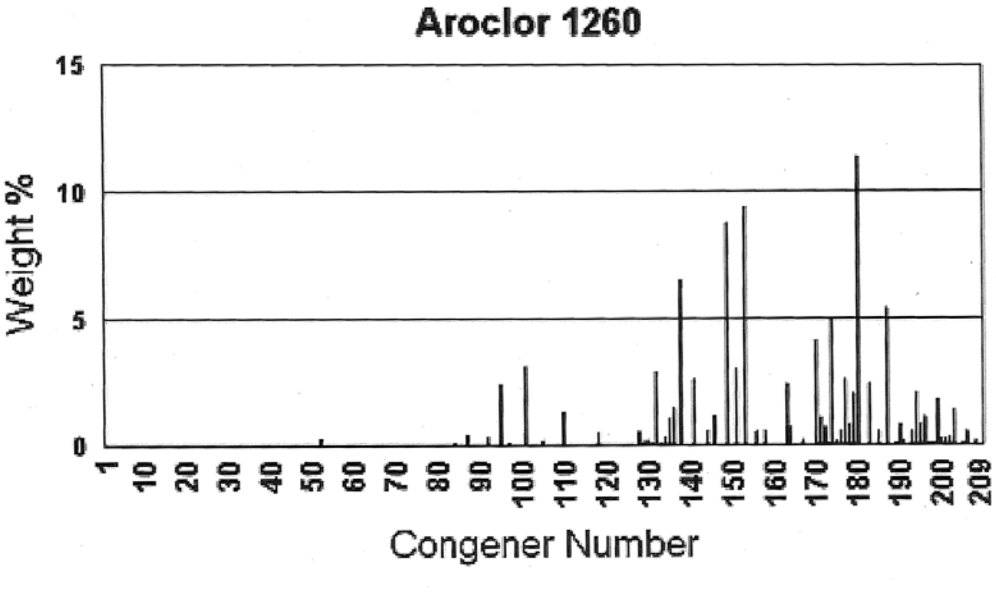

Figure 7. PCB Distribution in Aroclor1260 (EPA 2013e)

Additional fingerprints of common Aroclor mixtures can be found in Appendix C. Fingerprinting is an analytical technique that shows a distinct distribution of chemicals. Each Aroclor mixture has an identifiable distribution of PCB congeners. Aroclor fingerprinting is important as it can point toward potential PCB sources when contamination has been found in the environment. However, due to differential uptake by organisms, differential volatilization, and differential degradation, the congeners present in weathered mixtures in the environment will be different than the original congeners present in the Aroclors.

Analytical Methods

Because of their impact upon human health and the environment, considerable data exists on the presence of PCBs in a wide range of media. Historically, analytical methods were developed based upon the Aroclor fingerprints or values for total PCB concentrations. Recently, more sensitive and detailed congener-specific analyses have been developed to enable more detailed study of PCBs in the environment. PCBs are regulated under the Toxics Substances Control Act (TSCA), other Federal regulations (EPA 2013f) and state regulations such as Washington State's Dangerous Waste Regulations (WAC 173-303). Special analytical methods have been developed to meet these regulatory requirements. Methods range from traditional gas chromatography (GC), more recent high resolution GC mass spectroscopy, to new immunoassay techniques.

Numerous methods (Table 7 from National Environmental Methods Index) have been developed to analyze PCBs in a wide range of media using techniques with variable costs and detection levels. Although the list is not complete, it is indicative of the variety and type of methods currently available to test samples for PCBs. In Table 7 “Source” refers to the organization that developed the method, although it may now be required by different regulations.

For the purposes of this CAP, the three most commonly used analytical methods will be discussed in more detail:

- Aroclor methods
- Congener specific methods
- Screening methods

Table 7. Methods developed to test for PCBs in a wide range of media (NEMI, 2013)

Method Number	Source	Method Descriptive Name	Detection Level	Instrumentation	Relative Cost
530021	Abraxis	PCBs by Immunoassay, Lower Chlorinated, Magnetic Particle	5 ppb	IA	$
530011	Abraxis	Coplanar PCBs by Immunoassay, Microtiter Plate	14 ng/L	IA	$
530001	Abraxis	PCBs by Immunoassay, Higher Chlorinated, Magnetic Particle	0.1 ppb	IA	$
505	EPA-NERL	Pesticides and PCBs in Water GC-ECD	N/A	GC-ECD	$$$
525.3	EPA-NERL	Organics in Water Using GCMS	N/A	GC-MS	$$$
508A	EPA-NERL	PCBs by GC-ECD	N/A	GC-ECD	$$$
508.1	EPA-OGWDW/TSC	Chlorinated Pesticides, Herbicides, and Organohalides in Water by GC-ECD	N/A	GC-ECD	$$$
8082A	EPA-RCRA	Polychlorinated Biphenyls (PCBs) by GC	N/A	GC-ECD/ELCD	$$
508	EPA-TSC/NERL	Chlorinated Pesticides in Water Using GC-ECD	N/A	GC-ECD	$$$
ET013	Envirologix	PCB (polychlorinated biphenyl) immunoassay	.3 µg/g	IA	$
A00134	MWI	PCB (polychlorinated biphenyl) in water by immunoassay	.2 µg/L	IA	$
A00134/A00137	MWI	PCB (polychlorinated biphenyl) in soils/sediment by immunoassay	.5 µg/g	IA	$
130.10	NOAA NST	Organic contaminants in marine sediments by GC-ECD	.05 ng/g	GC-ECD	$$$
130.11	NOAA NST	Organic contaminants in marine animal tissues by GC-ECD	.05 ng/g	GC-ECD	$$$
SPMDs	USGS	Passive sampling of organic compounds in water, air, and soils/sediments by SPMDs	N/A	SPMD	$$$$
O-1104	USGS-NWQL	Organochlorine and organophosphorous compounds, dissolved	.01 µg/L	GC-ECD	$$$
O-3104	USGS-NWQL	Organochlorine and organophosphorous compounds, total recoverable	.01 µg/L	GC-ECD	$$$
O-5129-95	USGS-NWQL	Organochlorine Pesticides and Gross PCBs in Bottom Sediment by GC	50 µg/kg	GC-ECD	$$$$
525.2	EPA-NERL	Organics in Water Using GCMS	.11 µg/L	GC-MS	$$$
1668a (Tissue)	EPA-OGWDW/TSC	Chlorinated Biphenyls in Tissue by HRGC/HRMS	.011 ng/g	GC-MS	$$$$
1668a (Water)	EPA-OGWDW/TSC	Chlorinated Biphenyls in Aqueous Samples by HRGC/HRMS	112 pg/L	GC-MS	$$$$
1668a (Soil/Sediment)	EPA-OGWDW/TSC	Chlorinated Biphenyls in Soil, Sediment, and Mixed Samples by HRGC/HRMS	.011 ng/g	GC-MS	$$$$

ECD = Electron capture detector
ELCD = Electrolytic conductivity detector
GC = Gas Chromatography
HRGC = High Resolution Gas Chromatography
HRMC = High Resolution Mass Spectroscopy
MS = Mass Spectroscopy
MWI = Modern Water Inc.
NERL = New England Regional Laboratory
NOAA = National Oceanographic and Atmospheric Association
NST = National Standards and Trends
NWQL = National Water Quality Laboratory
OGWDW = Office of Ground Water and Drinking Water
RCRA = Resource Conservation and Recovery Act
SPMD = Semi-permeable membrane device
TSC = Technical Support Center
USGS = United States Geological Survey

Aroclor detection

EPA developed specific methods to comply with TSCA and other applicable legislation. In order to meet the requirements of the Resource Conservation and Recovery Act or RCRA, EPA developed Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, more commonly known as SW-846 (EPA 2012a). Included in SW-846 are two specific methods for analyzing PCBs in a wide range of media:

- Method 8082A: Polychlorinated Biphenyls (PCBs) by Gas Chromatography
- Method 8275A: Semi-volatile Organic Compounds (PAHs and PCBs) in Soils/Sludges and Solid Wastes Using Thermal Extraction/Gas Chromatography/Mass Spectrometry (TE/GC/MS)

Method 8082A is the more traditionally used as one of the earliest methods developed to meet regulatory requirements and is responsible for much of the legacy data reported as Aroclor mixtures or specific PCB congeners identified in the method. Method 8082A is '… *used to determine the concentrations of polychlorinated biphenyls (PCBs) as Aroclors or as individual PCB congeners in extracts from solid, tissue, and aqueous matrices, using open-tubular, capillary columns with electron capture detectors (ECD) or electrolytic conductivity detectors (ELCD).'* (EPA 2012a) The specific chemicals reported by this method (Table 8) are detected in the parts per billion (ppb) to parts per million (ppm) levels depending upon complexity of sample and matrix involved.

Congener detection

As technology improved and the need for congener specific analysis was identified, Method 1668C (USGS 2010) was developed. Method 1668 was created to analyze PCBs in water, soil, sediment, biosolids and tissue. It provides analytical results for '… *the 12 polychlorinated biphenyls (PCBs) designated as toxic by the World Health Organization (WHO): congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189* [and] *the remaining 197 CBs* [chlorinated biphenyls], *approximately 125 of which are resolved adequately on an SPB-octyl gas chromatographic column to be determined as individual congeners. The remaining approximately 70 congeners are determined as mixtures of isomers (co-elutions).'* (EPA 2010) Method 1668 requires the use of a high-resolution mass spectrometer for detection and, therefore, is considerably more expensive than Method 8082. Method 1668, however, is becoming more common as concerns have been raised about PCBs from non-legacy sources and potential degradation products from legacy Aroclor mixtures. Detection limits for Method 1668 can be in the low part per quadrillion (PPQ) levels in clean water to ppb levels or higher depending upon complexity of sample and matrix involved.

It is important to note that PCB detection methods have improved over time. Current methods provide detailed data on specific congeners while earlier methods provided data on specific PCB mixtures and homologs. This improvement of analytical methods can prove challenging as it is often difficult to compare data over time as the methods do not provide comparable information at similar detection levels.

Table 8. PCBs reported by Method 8082A (EPA 2012a)

Compound	CAS No.	IUPAC #
Aroclor 1016	12674-11-2	-
Aroclor 1221	11104-28-2	-
Aroclor 1232	11141-16-5	-
Aroclor 1242	53469-21-9	-
Aroclor 1248	12672-29-6	-
Aroclor 1254	11097-69-1	-
Aroclor 1260	11096-82-5	
2-Chlorobiphenyl	2051-60-7	1
2,3-Dichlorobiphenyl	16605-91-7	5
2,2',5-Trichlorobiphenyl	37680-65-2	18
2,4',5-Trichlorobiphenyl	16606-02-3	31
2,2',3,5'-Tetrachlorobiphenyl	41464-39-5	44
2,2',5,5'-Tetrachlorobiphenyl	35693-99-3	52
2,3',4,4'-Tetrachlorobiphenyl	32598-10-0	66
2,2',3,4,5'-Pentachlorobiphenyl	38380-02-8	87
2,2',4,5,5'-Pentachlorobiphenyl	37680-73-2	101
2,3,3',4',6-Pentachlorobiphenyl	38380-03-9	110
2,2',3,4,4',5'-Hexachlorobiphenyl	35065-28-2	138
2,2',3,4,5,5'-Hexachlorobiphenyl	52712-04-6	141
2,2',3,5,5',6-Hexachlorobiphenyl	52663-63-5	151
2,2',4,4',5,5'-Hexachlorobiphenyl	35065-27-1	153
2,2',3,3',4,4',5-Heptachlorobiphenyl	35065-30-6	170
2,2',3,4,4',5,5'-Heptachlorobiphenyl	35065-29-3	180
2,2',3,4,4',5',6-Heptachlorobiphenyl	52663-69-1	183
2,2',3,4',5,5',6-Heptachlorobiphenyl	52663-68-0	187
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	40186-72-9	206

Screening methods

In response to a need by industry to test wastes quickly and cheaply, manufacturers developed screening methods to test specific waste types. These methods were reviewed and adopted by EPA into SW-846. Specifically, PCB applicable screening methods listed in SW-846 include:

- Method 9077: Test Methods for Total Chlorine in New and Used Petroleum Products (Field Test Kit Methods)
- Method 9078: Screening Test Method for Polychlorinated Biphenyls in Soil
- Method 9079: Screening Test Method for Polychlorinated Biphenyls in Transformer Oil
- Method 4020: Screening for Polychlorinated Biphenyls by Immunoassay

Method 9077 is *'… used to determine if a new or used petroleum product meets or exceeds requirements for total halogen measured as chloride. An analysis of the chlorine content of petroleum products is often required prior to their use as a fuel. The method is specifically designed for used oils, permitting onsite testing at remote locations by nontechnical personnel to avoid the delays for laboratory testing'* (EPA 2012a). It provides results ranging from 300 to 4,000 parts per million (ppm).

Method 9077, however, tests for total chlorine and cannot differentiate PCBs from other chlorinated species such as chlorinated solvents commonly used in industry. Methods 9078 and 9079 test specifically for PCBs. Method 9078 is '*…used to determine the amount of PCB (polychlorinated biphenyl) contamination in soils such as sand, gravel, loam, sediment, and clay, assuming that PCBs are the sole source of organic halogens in the sample.*' Detection levels range from 2 to 2,000 ppm PCBs. The method provides inaccurate results if other chlorinated species are present and should be used with caution. However, in those instances where PCB contamination is known, it provides a quick and easy method to determine the extent of contamination and is often used as a screening tool to limit the number of samples sent to a laboratory for more detailed analyses.

Method 9079 is '… used to screen hydrocarbon based electrical insulating fluids for polychlorinated biphenyls (PCBs) at preset levels of 20, 50, 100, or 500 μg/g [ppm].' The method is calibrated using Aroclor 1242 as a standard and results for other Aroclor mixtures may vary slightly. Method 4020 is '… a procedure for screening soils and non-aqueous waste liquids to determine when total polychlorinated biphenyls (PCBs) are present at concentrations above 5, 10 or 50 mg/kg.' Method 4020 only works on soils containing more than 0.625 ppm PCBs.

Used correctly, Methods 9078, 9079 and 4020 are specifically designed to help meet regulatory requirements. Simple PCB kits meeting the requirements of these methods include but are not limited to:

- Dexsil® Clor-N-Oil Field Test Kit[3]
- Dexsil® Clor-N-Soil Field Test Kit[4]
- Dexsil® Clor-d-tect Field Test Kit[5]
- EnSys Field Test[6]
- RaPID Assay Field Test[7]

In addition to these wet chemical methods, several simple instrumentation and detection kits are also available to test for PCBs including, but are not limited to:

- Dexsil® L2000DX PCB/Chloride Analyzer System (LP-2000)[8]
- Hach® PCB in Soil Pocket Colorimeter II Test Kit[9]
- Hach® DR 2700™ Portable Spectrophotometer[10]

These field test kits are useful as they allow detection for PCBs in the field by individuals with limited technical knowledge and expertise.

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[3] More information available at: http://www.dexsil.com/products/detail.php?product_id=2, accessed 7/2013.
[4] More information available at: http://www.dexsil.com/products/detail.php?product_id=4, accessed 7/2013.
[5] More information available at: http://www.dexsil.com/products/detail.php?product_id=29, accessed 7/2013.
[6] More information available at: http://www.tttenviro.com/store/ensys, accessed 7/2013.
[7] More information available at: http://www.tttenviro.com/store/rapid-assay, accessed 7/2013.
[8] More information available at: http://www.dexsil.com/products/detail.php?product_id=13, accessed 7/2013.
[9] More information available at: http://www.hach.com/pcb-in-soil-pocket-colorimeter-ii-test-kit/product-parameter-reagent?id=7640220978, accessed 7/2013.
[10] More information available at: http://www.hach.com/dr-2700-portable-spectrophotometer/product?id=7640439006&callback=bp, accessed 7/2013.

PCB Uses and Sources

Legacy

Historically, PCBs were used in closed systems such as electrical transformers and capacitors, partially closed uses such as heat transfer and hydraulic systems, and open systems such as surface coatings, adhesives, plasticizers, inks, insulating materials, and pesticides (UNEP 1999). PCBs were valued for their stability, inability to conduct electricity and anti-microbial effects. 60% of worldwide and 77% of US production was used in the production of transformers and capacitors and total worldwide production from 1929 to 1989 is estimated at 1.2 million tons (Tanabe 1988).

PCBs were intentionally added to some products in open applications where the PCBs are in direct contact with the environment and may be transferred from the product into the environment. Plasticizers were the most common use of PCBs in products such as PVC (polyvinyl chloride), neoprene and other chlorinated rubbers. PCBs have also been used in paints and surface coatings as flame retardants and adhesives as plasticizers (UNEP 1999). PCBs were often added to caulk and paint in the field at varying amounts.

Current levels in the environment are due to cycling of PCBs from these historical uses with additional releases of PCBs from legacy uses and new inadvertently produced by-products of chemical manufacture. Specific Aroclor mixtures were often used in specific applications (Table 9). Companies have found alternatives for most PCB uses.

Table 9. Historical Aroclor Uses (from ATSDR 2000)

End Use	**Aroclor**								
	1016	1221	1232	1242	1248	1254	1260	1262	1268
Capacitors	•	•				•			
Transformers				•		•	•		
Heat transfer				•					
Hydraulics/lubricants									
Hydraulic fluids			•	•	•	•	•		
Vacuum pumps					•	•			
Gas-transmission turbines		•		•					
Plasticizers									
Rubbers		•	•	•	•	•			•
Synthetic resins					•	•	•	•	•
Carbonless paper				•					
Miscellaneous									

End Use	Aroclor								
	1016	1221	1232	1242	1248	1254	1260	1262	1268
Adhesives		•	•	•	•	•			
Wax extenders				•		•			•
De-dusting agents						•	•		
Inks						•			
Cutting oils						•			
Pesticide extenders						•			
Sealants/caulks						•			

Inadvertent Generation in New Products

PCBs may be found as contaminants in a wide range of chemical processes involving chlorine and can be found in recycled materials contaminated with PCBs. As part of 1984 TSCA rulemaking on PCBs the EPA identified about 200 chemical processes that may inadvertently create PCBs and narrowed the list to 70 chemical processes that are likely to contain PCBs as contaminants from manufacturing processes (Panero *et al.* 2005, see Appendix D for list). Most of these chemical processes have not been evaluated to determine if PCBs are actually a reaction byproduct and present in the final product. In addition there are other processes that may inadvertently generate PCBs that are not on this list. Nor have these processes been analyzed to determine how inadvertently generated PCBs enters the consumer supply chain.

Recent studies on PCBs from pigment manufacturing have shown that PCBs can still be found in products. Many of these products contain PCBs as an impurity created during the production process. Inadvertent sources include contaminants or byproducts from manufacturing processes using chlorinated compounds either as a reaction component or solvent. As shown in Table 10, PCBs have been found in various pigments at substantial levels (EPA 1982b).

Table 10. PCBs congeners found in specific pigments (EPA 1982)

PCB Congeners	Pigment	Levels found (µg/g or ppm)
PCB-11	Diarylide yellow	70
PCB-209	Phthalocyanine green	40
Mix of penta- and hexa-	Phthalocyane blue	90*

*Total of PCB congeners

According to one of the rules created by EPA to implement TSCA (49 FR 28172) products may contain low levels of PCBs if the certain conditions are met (see section on Regulations).

Over the last few years, researchers have begun to test consumer products for the potential presence of PCBs. Numerous organic pigments and dyes exist that may contain PCBs as an unintentional byproduct including diarylides (yellow and orange), naphtharylamides (oranges and reds), phthalocyanines (blue), and basic dye complex pigments (reds, violets, blues and greens) (Christie 2013). In general pigments are insoluble in their application medium and dyes are soluble, with inks mostly being used for textile coloration and pigments having broader uses (Christie 2013, Guo *et al.* 2014). Many of these pigments fall into the broad category of azo compounds. An azo compound contains one or more double-bonded nitrogen atoms (R-N=N-R′) where R and R′ are organic additions with varying degrees of complexity. Azo compounds are very efficient at absorbing light and emitting the radiation in specific wavelengths, thereby providing specific colors. Chlorinated compounds are often used in azo pigments as they can greatly increase the lifetime of the resultant product.

Hu and Hornbuckle (2010) conducted sampling of consumer paints containing specific azo (yellow) and phthalocyanine (blue and green) organic pigments and found PCB levels ranging from 2 to 200 ppb in 15 of 33 consumer paints tested. PCB-11 is also found in printed materials (Table 11) from various locations around the world (Guo *et al.* 2014).

Table 11. PCB-11 worldwide concentrations from printed materials

Printed Material (Country)	**PCB 11 concentration (ng/g or ppb)**
Black and white printed newspaper (Georgia)	1.6
Black and white printed newspaper (Moldova)	9.7
Black and white printed newspaper (China)	15
Color newspaper (Georgia)	6.5
Color newspaper (Moldova)	16
Food packaging box (Czech Republic)	6.8
Food packaging box (Ukraine)	5.0

As an example of dyes contaminated with PCBs, diarylide yellow comprises approximately 25% of the 250 million tons of organic pigments produced yearly worldwide (Rodenberg 2012) and testing has shown PCBs and especially PCB-11 are produced during pigment manufacture. PCB-11 is part of the structure of diarylide yellow (Figure 8) as indicated in the red box. PCB-11 can be produced either as a byproduct during the manufacturing process or from degradation of the pigment.

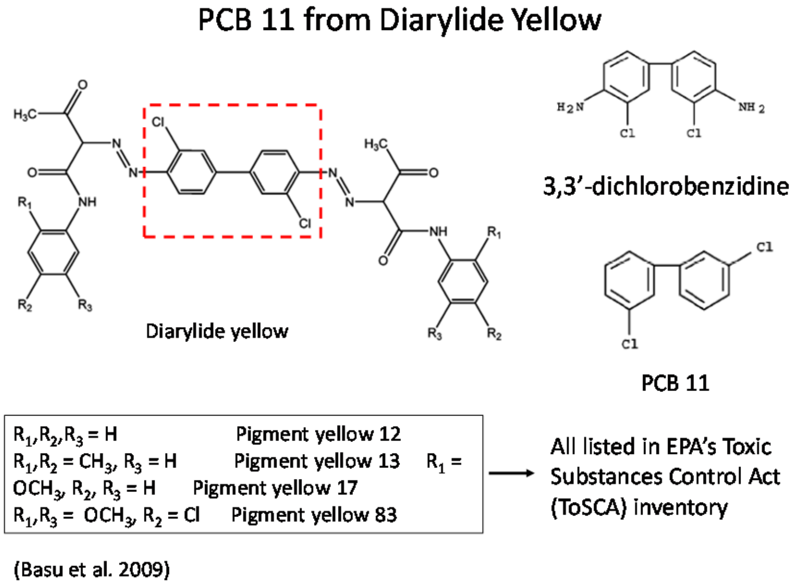


Figure 8. Diarylide yellow and PCB-11 (Rodenburg, 2012)

In addition to PCB-11, purification of the inorganic pigment titanium dioxide (TiO_2) produces larger molecular weight PCBs as a byproduct (Rodenburg 2012). Chlorine is reacted at high temperatures with titanium dioxide (TiO_2) ores containing other metal oxides such as rutile (TiO_2) or ilmenite ($FeTiO_3$) to form titanium tetrachloride ($TiCl_4$) which as a liquid is easily collected. $TiCl_4$ is then reacted with oxygen to make pure TiO_2 (UNEP 2007). During this product process, the larger molecular weight PCBs are created as a reaction byproduct.

Titanium dioxide can also be produced by a sulphate process that does not generate PCB contamination. The sulfate process uses 2.4-3.5 tons of concentrated sulfuric acid (H_2SO_4) per ton of titanium dioxide and the process creates large amounts of acid waste that must be further treated. The chloride process does not generate spent acids and, therefore, creates less waste to be dealt with. (UNEP 2007)

Research is continuing on alternatives to the organic azo pigments. The main challenges faced with replacements (Christie 2013) are:

- Required color performance
- Required degree of transparency or opacity
- Level of fastness or permanence to light, solvents, heat, chemicals, etc. demanded by specific applications
- Cost effectiveness
- Acceptable toxicological and environmental profile.

Research is continuing and alternatives have been identified which appear to address many of these concerns (Christie 2013).

Combustion

Lastly, PCBs are formed through incomplete combustion of products containing carbon and a chlorine source (ATSDR 2000). Given the widespread use of chlorinated compounds such as polyvinylchloride for packaging, tubing, and other applications, incomplete combustion forms a wide range of halogenated compounds such as chlorinated dioxins and furans and PCBs. Most municipal incinerators are not effective in destroying PCBs and it is recommended that PCB-contaminated waste be burned at temperatures above 1,100 degrees Celsius and that care is taken with the temperature, residence time and turbulence of the waste in order to guarantee complete combustion (UNEP 1999). There is only one municipal solid waste incinerator in Washington.

Methods of Manufacturing

PCBs were first mentioned in a publication in Germany in the 1880s. The Swann Chemical Company in Anniston, Alabama was the first US company to manufacture PCBs commercially by bubbling benzene through molten lead to create biphenyl with subsequent chlorination of the biphenyl. Monsanto purchased the Swann Chemical Company in 1935 (Erickson and Kaley 2011).

Much has been written about the methods in which PCBs were manufactured (Panero *et al.* 2005, ATSDR 2000, Pomerantz 1978). Similar methods were used to manufacture PCBs with the main variable being the starting materials of biphenyl and naphthalene. The manufacturing process for Aroclors involved the *'… chlorination of biphenyl with anhydrous chlorine in the presence of a catalyst, such as iron filings or ferric chloride. The degree of chlorination, which determines the nature of the Aroclor, was controlled by the chlorine-contact time (range, 12–36 hours) in the reactor.*' (ATSDR 2000)

Once the manufacturing process was complete, '*The crude product [was] blown with air, and a small amount of lime … added to remove hydrogen chloride and ferric chloride. The resulting chlorinated mixtures [were] batch-distilled to remove color and traces of hydrogen chloride and ferric chloride'* (HSDB 2013).

PCBs were also created using naphthalene which was *'… reacted to varying degrees with chlorine to produce a number of compounds designated by various trade names such as* ***Aroclor****'* (HSDB 2013).

Environmental Transformation and Degradation

Although very stable in the environment, the major pathways for degradation (ATSDR 2000) are:

- Vapor phase degradation with hydroxyl radicals
- Photolysis in water
- Aerobic biodegradation (preferentially less chlorinated congeners)
- Anaerobic microbial degradation (more highly chlorinated congeners favored)

PCBs in the atmosphere undergo complicated reactions (Figure 9) primarily with hydroxyl radicals created when water absorbs sunlight and separates into hydroxyl (•OH) and hydrogen (•H) radicals. Reactions with hydroxyl radicals are most prevalent. A radical is an atom or chemical that has a net charge of zero (neither negative nor positive) but has less than the preferred number of electrons in its outer shell. This instability causes a radical to be very reactive (ATSDR 2000).

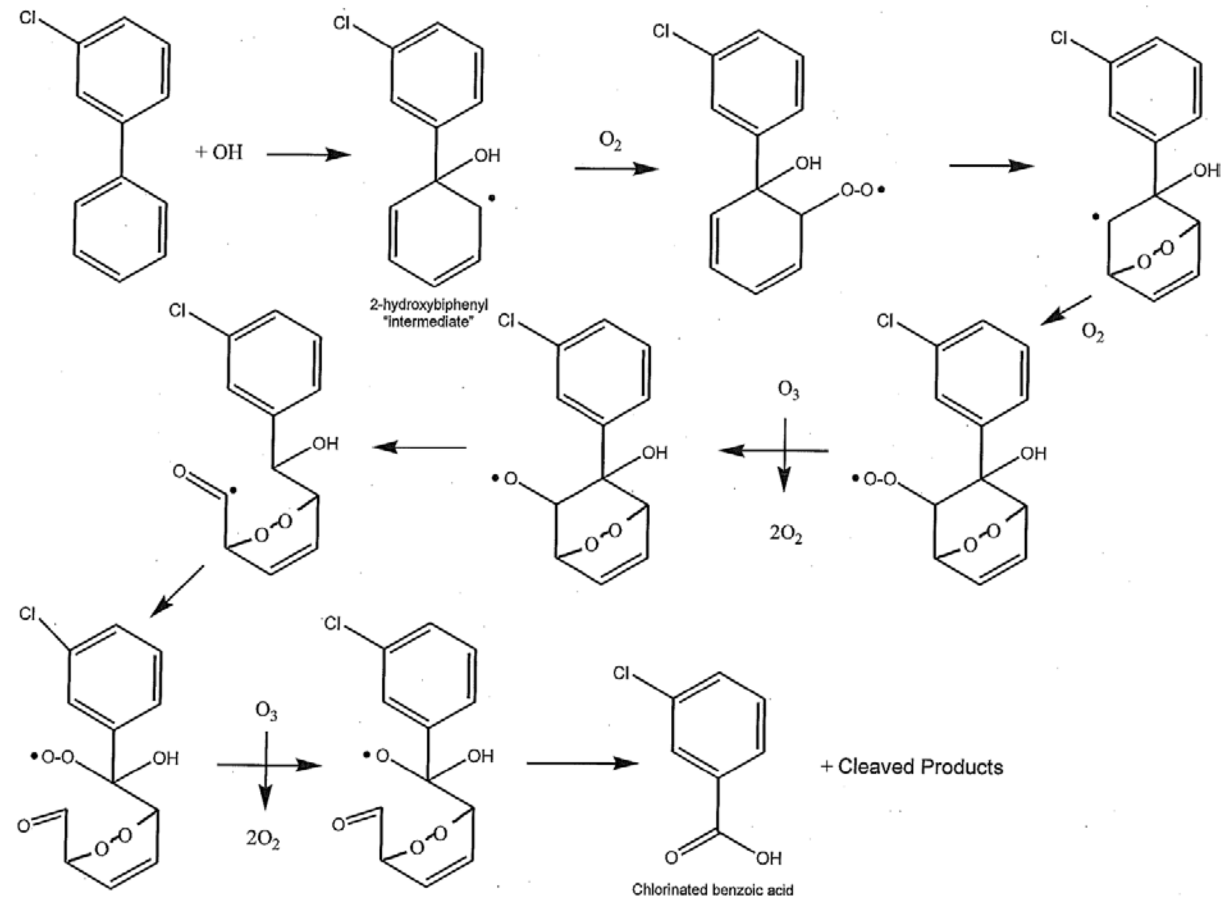
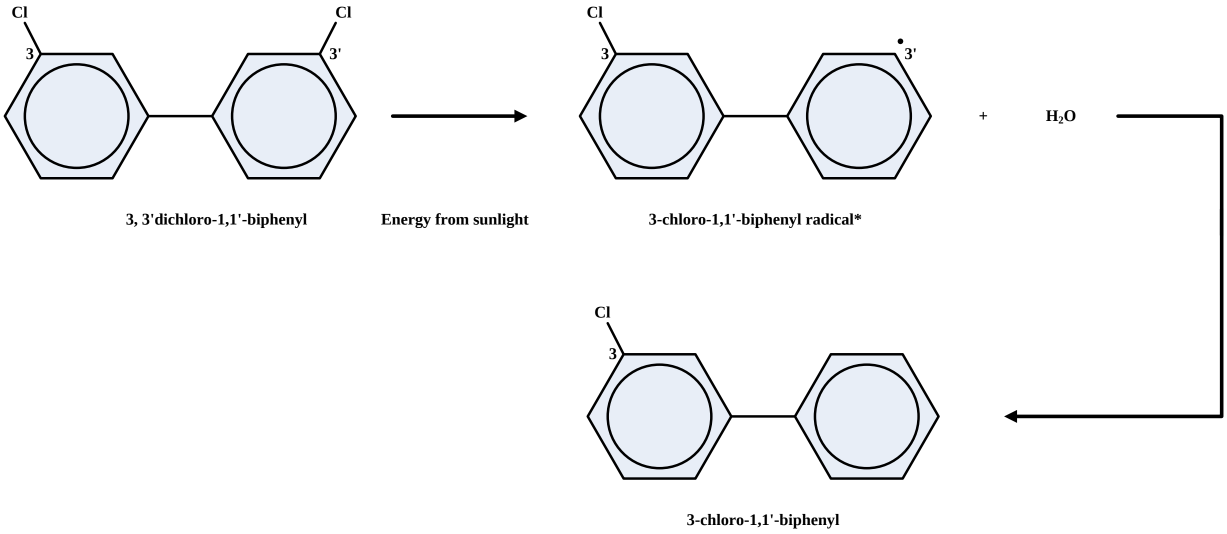


Figure 9. Hydroxyl photo-degradation pathways for PCBs in air (ATSDR 2000)

In water, photolysis is the primary pathway for degradation as other more common reaction mechanisms such as hydrolysis and oxidation do not appear to contribute substantially. In these reactions, a carbon to chlorine bond absorbs energy from sunlight and separates into PCB and chlorine radicals. The PCB radical reacts with water forming a stable PCB compound but with one less chlorine (Figure 10). This reaction is particularly important for the larger PCBs as the more chlorines present, the easier it is to cleave a carbon to chlorine bond. In large PCB molecules, cleavage occurs preferentially on the ring with the most carbons. (ATSDR 2000)



*Note: Although the radical is shown on the 3' position, the electron is actually dispersed throughout the benzene ring.

Figure 10. Photolysis of PCB-11

In sediment and soil, no abiotic process is known that significantly degrades PCBs. PCBs, however, have been found to degrade readily in both aerobic and anaerobic conditions. Both bacterial and fungal species have been shown to biodegrade PCBs using aerobic processes. Because of size restrictions, PCBs with 1 to 4 chlorine atoms are most likely to be degraded under aerobic conditions via a two step process (Figure 11). First, one of the two benzene rings is oxygenated and separated from the other ring. The remaining benzene ring is left as a chlorobenzoic acid. This combined process is called cometabolism.

After cometabolism has occurred, the remaining chlorobenzoic acid is further broken down into water and carbon dioxide (mineralization) in a series of reactions that continually add oxygen to the compound. Aerobic biodegradation of PCBs also occurs primarily in soil and surface sediments. Interestingly, PCBs with fewer chlorine atoms (1-3) degrade faster than those with more chlorine atoms. This causes a fractionating effect where less chlorinated species biodegrade first while those with higher levels of chlorine atoms are left behind for long-term build up in the environment. (ATSDR 2000)

Anaerobic degradation of PCBs is a much slower process compared with aerobic degradation and occurs primarily by reductive dechlorination where chlorine atoms are removed one after the other from a PCB molecule. At least eight distinct and complicated anaerobic pathways have been identified which may occur alone or in combination. Different pathways may favor chlorine in specific positions on the PCB molecule. (ATSDR 2000)

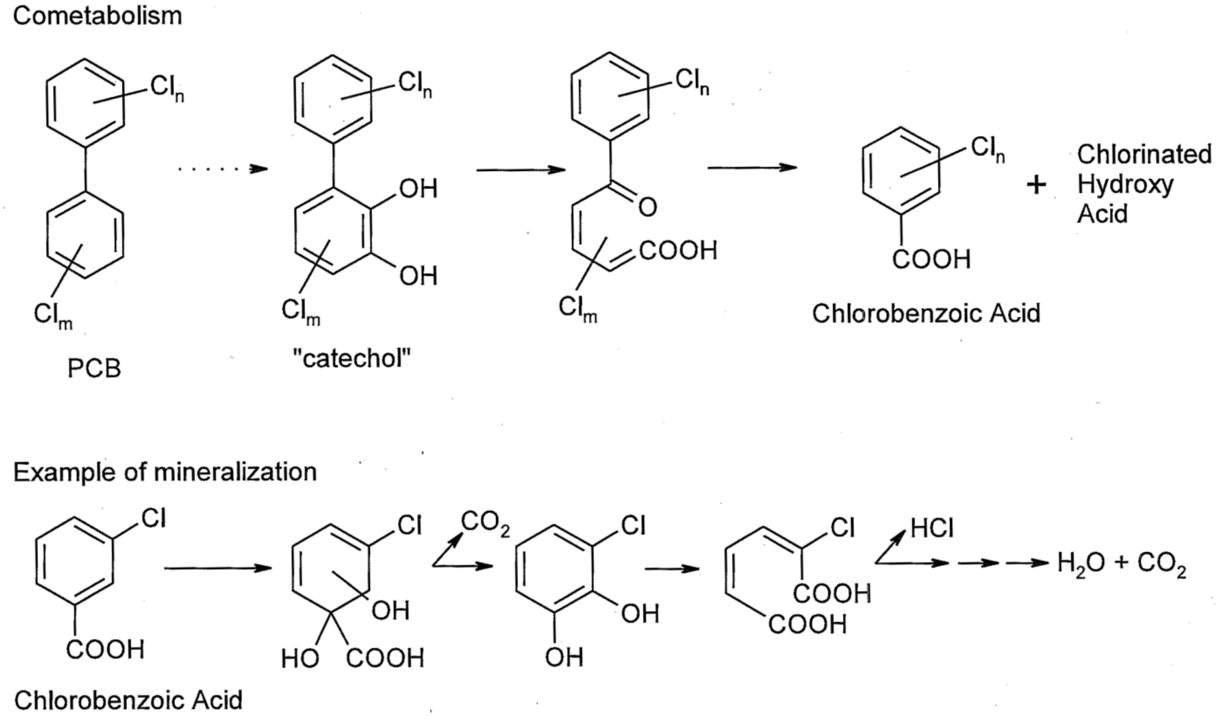


Figure 11. Pathways for Aerobic Degradation of PCBs (ATSDR 2000)

Production, Uses, and Releases

According to the PBT Rule (WAC 173-333) chemical action plans (CAPs) must include a section on “production, uses and releases” that contains information on the production of the chemical and estimates on the amount of the PBT used and released from all sources or activities in Washington.

From 1929 to 1979 the production of PCBs in the US was approximately 1.4 billion lbs (600,000 metric tons), with the largest use for electrical equipment (EPA 1997a). Monsanto, the primary manufacturer of PCBs in North America, voluntarily limited production to certain Aroclors in 1971 (ATSDR 2000) and commercial production was stopped by 1979 under TSCA. Washington’s portion was estimated based on population size to give an estimate of the expected uses in Washington State.

Table 12. Industrial Uses of PCBs (1929-1975) from EPA 1997

PCB Use	Pounds (millions)	Percentage of Total	Washington’s portion (millions of pounds)	Washington’s portion (metric tons)
Capacitors	630	50.3%	13	5,700
Transformers	335	26.7%	7	3,040
Plasticizer uses	115	9.2%	2	1,040
Hydraulics and lubricants	80	6.4%	2	730
Carbonless copy paper	45	3.6%	1	410
Heat transfer fluids	20	1.6%	0.4	180
Petroleum additives	1	0.1%	.02	9
Miscellaneous industrial uses	27	2.2%	.5	250
TOTALS	1,253	100.0%	25	11,400

EPA defines transformers and capacitors as closed uses. There are partially closed uses, such as hydraulic fluids, heat exchange fluids, and gas pipelines. There is a much larger variety of open uses as detailed in Table 13. In closed sources PCBs are contained, barring accidental spill or leakage. In partially contained sources PCBs are partially contained and there is some exposure to the environment. In open sources PCBs are exposed to environment with no containment.

Table 13. Examples of legacy uses of PCBs

Class	US consumption	Examples
Closed	75%	Industrial scale transformers, capacitors, voltage regulators
		Fluorescent light ballasts
		Consumer electrical items (fridges, televisions, washing machines)
		Manufacturing machinery (capacitors, transformers, associated switchgear)
Partially closed	10%	Hydraulic fluids
		Heat exchange fluids
		Gas pipelines
Open	15%	Plasticizer in paints, resins, synthetic rubber, surface coatings, wax
		Sealants, waterproofing compound, glues and adhesives
		Caulking compounds
		Pesticide extenders
		Pigments and dyes
		Carbonless copy paper
		Microscope immersion oil
		Sound proofing materials
		Window glazing

We do not have enough information to estimate the historic use of PCBs in all of these applications or how much is still in use in Washington.

We cannot estimate the amount of PCBs currently in Washington State from partially closed applications, i.e. hydraulic fluids, heat exchange fluids, and gas pipelines. Hydraulic fluids containing PCBs were used in industrial applications that required heat and/or fire resistance. From 1929 to 1975 about 6% of PCBs produced were used for hydraulic fluids and lubricants (EPA 1997a). About 2% of PCBs produced were used heat transfer fluids (EPA 1997a) during the same time period. PCB-based oils were also used in gas transmission compressors. The compressors were used to move natural gas through thousands of miles of pipelines across the U.S. PCBs were also used as a fine mist into underground metal gas pipes to slow corrosion and lubricate the pipelines. PCBs remain in the pipelines until remediated, contributing to environmental releases through leaks and spills.

Closed Legacy Uses

Transformers and Large Capacitors

PCBs have not been manufactured in the US for use in transformers and capacitors since 1979. Although many PCB-containing transformers have been retired, some remain in use. The estimated lifetime of transformers may be as long as 85 years and 20 years for capacitors (Ecology 2011b). While transformers and capacitors are considered “totally enclosed” under TSCA, there are leaks and spills from such equipment until it is retired and replaced.

Federal regulations classify transformers into three groups:

1. *PCB transformers* with > 500 ppm PCBs.
2. *Contaminated transformers* with 50-500 ppm PCBs.
3. *Non-PCB transformers* have less than 50 ppm PCBs.

Transformers are used to transform electricity from one voltage to another through electromagnetic induction. For example, they are used to convert a power generator’s low-voltage electricity to higher voltage levels for transmission or to convert high voltages to lower voltages at the end user. Examples include pole-mounted, pad-mounted, and underground distribution transformers and larger transformers at substations. Utilities operated about 80% of mineral oil transformers (Panero *et al.* 2005). Transformers are also found in institutional, commercial, or other private facilities, including schools, mines, and railways.

Capacitors are passive electronic components used to store energy. They have many uses and come in many different sizes. This section includes large capacitors and small capacitors are discussed in the following section.

The size of transformers and capacitors vary and the amount of PCBs per unit also varies (see side bar for regulatory classification and the regulations section for more information). Mixtures of PCBs were marketed under different names in different areas. Askarel was the trade name used in the US for the blend of PCB and trichlorobenzene used for transformers. Askarel transformer fluid was typically 60-70% PCB by weight. Other transformers used mineral oil as the dielectric fluid. Transformers that were manufactured after 1979 are certified to be PCB-free by the manufacturer. Prior to that date some mineral oil transformers were contaminated with PCBs, often during manufacture when the same equipment was used for both Askarel and mineral oil fluids.

Capacitors were typically filled with nearly pure PCB oil and the largest capacitors contained as much as 35 kg PCB (Ecology 2011b). The typical large capacitor contained 31 lbs (14 kg) of PCBs (Federal Register Vol 47, No. 78).

A 1987 EPA report on sources of PCBs includes accidental release estimates from a 1982 study by the Edison Electric Institute and the Utility Solid Wastes Activity Group (USWAG/EEI) in response to an order issued by the US Court of Appeals for the District of Columbia Circuit. The

EEI/USWAG study gathered survey data from 98 of the 100 largest utilities on leaks and spills. It also estimated the number of pieces of equipment and concentrations of PCBs in the equipment based on data from utilities (USWAG/EEI 1982). This is the only study on leaks that was identified.

Estimate in Washington

An earlier report by Ecology overestimated PCBs in transformers and large capacitors in the Puget Sound basin (Ecology 2011b) in several ways. The earlier estimate relied on an EPA database of registered PCB transformers that was not up to date, estimates of unregistered PCB transformers, an assumption that the PCB transformers in Washington are Askarel transformers with 60% PCBs, and the leakage rates did not take into account the lower concentrations of PCBs in transformers currently in use. Conversations with public and private utilities in Washington, non-utility users of PCB transformers, and other experts led to much lower estimates here.

It is not appropriate to use national estimates or estimates from other regions for Washington State. Compared to other regions of the country, public utilities in Washington State have been the most progressive in testing equipment for PCBs and disposing of equipment with PCBs (Mark Pennell, personal communication).

Transformers

There are 252 registered transformers in the EPA PCB Transformer Registration Database with 121,053 kg of PCB oil in Washington (Appendix F). These are PCB transformers (>500 ppm) that were required to be registered with the EPA in 1998. The regulations do not require EPA to update the database when PCB transformers are taken out of use. We were able to contact most of the parties who registered transformers and found that most of the transformers had been disposed of (Table 14).

Table 14. PCB transformers in use in Washington

Still in use	**14**
Disposed of	228
Unknown	10
Total	252

The PCB transformer registry does not reflect the actual number of PCB transformers still in service and no current inventory of PCB equipment exists in the US (EPA/EC 2009). The EPA states that the database is “not particularly useful for determining the amount of PCB equipment that is remaining in service” (EPA/EC 2009). Various attempts have been made to estimate the number of units remaining in use. The Great Lakes Binational Toxics Strategy 2009 Biennial Report (EPA/EC 2009) estimates that 64,312 PCB transformers remained in use throughout the US while there are about 14,150 registered transformers in the EPA database. Scaled down from the national to the state based on 2010 population, an estimated 1,401 transformers remained in use in Washington in 2007. This estimate assumes that about 80% of the PCB transformers still in use were not registered with EPA. Based on conversations with public and private utilities in Washington, there is not that much unknown equipment in use. A more reasonable estimate would be about 20% of transformers are unknown and never registered. Some utilities know the PCB concentration of all their transformers.

Using the 14 known PCB transformers still in use from the EPA database, adding an additional 20% results in an additional three PCB transformers still in use in Washington. If the other 10 registered PCB transformers whose status is unknown are all still in use, the total number of PCB transformers (> 500 ppm PCB) in Washington could be as high as 27, including the additional 20% of unknown and never registered PCB transformers. Based on the sizes and PCB concentrations of some of the known PCB transformers still in use, we have estimated they each contain about 665 gallons of fluid that is 1500 ppm PCB. Askarel transformers were less than 0.2% of utility transformers nationwide (USWAG/EEI 1982) and were used even less frequently in Washington State. Askarel transformers contain 60-70% PCBs and the more common mineral oil transformers have a much lower concentration of PCBs. When national data was compiled for the USWAG/EEI study (1982) 90% of the mineral oil transformers had <50 ppm PCBs. As utilities have identified and removed PCB contaminated transformers, the average concentration of PCBs has become even lower.

There do not seem to be known Askarel transformers in Washington, but each leak/spill from an Askarel transformer has the potential to release a significant amount of PCBs. The USWAG/EEI study estimated that each leak/spill would release 0.56 - 64.5 lbs (0.25 – 29 kg) of PCBs.

There are still some transformers with lower levels of PCBs, mostly < 50 ppm, that are considered PCB contaminated (50-500 ppm) or non-PCB (1-50 ppm) in the regulations. These have never been required to be tracked or reported. Utilities in Washington have been testing transformers and many have been disposing of transformers with any detectable level of PCBs (>1-2 ppm). Based on the number of these transformers that are known to be still in use by utilities, the amount of older equipment that is untested and has unknown levels of PCBs, there are about 40,000 PCB contaminated (50-500 ppm) and non-PCB (1-50 ppm) transformers in the state that have a concentration of about 25 ppm PCBs. The transformers used in distribution lines on top of poles have about 20 gallons of fluid.

Large Capacitors

Less is known about the number of large PCB capacitors in Washington compared to the number of PCB transformers. Capacitors were never required to be tested or registered. The Puget Sound study (Ecology 2011b) used the national estimate of 1,293,000 large capacitors still in use from The Great Lakes Binational Toxics Strategy 2009 Biennial Report (EPA/EC 2009). Scaled down from the national to the state level based on 2010 population size, an estimated 28,162 large PCB capacitors could remain in use in Washington. However, based on conversations with some of the 61 public and private utilities, there are very few large PCB capacitors remaining in Washington State. PCB capacitors were never required to be inventoried and not all equipment is known, but utilities we asked were confident that all the large PCB capacitors had been removed from 10 to more than 20 years ago. About 15% of large PCB capacitors were owned by non-utilities (EPA 1987) and we have not tried to identify where those were used or if they are still in use. If we estimate 95% of the PCB capacitors have been disposed of, then there would be about 1,400 remaining still in use. We do not have any evidence for which non-utilities in Washington had PCB capacitors or how many of those capacitors are still in use. The estimate that 5% remain in use is based on the hypothesis that non-utilities have also removed capacitors over time, but have not removed all of them.

Other equipment not estimated

Utilities have other equipment that historically contained PCBs, such as reclosers, switches, circuit breakers, bushings, etc. This equipment contained much less PCBs compared with the transformers and capacitors (USWAG/EEI 1982). We have not attempted to estimate how much of the old PCB-containing equipment still remains in use. Some utilities have been testing and removing this equipment.

Leakage and Spillage Rates

In the Puget Sound study (Ecology 2011b) the leakage rates were based on PCBs/unit for Askarel transformers, which does not take into account the lower concentrations of PCBs in transformers currently in Washington.

The USWAG/EEI study (1982) found about 2% of all transformers and 0.77% large capacitors had moderate leaks or spills each year. The study includes lower rates for equipment that had > 50 ppm PCBs. They did not include equipment with < 50 ppm PCBs that is considered non-PCB in federal regulations, but we are including that equipment here. The average amount of PCBs leaked/spilled per event was 0.00004 – 0.005 lbs (18 mg – 2.27 g) for mineral oil transformers and 2 – 17.1 lbs (0.9 – 7.76 kg) for PCB capacitors. As mentioned earlier, the average amount of PCBs per leak/spill for Askarel transformers was 0.56 - 64.5 lbs (0.25 – 29 kg) of PCBs.

Leaks from transformers and large capacitors were estimated in San Francisco Bay (McKee *et al.* 2006) and NY Harbor (Panero *et al.* 2005). Both of these studies relied on the EPA transformer database that is not accurate for Washington.

This results in a total annual release estimate of < 2 kg for transformers and 10-80 kg for capacitors in Washington State (Table 15).

Table 15. Release estimate for transformers and capacitors

Equipment Type	PCB concentration	Number of units	Reservoir	PCB spill/leak rate (annual)	PCBs released per spill/leak (kg)	Annual PCB release
Transformers	>500 ppm	14 - 27	100-200 kg	2%	0.000018-0.00227	5 mg – 1.2 g
	1-500 ppm	40,000		2%		14 g- 2 kg
Large Capacitors	100 %	1,400	20 metric tons	0.77%	0.9- 7.76	10-80 kg

There is uncertainty in the number of electrical units still in use and the older data on leakage rates may not reflect current operating conditions. The estimates do not account for spill response, thus actual amounts of PCBs released to the environment may vary. Indoor spills in particular are likely to be contained and cleaned up. Additional emissions from direct volatilization from equipment are likely, but not estimated due to lack of information.

Opportunities for Reduction

- Status quo
  - 1998 EPA registry for known transformers > 500 ppm
  - Voluntary removal
- Develop a state inventory of equipment that includes the number of units and the amount of PCBs.
- Require utilities and other owners of transformers, capacitors, and other electrical equipment to develop and implement a plan for removal.
- Require complete change out to remove old units (with proper disposal) by a certain date.

Based on conversations with public and private utilities in Washington, they have been actively testing and removing equipment with PCBs beyond what is required by federal law. Several utilities in Washington (personal communication) and other states (Panero *et al.* 2005) use serial numbers of transformers to identify additional transformers that are likely to have PCBs, once one transformer in a batch has been identified as having PCBs. Many utilities are disposing of equipment with any detectable level of PCBs (> 1 ppm).

Small Capacitors

Capacitors containing less than three pounds of PCB oil are considered small capacitors. Small capacitors containing PCBs have been used in a number of items including motors, appliances, and light ballasts. Small capacitors generally contain 45-270g of PCBs in oil and lamp ballast capacitors contain 45-70 g PCBs (EPA 1982 proposed rule in the Federal Register).

Wisconsin found submersible well pumps that contain PCB filled capacitors and in 1992 estimated that 10,000 -15,000 of their 800,000 wells contained capacitors with PCBs (Wisconsin DNR 2001). This only applies to equipment that was manufactured before 1979. Wisconsin has recommendations for owners to identify such pumps and prevent exposure. It is unknown how common this is in Washington. There is a report of one contaminated well from a pump in Whatcom County in 1990 (Seattle Times January 8, 1990).

Estimate in Washington

Several studies estimate the number of small PCB containing capacitors remaining in use that are not light ballasts. In 1992 the University of Illinois estimated that 10-25% of US household appliances contained capacitors with PCBs (Panero *et al.* 2005). EPA (1982b) estimated that historically there were 870 million small capacitors in use throughout the US in 1977 in industrial machines and small appliances. EPA (1987) also estimated a 10% annual disposal rate in 1982. Scaling the national estimate to Washington based on population and applying annual disposal rates of 20% and 10% yields an estimate of 12,000 to 586,000 small capacitors still in use in 2010.

Globally, one third of all PCB production may have gone into lighting ballasts (Ecology 2011b). National estimates of lamp ballasts currently in use include 300 million (US Army 2001) and 500 million (Missoula County 2010). In 1998 EPA, citing an unnamed industry source, estimated that 1 billion small lamp PCB ballasts remained in use in the US (EPA 1998). Scaling this estimate to Washington based on population and applying annual disposal rates of 20% and 10% yields an estimate of 1.7 million to 6.2 million such ballasts still in use in 2010 in Washington.

While we have some information on the number of PCB containing capacitors collected in Washington as hazardous waste or moderate risk waste, the information is not complete enough to use for estimating the number of units still in use.

A range of 12,000 to 6.2 million non-lamp ballast small capacitors and lamp ballasts remains in use in Washington State. While small capacitors may contain 45-270 g PCB per unit, most of the remaining units are likely to be lamp ballasts, which typically contain 45-70 g PCB per unit. For the estimate we used 57.5g PCB/unit as an average. The assumed leakage rate is 4.2 kg/metric tons of PCBs, from the 1982 study on large capacitors (EPA 1982b). This results in an estimate of 400- 1,500 kg for lamp ballasts and 3-150 kg annually for other small capacitors (Table 16).

Table 16. Lamp ballasts and other small capacitors

Equipment Type	Basis for estimate	Number of units	PCBs (kg)	PCB spill/leak rate (annual)	Annual PCB release kg/yr)
Other small capacitors	Scaled from national estimate	12,000-586,000	690-33,695	4.2%	3-150
Lamp ballasts	Scaled from national estimate	1.7-6.2 million	97,750-356,500		400-1,500

There is uncertainty around both the estimate of how many small PCB capacitors remain in use and how much leaks each year. Additional emissions from direct volatilization from equipment are likely, but not estimated.

Opportunities for Reduction

- Status quo
    - Continued use of old capacitors, with expected 10-20% annual disposal/replacement rates
- Educate consumers on which lamps and small appliances are likely to contain PCBs, including appropriate disposal options
- Statewide program to remove small capacitors.
- Remove PCB-containing lamp ballasts in schools.
- Investigate the status of PCB containing materials in schools.

Removal of old light ballasts could be linked to changes for energy efficiency. EPA has national guidance for schools to replace PCB ballasts. NY settled a lawsuit in 2013 after widespread PCB contamination was found in schools and some fires (http://www.epa.gov/region2/pcbs/).

Open Uses

Caulk

PCBs were used in caulk and joint sealants to improve the flexibility, increase the resistance to erosion, and improve adherence to other building materials from the 1950s to the 1970s (Robson *et al.* 2010). Monsanto voluntarily stopped producing PCBs for open uses, such as caulk, in 1971 (ATSDR 2000). While the use of PCBs in open products above 50 ppm was banned in the US effective in 1979 under TSCA, materials that contain PCBs were not required to be removed. The use of PCB-containing caulk was a common practice in the 1970s and caulk formulations changed during the late 1970s (Herrick *et al.* 2004). The studies on PCBs in caulk have focused on buildings built from about 1950 to 1980 to include using up the existing stocks of PCB-containing caulk.

Sealants with high levels of PCBs have been found at varying levels in buildings in several studies. All of the studies found congener profiles consistent with Aroclors 1248, 1254, and 1260. In general, PCBs were used at 5-30% in caulk (Priha *et al*. 2005). PCBs can be lost from caulk through volatilization, as well as wash-off and erosion. PCBs in caulk are associated with higher levels of PCBs in indoor air and dust, and the external soil (Priha *et al*. 2005, Herrick *et al*. 2007, SAIC 2011). Larger amounts of PCBs may be lost during renovations or destruction. Certain removal practices can reduce the amount of PCBs released both to workers and the environment (Sundahl *et al*. 1999).

Herrick *et al*. (2004) found PCBs in schools and other buildings in the Boston area. In 13 of the 24 buildings sampled, PCBs were found at concentrations of 2 to 36,000 ppm. PCB levels in the air ranged from 111 to 393 ng/m^3 and in dust samples up to 81 ppm.

There was a nationwide comprehensive survey in Switzerland (Kohler *et al*. 2005). In this study, 1348 caulk samples from concrete buildings built between 1950 and 1980 were analyzed for

PCBs. Forty-eight percent of the caulk samples contained PCBs, from < 50 ppm up to 550,000 ppm (55%).

The amount of PCBs in caulk was estimated in Toronto, Canada (Robson *et al*. 2010, Diamond *et al*. 2010). This study was based on a smaller sample size and found PCB-containing caulk in 14% of 95 buildings at concentrations of 0.57 ppm to 82 ppm. In Toronto, institutional and commercial buildings and infrastructure (e.g., bridges and parking lots) made of concrete were most likely to have PCB-containing caulk. They detected PCB in caulk in one single family detached home. As expected, they did not detect PCBs in caulk in buildings built before 1945 or after 1980. Based on the number of concrete institutional and commercial buildings built between 1945 and 1980, the size of the buildings, the amount of caulk in a typical building, the percentage estimated to have caulk, and the average concentration of PCBs in caulk, the authors estimated 13 metric tons of PCBs are in caulk in Toronto. The authors further estimated that up to 9% of the PCBs in caulk had been lost via volatilization. The observed congener pattern is consistent with volatilization of lower chlorinated congeners and comparative enrichment of higher chlorinated congeners (Robson *et al*. 2010).

There was also a study of PCB in caulk in the San Francisco Bay area as part of implementing the TMDL (Klosterhaus *et al*. 2011, 2014). This report estimates PCBs in buildings and how much is released to runoff during renovation and demolition. PCBs were detected in 88% of the 25 samples from 10 buildings. The concentrations ranged up to 220,000 ppm (22%) with 40% of the samples exceeding 50 ppm. The median and range were similar to the studies in Boston and Switzerland. The mid-range estimate was 10,500 kg of PCBs in caulk in existing buildings, using a similar method as was used in the Puget Sound Study (Ecology 2011b, Klosterhaus *et al*. 2011, 2014). Information on the number of renovations and demolitions in the San Francisco Bay area each year was used to estimate that 0.04 kg PCB is released each year to stormwater from renovation and demolition. Washington does not have information on the number of commercial buildings of that age and construction type that are renovated or demolished each year.

As part of the Lower Duwamish Waterway (LDW) cleanup in Seattle, Science Applications International Corporation (SAIC) investigated PCBs in old caulk and paint in the LDW (SAIC 2011). This was part of an effort to find additional sources of PCBs in the cleanup area, especially since high levels of PCBs in paint, caulk, and other building materials had been found at the former Rainier Brewery and North Boeing Field. They detected Aroclors in 8 of 17 composite caulk samples from representative buildings with detected concentrations from 3 to 920 mg/kg. The focus was on industrial buildings from 1950-1977. As expected, they did not find PCBs in a sample from buildings built in the 1940s. Surprisingly, they reported another building in the Seattle area that was built in 1989 and contained PCBs in caulk up to 1000 mg/kg. The use of PCBs in caulk in North America has not been reported this late. The number of samples with detectable PCBs (47%) is in agreement with the larger comprehensive study in Switzerland (Kohler *et al*. 2005).

Estimate in Washington

The report on sources of toxic chemicals released in the Puget Sound Basin (Ecology 2011b) estimated 59 metric tons of PCBs are in building sealants in that area with about 110 kg released annually. This estimate was based on the number of existing masonry commercial buildings that were built between 1945 and 1980, the average size of those buildings and the distribution of PCB concentrations in caulk found in the more comprehensive survey by Kohler *et al*. (2005). This is likely to underestimate the amount of PCBs in sealants because it does not consider all uses in buildings, such as around windows, uses in residential buildings, or in other structures, such as bridges and sidewalks. The annual release estimate was based on a release rate coefficient of 0.0018/yr from long term loss rates in Robson *et al*. 2010.

The estimate for the Puget Sound Basin was based on detailed information about buildings in Pierce and Snohomish Counties and then scaled up to the rest of the study area by population. The estimated volume of masonry buildings built from 1945 to 1980 in Pierce and Snohomish Counties was 21,941,562 m^3. To estimate PCBs in caulk for the state we scaled up the volume of masonry commercial buildings that were built between 1945 and 1980 by population, leading to an estimate of 97,702,645 m^3 with 5,373,645 kg of caulk for the state.

The large study in Switzerland (Kohler *et al*. 2005) found 48% of the targeted buildings had PCB- containing sealants. Applying this to the state estimate on sealants leads to 2,573,976 kg of PCB-containing sealants. The PCB concentration ranges from Kohler *et al*. (2005) were applied to the estimated mass of PCB-containing sealants in Washington, yielding an estimate of 87 metric tons of PCBs in sealants in Washington with 157 kg released annually (Table 17).

Table 17. Estimates from caulk

sealant quantity (kg)	sealants with PCBs (kg)	PCB conc bin (mg/kg)	bin mid point	% for each bin	PCB quantity (kg)	Annual releases (kg)
5,373,645	2,573,976	20-50	35	0.121	11	
		50-100	75	0.0772	15	
		100-1,000	550	0.1899	269	
		1,000-10,000	5,500	0.1815	2,569	
		10,000-100,000	55,000	0.2316	32,787	
		>100,000	100,000	0.2003	51,557	
Total				1.0	87,208	157

In addition, PCBs are released into the environment during renovation and demolition of buildings that contain PCBs in caulk and other building materials. In order to estimate this we need to know how many buildings of that age and construction type are demolished or renovated in the state, which we do not know.

Opportunities for Reduction

- Status quo
    - PCBs may be found and remediated during source identification efforts.
- Require removal or remediation of all PCB containing caulks, statewide.
- Develop best practices for demolition and renovation.
- Investigate the status of PCB containing materials in schools.
- Remove or remediate PCB-containing caulk in schools.
- Partner with EPA and federal facilities to identify and remove caulk and other PCB-containing materials.

Many schools in Washington were built when PCBs were used in caulk, lighting ballasts, paint, and other building materials. EPA has information on PCBs in caulk and other building materials that includes how to test for PCBs and how to safely remove PCB-containing materials (http://epa.gov/pcbsincaulk/index.htm). Their outreach has been focused on schools, due to the sensitivity of developing children. There are reports of methods for removing PCBs where more than 99% of the PCBs in caulk were captured following the use of BMPs specifically aimed at preventing PCB releases (e.g., Sundahl *et al.* 1999).

Caulk, other building materials, and other historic uses of PCBs are found on Navy vessels and other military equipment (EPA 2006). This is an opportunity for Ecology to partner with EPA and federal facilities to expand PCB source identification and removal activities.

Inadvertent generation in new products

PCBs are no longer intentionally manufactured in the U.S. and the manufacture, processing, and distribution in commerce of PCBs at concentrations of 50 ppm or greater is not allowed. EPA promulgated a rule under TSCA in 1984 for inadvertent generation of PCBs that are not in closed or controlled manufacturing processes (49 FR 28172). The concentration of inadvertently generated PCBs in products must have an annual average of < 25 ppm, with a maximum of 50 ppm. In addition, EPA required manufacturers with processes inadvertently generating PCBs and importers of products containing inadvertently generated PCBs to report to EPA any process or import for which the PCB concentration is greater than 2 mg/kg for any resolvable PCB gas chromatographic peak. More details on TSCA are in the section on Regulations.

As part of this rulemaking on inadvertently generated PCBs, EPA generated a list of 200 chemical processes with a potential for generating PCBs (Appendix D) and narrowed it to 70 with a high potential to inadvertently generate PCBs. The list does not include every process that inadvertently generates PCBs and not everything on the list inadvertently generates PCBs. In general, PCBs can be produced when chlorine and carbon are present with elevated temperatures or catalysts.

The final rule also includes an estimated annual production of inadvertently generated PCBs of 100,000 lbs (45,400 kg). Scaled to population, Washington's share of that would be about 900 kg a year. Only 11% of the PCBs were estimated to enter products, or 100 kg annually in Washington. As the economy has grown over the last 30 years, the amount of inadvertently generated PCBs may also have grown. The 100,000 lbs was an estimate from a consensus proposal from the Environmental Defense Fund, Natural Resources Defense Council, and Chemical Manufacturers Association (now known as the American Chemistry Council) that included all inadvertent generation of PCBs, without being broken down into how much came from each process. Products that are mentioned include paints, printing inks, agricultural chemicals, plastic materials, and detergent bars. The 1982 economic analysis for this rule mentions 135 manufacturing processes that generate PCBs at less than 50 ppm from a Chemical Manufacturers Association survey. The economic analysis also includes a list from EPA of about 20 "end-products of manufacturing processes in which PCBs are incidentally generated."

In their rule on inadvertent production, EPA specifically mentions surfactants as the component of detergent bars that is likely to contain PCBs. EPA also mentioned PCBs are likely to be in surfactants in skin lotions and creams that are regulated by the FDA. We have no estimate for how many PCBs are inadvertently produced in surfactant.

Reports to EPA on inadvertent generation

As mentioned above, the 1984 rule under TSCA (49 FR 28172) requires manufacturers to report inadvertent generation of PCBs. There are 77 reports for inadvertently generated PCBs from 1994 to present (Table 18). Some information on each report is in Appendix E. There are additional reports included in the docket for related topics, such as requests to produce small amounts of PCBs for research purposes. A lot of the information in the reports has been redacted to remove confidential business information (CBI). In general the reports repeated the federal requirements while stating the company is in compliance and without giving specific information about the concentration of PCBs in the products or the total amount of the products. None of the reports were for facilities in Washington State.

Many reports include a statement that the materials may contain PCBs > 2 ppm, but likely do not and the reporter was being very conservative in reporting anything that might contain PCBs > 2 ppm. The reports assert that no products contained more than 50 ppm or more than 25 ppm for an annual average (which are the limits in rule).

Table 18. Reports to EPA on inadvertent generation 1994-present

Chemical or process	Number of reports
Pigments and dyes	53
GE silicones	8
Vinyl chloride production	3
Unique	6
Unknown	7
Total	77

Some of the reports in Table 18 in the category of pigments and dyes list individual pigments (yellow, red, green, blue violet and orange with Color Index (CI) numbers), some include a general description such as “imported dyes,” while others do not include any specific information, but come from a division of the company such as the “Pigments Division.”

Eight reports are from GE Silicones. There is no additional information on the products.

There are three reports from three different companies regarding vinyl chloride production, one of which was a unique incident involving diesel contamination. Geon stated they are reporting on 740 lbs of PCBs in 62,676,000 lbs of chemical feedstocks used in a vinyl chloride monomer manufacturing facility in Texas. The third report is for incidental PCBs generated in the chlorination step of a process stream to remove an impurity.

There are six reports from six different companies on unique compounds or processes. These reports are for trichlorobenzene manufacture, 2,4,6-Trichlorophenylhydrazine (2,4,6-TCPH), 2,6-Dichloro-4-Nitro Aniline, a pesticide intermediate, chlorothalonil production process, and one report for electrical capacitors. The one report for electrical capacitors also included the information that PCBs were at 3.9 ppm in 134 liters. The report on 2,4,6-Trichlorophenylhydrazine stated the concentration was usually 9-12 ppm.
Seven reports were for unknown compounds or processes. Four of these were completely redacted with a place holder stating there was a report. Two reports redacted the name of the company in addition to the compounds. One report was for two containers of a non-PCB product with 4 and 5 ppm PCBs.

Pigments and dyes

More details on generation of PCBs during manufacturing are provided in the earlier section on Chemistry. PCBs are known to be inadvertently generated in certain pigments and dyes, including diarylides (yellow and orange), naphtharylamides (oranges and reds), phthalocyanines (blue), and basic dye complex pigments (reds, violets, blues and greens) (Christie 2013). PCB-11 is thought to be primarily from pigment production and not from legacy uses of Aroclors (Hu and Hornbuckle 2010, Guo *et al.* 2014), and so is useful as an indication of inadvertent generation of PCBs, especially from pigments. Specifically, the ratio of PCB 11 to a characteristic dechlorination end product, PCB-4, indicates that dechlorination is not a significant source of PCB 11 where it has been examined (Rodenburg *et al.* 2010). PCB-11 has been seen to be strongly correlated with PCBs 35 and 77 (Rodenburg 2014). PCB-77 is one of the dioxin-like congeners.

Hu and Hornbuckle (2010) found PCBs in azo and phthalocyanine pigments, including PCB-11 and higher chlorinated PCBs 206-209. Previously PCB-209 was only thought to be found in ferric oxide as a by-product of titanium dioxide production (Panero *et al.* 2005). PCB-11 and PCB-209 have been found in Washington's environment and animals (Ecology EIM database).

Higher chlorinated PCBs are inadvertently generated during the production of the inorganic pigment titanium dioxide using the chlorine process (UNEP 2007). We were unable to locate estimates on the amount of PCB inadvertently generated in this process.

PCBs have been detected in general consumer products purchased in Washington. Individual congeners were detected between 1 and 45 ppb. Four congeners known to be associated with pigments (PCB 11,206,208, and 209) were selected for the initial study and were tested for in 74 samples from 68 products (Ecology 2014). The products included packaging, paper products, paint and colorants, and caulk. Ecology is in the process of reporting on the results of all the congeners for the same samples. As in previously published work (Hu and Hornbuckle 2010), we also see a wide selection of congeners in the consumer products.

Estimate in Washington

While different researchers have detected PCBs in pigments and consumer products, we don't have a good estimate for how much is released in Washington each year. Panero *et al*. (2005) estimated PCB-11 represents 5-20% of the PCBs entering NY harbor. Guo *et al.* (2014) estimated that between 5 and 7800 kg[11] of PCB-11 are produced worldwide each year from diarylide yellow in 2006. The US market consumes approximately 20% of global organic pigments (Guo *et al.* 2014). Washington is approximately 2% of the US population, which leads to an estimate for Washington's share of PCB-11 from yellow pigment of 0.02 and 31 kg per year. This is the amount of PCB-11 in products, with an unknown amount entering the environment.

The Color Pigments Manufacturers Association (CPMA) estimated that the total annual amount of these pigments (phthalocyanine and diarylide) imported or manufactured in the US is about 90 million lbs (41,000 metric tons). They further estimated inadvertently generated PCBs in these pigments with an upper bound of 1.1 tons per year and a more reasonable estimate of 1000 lbs

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[11] Jia Guo is an author on an earlier paper (Rodenburg et al. 2010) that estimated worldwide production of PCB 11 from diarylide yellow pigment production at 1.5 t in 2006. This estimate was revised in Guo 2013 and Guo et al. 2014.

per year (CPMA 2010). Using the lower annual estimate of 1000 lbs (450 kb), leads to an estimate of 9 kg per year in Washington, that is within the range of the estimate above.

There are permitted releases in Washington State that are pathways for PCBs to get from sources such as pigments in paper and other consumer goods into waterways. Looking at the PCBs in these permitted pathways illustrates that some PCBs from pigments are released in Washington, even thought the permittees are not the source of the PCBs. Paper mills that recycle paper and municipal wastewater treatment plants discharge small amounts of PCBs into Washington waterways. In 2012 the average PCB concentrations in the discharge of two paper recycling mills were 2,520 and 1079 pg/L, respectively. Based on flow rate, the estimated PCB loading for these two facilities is 28 g per year, with 3.8 g being PCB-11. It is suspected that dyes from clothing and other consumer products such as soaps, lotions, and creams are also contributing PCBs to municipal wastewater treatment plants. For example, the Spokane River Source Assessment (Ecology 2011c) estimated that the Spokane waste water treatment plant was discharging 194 mg of PCBs/day.

Opportunities for Reduction

<u>Inadvertent generation</u>

- Status quo
    - Continue to permit products containing less than 50 ppm (with discount factor for mono- and bi-chlorinated biphenyls- see Regulations section) to be sold in Washington.
    - Implement RCW 39.26.280- Preference for PCB free products by state agencies.
- Assess alternatives for pigments and dyes to identify the availability of safer materials.
- Encourage businesses to use alternate processes/materials that do not generate PCBs.
- Conduct research using green chemistry to develop new processes that do not inadvertently generate PCBs.
- Test products to determine the extent of PCBs in products likely to contain PCBs.
- Require labeling to educate consumers on what products contain PCBs and which ones do not.
- Petition EPA to revise the federal regulatory limit on PCBs in products to align with the federal Clean Water Act.

There are many processes that might inadvertently generate PCBs, but not much is known about most of them. If the state doesn't make progress in reducing inadvertent generation of PCBs, permitted facilities might be forced to close or eliminate environmentally beneficial processes (such as recycling), which are undesired outcomes.

Commercial and industrial releases

Toxics Release Inventory (TRI)

The federal Toxics Release Inventory (TRI) includes permitted estimated releases from facilities that discharge from certain industries. The TRI database is authorized under the federal Emergency Planning and Community Right to Know Act to aid in community planning in case of an emergency and to generally inform the public about releases of toxic chemicals.

PCBs are subject to reporting and listed with the general CAS number 1336-36-3 for all PCBs. Because PCBs are PBTs, there is a lower level for reporting and the reporting threshold is 10 lbs.

There are only two reporters of PCBs in Washington on the TRI. Burlington Environmental in King County and Perma-Fix Northwest in Benton County are both hazardous waste treatment and disposal companies. From 2007-2011 they reported an average off-site waste disposal of 25,000 pounds (Table 19).

Table 19. Table of TRI reports from 2007-2011

Year	Reporter	Offsite waste reported (pounds)
2007	BURLINGTON ENVIRONMENTAL INC	485
2007	PERMA-FIX NORTHWEST RICHLAND INC.	14,163
2008	BURLINGTON ENVIRONMENTAL INC	389
2008	PERMA-FIX NORTHWEST RICHLAND INC	710
2009	BURLINGTON ENVIRONMENTAL INC	565
2009	PERMA-FIX NORTHWEST RICHLAND INC	11,869
2010	BURLINGTON ENVIRONMENTAL INC	1,081
2010	PERMA-FIX NORTHWEST RICHLAND INC	61,554
2011	BURLINGTON ENVIRONMENTAL LLC	1,000
2011	PERMA-FIX NORTHWEST RICHLAND INC	31,543

National Emissions Inventory (NEI)

The National Emissions Inventory (NEI) is a comprehensive and detailed estimate of air pollutants from all air emissions sources. The NEI is prepared every three years by the EPA based primarily upon emission estimates and emission model inputs provided by State, Local, and Tribal air agencies for sources in their jurisdictions, and supplemented by data developed by the EPA. According to the most recent NEI for 2008, there were 439 lbs (199 kg) of PCBs released to the air in Washington State from residential waste burning and 0.8 lbs (0.4 kg) released from commercial marine vessels. In addition to these sources, the Spokane Regional Clean Air Agency reported about 1 lb of PCB emitted from the Waste to Energy facility in 2011.

To obtain emission estimates for residential waste burning, EPA applies emission factors to an assumed mass of residential waste burned at the county level across the country. Some of the key assumptions are that residential waste burning only occurs in rural counties, and roughly 28% of the waste generated in these counties is burned in backyard burn barrels. This estimate is very uncertain, but can only be improved with location specific information regarding local compliance with residential waste burning rules.

Summary

Table 20 below summarizes the estimates for uses and sources in Washington State found in this section.

Table 20. Summary of Uses and Releases for Washington State

Source		Historic reservoir	Annual releases (kg/yr)
Closed	transformers	100-200 kg	< 2
	large capacitors	20 metric tons	10-80
	lamp ballasts	100-350 metric tons	400-1,500
	small capacitors	1-34 metric tons	3-150
	other closed uses		unknown
Partially closed			unknown
Open	caulk	87 metric tons	160
	other open uses		unknown
	pigments and dyes		(PCB-11) 0.02-31
	other inadvertent generation		900
	residential waste burning		199
	commercial marine vehicles		0.4

Pathways and Environmental Fate

Current PCB levels represent both historical and ongoing loadings and cycling among environmental compartments. We consider sources to be the original use of the material, such as PCBs in transformers. PCBs move through pathways such as stormwater and expose people and wildlife.

Unfortunately, we don't know where much of the PCBs that were produced prior to 1979 are currently located. For example, small capacitors used large amounts of PCBs, but since they were used in unregulated appliances, we don't know how many are still in appliances in people's homes, how many were disposed of in municipal waste landfills (and how much PCBs have since leaked out of those landfills or volatilized), and how many were disposed of outside of landfills.

Pathways

Assessments of both Puget Sound (Ecology 2011a) and freshwater systems (Ecology 2011c, King Co 2013b) have found the largest pathway for PCBs to reach the aquatic environment statewide is stormwater. Figure 12 shows the estimated loadings to Puget Sound by pathway (Ecology 2011a) and Figure 13 shows the relative stormwater loadings by type of land cover. In the Puget Sound study, we looked at the concentration of PCBs and other chemicals in surface runoff from four land-cover types: commercial/industrial, residential, agricultural, and forest, field, and other undeveloped lands. The concentration of PCBs in surface runoff was higher from commercial/industrial areas, especially during storm events, but the total loading was lower since industrial/commercial lands occupy less area than other land covers. Overall loads from forests accounted for 83% of the load (Ecology 2011g).

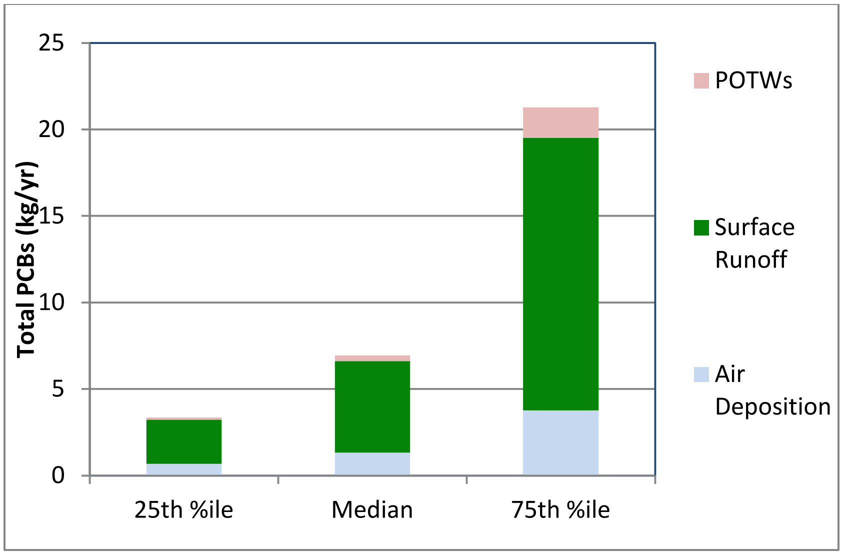


Figure 12. Total estimated PCB loading to Puget Sound by pathway (kg/yr)

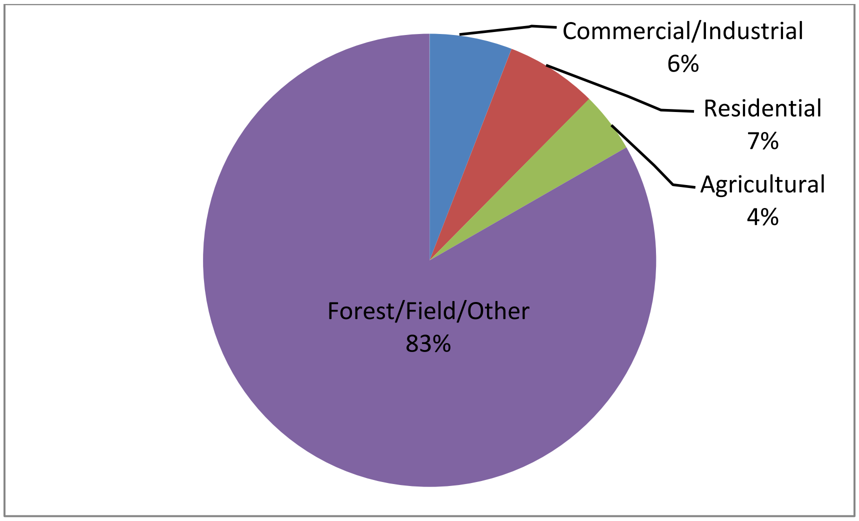


Figure 13: Relative contributions of different land use covers to PCBs in surface runoff in Puget Sound (Ecology 2011g)

Figure 14 shows the relative importance of different pathways in three freshwater systems in Washington. Publically owned treatment works (POTWs) are a smaller pathway in all the systems, with less than 10% of total loading. Direct air deposition was estimated to be the second largest pathway in the Puget Sound and Lake Washington study (Ecology 2010d, King County 2013b).There is a large and variable amount of PCB loading from unknown pathways.

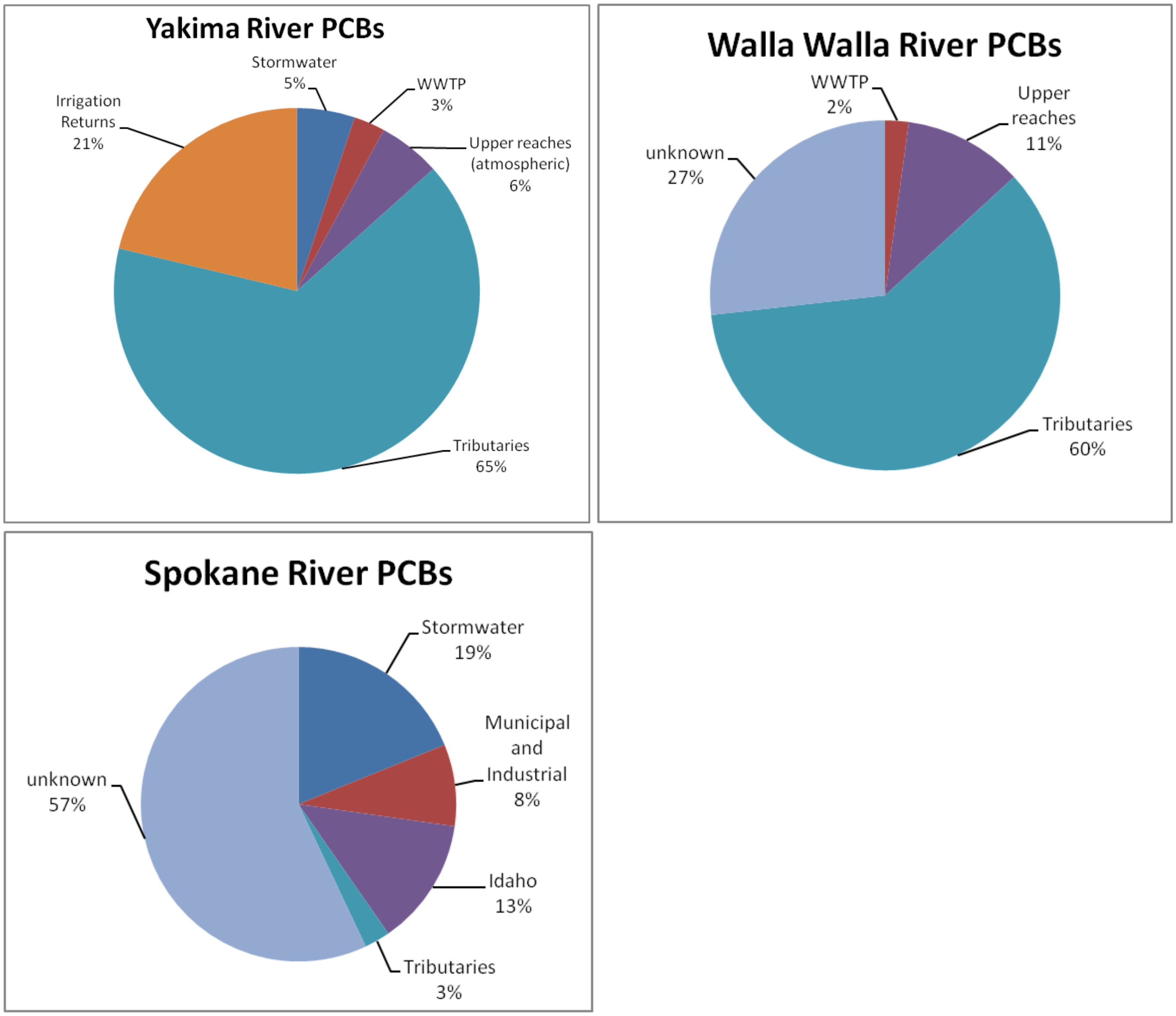


Figure 14. Relative importance of pathways assessed in freshwater systems

Salmon

Pacific salmon returning to spawn are another pathway for PCBs to enter Washington. Salmon have complex life histories and long-range migrations for feeding. The accumulation of PCBs in fish depends on many things including contaminated habitats, which food they eat and the levels of PCBs in food, lipid level, and age. Chinook salmon are 3-5 times more contaminated than coastal Chinook (West 2011). Most (99%) of the final weight of adult Chinook is achieved in salt water, both ocean and Puget Sound, and >96% of the PCBs in adult Chinook accumulated during their marine life history phase (O’Neill and West 2009). O’Neill estimated that 0.265 kg/yr PCBs enters Washington through this pathway (Ecology 2011a). This estimate comes from whole body PCB concentrations for five species of Pacific salmon and their estimated biomass.

Motor oil

The City of Spokane reported measurements of PCBs in motor oil in their 2013 Adaptive Management Plan for Reducing PCBs in Stormwater Discharges from the Wastewater Management Department. The concentration of total PCBs in four samples of motor oil ranged from 14 to 116 ppb with an average of 54 ppb. In the PAH CAP (Ecology 2012a), Ecology estimated that 9,737,812 kg of motor oil is released annually in Washington from drips and leaks and another 1,555,179 kg of used motor oil is released to the environment through improper disposal. Using the average concentration of PCBs in motor oil from sampling in Spokane (54 ug/kg) and the statewide estimate of drips and leaks from motor vehicles and improper disposal of used motor oil in Washington (11,292,991 kg), gives an estimate of 0.6 kg of PCBs per year from motor oil.

PCBs are not created in motor oil, so motor oil is not considered a source here. The PCBs in motor oil are likely contamination from an unknown source. The homologue pattern is different from the PCBs found in sediments from stormwater catch basins in Spokane, with a much larger percentage of mono and dichlorobiphenyls and smaller percentage of higher chlorinated congeners. Of course, the congeners in sediment have been weathered and would no longer match the profile of the original source.

Environmental Partitioning

The estimates we do have for the fate of all the PCBs produced are not current. Newer publications cite estimates in earlier publications. These estimates vary, but they agree that much of the PCBs that were produced up to 1979 are still in use. This is a large reservoir of PCBs that are slowly leaking out into the environment. For transformers in particular, we know that much of the PCBs in transformers have been removed since these estimates were made. Transformers and capacitors were the largest use of PCBs and have been targeted for PCB removal.

In 1997 EPA estimated the inventory of PCBs as of 1977 as “Of the 700,000 [short] tons of PCBs produced, 150,000 tons had been landfilled; 75,000 tons had entered the air, water, and soil; 25,000 tons had been incinerated; and 375,000 tons remained in electrical equipment. The remainder, approximately 75,000 tons, had been exported.”

Converting this 1997 EPA estimate of short tons into metric tons leads to:

- 636,000 Produced (1927-1976)
- 568,000 Used (68,000 exported)

- 340,000 Remaining in use (60%)
- 228,000 Disposal/environment
- 132,000 Landfill (23%)
- 68,000 Environmental media (12%)
- 28,000 Incinerated (5%)

Table 21 shows estimates for the status of PCBs. The estimates in Keeler (1993) for the status of PCBs in the US as of 1982 are similar to those of the EPA above. The Canadian government estimated PCBs in Canada as of 1992 (CCME 1995) and Tanabe (1988) estimated similar percentages worldwide in 1985 (Table 21). All of these estimates include a large percentage of PCBs still in use and a small percentage destroyed by incineration. Unfortunately, we do not have more current estimates of PCB stocks and many of the PCBs that were in use at the time of these estimates have been taken out of use for disposal.

Table 21. Estimates for the status of PCBs (in metric tons)

Status	**US 1977 (EPA 1997)**	**US 1982 (Keeler *et al* 1993)**	**Canada 1992 (CCME 1995)**	**Global 1985 (Tanabe 1988)**
Produced	636,000	640,000		1,200,000
Used	538,000	582,000 (91%)	40,000	1,200,000
Remaining in Use	340,000 (40%)	346,000 (54%)	15,000 (38%)	780,000 (65%)
Landfill/Storage	132,000 (23%)	134,000 (21%)	6000 (15%)	
Environment	68,000 (12%)	70,000 (11%)	12,400 (31%)	370,000 (31%)
Incinerated	28,000 (5%)	19,000 (3%)	6,200 (16%)	50,000 (4%)

Tanabe (1988) also broke down the global PCBs in the environment into different media (Table 22). Not shown in Table 22 is that the largest global reservoir of PCBs is ocean water (while PCBs are not very soluble in water, the vast quantities of oceans worldwide hold more than half of the PCBs in the environment). Table 22 only includes estimates from the terrestrial and coastal waters and not ocean water.

Table 22. Global PCBs from Tanabe 1988 for PCBs on land, rivers and coastal waters

	PCB loads (metric tons)	**percent**
air	500	0.35
river and lakewater	3,500	2.45
seawater	2,400	1.68
soil	2,400	1.68
sediment	130,000	90.85
biota	4,300	3.00
Total	**143,100**	**100**

The estimates from Tanabe 1988 in Table 22 agree well with the model for Puget Sound (Ecology 2009b) and Lake Washington (King County 2013). For Puget Sound it was estimated approximately 97% (1440 kg) of the total mass of PCBs currently in the aquatic ecosystem of Puget Sound is contained in the active sediment layer (top 10 cm), <1% (10kg) is stored in the water column, and <3% (40 kg) is stored in the biota. O’Neill and West (2007) estimated PCBs in biota using PCB concentrations and biomass. Their total estimate is less than 40 kg of PCBs in Puget Sound biota.

Wildlife Health

Introduction

PCBs have similar effects in wildlife, people, and model organisms used to study people in laboratory experiments. Thus, this section and the section on Human Health have many similarities, although the health effects that are measured often differ between people and wildlife. Negative effects of PCBs in wildlife are of concern because of the effects on animal populations, because animal populations may be sentinels for human health, and because we are also part of the food chain and are exposed to PCBs through our diet.

PCBs can be acutely toxic to wildlife, but most of the impacts occur due to chronic exposure. Data are most prevalent on mortality, reproduction, development, and endocrine effects. In addition to toxicity endpoints, the induction of enzymes and genes are also used to assay PCB effects. Other endpoints include cancer, immunological, neurological/behavioral, and hepatic effects. Experimental studies are often performed for certain endpoints because of correlations seen in the field with PCB levels and specific endpoints.

Wildlife is exposed to varied mixtures of PCBs in the environment. Different PCB congeners behave differently in the environment; they preferentially partition into different media and they are preferentially degraded and bioaccumulated. In addition, there are multiple sources of PCBs that contain different mixtures of congeners that release PCBs into the environment. Therefore, the actual environmental conditions are different than many of the laboratory studies on specific Aroclor mixtures or specific congeners.

Sensitivity to PCBs varies among species and within species. For example, fish are most susceptible in early life stages. Inter-species variation is also due to different lipid levels, because PCBs are lipophilic and sequestered in lipid-rich tissues. PCBs are biomagnified up the food chain, so organisms on higher trophic levels have higher concentrations of PCBs. There are other differences among species that affect PCB metabolism. For example, invertebrates lack the enzyme systems that react with dioxin-like PCBs.

Although environmental levels of PCBs have declined substantially since they first came under regulation in the 1970s, the rate of decline has slowed in recent years and significant contamination continues to be widespread in Washington State..

Puget Sound is a regional hot spot for PCBs compared to the Pacific coast and British Columbia. Within Puget Sound, the most contaminated areas are in the main basin, especially Seattle’s Elliott Bay and Tacoma’s Commencement Bay, and, to a lesser extent, Everett Harbor and the Bainbridge Basin. Puget Sound’s food web, from plankton on up to harbor seals and killer whales, has significant PCB contamination. Herring and Chinook salmon are notably affected.

Hot spots for PCBs are also present in Washington rivers and lakes. Based on PCB levels in resident fish species, major waterbodies of most concern are the Wenatchee River, Lake Washington, the Columbia River, and the Spokane River.

Health effects in wildlife

Table 23 (from ATSDR 2000) summarizes PCB effects seen in laboratory experiments and field studies with wildlife species. Most species have mortality at high doses.

Adverse effects in birds include:

- Reduced egg hatchability and live births
- Reduced avoidance response
- Altered mating, reproductive, parenting, and nesting behavior
- Suppression of immune response

Adverse effects in fish include:

- Reduced hatchability in eggs
- Altered muscle coordination
- Depressed immune system with increased susceptibility to infections
- Loss of fins and tails in flatfish

Adverse effects in mammals include:

- Loss of embryos and fetuses and reduced live births
- Alteration in the immune system in mink, sea lions, and seals
- Tumors and deformities of skeleton and skin in seals

Table 23. PCB Hazards in Wildlife with references noted in original (ATSDR 2000 Table 3-6)

Adverse effect	**Wild mammals**				**Birds**			**Reptiles**	**Amphibians**		**Fish**	
	Primate	Mustelid	Cetacean, pinniped	Other	Piscivore	Galliform	Other	Turtle	Frog	Toad	Freshwater	Marine
Mortality	OE1	OE1		OE3	OE3	OE1	OE3		OE1	OE1	OE1	OE3
		OE3				OE3			OE3	OE3	OE2	
		OE4									OE3	
Systemic effects												
Respiratory		OE4				OE3						OE3
Cardiovascular		OE3	OC4			OE3						
		OE4										
Gastrointestinal	OE1	OE1	OC4			OE3						
	OE3											
Hematological		OE4									OE3	
Musculo-skeletal						OE3					OE3	
Hepatic	OE3	OE1			OE3	OE1	OE1				OE3	OE3
		OE3				OE2	OE3					
		OE4				OE3						
		OE5				OE5						
Renal		OE4	OC4			OE3					OE3	
Endocrine	OE3	OE3	OE3		OE3	OE3	OE1				OE3	OE3
		OE4	OE4		OC4		OE3					
		OE5	OC4									
Dermal/ocular	OE1	OE3	OC4								OE3	
	OE3											
Body weight	OE1	OE1				OE2	OE1			OE3	OE3	
	OE3	OE3										
Metabolic		OE5					OE1		OE2		OE3	

Adverse effect	**Wild mammals**				**Birds**			**Reptiles**	**Amphibians**		**Fish**	
	Primate	Mustelid	Cetacean, pinniped	Other	Piscivore	Galliform	Other	Turtle	Frog	Toad	Freshwater	Marine
Enzyme induction		OE1				OE1	OE1				OE1	OC4
		OE3				OE2	OE2				OE3	
		OE4				OE3	OE3					
		OE5										
Blood chemistry	OE1	OE5				OE3	OE1				OE3	
Immunological/ lymphorecticular	OE1	OE4	OE4		OC4	OE1	OE1				OE3	OE3
	OE3		OC4			OE3	OE3					
Neurological/ behavioral	OE2	OE2		OE3		OE3	OE3				OE2	OE3
	OE3	OE4									OE3	
Reproductive	OE3	OE1	OC4	OE3	OC4	OE3	OE1	OC4			OE3	OE3
		OE3	OE4				OE3				OC4	OC4
		OE4										
		OE5										
		OC4										
Developmental	OE3	OE3		OE3	OE1	OE1		OE4	OE1	OE1	OE3	
		OE4			OC1	OE3			OE3	OE3	OC4	
					OC4							
Egg shell					OC4	OE3	OE3					
							OC4					
Genotoxic							OE3					

O= observed effect E= experimental observation C= correlational field observation
1 = dioxin-like PCB congener (AhR binder; planar; chlorine para-substituted and non- or mono-*ortho*-substituted)
2 = non-dioxin-like PCB congener (poorly binds to AhR; non-planar; chlorine di-, tri-, or quatro-*ortho*-substituted)
3 = commercial PCB mixture (e.g., Aroclor 1016)
4 = “weathered” (i.e., environmentally degraded and/or metabolized) PCB mixture, usually in combination with other chemicals (e.g., PCBs in wild-caught fish)
5 = unspecified PCB

Examples of major endpoints

Reproduction and development

PCBs affect reproduction and development in different species. Mink are particularly sensitive to the reproductive effects of PCBs (Eisler 1986). Farm-raised mink fed a diet of PCB-contaminated fish from the upper Hudson River at the same levels wild mink are exposed to PCBs in food, showed effects on reproduction and offspring growth and mortality (Bursian *et al*. 2013). Females with higher levels of PCBs had fewer live kits per litter. Kit mortality increased over time, with no kits surviving in the animals fed higher levels of PCBs. The surviving kits also had lower body masses after 6 weeks. The effects on reproductive performance were similar to those seen in earlier studies on mink fed contaminated fish from Saginaw Bay (Heaton *et al*. 1995a).

Immune System

PCBs are linked to increased disease susceptibility in several species. Captive harbor seals exhibit negative effects on their immune system after being fed PCB-contaminated herring, as assayed by immune cell function and response (Ross *et al*. 1996). This research was undertaken to understand factors contributing to virus-caused mass mortalities of marine mammals, especially when attributed to a virus that does not always cause mass mortalities. The results suggest higher levels of PCBs contribute to higher virus-caused mortality.

Cancer

PCBs have been shown to cause cancer in laboratory animals (ATSDR 2000) and are considered to be probable human carcinogens by EPA. PCBs are thought to cause cancer indirectly, rather than by direct alterations to DNA.

Cancer is less well studied in wild populations compared to laboratory species, partly due to lower incidence. However, beluga whales in the St. Lawrence estuary and Hudson Bay have been found to have a high incidence of cancers and high levels of PCBs (Mikaelian *et al*. 2003). There is also evidence linking cancer in St. Lawrence estuary belugas to PAHs from nearby point sources (Martineau *et al*. 2002), illustrating the difficulties in pointing to a specific group of chemicals in these marine mammals with many different industrial contaminants. PCB levels in California sea lions have also been found to be significantly associated with death from cancer (Ylitalo *et al*. 2005).

Mechanisms of action

Endocrine

PCBs interfere with estrogen and thyroid hormone levels. Studies on PCB endocrine disruption have been done in the laboratory with model animals and cell cultures (see section on Human Health). The endocrine system regulates all biological processes, although endocrine disruption is often used just to refer to the disruption of thyroid hormones and the sex hormones estrogen and androgen. These hormones are important for growth and development, especially of the brain and nervous system and reproductive systems. While hormones are important throughout the life cycle, they are particularly important during fetal development. Hormones are signaling molecules that function at low levels, and compounds that either mimic or block natural hormones may have effects at low levels.

Ah-receptor dependent

Similar to dioxins, non-ortho (co-planar) and mono-ortho PCBs can bind to the aryl hydrocarbon (Ah) receptor. Subsequent to binding of the Ah receptor, there are changes in gene expression (e.g., induction of cytochrome p450 CYP1A1/1A2) leading to toxic responses. Induction varies by degree and pattern of chlorines and is the basis for the World Health Organization (WHO) toxic equivalency factors (TEFs) for dioxins and dioxin-like PCB congeners. These have been reviewed and modified several times. In 2005 WHO updated the TEFs for humans and mammals to replace the 1998 values (Van den Berg *et al*. 2006, see Table 29 in the Human Health Section). The adverse effects for these compounds are mediated through the Ah receptor and the relative potencies are compared to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Consensus TEFs for wildlife were developed in 1998 (Van den Berg *et al*. 1998). The WHO working group harmonized the TEFs across different taxa as much as they could, but there are large differences in responses among different taxa.

Table 24. WHO TEFs for fish and birds (Van den Berg *et al*. 1998)

Type	**Congener**	**TEFs**	
		Fish	Birds
Co-planar PCBs	3,3',4,4'-TCB (77)	0.0001	0.05
	3,4,4',5-TCB (81)	0.0005	0.1
	3,3',4,4'-5-PeCB (126)	0.005	0.1
	3,3',4,4',5,5'-HxCB (169)	0.00005	0.001
Mono-ortho PCBs	2,3,3',4,4'-PeCB (105)	<0.000005	0.0001
	2,3,4,4',5-PeCB (114)	<0.000005	0.0001
	2,3',4,4',5-PeCB (118)	<0.000005	0.00001
	2',3,4,4',5-PeCB (123)	<0.000005	0.00001
	2,3,3',4,4',5-HxCB (156)	<0.000005	0.001
	2,3,3',4,4',5'- HxCB (157)	<0.000005	0.0001
	2,3',4,4',5,5'- HxCB (167)	<0.000005	0.00001
	2,3, 3',4,4',5,5'- HpCB (189)	<0.000005	0.00001

PCBs in Washington's Environment

Air and Soil

Due to long-range regional and global atmospheric transport, PCBs are present in all parts of the environment. Most of the PCBs in air come from volatilization of PCB-contaminated soil and surface water. In the atmosphere, PCBs are primarily associated with the gaseous phase; approximately 10% is adsorbed to particulates, especially the higher chlorinated forms. Less chlorinated compounds travel farther than highly chlorinated compounds, which tend to stay closer to the source of contamination. Atmospheric deposition is, in turn, the dominant source of PCBs to most soil and water surfaces. The cycle of persistent compounds like PCBs depositing onto soil and then revolatilizing back into air is often referred to as the grasshopper effect.

PCB levels in the atmosphere have been decreasing slowly since the late 1970s when EPA began restricting their use (EPA Integrated Atmospheric Deposition Network http://www.epa.gov/glnpo/glindicators/air/airb.html, Venier and Hites 2010, ASTDR 2000). Due to residual sources in the U.S. and long-range transport from other countries, PCB levels in air may be leveling off after a period of decreasing.

Air in rural and remote locations has lower PCB levels than urban air, which is a source to nearby environments. Nationally, average total PCB concentrations at background locations (not near known sources of PCBs) are in the approximate range of one to several hundred pg/m^3 (Hornbuckle and Robertson, 2010). In contrast, concentrations near Lake Superior in the 1970s were well over 1,000 pg/m^3 due to influences from upstate New York and the East Coast (EPA Integrated Atmospheric Deposition Network)

The limited data available for PCBs in Washington's air has been from measurements of wet (rainfall) and dry (particulate) deposition rates to water and land surfaces (ng/m^2/day) rather than mass per unit volume. In 2008, Brandenberger *et al*. (Ecology 2010d) recorded PCB fluxes to the Puget Sound basin at seven stations from Nisqually River to Padilla Bay. The median flux across all stations and rain events was 0.51 ng/m^2/day. Similar results were obtained for most areas, except Tacoma's Commencement Bay had a median of 1.8 ng/m^2/day. Brandenberger *et al*. concluded that PCB deposition rates to the Puget Sound basin were similar to background sites in New Jersey (0.82 ng/m^2/day; 1999-2000), but lower than Chesapeake Bay (9.0 ng/m^2/day; 1990-1991) and Jersey City, NJ (11 ng/m^2/day; 1999). King County recently completed an air deposition study at six stations in the Lower Duwamish/Green River watershed (King County 2013a). Station locations included three in the Lower Duwamish River area, two in downtown Kent and one in Enumclaw. Median fluxes of total PCBs ranged from 1.1 ng/m2/day in Enumclaw to 16.9 ng/m2/day in the South Park neighborhood of the Lower Duwamish River. King County has also measured air deposition to Lake Washington at one station near Sand Point; a median flux of 1.39 ng/m2/day was estimated from these measurements (King County 2013b).

The Western Airborne Contaminants Assessment Project for national parks in the western U.S. included Mount Rainier, Olympic, and North Cascades parks (Landers *et al*. 2008). The results, however, are of limited use for present purposes in that only eight PCB compounds were analyzed and detection frequency was low.

Meijer *et al*. (2003) estimated that the contemporary PCB burden in background soils is about 2% of the known production volume. PCB levels in U.S. background soils generally average from several hundred to several thousand ppt dry weight (Hornbuckle and Robertson, 2010). An EPA nation-wide survey of soil at 27 remote or rural sites in 2003 put the average total PCB concentration at 3,089 ppt (EPA 2007). The single Washington site sampled during the study – Lake Ozette on the northwest coast – had 2,419 ppt.

With the exception of site-specific determinations for contaminated sites, the PCB background in Washington soils has not been well characterized. Relatively more is known about PCBs in Washington's marine and freshwater environment, as discussed below.

Marine and Fresh Waters

Historical vs. Recent Trends

PCB levels in Washington's marine and fresh waters have decreased substantially since peaking in the 1970s. This has been attributed to EPA's restrictions and bans on PCBs in the late 1970s and early 1980s, similar actions in Canada and other countries, contaminated site cleanups, improved wastewater treatment, losses through volatilization and metabolism of lighter compounds, and deep burial in aquatic sediments.

Although historical declines have been documented, there are components of Washington's marine and freshwater ecosystems where a decreasing trend is no longer evident. In most cases, the time-trend for PCBs can be characterized by an initial rapid decline after the ban, followed by a slowing and, ultimately, low to negligible rate of decrease over recent years, waterbodies benefitting from cleanups being a notable exception. Current PCB levels continue to be a concern for the health of fish, wildlife, and humans in Washington.

The effect of the 1970s and 1980s regulations can be clearly seen in age-dated sediment cores from Puget Sound and Lake Washington (Figure 15). A rapid increase in concentrations occurred in both Puget Sound and Lake Washington into the mid-1970s, reaching 35 ppb and 250 ppb, respectively, in sediments at these two locations. Concentrations in the recent past declined to around 10 to 20 ppb. (Detections shown prior to the mid-1930s when PCBs were first introduced are analytical noise.) A sediment core from Lake Spokane (lower Spokane River) in eastern Washington showed a similar steep decline in the 1960s and 1970s, followed by a gradual reduction over a 20-year period from approximately 1980 to 2000 similar to what was observed in Lake Washington (Ecology 2011c).

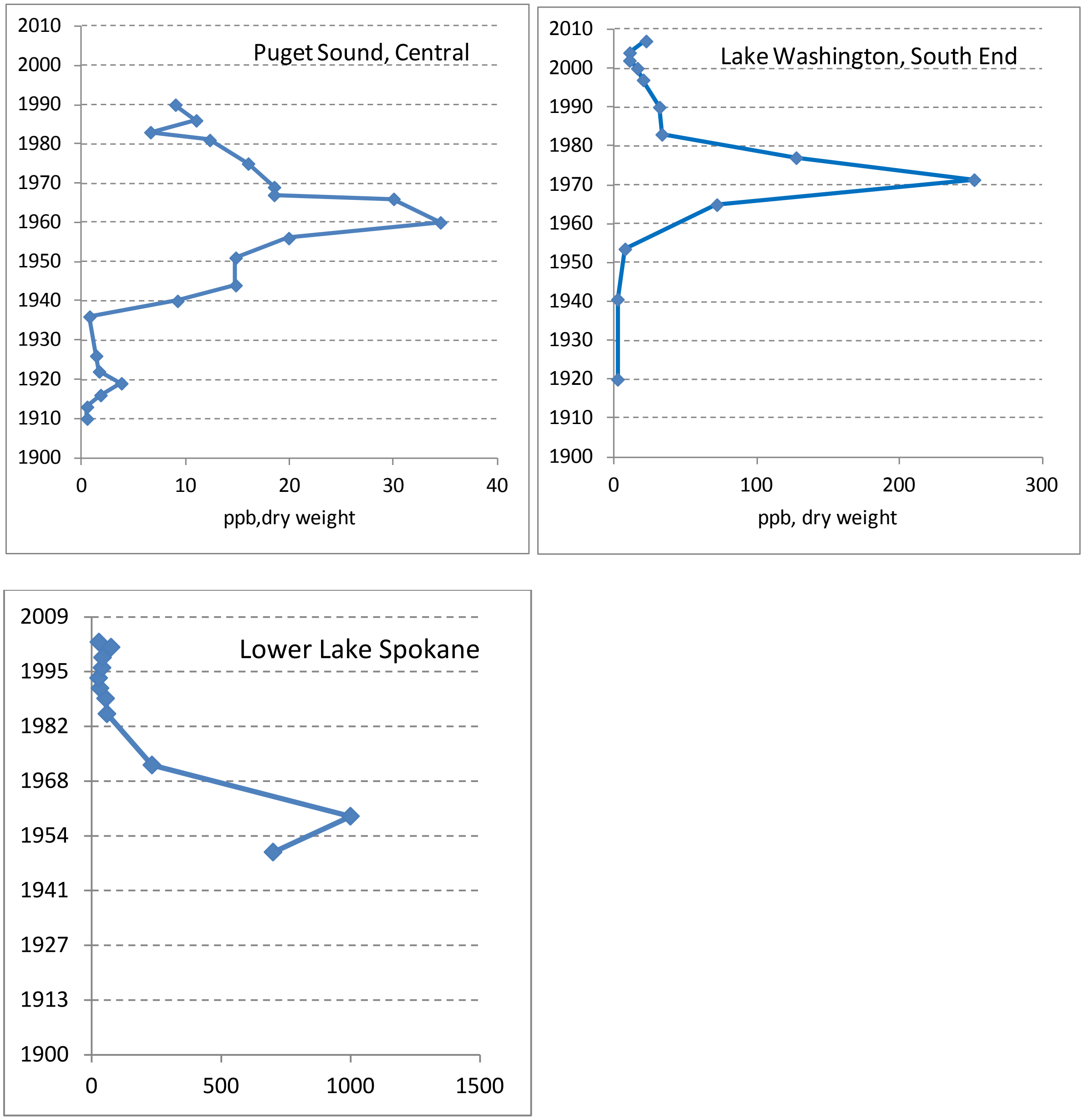
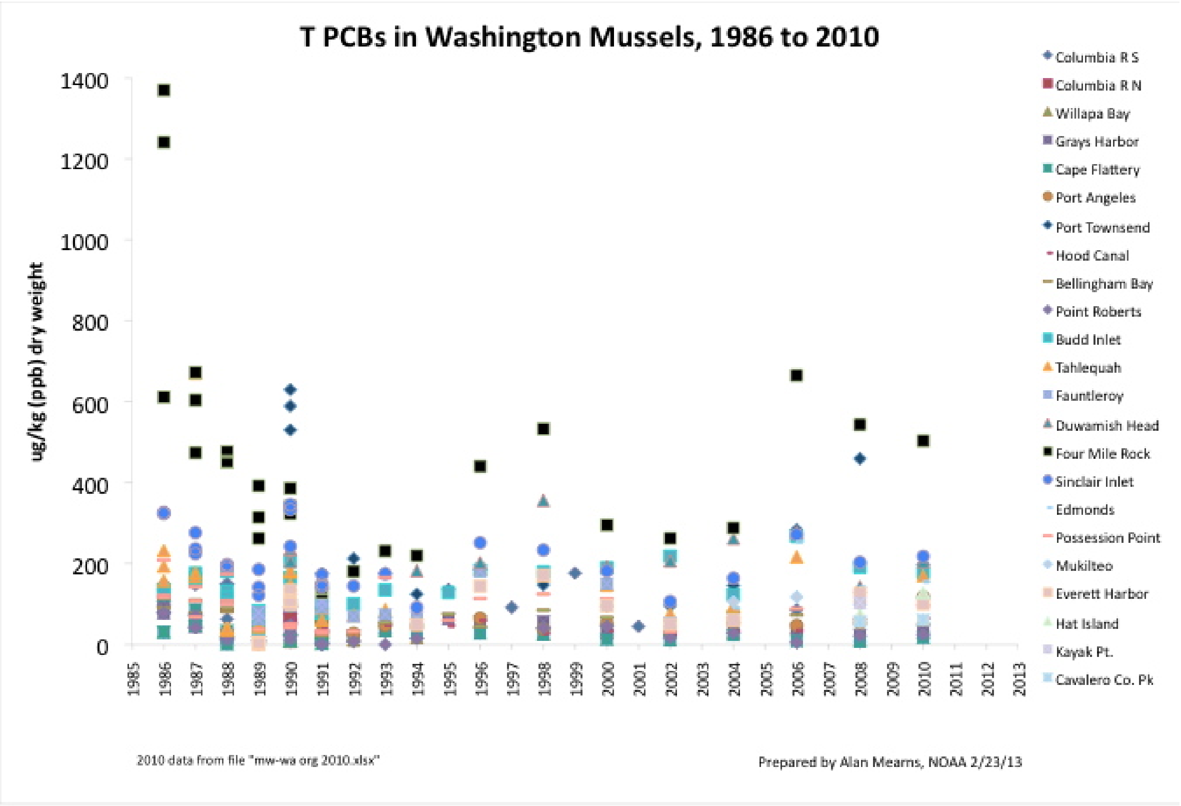


Figure 15. Total PCBs in Age-Dated Sediment Cores from Puget Sound, Lake Washington, and Lake Spokane

NOAA's Mussel Watch has monitored PCBs in marine mussels from the mouth of the Columbia River to Puget Sound since 1986. Results show that PCBs have been declining slowly, although somewhat erratically, in Washington's marine waters (Figure 16). After a steep decline in the mid-1980s, there have been two spikes of unknown origin, most obvious at the regional hot spot: Four-mile Rock in Elliott Bay. PCB levels in Puget Sound mussels remain well above national median concentrations (Mearns 2013, O'Connor and Lauenstein 2006).



2010 data from file "mw-wa org 2010.xlsx"

Prepared by Alan Mearns, NOAA 2/23/13

Figure 16. Total PCB Concentrations in Marine Mussels from Columbia River to Puget Sound: 1986 – 2010

(Data from NOAA National Mussel Watch Program, prepared by Alan J. Mearns, NOAA, Seattle)

Compared to historical levels, PCBs have declined in Puget Sound harbor seals (1972 to 1997) and killer whales (1993-1995 vs. 2004-2006) that inhabit or transit Puget Sound (Calamabokidis *et al*. 1999, Krahn *et al*. 2007, Hickie *et al*. 2007). Despite these declines, levels of PCB sassociated with health impacts are observed in seals from this region (Strait of Georgia) and most Southern Resident killer whales exceed health effects thresholds for PCB residues (Cullon *et al*. 2009, Hickie *et al*. 2007, Krahn *et al*. 2009). The PCB decline in these animals has been slowed by continued atmospheric delivery of PCBs from other parts of the world and internal cycling (Johannessen *et al*. 2008). Figure 17 shows the PCB changes observed in the blubber of South Puget Sound harbor seals up until 1997.

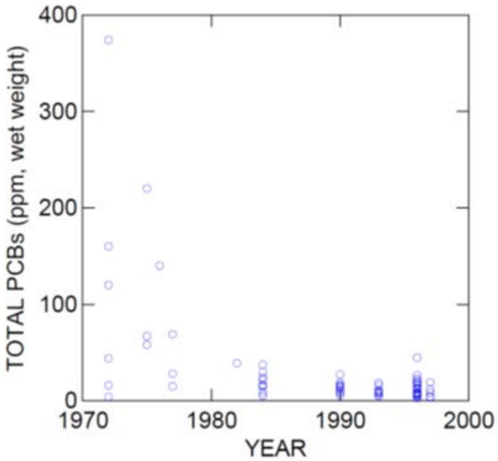


Figure 17. Historical Decline in PCB Levels among South Puget Sound Harbor Seals: Blubber Samples 1972-1991 (Calambokidis, 1999)

Monitoring by the Washington Department of Fish and Wildlife (WDFW) for the Puget Sound Estuary Monitoring Program (PSEMP) gives a mixed picture of PCB time-trends in edible tissues of marine fish (West 2011, West *et al*. 2011). Levels have declined in coho salmon from central Puget Sound, but only until the 1990s. Trend data do not exist for Chinook salmon. There is no evidence of a PCB decline in four stocks of Puget Sound herring. English sole from all urban and non-urban monitoring locations except Sinclair Inlet show no significant change in PCB concentrations over the past 20 years (Figure 18). There is some evidence of improvement in Sinclair Inlet in recent years, which has been attributed to reduced stormwater loading, and dredging and capping of contaminated sediments in 2000-2001 (O'Neill *et al*. 2011). Sole are a bottom-living species that demonstrate the link between PCBs in sediment and biota.

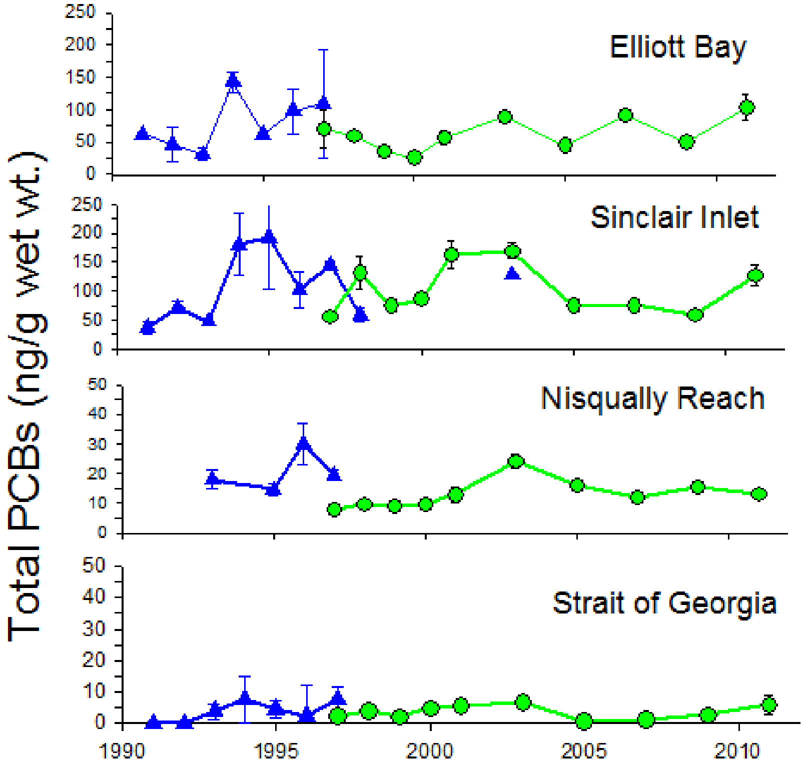


Figure 18. 20-year Time Series for PCBs in English Sole from Selected Urban and Non-urban Locations in Puget Sound
(prepared by James West, WDFW; parts per billion; symbol shift indicates change in analytical method)

Long-term trend data are limited for Washington freshwater fish. PCB levels have declined in Spokane River fish since the early 1990s due to cleanup of hazardous waste sites, excavation and capping of contaminated river sediments, and reduced discharge from industrial and municipal treatment plants (Ecology 2011a, EPA 2009).

The U.S. Geological Survey (USGS) analyzed changes in PCB residues in whole fish samples collected from 16 stations in the Columbia River Basin between 1970 – 1986, and in 1997 (Hinck *et al*. 2004). Not surprisingly, a number of sites had lower levels in 1997 than in the 70s or 80s. USGS observed, however, that criteria for the health of fish or wildlife were still exceeded and concluded that PCBs remain a cause for concern. Historical declines have also been documented for PCBs in Columbia River otter, mink, eagle, and osprey (EPA 2009), all of which prey largely on fish. Here again, the comparison is primarily with samples collected in the 70s and 80s.

Current Levels and Spatial Patterns

Water

Due to the extremely low solubility of PCBs and the high cost of analysis, there have been few attempts to measure concentrations in the water column. As part of the Puget Sound Toxics Loading Analysis (PSTLA), Ecology analyzed PCBs at four sites in Puget Sound, three sites at the eastern end of the Strait of Juan de Fuca, and five major Puget Sound rivers in 2009-2010 (Ecology 2011d). Average concentrations in the Strait of Juan de Fuca (20 ppq) and Puget Sound (31 ppq) were similar to that previously reported for the Strait of Georgia (42 ppq) by Canadian researchers (Dangerfield *et al*. 2007). The mean total PCB concentration in the five Puget Sound rivers was 16 ppq. The Puyallup and Stillaguamish Rivers tended to have higher concentrations (up to approximately 40 and 60 ppq, respectively) than the Skagit, Snohomish, or Nooksack (less than 20 ppq). King County (2013b) measured PCB concentrations in Lake Washington, the Ship Canal, Sammamish and Cedar rivers, and three major tributaries to the Lake. The total PCB concentrations in Lake Washington ranged from an average of 54 ppq during mixed conditions to 62 ppq in the hypolimnion and 229 ppq in the epilimnion during stratified periods. Concentrations in the two rivers were similar and together averaged 90 ppq. Ship Canal concentrations averaged 108 to 295 ppq. Concentrations in tributaries were higher than the Ship Canal, ranging from a mean of 451 ppq during baseflow conditions to 2,985 ppq during storm events. Williston (2009) and Gries and Sloan (Ecology 2009a) report concentrations in the Green/Duwamish River, up to 2,360 and 1,600 ppq total PCBs, respectively.

A surface water study conducted for Puget Sound Toxics Loading Analysis (PSTLA) in 16 Puyallup and Snohomish county streams found higher PCB levels during storm-events than for baseflow conditions (Ecology 2011g). The median total PCB concentration was 348 ppq for storm-event samples compared to 227 ppq for baseflow samples. Washington’s human health water quality criterion for PCBs is 170 ppq . Of the 70 samples analyzed, approximately 1/3 exceeded the criterion, primarily storm event samples. Except for a single sample, Washington’s aquatic life criteria (ranging from 0.014 to 10.0 ppb) for PCBs were not exceeded

PSTLA estimated the total PCB load to Puget Sound and the U.S. portions of the Straits of Georgia and Juan de Fuca was 3-20 kg per year (Ecology 2011a). Surface water was identified as the major PCB pathway, accounting for 74-76% of the total load (2.55–15.77 kg/yr). The concentration of PCBs in surface runoff was higher from commercial/industrial areas, especially during storm events, but the total loading was lower since industrial/commercial lands occupy less area than other land covers. Overall loads from forests accounted for 83% of the stormwater load (Ecology 2011g). Atmospheric deposition and publicly owned treatment works (POTWs) accounted for 18-20% (0.68-3.76 kg/yr) and 4-8% (0.126-1.75 kg/yr), respectively, of the loading (Ecology 2011a). PSTLA concluded there was insufficient data to estimate PCB loading from groundwater (Ecology 2011f).

Ecology and USGS have used passive sampling techniques (e.g., semi-permeable membrane devices (SPMDs)) to concentrate and estimate PCB concentrations in other freshwater areas (McCarthy and Gale 1999, Ecology 2012b, Ecology 2011a, Ecology 2005, Ecology 2004, Ecology 2010b, Ecology 2011m). Rivers, their tributaries, and lakes that have exceeded the human health criterion to the greatest extent are:

- Columbia River: Wenatchee River, Willamette River (Oregon), Lake River
- Spokane River: (major pathway is stormwater)
- Yakima River: Granger Drain and Sulphur Creek Wasteway (stormwater also a major pathway)
- Walla Walla River: Garrison Creek
- Lake Washington

Water Quality Assessment list

There are 158 303(d) listings for PCBs in Washington’s 2012 Water Quality Assessment. The federal Clean Water Act, adopted in 1972, requires that all states restore their waters to be “fishable and swimmable.” Washington's Water Quality Assessment lists the water quality status for water bodies in the state. The assessed waters are grouped into categories that describe the status of water quality. The 303(d) list comprises those waters that are in the polluted water category, for which beneficial uses– such as drinking, recreation, aquatic habitat, and industrial use – are impaired by pollution.

For the water body segments found to be impaired (category 5) Ecology conducts a total maximum daily load (TMDL) analysis and develops a cleanup plan for meeting water quality standards. Table 25 shows the PCB listings. There are 158 listings for PCBs in category 5. There are ten listings for PCBs in category 4a, which means a TMDL is completed and a plan is in place to meet water quality standards. Sinclair Inlet is in category 4b, which is similar to category 4a, but there is a pollution control plan instead of a TMDL. Fifty-six waterbody segments across the state are in category 2, meaning there is some evidence for elevated levels of PCBs, but there is not sufficient evidence to list it as impaired.

Figure 19 is a state map of the category 5 and 4 listings along with the Washington DOH fish consumption advisories. DOH guidance to develop fish consumption advisories differs from Ecology’s procedures to identify impaired waters. See the section on Human Health for a more detailed explanation. While the details of how a water body segment is considered impaired differs from how a fish consumption advisory is developed, there is a lot of overlap as seen in Figure 19.

Table 25. Water Quality Assessment for PCBs

Number of Waterbody Segments	Category	Description
158	5	Polluted waters that require a TMDL
11	4a and 4b	Polluted water that have a plan in place
56	2	Waters of concern

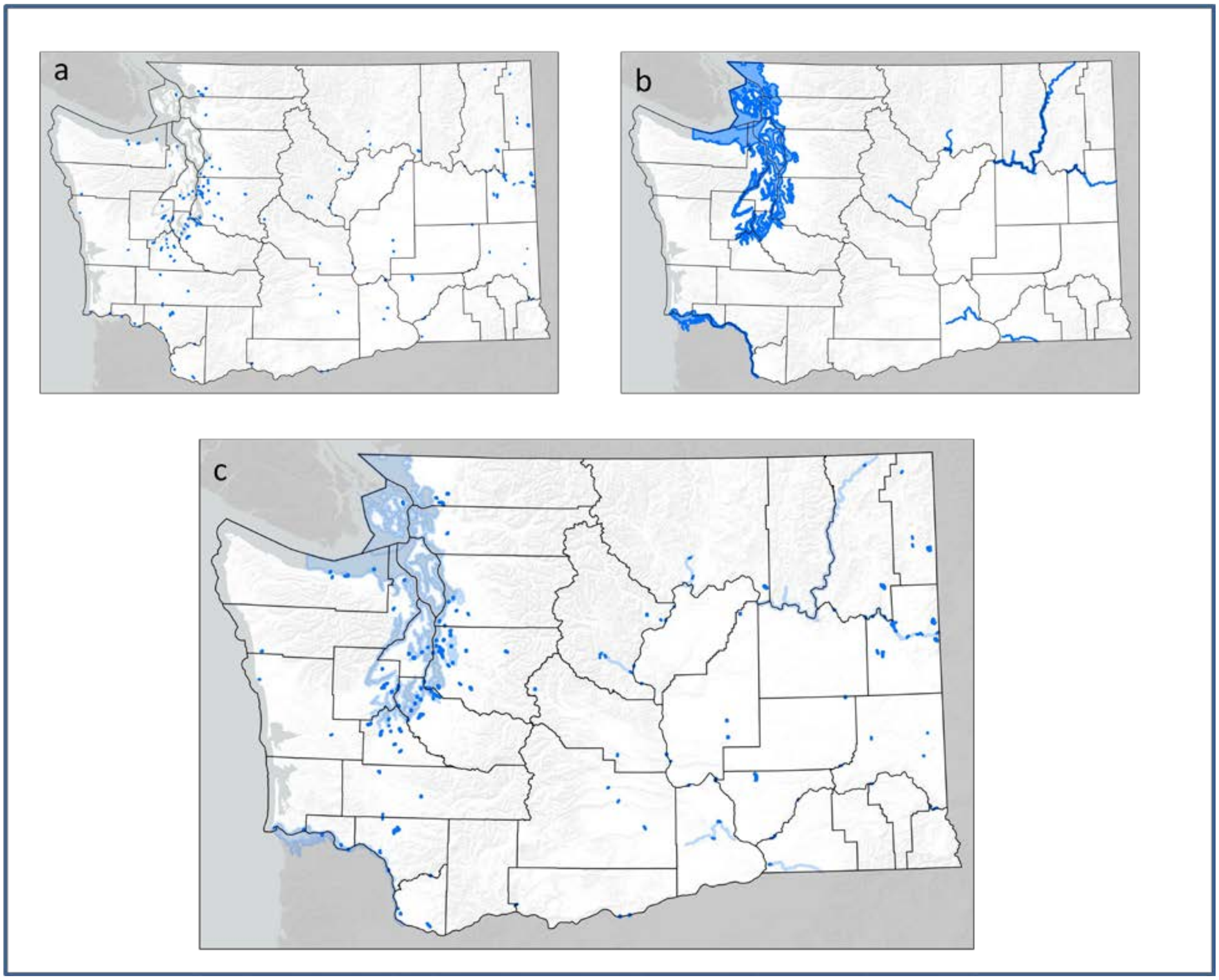


Figure 19. a. Category 4 and 5 303 (d) listings (blue dots). b. Waterbody-specific fish consumption advisories (blue lines, see section on Human Health). c. Overlap of water quality listings and fish consumption advisories.

Marine Sediments

PCBs have been extensively monitored in the marine sediments of Washington. Ecology has PCB data for 630 random sediment monitoring sites in Puget Sound and vicinity up through 2011, collected for PSEMP (e.g., Ecology 2013a).The highest levels are found in urban bays - Elliott Bay, Commencement Bay, Everett Harbor, and the Bainbridge Basin - with concentrations generally diminishing with distance from the shoreline (Figure 20). Particularly high PCB concentrations occur in the Duwamish and Hylebos Waterways in Seattle and Tacoma. Much lower levels are typically encountered in other marine areas.

Total PCBs in Washington marine sediments range from approximately 5 to 2,000 ppb (dry weight), with an overall median of approximately 15 ppb for the greater Puget Sound area. Ninety percent of PSEMP stations have a total PCB concentration below 40 ppb. Less than one percent exceed Washington State sediment quality standards (12 ppm, organic carbon normalized). For perspective, the mean concentration reported for total PCBs in bottom sediments from the Duwamish Waterway Cleanup site is 1,100 ppb, with maximum concentrations as high as 220,000 ppb, dry weight (EPA 2013g).

Freshwater Sediments

The PCB data on freshwater sediments are limited to studies focused on specific waterbodies or cleanup sites rather than large-scale monitoring programs as in Puget Sound. Spatial patterns for PCBs in Washington rivers and lakes are best illustrated with the more comprehensive fish tissue data, discussed below.

A regional freshwater sediment study by Ecology assessed the background for PCBs in northeast Washington (Ecology 2011h). Sediment samples were collected from fifteen lakes and one river thought to be minimally impacted by local human activity. Median and 90th percentile total PCB concentrations were 2.5 and 6.3 ppb, respectively. Atmospheric deposition is assumed to be the predominant PCB source to these waterbodies. By way of comparison, PCB levels in surface sediments of urban/industrial waterbodies such as Lake Washington and Lake Spokane approach 50 - 60 ppb (Ecology 2010a, Ecology 2011c).

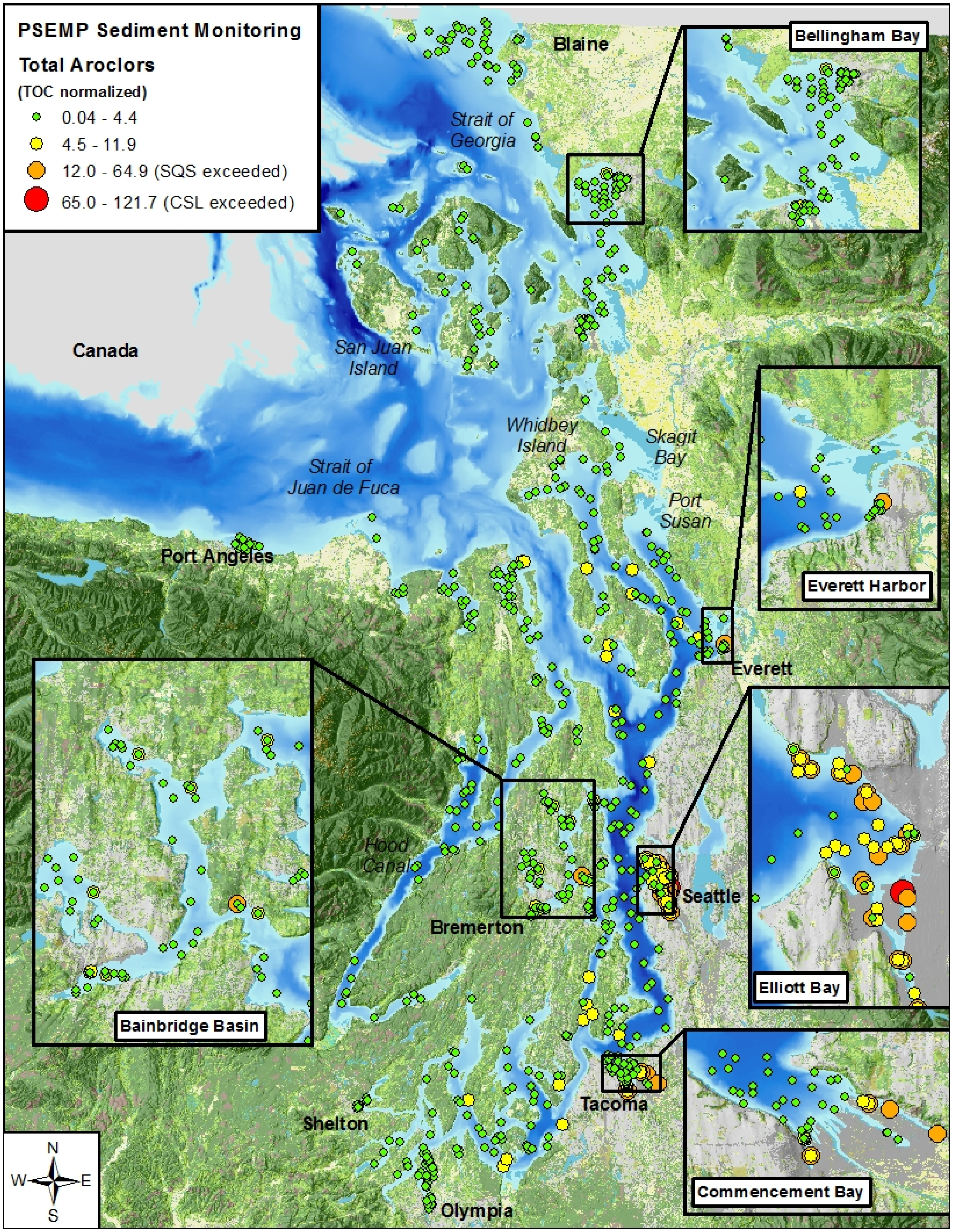


Figure 20. Distribution of PCBs in Marine Sediments from Puget Sound to Strait of Georgia (prepared by Sandra Weakland, Ecology Environmental Assessment Program; parts per billion, normalized to total organic carbon).

Fish

WDFW has monitored PCB levels in Puget Sound marine fish since 1992. Figure 21 summarizes the total PCB concentrations measured in edible tissues of four important marine and anadromous species. The highest concentrations have been observed in herring (whole fish), followed by Chinook salmon, English sole, and coho salmon, in that order. Median and 90th percentile concentrations for these species are 159/234 ppb (herring), 44/95 ppb (Chinook), 23/135 ppb (sole), and 10/26 ppb (coho). The fish tissue equivalent of Washington's human health water quality criterion for PCBs is 5.3 ppb. For more information on exposure to people from fish and fish advisories, see the section on Human Health. All samples of herring and Chinook, and most (70 – 80%) of the English sole and coho have exceeded the criterion.

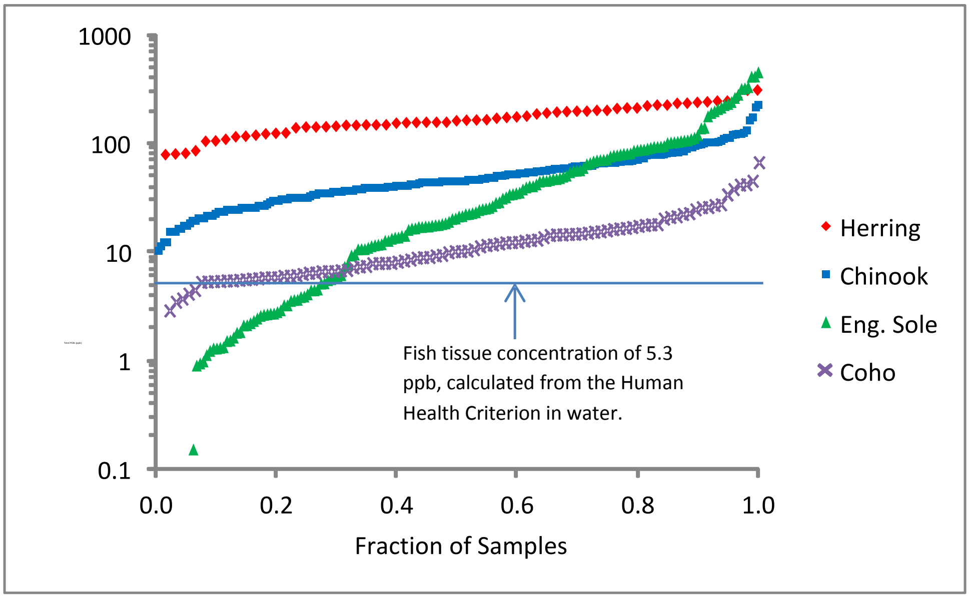


Figure 21. PCBs in Edible Tissues of Four Species of Puget Sound Fish (1992-2010 data provided by James West, WDFW; N =60 – 210)

Puget Sound herring are 3 to 9 times more contaminated with PCBs compared to Strait of Georgia herring (West *et al*. 2008). The high concentrations in this pelagic species suggest continued input of PCBs to the water column, rather than direct uptake from contaminated sediments (O'Neill *et al*. 2011). WDFW's herring studies show Puget Sound is a regional hot spot for PCBs in the food web on the Pacific coast (Figure 22). Within Puget Sound there is a gradient of decreasing PCB levels in plankton and several pelagic fish species moving away from urban areas (West *et al*. 2011).

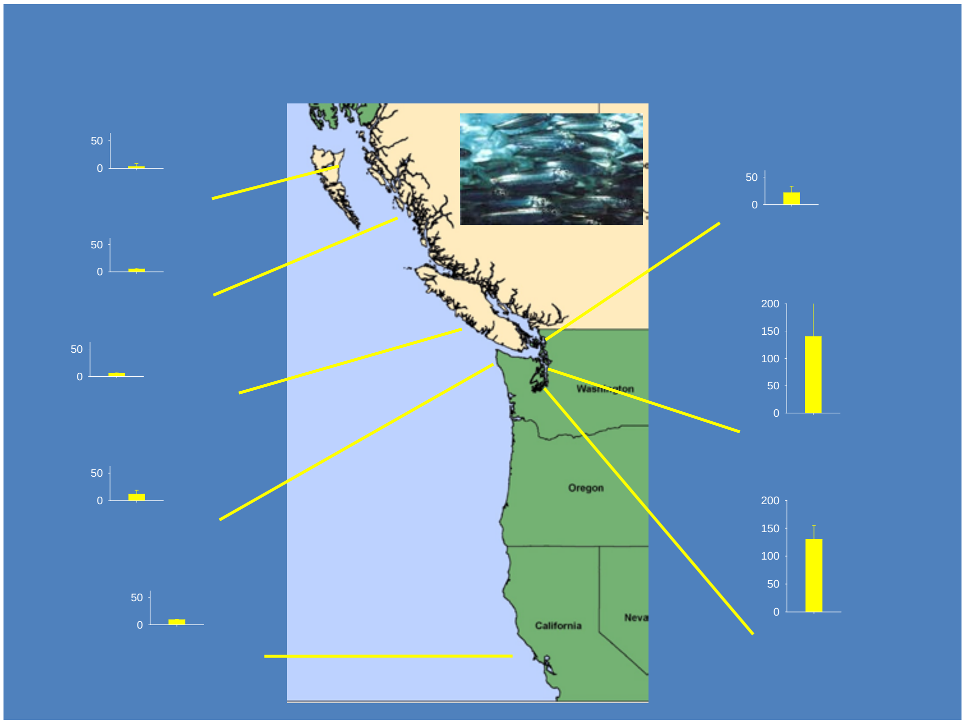


Figure 22. PCB Spatial Patterns in Herring: British Columbia, Washington, and California (prepared by James West, WDFW, and Sandie O'Neill, NOAA-NWFSC)

A high percentage of Chinook are resident in Puget Sound, with 29% of sub-yearlings and 45% of yearling out-migrants displaying resident behavior (O'Neill and West, 2009). Puget Sound Chinook are 3 to 5 times more contaminated than coastal Chinook (West 2011). According to O'Neill *et al*. (2011), 23-100% of juvenile Chinook from Puget Sound urban bays and 19% of returning adult Chinook have PCB levels above effects thresholds. The lower levels in coho are more reflective of combined oceanic and Puget Sound conditions.

English sole show a strong north-south gradient in PCB concentrations, increasing from the Strait of Georgia into Puget Sound (Figure 23). Sole from urban bays, especially the Duwamish River estuary, have much higher PCB levels than fish from non-urban locations. The degree of contamination in Puget Sound sole is positively correlated with PCB levels in the sediments (West 2011). Adverse effects on reproduction, growth, and immune response in English sole and other fish species have been attributed to the elevated levels of PCBs and other legacy contaminants in Puget Sound embayments (Collier 2009).

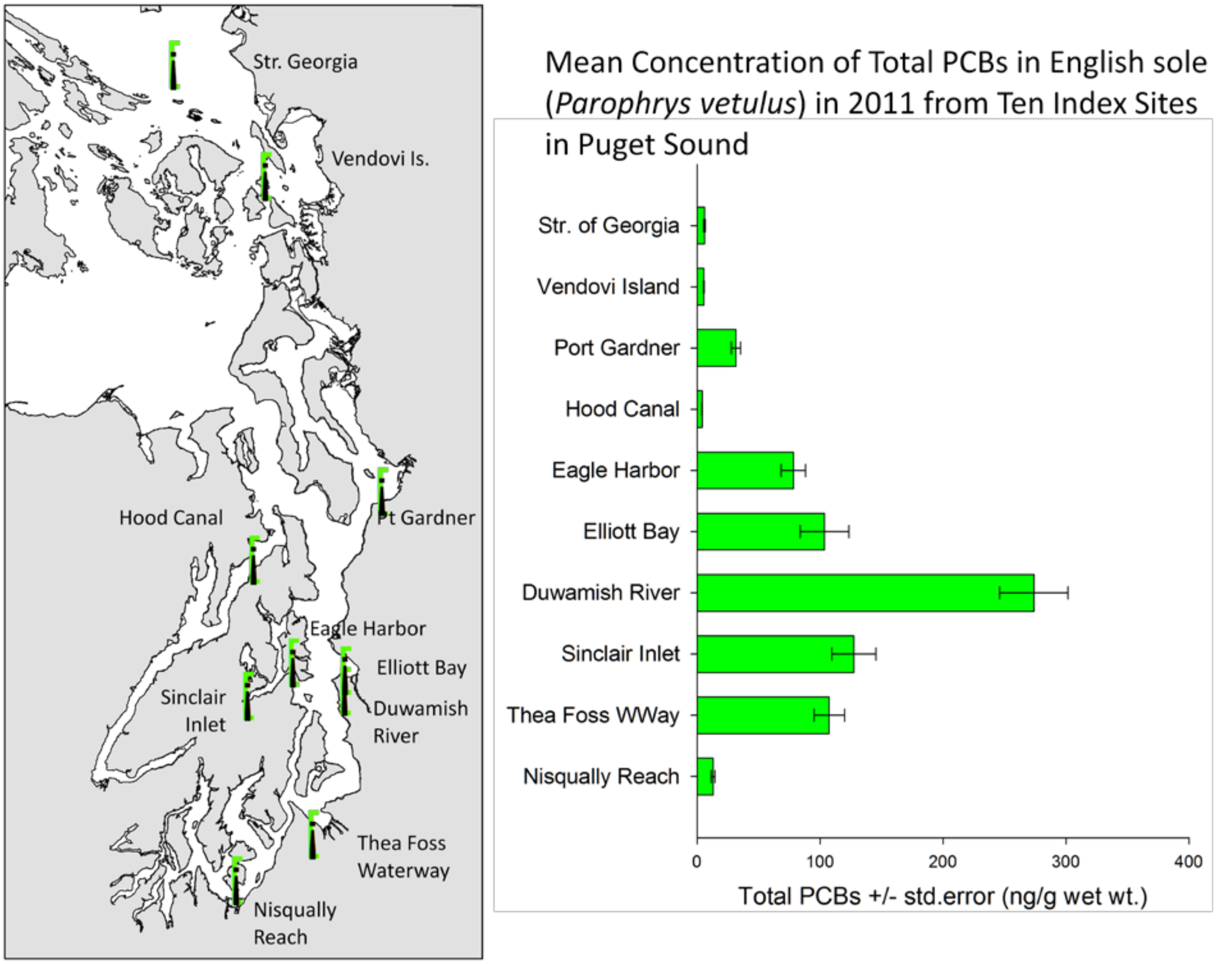


Figure 23. PCB Spatial Patterns in English Sole Muscle: Puget Sound and Vicinity (prepared by James West, WDFW; parts per billion).

A Pacific coast survey by the National Marine Fisheries Service showed outmigrating juvenile Chinook salmon typically have 2 to 5 times higher concentrations of PCBs and other contaminants compared to outmigrating coho (Ecology 2007). Of the 12 estuaries sampled, PCBs were highest in Chinook from the Duwamish River and Columbia River. The average PCB content in juvenile Chinook from these areas was near or above effects thresholds for growth and survival. For the Columbia River, the tidal freshwater portion of the estuary between Portland and Longview appears to be an important source of contamination. PCB levels were higher in fish that feed and rear in the lower river as opposed to those that migrate more rapidly through the estuary (Arkoosh *et al*. 2011, Johnson *et al*. 2013).

Figure 24 summarizes data obtained since 1997 on total PCBs in muscle tissue of resident freshwater fish collected throughout Washington, drawn from studies by EPA, Ecology, and others (CH2MHill 2007, Delistraty 2013, EPA 2002, Ecology 2004, Johnson *et al*. 2007, Ecology Washington State Toxics Monitoring Program, e.g., Seiders *et al*. 2012). The statewide natural background for PCBs in edible fish tissue has been estimated at 6.5 ppb (90th percentile;

Johnson *et al*. 2010). Large areas of the state have relatively low PCB levels (<20 ppb) not greatly above background. However, elevated to high concentrations are also commonly encountered, especially in the Columbia River, some of its major tributaries, and the Seattle urban area. In approximate decreasing order, the following ten rivers and lakes are reported to have the highest total PCB concentrations in fish muscle samples (1,100 to 60 ppb, site average):

- Wenatchee River
- Lake Washington
- Middle Columbia River
- Green Lake (Seattle)
- Spokane River
- South Fork Palouse River
- Upper Columbia River
- Walla Walla River
- Lower Columbia River
- Snake River

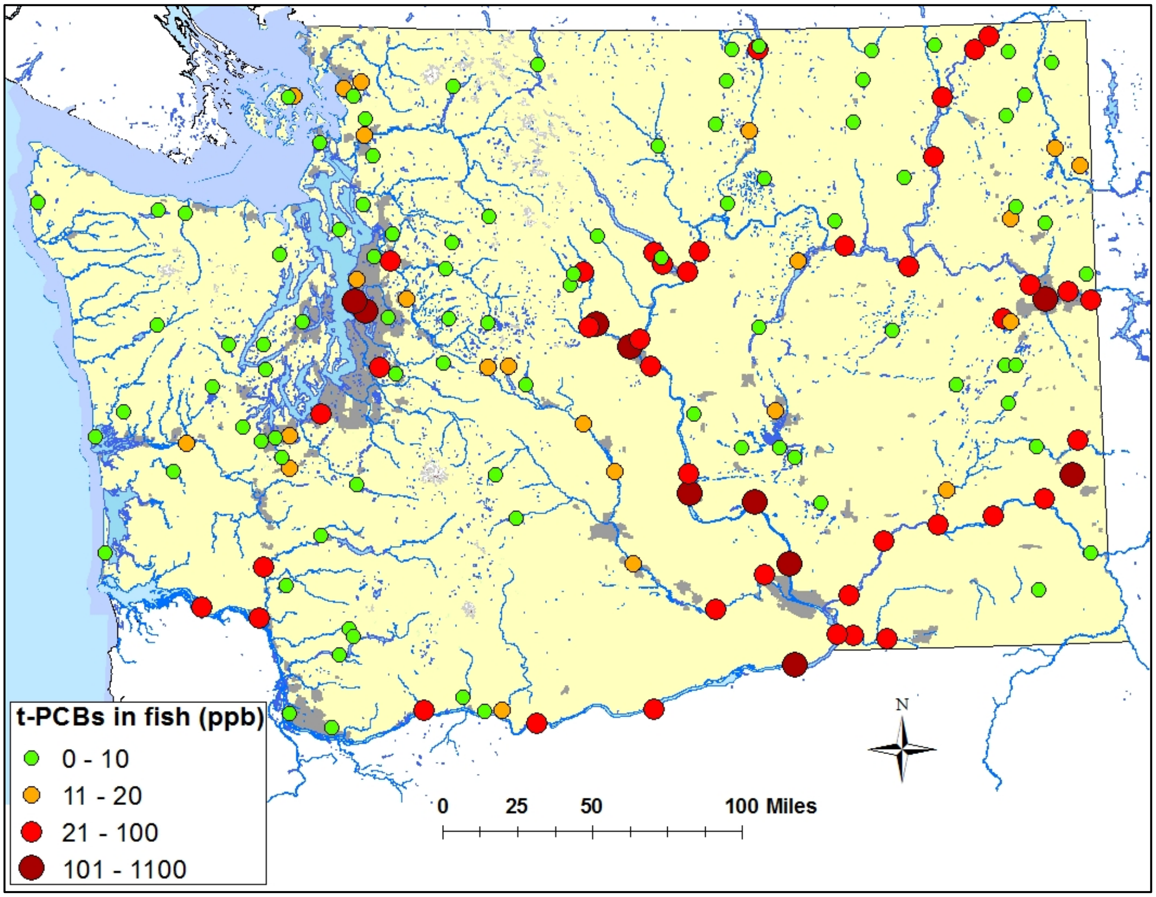


Figure 24. Average PCB Concentrations in Fish Muscle Samples from Washington Rivers and Lakes
(prepared by Keith Seiders, Ecology Environmental Assessment Program; 1997-2010 data, N = 587).

Figure 27 in the section on Human Health shows statewide data on PCB levels in fish tissues (fillet). There is a line at 5.3 ppb, which is equivalent to the human health water quality criterion, and a line at 23 ppm, which DOH uses as a screening level for advisories. About 60% of samples exceed the 5.3 ppb level calculated from the water quality criterion. The median concentration statewide for total PCBs in freshwater fish is approximately 10 ppb. Ninety percent of samples are less than 85 ppb.

High mountain lakes experience enhanced atmospheric deposition of PCBs due to colder temperatures and greater amounts of precipitation (Blais *et al*. 1998, Gillian and Wania 2005). USGS analyzed PCBs in fish from 14 pristine Washington lakes over 3,000 ft. elevation (Moran *et al*. 2007). Although a relatively insensitive analytical method was used, total PCB concentrations of 17 – 20 ppb were found in approximately 20% of the tissue samples.

Mammals and Birds

Southern Resident killer whales are among the world's most PCB-contaminated marine mammals, which has been implicated in a range of negative health effects (Alva *et al*. 2012). It is estimated that Southern Residents have 4 to 7 times the daily PCB intake compared to Northern Residents (Cullon *et al*. 2009). Salmon, especially Chinook, comprise most of their diet and are thus the major source of contamination (Cullon *et al*. 2009). Transient killer whales have higher levels of PCBs compared to either resident population (Ross 2006) and are in a higher trophic level, eating marine mammals (Ross *et al* 2000). PCBs have been seen to cause reproductive impairment, immunotoxicity, skeletal abnormalities, endocrine disruption, and negative effects on population growth rate in marine mammals (Alva *et al*. 2012). While there are no established health effects thresholds for PCBs in killer whales, the levels in Puget Sound killer whales is above the health effects threshold for harbor seals that is based on immune system and endrocrine endpoints and predicted to remain high for decades, mostly driven by the long half lives of PCBs (Hickey *et al*. 2007).

Total PCBs in blubber biopsy samples collected in 1993-1997 averaged 146 ppm (lipid weight) in Southern Resident males vs. 37 ppm in Northern Resident males and 251 ppm in Transient males (Ross *et al*. 2000). Southern resident males sampled in 2004/2006 averaged 62 ppm (Krahn *et al*. 2007). Females off-load PCBs during calving and lactation, resulting in lower concentrations than males, by about a factor of three in the 1993-1997 study. PCB levels rise quickly in nursing calves, then the levels fall as the PCBs are diluted with growth, with levels in males increasing with age and females increasing until the onset of reproduction (Hickey *et al*. 2007).

A north-south gradient in increasing PCB levels has also been observed in harbor seals, which are non-migratory. Ross *et al*. (2004) reported average total PCB concentrations in adult seal blubber of 1.1 ppm in Queen Charlotte Strait, 2.5 ppm in the Strait of Georgia, and 18 ppm in Puget Sound. More recently, WDFW analyzed the blubber of 24 seal pups at four locations in Puget Sound (Ecology 2011i). Total PCBs ranged from 1.0 to 9.4 ppm. Concentrations increased following the order Hood Canal < Whidbey Basin < South Sound < Main Basin (Figure 25). As with killer whales, indicators of adverse health impacts have been observed in harbor seals and linked to PCBs or other persistent organic pollutants (Cullon *et al*. 2012, Ecology 2011i, Mos *et al*. 2010).

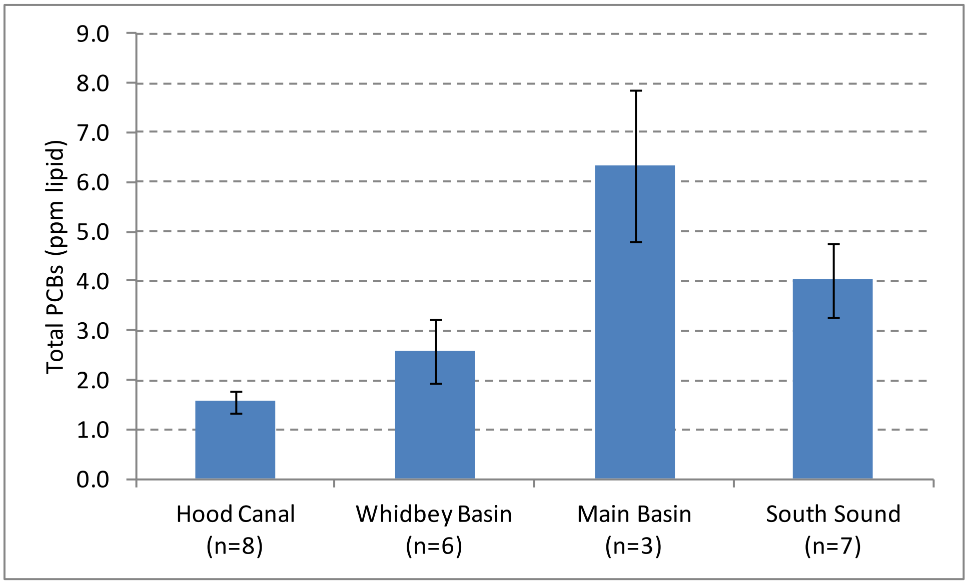


Figure 25. PCBs in Blubber of Puget Sound Seal Pups, 2009 (from Ecology 2011i; mean and standard error)

USGS and USFWS have analyzed PCBs in lower Columbia River wildlife. Their most recent data (1990-2004) show average wet weight concentrations of 0.2 ppm in mink livers, 0.5 ppm in otter livers, 0.8 ppm in osprey eggs, and 5.4 ppm in eagle eggs (Henny *et al*. 1996, Grove *et al*. 2007, Henny *et al*. 2007, Buck *et al*. 2005).

Another USGS study reported mean total PCB concentrations of 0.8 ppm in osprey eggs collected from the lower Duwamish River in 2006-07, but noted these birds had been feeding largely on hatchery raised salmon smolts (Johnson *et al*. 2009). The significance of hematological and biochemical differences observed between eggs from the Lower Duwamish and a reference site (upper Willamette River) was unclear. The same study reported 2.6 ppm, 1.9 ppm, and 0.7 ppm total PCBs, respectively, in osprey eggs collected from Lake Washington, the Lower Duwamish River, and Snohomish River estuary in 2002-2003.

Cleanup Sites

There are 336 hazardous waste sites listed in Ecology's Integrated Site Information System (ISIS) as having confirmed or suspected PCBs. Many sites had multiple media with confirmed or suspected PCB contamination. Of the sites with confirmed or suspected PCBs in sediments, all but 15 also had soil with confirmed or suspected PCB contamination.

Table 26. PCB clean up sites

Medium	# of Sites	Confirmed	Suspected	Remediated	Below CUL
Soil	295	165	99	11	20
Groundwater	173	60	109	2	2
Sediment	62	47	11	1	3
Surface Water	89	19	64	6	0
Air	18	3	14	0	1

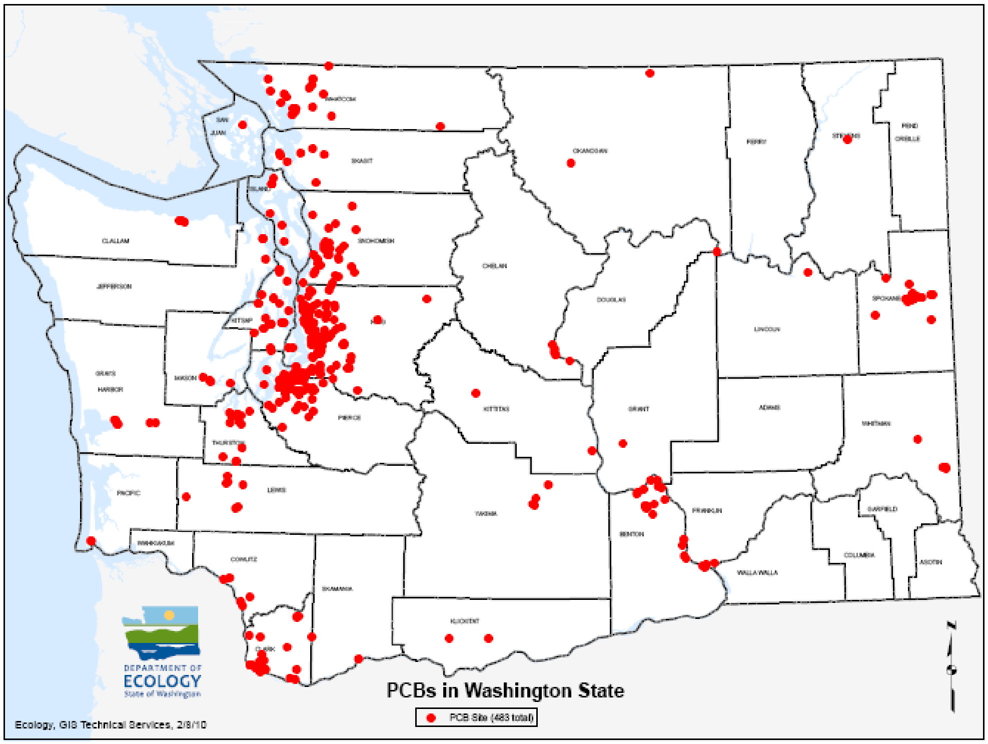


Figure 26. Figure of 483 PCB cleanup sites in Washington in 2010

Waste

Landfills

All Shred Residue

The material that remains after other parts are removed from automobiles at end of life for reuse or proper disposal is sometimes shredded and nearly all is used as landfill cover. PCBs may be present in automobiles in hydraulic fluids, plastics, voltage regulators, electric motors, switches, small capacitors, and light ballasts, leading to PCBs in the shredder waste. The all shred residue (ASR) is not just from end of life vehicles, but also includes consumer goods and commercial scrap. Feedstock sources may come from in or out of state. This material is difficult to sample, due to its heterogeneity in waste streams, metal extraction processes, and changes in manufacturing materials.

PCB concentrations in untreated shredder waste have been measured between 0.59 – 129 mg/kg and treated shredder waste contains 2.6 - 45.1 mg/kg (McKee *et al*.2006). McKee *et al*. further estimated that there is 270,000 tons of shredder waste from automobiles and appliances in California, leading to an estimate of 30-6,970 kg of PCBs (Average = 3,500 kg) in untreated shredded waste and 140-2,440 kg of PCBs (Average = 1,300 kg) of treated shredder waste in the Bay Area.

We have some information on PCBs in shredder residue in Washington in a 2013 report prepared for EPA Region 10 (Toeroek 2013). In this study Ecology and EPA sampled four facilities for PCBs (using Method 8082) and other analytes. There were different sampling protocols to look at variation, and all included a 9.5 mm sieve. Based on observations during the sampling, end of life vehicles were only shredded during two of the four days sampling occurred and all samples included consumer goods and commercial scrap. PCB concentrations ranged from 0.4 - 59 ppm (mg/kg) for the Aroclors tested, with a mean of 19 ppm, which is similar to the other results mentioned above.

Across Washington, shredders generate over 500 tons of ASR daily (Full Circle Environmental and Ecology 2011) and landfills reported disposing of 230,157 short tons (208,983 metric tons) of ASR in 2012. Using the range of concentrations found of 0.4 - 59 and the average concentration found of 19 ppm, results in an estimated 80 to 12,000 kg (12 metric tons) with an average of 4,000 kg (4 metric tons) of PCBs in 208,983 metric tons of ASR disposed of in Washington landfills each year.

Electrical equipment

Under federal TSCA, non-leaking small capacitors are allowed to be disposed of as solid waste. However, Washington State applies its own regulations to PCB electrical equipment containing 2 ppm PCBs or more and to materials contaminated to 2 ppm PCBs or more by electrical equipment. Unless the waste meets specific exclusions under the Washington State PCB rule (WPCB), these items must be properly disposed of and reported to Ecology as WPCB waste by the generator in annual data source reports. The waste code is for proper disposal and does not include more information on concentrations.

From 2009 – 2012, 10,577 MT of PCB-contaminated waste were reported under WPCB (Table 27).

Table 27. PCB-contaminated waste reported under WPCB

Year	WPCB (MT)
2009	2,322
2010	2,616
2011	1,310
2012	4,310

PCB-ballasts are considered moderate risk waste (MRW) when they are disposed of by households (household hazardous waste) and small businesses (small quantity generator waste). The weights reported in Table 28 include ballasts and shipping containers and we have not corrected for that due to the unknown weights of the shipping containers. Estimating that each ballast weighs 1.6 kg, and contains 44g of PCBs the estimated amount of PCBs ranges from 340 to 560 kg each year. Most of these PCB-ballasts go to a hazardous waste landfill outside of Washington State.

Table 28. PCB-ballasts collected as MRW (2010-2012)

Year	PCB-ballasts MRW (lbs)	PCBs (kg)
2010	32,871	410
2011	44,996	560
2012	26,885	340

Biosolids

Biosolids fall under the Clean Water Act (CWA) and the 503 rule (40 CFR 503). There are no requirements to monitor PCBs in biosolids, nor a regulated level of PCBs in biosolids. EPA(1995) made a "policy decision to delete all organic pollutants from land application and surface disposal sections of the final Part 503 rule because these pollutants met one of the following criteria: (1) the pollutant has been banned or restricted for use in the United States or it is no longer manufactured for use in the United States; (2) the pollutant is not present in biosolids at significant frequencies of detection based on data gathered in the NSSS [the National Sewage Sludge Survey], or (3) the limit for a pollutant from the biosolids exposure assessment is not expected to be exceeded in biosolids that are used or disposed based on data from the NSSS."

EPA continues to investigate pollutants in sewage sludge and uses risk analysis to ascertain which pollutants require monitoring and regulatory levels.

While neither federal nor state regulations require testing of biosolids for PCBs, some jurisdictions such as King County, have tested for PCBs in biosolids (King County 2007). In 2006 Aroclor 1248, 1254, and 1260 were detected and other Aroclors were not detected at the West Point Treatment Plant. Only Aroclor 1254 was detected at the South Treatment Plant. Historically PCB Aroclors have been detected in King County biosolids at the ppb level. We do not have enough information to estimate the amount of PCBs in biosolids in Washington.

PCBs have also been measured in a few samples of Canada Goose guano in the Lower Duwamish area. In four composite samples the total Aroclor PCBs ranged from 28-103 ppb with an average concentration of 58 ppb. This is generally indicative of the ubiquitous nature of PCBs in Washington. This is not enough information to estimate the amount of PCBs in goose guano in Washington.

Environmentally Significant PCBs

As a result of partitioning, transformation, and bioaccumulation, PCB mixtures in the environment do not resemble the commercial products. About half of the 209 possible congeners account for most of the environmental contamination. Based on toxicity, prevalence, and relative abundance, less than 40 congeners are most commonly found in the environment.. Twenty-five of these account for 50-75% of the total PCBs in biological tissues (McFarland *et al*. 1989).

In Washington and elsewhere, PCBs with three to six chlorines (tri- through hexachlorobiphenyls) are the dominant compounds found in environmental samples. Less chlorinated compounds are more volatile and more readily metabolized and eliminated from organisms. Highly chlorinated compounds are relatively less abundant, more tightly bound to sediment particles, and taken up poorly by fish and other aquatic animals.

Twelve PCBs have a co-planar configuration that imparts dioxin-like toxicity (Tables 20 and 25). These compounds are frequently detected in Washington's environment. PCB-118 is the co-planar most often encountered in the highest concentrations (Cleverly *et al*. 1996, Ecology 2011i most toxic co-planar, PCB-126, is typically present at the lowest concentrations.

Although their toxicity is low relative to dioxin - a tenth or less – these PCBs can impart a significant fraction of the total dioxin toxicity equivalents (TEQ), particularly in higher animals. Co-planar PCBs accounted for up to 89% of the total TEQ in harbor seal pups collected from Puget Sound in 2009 (Ecology 2011i). PCB-118, -105, and -156, in that order, were the major contributors to the TEQ. Cullon *et al*. (2009) reports that PCBs explained the majority of the TEQ in adult salmon from British Columbia and Puget Sound waters. In contrast, the PCB TEQ in Washington freshwater fish is typically much lower than the dioxin TEQ, by an order of magnitude or more in most cases (CH2MHill 2007, USDOE 2010, Ecology 2010c).

PCB-11, a non-legacy PCB, has been identified in Columbia River water and clams (Ecology 2005, McCarthy 2007). In some samples, PCB-11 was either the most or second-most abundant congener detected. PCB-11 is neither associated with historical commercial PCB products nor a breakdown product of the commercial mixtures. The source has been traced to pigments currently used in paint (Hu and Hornbuckle, 2010). Reports of PCB-11 in environmental samples have become widespread in North America (Litton 2006, Grossman 2013). PCB-11 is considered a significant source of contamination to air, soil, and water (Hornbuckle and Robertson 2010).

Model Predictions

Ecology modeled the long-term fate and bioaccumulation of PCBs in Puget Sound (Ecology 2009b). Pertinent findings from Ecology's box model include the following:

- Approximately 97% of the total mass of PCBs in the aquatic ecosystem of Puget Sound is in the active sediment layer (top 10 cm), <1% is in the water column, and <3% is in the biota.
- Decreases in PCBs in sediment and biota are possible by the year 2020 in the urban bays due to burial and transport of sediments**.**
- Increases in PCBs in sediment and biota are possible by the year 2020 in the larger basins.
- Considering the wide range of uncertainty in loading from outside of the Puget Sound basin, it is possible the mass of PCBs in the aquatic ecosystem of Puget Sound may either increase or decrease over time at the current loading levels.

Ecology is currently re-evaluating this model using more recent data.

A delayed response to environmental declines in PCB levels is predicted for long-lived species like killer whales (~50-year lifespan). According to an individual-based model, Southern Resident killer whales may not fall below PCB effects thresholds for several more generations (Mongillo *et al*. 2012, Hickie *et al*. 2007).

Food web models for Lake Washington and the Spokane River conclude that PCB residues in fish are driven mainly by levels in the sediments in Lake Washington and are an important factor in the Spokane River (Ecology. 2010a and 2011c). Thus, recovery in these water bodies may respond slowly to reductions in external PCB loading.

Results of a mass balance model for the Willamette River basin in Oregon demonstrated that the PCB levels observed in fish could be due entirely to atmospheric deposition from global legacy sources (Hope 2008). In this analysis, PCB sources within the Willamette basin were assumed to be insignificant. Portland was discounted because it occupies a short segment of the lower river isolated by Willamette Falls.

Local Hazard Assessments

Spokane River

The Spokane River has elevated levels of PCBs in Washington. Ecology calculated hazard quotients (HQs) for different endpoints and receptors in six different parts of the river for aquatic life and fish-eating wildlife (Ecology 2001). HQs are ratios of the level of PCBs in the environment and the level at which no adverse effects are expected. If the HQ is greater than 1, then adverse health effects are possible, but do not necessarily occur.

The primary ecological hazards identified were:

1. Possible adverse effects on the sustainability of salmonid populations and fish-eating mammals, primarily in the reach between Trentwood and Nine-Mile Dam.

PCB levels in salmonid fish tissue were high compared to the National Marine Fisheries Service (NMFS) effects threshold for sublethal effects (HQs of 2.2-4.1).

The levels of PCBs in water were high compared to the Great Lakes criterion for reproductive effects on fish-eating mammals (HQs of 4.5-17). Also the PCB levels in fish tissue were high when compared to the British Columbia guideline for reproduction in fish eating wildlife (HQs of 2-6) and compared to the lowest observable effects levels (LOEL) for mink and otter reproduction (HQs of 1.5-2.4).

2. Possible adverse effects on benthic invertebrates in the Trentwood to Monroe Street Dam reach in areas where PCBs have been concentrated in fine-grained sediments, such as behind Upriver Dam. The levels of PCBs in sediment were high compared to the threshold effect for abundance and diversity of benthic invertebrates (HQs of 2.5-9.8)

Puget Sound

As part of the larger, multi-year, multi-agency, project to study toxic chemicals in Puget Sound, the Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011 (Ecology 2011a) included a hazard evaluation to estimate the relative hazard posed by the 17 chemicals of concern assessed in the Puget Sound studies. This was not a risk assessment, but part of the effort to prioritize efforts on pollutants in Puget Sound. The hazard evaluation was for the entire Sound, not for hot spots where there are higher levels of contamination, such as in cleanup sites. PCBs were ranked as having the highest level of concern for a range of media and receptors in both the freshwater and marine aquatic environments.

PCBs were found to be at the highest level of concern (Priority 1) for the five categories assessed. The category and the reason PCBs were placed in Priority one is given below for each.

- Aquatic life through surface water exposure. The 90th percentile of observed concentrations of Aroclors was above the chronic Water Quality Standard (WQS) for aquatic species in freshwater.
- Benthic organisms through sediment exposure. The 90th percentile of the observed concentrations exceeds the Sediment Quality Standard for Aroclors for freshwater (FP-SQS) and offshore marine sediment (SQS).
- Tissue Residue Effects. The 90th percentile of observed concentrations was above the 10th percentile of the effects concentration for non-decapod invertebrates for both Aroclors and total congeners.
- Wildlife through seafood consumption. Using Great Blue Heron, Osprey, River Otter, and Harbor Seal as representative species, the daily dose was more than the lowest effect dose divided by10.
- Human health through seafood consumption. The 90th percentile of observed tissue concentrations was above National Toxics Rule (NTR) water quality criteria for freshwater, nearshore marine, and offshore marine for both Aroclors and congeners for bivalves, fish and invertebrates. Tissue criteria were back calculated from the NTR based water quality criteria.

Environmental data from January 2000 to July 2010 were collected from a variety of sources, and the largest source of data was Ecology’s Environmental Information Management (EIM) system. Information on effects levels were found in the scientific literature and regulatory benchmarks. Comparisons to effects levels, criteria, and guidelines were done separately for both PCB Aroclor and congener data. Box Plots showing these comparisons can be found in the Assessment report Appendices D3-D7 (https://fortress.wa.gov/ecy/publications/summarypages/1103055.html).

Human Health Effects of PCBs

Introduction

There is a very large body of toxicological and epidemiological research on the health effects of PCBs. Research conducted in experimental animals has shown that PCBs can cause a wide variety of adverse health effects including, immune suppression, adverse reproductive effects, abnormal motor and cognitive development, injury to the liver and other internal organs, changes in the endocrine system, and cancer. Epidemiological studies have found evidence of similar adverse effects on human development and behavior, reproduction, immune function, and cancer (ATSDR 2000). The International Agency for Research on Cancer (IARC) recently changed their classification of PCBs and dioxin-like PCBs from “probable human carcinogens” to “human carcinogens” to recognize that there is now sufficient evidence in humans and animals. (Lauby-Secretan *et al*. 2013).

The primary historic uses of PCBs were banned in 1979 but existing electrical equipment and other closed systems containing PCBs were permitted to remain in use (40 CFR part 761). Caulk, joint sealant, paint, and other building materials sold before 1979 may have contained PCBs and could still be in place. PCBs have continued to slowly escape from these historic sources with rapid releases during leaks, fires, and building demolition.

Historically, PCB oils and equipment containing those oils have been disposed in ways that allowed PCB release into the environment. A number of waste sites in Washington have been identified as contaminated with PCBs. Many have been cleaned up but additional clean-up remains. Because many PCBs are persistent and bioaccumulative, these legacy sources of PCBs continue to cycle through air, water, soil, sediments, and biota. Although general environmental levels have dropped dramatically since 1979, human exposure to legacy PCBs in fish, other foods, and air will continue into the future.

In addition, PCBs are inadvertently formed during current production of certain pigments and ink (Hu and Hornbuckle 2010). These PCBs have been detected in colored papers, cardboard, plastics, and textiles and may be released to the environment during manufacturing, use, disposal, or recycling of consumer products (Litten *et al*. 2002, Rodenburg *et al*. 2010). PCB 11 has emerged as a useful indicator of these new sources of exposure since commercial PCBs mixtures did not contain more than trace amounts of PCB 11 (Grossman 2013).

There are 209 possible configurations of chlorine substitutions of the biphenyl molecule. Each possible configuration (called a congener) is assigned a number and most can now be quantified analytically. Because congeners vary in their toxicity and their resistance to metabolism, risk assessment of PCB mixtures is complex. One of the earliest discoveries in the search for common mechanisms of toxicity was that certain congeners have dioxin-like ability to bind to the aryl hydrocarbon (Ah) receptor. Dioxin-like PCBs are planar or nearly planar in structure (Van den Berg *et al*. 1998). Their interaction with the Ah receptor is dose-dependent, saturable, and induces hepatic enzymes, including aryl hydrogen hydroxylase (also called cytochrome p450 CYP1A1) and 7-ethoxyresorfin *O*-deethylase (CYP4501A2) (Seegal 1996). These enzymes metabolize (or breakdown) a number of environmental chemicals but also act on important endogenous chemicals such as hormones, retinoids, and neurotransmitters (ATSDR 2000).

Several toxic responses have been well correlated with the Ah-receptor binding affinity, including body weight reduction, hepatotoxicity, and thymic atropy (Seegal 1996). Laboratory animals exposed solely to coplanar PCBs have shown reproductive problems, increases in brain levels of biogenic amines including dopamine, alterations in fetal and neonatal plasma thyroid hormone levels, and neurobehavioral effects (Brouwer *et al*. 1995). Available evidence in lab animals suggests that the maturation of the immune system is especially vulnerable to adverse effects of dioxin-like compounds (Holladay and Smialowicz 2000). Toxic equivalency factors (TEF) for 12 PCB congeners have been developed to facilitate human health risk assessment of mixtures of dioxin-like chemicals (Van den Berg *et al*. 1998, 2005, see Table 24 and Table 29).

EPA and ATSDR have established health recommendations concerning oral intake and inhalation of PCBs. These screening levels help public health agencies and communities identify exposures of concern. The three primary pathways of current PCB exposure for the U.S. general public are diet, indoor air, and ambient air. In addition, ingestion of PCB residues in house dust could be a significant contributor to exposures in toddlers (ATSDR 2000, Harrad *et al*. 2009). Although background exposures in the U.S. population appear to have dropped below levels of concern, special populations at higher risk for exposure exist and require attention. These include people who work around PCB contaminated equipment or materials, who consume fish and seafood from contaminated waters, or who live or work in a building with PCBs in building materials or fluorescent light ballasts.

Historical Episodes of PCB Poisoning

Acute poisoning to PCBs has been documented in people following accidental food contamination and workplace accidents. These incidents underscore why people must be protected from direct contact with concentrated PCB liquids or materials during source removal, transport, and disposal. There have been two episodes of mass human poisoning by inadvertent community-wide consumption of PCB contaminated rice oil. One occurred in Japan in 1968 and the other in Taiwan in 1978-79. Affected people in Japan were diagnosed with “Yusho” which means “the oil disease” and in Taiwan with “Yu-Cheng,” the term for “oil disease” in Taiwanese. About 1700 adults were acutely affected in the Japanese incident. Exposure of adults resulted in increased skin pigmentation, severe acneform eruptions, swelling of the meibomian gland with eye discharge, thickening of the nail bed, numbness in extremities, and respiratory disease (Urabe and Asahi 1985, Ikeda 1996, Nakanishi *et al*.1985). Affected women who were pregnant at the time gave birth to children with physical abnormalities (dental disorders, hyperpigmentation of skin) and severe neurodevelopmental problems (Seegal 1996). Exposure monitoring for PCBs in blood of Yusho patients did not begin until five years after the onset of disease.

About 2000 persons were initially affected with illness in the Taiwan incident. Symptoms included hyperpigmentation, acneform eruptions, swelling of eyelids and increased discharge from the eyes, as well as systemic complaints (Lu and Wu 1985). Women who were pregnant at the time of exposure gave birth to children who showed hyperpigmentation, nail deformities, conjunctival discharge and swelling. Eight of the 39 infants born with hyperpigmentation during the four years following the incident died (Hsu *et al*. 1985). A cohort of most of the Taiwanese children (*n* =118) born to affected mothers up to six years past the incident has been followed and tested annually for cognitive deficits. A comparison population with the same number of children was matched on maternal age, child's birthdate, gender, and neighborhood of residence. Blood PCB levels of Yu Cheng patients were measured early in the disease outbreak and were high (44.4% of 613 patients sampled had blood levels of PCBs between 51-100 ppb). The highest value reported was 1156 ppb (Hsu *et al*. 1985). Yu-Cheng offspring have been shown to have persistent cognitive deficits, lower IQ, and higher rates of problem behaviors compared to neighborhood controls (Lai *et al*. 2002).

Immune effects were also reported in both groups of poisoned people including an increase in respiratory and skin infections and changes in immune parameters such as immunoglobulins and T cells (Lu and Wu, 1985). Studies also detected depressed responses to tuberculin tests (Lu and Wa 1985, Nakanishi *et al.* 1985). Infants born to mothers who had Yu-Cheng disease had more episodes of bronchitis or pneumonia during their first six months of life and had higher frequencies of ear infection and respiratory tract infection in a six-year follow-up (Yu *et al*. 1998).

There is debate about the degree to which these two mass poisonings are relevant to current assessments of PCB exposure (Schantz 1996, Seegal 1996). The levels of PCB intake were very high compared to environmental sources. PCBs in both incidents had been repeatedly heated to high temperatures in a heat exchanger before contamination of rice oil occurred. The high temperatures changed the chemical composition of the oil creating high concentrations of polychlorinated dibenzofurans (PCDF) and other toxic compounds. Many of the developmental and physical effects seen in these populations, however, are also observed in monkeys dosed with pure PCB mixtures.

Developmental abnormalities have also been observed in occupationally exposed populations. A seven-year follow-up study of capacitor manufacturing workers in Japan and their children evaluated effects on children born to mothers who had PCB blood and breast-milk levels that were 10-100 times the normal background and markedly higher than the blood of Yusho patients. Forty children were examined once a year for five years and none were diagnosed with PCB poisoning. Some of the children were found to have decay of nails, gingival pigmentation, mottled enamel, and dental caries that were typical symptoms in Yusho but were less serious in this study population (Hara 1985).

Endpoints of Human Health Concern

Cancer

There is clear evidence that commercial PCB mixtures cause cancer in animals in a dose-dependent manner (EPA 1996b, ATSDR 2000). Cancers observed primarily involve thyroid and liver tissue. Studies of workers exposed to commercial PCB mixtures found increases in liver and bile-duct cancers and malignant melanoma across multiple human studies (NTP 2011, Lauby-Secretan *et al*. 2013).

EPA and NTP consider PCBs to be probable human carcinogens and recently International Agency for Research on Cancer (IARC) strengthened its classification of PCBs to “human carcinogens” based on new evidence of melanoma in epidemiological studies (Lauby-Secretan *et al*. 2013). EPA concluded that the types of PCBs likely to be bioaccumulated in fish and bound to sediments are likely to be the most carcinogenic PCB mixtures (EPA 1996b).

PCB mixtures and individual congeners can act as tumor promoters (ATSDR 2000, WHO 2003, EPA 1996b). Tumor promotional activity has been observed by congeners that are aryl hydrocarbon agonists (dioxin-like congeners), that induce cytochrome P450 1A and 2B isozymes, and induce P450 CYP2 and CYP3 families of enzymes and have a phenobarbital pattern of enzyme induction (ortho-substituted congeners). Oxidative stress and disruption of intercellular communication have also been proposed as mechanisms for cancer promotion (EPA 1996b, WHO 2003).

Certain PCB congeners have been shown to be direct tumor inducers as well. In a series of recent investigations, the National Toxicology Program (NTP) demonstrated that dioxin-like congeners, PCB 118 and PCB 126, were able to induce lung, liver, bile duct, oral, and uterine cancers in rodents (NTP 2006). Certain non-dioxin-like congers that are likely to be in air, such as PCB 3, also appear to undergo metabolic activation in rodents to reactive species that are genotoxic and can initiate DNA and chromosomal damage (Xie *et al.* 2010; Ludewig and Robertson, 2013). Few studies of genotoxicty in humans have been conducted but these have been negative for environmental PCB exposures (Ludewig and Robertson, 2013).

Immune Effects

Numerous immune effects have been measured in laboratory animals exposed to PCBs (ATSDR 2000). Changes in the immune system were selected by both ATSDR and EPA as the most sensitive non-cancer endpoint for chronic exposure to PCBs. In the critical study chosen by these agencies (Tryphonas *et al*. 1989, 1991a, 1991b), PCB-treated rhesus monkeys had a dose-related reduction in antibody response to an injected antigen (sheep red blood cells). The diminished production of immunoglobulins IgM and IgG, in response to antigen was statistically-significant at two time points during the study (27 months and 55 months) at the lowest dose of Aroclor 1254 tested (5 µg/kg/d). No differences in baseline serum concentrations of IgG, IgM, or IgA were evident. Both EPA's Reference dose for chronic exposure and ATSDR's minimal risk level were derived from findings of this study at the 5 ug/kg/d dose level (EPA 1994, ATSDR 2000). Body burdens after 25 months of dosing at 5 µg/kg/d were reported to be 10.3 ppb in blood (8.4 ppm in blood when expressed on a lipid basis) and 2.2 ppm in adipose tissue (7.5 ppm in adipose when expressed on a lipid basis) (Arnold *et al*. 1993a, 1993b).

The experiment above continued into a breeding phase to measure reproductive and developmental outcomes in the rhesus monkeys. Female monkeys treated for 37 months with Aroclor 1254 were bred to unexposed males. Among other things, offspring were tested for immunological function. A reduction in IgM titres to sheep red blood cells were statistically significant for the 5 µg/kg/d dose level at multiple post-natal time points (Arnold *et al*. 1999).

Statistically significant but clinically mild developmental abnormalities were observed in offspring at the 5 µg/kg/d dose level including nail and nail bed changes, and inflammation and/or enlargement of the tarsal glands. There were also adverse reproductive effects that were elevated but did not reach statistical significance at the 5 µg dose (Arnold *et al*. 1999).

A number of epidemiological studies have reported immune effects associated with human environmental exposures to PCBs. Inuit children with high exposure to PCBs and other organochlorines, were reported to have higher incidence of ear infection and lower (but not upper) respiratory tract infection during the first five years of life (Dallaire *et al*. 2006). Early life exposures to PCBs have also been associated with reduced response to childhood vaccinations in European children (Weisglas-Kuperus *et al*. 2000, Heilman *et al*. 2006) and reduced size of the thymus (Park *et al*. 2008).

Neurological and Neurodevelopmental Effects

Extensive animal research on neurologic impacts of PCB shows adverse effects in adults and the young with fetal and early postnatal periods being the most sensitive in producing adverse effects in rodents and monkeys (Brouwer *et al*. 1995). Hyperactivity and learning and memory impairments are very sensitive to developmental PCB exposure in non-human primates (Bowman *et al*. 1978, Schantz *et al*. 1991). ATSDR based their health advice for oral PCB exposure over intermediate durations on learning and memory impairments observed after postnatal exposure to a PCB in male rhesus monkeys (ATSDR 2000). In this study, Rice *et al*. created a congener mixture that represented 80% of the congeners present in breast milk in Canadian women and administered it for 20 weeks post-natally at a dose estimated to be equivalent to nursing from a mother with 50 ppb PCB in breast milk (7.5 µg/kg/d). Behavioral tests were conducted 3-5 years later. Treated monkeys were slower to learn new responses, adapt to new response patterns, and inhibit a response that was previously rewarded (Rice 1999). This study also measured effects at the lowest and only dose tested.

A number of studies have reported developmental effects in children although PCB levels in cord blood at birth or in the mothers were significantly higher than current body burdens in most populations (Jurewicz *et al.* 2013). Some studies, such as the Michigan Maternal/Infant Cohort and the Oswego Newborn and Infant Development Project, compared pregnant women who consumed Great Lakes fish to mothers who did not. Other studies, such as the North Carolina Breast Milk and Formula Project and the Dutch PCB/Dioxin Study, focused on mothers in the general population. These studies reported a range of subtle neurobehavioral effects such as abnormal newborn reflexes, cognitive and memory deficits including decreased IQ and changes in physical activity that were associated primarily with *in utero* not lactational PCB exposure (Jacobson and Jacobson 1996, Stewart *et al*. 2008, Brouwer *et al*. 1995). Although some studies have measured effects of lactational exposure to PCBs via breast milk, breast feeding appears to have a net positive effect on children with regard to mental and physical development (Anderson *et al.* 1999, Boersma and Lanting 2000, Pan *et al*. 2009). Fish consumers had higher proportions of PCB congeners with 7-9 chlorines and, in one analysis, these congeners were shown to be more closely associated with the neurobehavioral effects observed (Stewart *et al*. 1999). In another study, maternal body burden of dioxin-like mono-ortho substituted congeners (PCBS 118 and 156) were most strongly associated with neurobehavioral outcomes in children (Park *et al*. 2010).

Several researchers have proposed potency schemes for neurotoxicity of PCB mixtures that include both dioxin-like and non-dioxin-like PCB congeners. One neurotoxicity equivalency scheme is based on congener potency in interfering with intracellular signaling pathways and calcium ion modulation in the nervous system (Simon *et al.* 2007). Another is based on congener potency in altering brain dopamine and blood thyroid hormone levels (Yang *et al.* 2009). Although these schemes are not sufficiently developed for risk assessment, they point to the need to expand beyond TEQ of dioxin-like congeners when assessing potential neurotoxicity of PCB mixtures.

Reproductive Effects, including Birth Defects

Reproductive effects of PCBs have been demonstrated in a variety of animal species including non-human primates (ATSDR 2000). Oral PCB exposures reduced birth weight, conception rates and live birth rates of monkeys exposed during preconception and gestation (Arnold *et al*. 1995). Similar results have been observed in rodents. Developmental exposures in rodents resulted in lasting changes in reproductive tissue that were measurable at puberty and into adulthood (WHO 2003).

Investigations of reproductive effects have also been carried out in human populations exposed to PCBs. Longer time-to-pregnancy for couples trying to get pregnant has been reported to correlate with higher levels of certain PCB congeners (Axmon *et al*. 2005, Buck Louis *et al*. 2013). Obvious growth retardation was observed in offspring following the Yusho and Yu-Cheng incidents. Children born to women who worked with PCBs in factories showed decreased birth weight and a significant decrease in gestational age with increasing exposures to PCBs (Taylor *et al*. 1989, Hara 1985). Studies in fishing populations believed to have high exposures to PCBs also suggest similar decreases in either birth weight or gestational age or both (Fein *et al*. 1984, Rylander *et al*. 1995). Govarts *et al*. 2012 reported that birth weight decreased with increasing cord serum concentration of PCB-153 after adjustment for potential confounders in 12 of 15 study populations in Europe. Several studies have observed persistent deficits in physical growth into childhood following prenatal exposure to PCBs, particularly in girls (Jacobson and Jacobson 1997, Lamb *et al*. 2006, Blanck *et al*. 2002). Other investigations did not detect lower weight or shorter gestation times in other populations, including fish consumers (Rogan *et al*. 1986, Patandin 1999, Dar *et al*. 1992, Buck *et al*. 2013, Cupul-Uicab *et al*. 2013).

Endocrine Effects

There has been significant discussion and research on the effects of PCBs on the endocrine (or hormone) system. A number of PCB congeners and their metabolites display weak estrogenic, antiestrogenic effects, or antiandrogenic effects (Goncharov *et al.* 2009, Hamers *et al*. 2011, Brouwer *et al*. 1999, Birnbaum 1994). Certain PCBs and their metabolites appear able to directly interfere with estrogen or androgen receptors and bind directly to the estrogen receptor while others may act indirectly by inducing enzymes that then change estrogen metabolism (Brouwer *et al*. 1999, Kester *et al*. 2000, Hamers 2011).

The strongest evidence is for disruption of thyroid hormone levels. Hydroxylated PCB metabolites are structurally similar to the thyroid hormone thyroxine (T4) and may interfere with hormone receptor binding directly. They have been shown to competitively displace binding of thyroid hormone (T_4) to transthyretin in rodents and to disrupt the normal delivery of thyroid hormone from maternal plasma to the rodent fetus *in vivo* (Porterfield 2000, Brouwer *et al*. 1999). In addition, PCBs and their metabolites may act indirectly by interfering with thyroid hormone metabolism. For example, activation of the Ah receptor by dioxin-like PCBs, induces production of the enzyme uridine diphosphoglucuronyl transferase that metabolizes T4 and may accelerate T4 clearance from the liver (Porterfield 2000, Koopman-Esseboom *et al.*1994). Thyroid hormones are essential for regulating metabolism and normal growth and brain development. They also promote normal cardiovascular, reproductive and nervous system functioning.

Dioxin-like PCBs have been associated with changes in thyroid hormone levels in infants (Koopman-Esseboom *et al*. 1994, Nagayama *et al*. 1998, Pluim *et al*. 1992). A more recent study by Wilhelm *et al*. 2008 looked for but did not find any decrease in thyroid hormones related to dioxin-like PCBs or total TEQ at current exposure levels in Germany. Chevrier *et al*. 2008 reported that blood concentration of thyroid stimulating hormone in newborns was associated with non-dioxin like PCB congeners (PCBs 99, 138, 153, 180, 187, 194, and 199). Similar results, higher TSH and lower free T4 levels with increasing PCB levels, were reported in adolescents, although only in the group that had not been breast-fed (Schell *et al*. 2008).

Established Health Guidelines for PCB Mixtures

EPA's approach to cancer risk assessment of PCB mixtures

EPA uses a tiered approach to cancer risk assessment for PCB exposure. EPA recognized that selective bioaccumulation in the environment creates dietary PCB mixtures that differ markedly from Aroclor mixtures produced commercially. The tiers attempt to address the likely differences in toxicity and persistence of PCB mixtures. The tiers also reflect that PCB mixtures comprised mostly of congeners with more than four chlorines are more persistent and more carcinogenic than more lightly-chlorinated, less persistent congeners.

EPA recommends that risk assessors use a cancer slope factor of 2.0 per mg/kg/d for PCB mixtures present in the food chain. This most potent assumption should also be applied to protect all early life exposures. A less potent assumption of 0.4 per mg/kg-d can be used in assessments of ingestion of water soluble congeners and inhalation of evaporated congeners. A third tier (cancer slope equal to 0.07 per mg/kg-day) is provided for assessment of exposure to PCB mixtures with less than one half percent congeners of four or more chlorines. (Cogliano 1998)

Dioxin-like congeners and Toxic Equivalency (TEQ) approach.

Mixtures of PCBs congeners that have dioxin-like toxic effects can be evaluated by their toxicity relative to the most toxic dioxin, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Dioxins and dioxin-like compounds have a common mechanism of action mediated by the aryl hydrocarbon receptor (AhR) but differ in their potency. Their potency relative to TCDD is reflected in their Toxic Equivalent Factor (TEF) developed by the World Health Organization for 7 dioxins, 10 dibenzofurans, and 12 PCB congeners. TEFs for PCBS are shown in Table 29 (Van den Berg *et al*. 2006). The most potent PCB congener has a TEF =0.1 which means that it is 1/10 as toxic as TCDD. The TCDD Toxicity Equivalent (TEQ) of a mixture can be calculated by summing the individual congener concentration and their TEFs as shown in the equation below.

$$TEQ = \Sigma (TEF_i \cdot C_i)$$

Where:

TEQ = TCDD toxicity equivalance

TEF_i = Toxicity equivalency factor for an individual congener

C_i = Concentration of individual congener

Table 29. Toxicity Equivalence Factors for PCB Congeners

Class	Congener	Mammal Toxicity Equivalence Factor (TEF)
Co-planar PCBs	3,3',4,4'-TCB (77)	0.0001
	3,4,4',5-TCB (81)	0.0003
	3,3',4,4'-5-PeCB (126)	0.1
	3,3',4,4',5,5'-HxCB (169)	0.03
Mono-ortho PCBs	2,3,3',4,4'-PeCB (105)	0.00003
	2,3,4,4',5-PeCB (114)	0.00003
	2,3',4,4',5-PeCB (118)	0.00003
	2',3,4,4',5-PeCB (123)	0.00003
	2,3,3',4,4',5-HxCB (156)	0.00003
	2,3,3',4,4',5'-HxCB (157)	0.00003
	2,3',4,4',5,5'-HxCB (167)	0.00003
	2,3,3',4,4',5,5'-HpCB (189)	0.00003

Source: TEFs recommended by World Health Organization (Van den Berg et al. 2006).

The EPA recently set the daily level of exposure considered safe for humans over a lifetime (also known as the Reference Dose or the RfD) at 0.7 picograms per kilogram of body weight of TCDD or toxicity equivalent as calculated by the equation above (EPA 2012d). This number is believed to protect against the most sensitive non-cancer endpoints observed. It is based on observations of health effects at 20 pg/kg/d in two studies conducted after an industrial accident in Seveso, Italy. The follow-up studies detected reduced sperm counts in men exposed in childhood and increased thyroid hormones in infants of mothers exposed during pregnancy (Mocarelli *et al*. 2008, Baccarelli *et al*. 2008). An earlier health guideline for acceptable daily intake of dioxin-like compounds, set by the World Health Organization/United Nations in 2001, was based on older data. The newer EPA RfD is three times lower (see Table 30). EPA is currently developing its health guidance for dioxin cancer assessment.

Other Health Guidance

There are a number of health standards that address exposures to PCBs in people. For assessment of dietary intake, the Washington State Department of Health (Health) uses the EPA RfD and TEFs as described in WHO 2005 for non-cancer endpoints and an upper bound cancer slope factor of 2.0 per mg/kg/d for cancer.

The EPA standard for PCBs in drinking water is 0.5 µg/L and the FDA adopted the same standard for bottled water (see Table 30). The FDA has also set residue limits for PCBs in various foods to protect against harmful health effects including a maximum of 0.2 mg/kg in infant and junior foods, 0.3 mg/kg in eggs, 1.5 mg/kg in milk and other dairy products (fat basis), 2 mg/kg in fish and shellfish (edible portions), and 3 mg/kg in poultry and red meat (fat basis). The FDA regulatory action level for PCBs in fish is much higher than human health risk levels established under the National Toxics Rule or used by Health to assess fish. The FDA action level reflects FDA's higher tolerance for PCBs in food and the agency's emphasis on the net benefit to consumers of eating fish, despite contamination.

The National Toxics Rule sets water quality criteria for PCBs to protect human health over a lifetime of drinking water and eating fish from surface water. The NTR includes an equivalent fish tissue criteria (5.3 ppb) for PCBs. This serves as an "equivalent" measure of water quality in that fish living in water at the surface water criteria (0.00017 µg/L) should not exceed 5.3 ppb PCB in tissue. While Health supports Ecology's use of the NTR criteria for identifying problems and controlling water pollutant sources, Health does not use the NTR criteria to establish fish consumption advisories.

Health establishes fish advisory screening levels for mercury, PCBs, and other contaminants by using an approach similar to that outlined in EPA's Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Vol. 1-4 (EPA 2000b). This guidance provides a framework for state development of fish consumption advisories, based on best available science, and established procedures in risk assessment, risk management, and risk communication. Health's current screening level for PCBs also incorporates recommendations from the American Heart Association that people should consume two meals of fish per week to gain the known health benefits associated with fish consumption. The Health screening value of 23 ppb is derived from assumptions of two meals/week consumption rate, average body weight of a person, and EPA's RfD for protection of human health effects. Health uses this value to identify populations of local fish that may need a fish advisory. This is a starting point for state advisories which need to balance the many health benefits of fish with the possible risks of PCB ingestion. More on information about how Health develops PCB fish advisories is at: http://www.doh.wa.gov/AboutUs/ProgramsandServices/EnvironmentalPublicHealth/EnvironmentalHealthSafetyandToxicology/FishAdvisories.

For inhaled PCBs, EPA calculated indoor air guidance for schools ranging from 0.07-0.60 µg/m3 depending on the age of the children (see Table 30). These EPA calculations account for additional average exposures through diet, water, air and other sources and would maintain children's exposure levels below the RfD of 0.02 µg/kg/d (EPA 2012c). Residential indoor air levels would need to be lower to reflect the longer hours spent at home.

Public health guidance for PCBs in ambient air are lower still and assume exposure 24 hours a day and seven days a week. For inhalation of evaporated congeners, EPA IRIS assessment considers a concentration of 0.01µg/m^3 to be conservative protection against cancer risk (EPA 1997b). A variety of higher occupational inhalation exposure limits were established more than 10 years ago, assume exposures to adults only, and assume exposure during a standard work week (see Table 30).

Table 30. Established health regulations/guidance for PCBs

	Exposure Limits	**Agency**	**Reference**
Total oral daily intake-chronic	Oral Reference dose (RfDs 0.07 µg/kg/day (Aroclor 1016) 0.02 µg/kg/day (Aroclor 1254)	EPA, 2000	EPA, IRIS http://www.epa.gov/iris/subst/0462.htm http://www.epa.gov/iris/subst/0389.htm
Total daily intake of dioxin-like chemicals (TEQ)	0.7 pg/kg/day	EPA, 2012	EPA, Dioxin Assessment http://www.epa.gov/iris/subst/1024.htm
Total daily intake of dioxin-like chemicals (TEQ)	2.3 pg/kg/day	WHO 2001	World Health Organization, Joint Expert Committee on Food Additives
Minimal Risk Level for chronic oral intake	MRL is 0.02 µg/kg/d (based on Aroclor 1254)	ATSDR, 2000	Toxicological Profile for PCB http://www.atsdr.cdc.gov/toxprofiles/tp17.pdf
PCBs in specific foods	0.2-3.0 ppm in various categories of food.	FDA 1996	21 CFR 109
PCBs in edible fish entering interstate commerce	2.0 ppm	FDA, 2011	http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf
PCBs in fish	Screening level of 23 ppb in fish tissue (fillet)	DOH	See DOH website http://www.doh.wa.gov/CommunityandEnvironment/Contaminants/PCBs
PCBs in fish	5.3 ppb Fish tissue equivalent for	NTR, 1999	National Toxics Rule 64 FR 61182 http://www.gpo.gov/fdsys/granule/FR-1999-11-09/99-25559

	surface water quality criteria		
Drinking water	MCL is 0.5 μg/L (or 500 ppt). The MCL Goal is set at zero.	EPA1992 (reviewed 2010)	http://water.epa.gov/drink/contaminants/basicinformation/polychlorinated-biphenyls.cfm
Bottled water	0.5 μg/L	FDA, 1999	21 CFR 165.110
Ambient Air	0.01 μg/m^3 based on cancer risk of 1 in 1,000,000	EPA, 2000	EPA IRIS http://www.epa.gov/iris/subst/0294.htm
Indoor air – schools*	0.07-0.60 μg/m^3 depending on age of children present.	EPA	http://www.epa.gov/pcbsincaulk/maxconcentrations.htm
Occupational air	1.0 μg/m^3	NIOSH, 2000	Http://www.cdc.gov/niosh/npg
Occupational air	1,000 μg/m^3 (Aroclor 1254); 500 μg/m^3 (Aroclor 1242)	OSHA	1998-29 CFR 1910.10003

PCB Exposures in People

PCBs are absorbed primarily from the diet and air, accumulate in fatty tissues, and are excreted, often very slowly, from the human body. PCBs are readily absorbed from the gastrointestinal tract. Absorption efficiency across the gut is higher with more chlorinated congeners. Once in the blood stream, PCBs are rapidly cleared and initially accumulate in liver and muscle tissue. In general, PCBs then redistribute to adipose tissue and skin but this varies depending on the congener (ATSDR 2000). For instance, PCB 126 is a coplanar PCB and binds very tightly to CYP1A2 and subsequently concentrates in the liver of rodent. Other highly persistent PCBs (e.g., PCB 153) are stored primarily in the adipose tissue and skin. There are also gender differences in storage of PCBs (Feeley and Jordan 1998). Metabolism of PCBs involves metabolic enzymes called cytochrome P_{450} enzymes (CYP). Specific subtypes involved in PCB metabolism are CYP1A1 and 1A2, CYP2B1 and 2B2, and CYP3A. Metabolism can lead to biologically active arene oxides and hydroxylated and methysulfonyl metabolites. Elimination of PCBs from the body is largely dependent on biotransformation of congeners to more polar metabolites. Half-lives for PCBs congeners in humans are estimated at 1.4-4.9 years for lightly chlorinated PCB 28 and 10-15 years for the more chlorinated congeners such as PCB 153, 170, and 180 (Ritter *et al*. 2011). Longer half-life estimates have also been reported (ATSDR 2000, Milbrath *et al*. 2009). Because PCBs are more readily absorbed than excreted, they accumulate in the body over time.

PCB Body Burden in the General U.S. Population

PCBs are widely detected in adipose tissue and blood of people (Lordo *et al*. 1996, CDC 2009). PCB in serum is a common indicator of body burden since there is a dynamic equilibrium between PCBs stored in fat and PCBs circulating in blood. Most studies of PCBs in serum report lipid-adjusted measurements to correct for short-term fluctuation in circulating lipids.

Since the 1980s, body burdens of PCBs in the U.S. have declined by more than 80% and continue to decrease (CDC 2009, Longnecker *et al*. 2003, Woodruff *et al.* 2011, Xue *et al.* 2014). Recent estimates of body burden of PCBs in the U.S. general population are available from the National Health and Nutritional Examination Study or NHANES (CDC 2009). This survey sampled serum for 34 PCB congeners in 2001-2002 and added four dioxin-like PCB congeners in 2003-2004 for a total of 38 congeners. In the 2003-2004 survey, 100% of the 1866 participants sampled had detectable levels of PCBs in their serum (Patterson *et al*. 2009). The primary congeners detected were PCB 153, 180, and 138/158. PCB 28, 74, 118, 170, and 187 were also frequently detected (Table 31 lists NHANES results). The sum of 35 PCB congeners in participants had a mean of 134.4 ng/g blood lipid (0.820 ng/g whole weight blood). Five percent of the participants sampled had a sum of PCB in blood higher than 530.7 ng/g lipid weight (3.531 ng/g whole weight) (Patterson *et al*. 2009). The TEQ of total dioxins, furans and dioxin-like PCB in the NHANES 2001-2002 survey was calculated to be 30.4 pg/g lipid for the general population. The nine PCB congeners with dioxin-like properties contributed 38-41% of the TEQ depending on the age of the participant (Ferriby *et al*. 2007). Both studies showed that increasing PCB body burden is strongly associated with increasing age.

Table 31. Sum of 35 PCB congeners in 2003-04 NHANES survey (Patterson *et al*. 2009)

Age of participant	50th percentile for population (CI)	95th Percentile for population (CI)	Population sample size
12-29 years	51.2 (48.2-56.1)	139.0 (110.8-164.3)	585
20-39 years	75.4 (71.2–81.7)	226.5 (170.6-300.5)	452
40-59 years	174.4 (159.9-201.9)	470.7 (373.5-650.9)	383
60+ years	334.5 (308.7-351.8)	929.4 (752.2-1167.9)	446
Total (all ages)	131.8 (121.8-145.5)	530.7 (498.4-570.2)	1866

Serum levels in ng/g blood lipid
CI is the 95% confidence interval for the estimate of percentile in the study population.

Greater body burdens of PCB congeners that readily bioconcentrate have been observed in avid consumers of seafood or land and marine mammals that eat a diet rich in fish. (Dewailly et al. 1993; Ayotte *et al*. 1997, Muckle *et al.* 1998, Fängström *et al.* 2002, Grandjean *et al.* 2001).

Lightly chlorinated PCB congeners (congeners 1-52) may be elevated in people exposed to PCBs in ambient or indoor air. Disposal and recycling workers may have elevated exposures to the full spectrum of PCB congeners in the initial Aroclor mixtures.

PCB Exposures to Developing Children

Fetal and early life are considered the most sensitive life stage for PCB toxicity so it is important to understand early life exposure to PCBs. PCBs cross the placenta of experimental animals and humans. When PCB level is adjusted for percent lipid in the blood, there is no difference between PCB blood levels in maternal serum and cord blood at the time of birth (Jacobson *et al*. 1984).

PCBs stored in fat and fatty tissues are mobilized as serum lipids increase during the normal course of pregnancy. Median concentration of total serum lipids increased 43% and median serum levels of PCBs increased 34% between the first and third trimesters in a study of 67 women. The increase was completely explained by the increase in lipids; when results were lipid normalized there was no difference in µg PCB/g serum lipid (Longnecker *et al*. 1999).

The body burden of PCBs accumulated over a lifetime is thought to be the primary determinant of circulating levels of PCB during pregnancy; however, a study reported by Humphrey in 1989 demonstrated that a single meal could conceivably expose a fetus to a transient peak of PCBs. In his measurements following a meal of Great Lakes fish (fish contained 4-10 ppm PCB) he observed a short-term spike of 250-500% above serum baseline in healthy volunteers. Most fish consumed in the U.S. today are about 1000 times less contaminated than the fish used in Humphrey’s experiment.

Breast milk has healthy fat to support the rapid growth of babies. PCBs can accumulate in fat and be transferred to babies during nursing. The PCB body burden of children at four years old is strongly related to the level of contamination in milk and duration of lactation (Swain 1991, Patandin *et al*. 1999, Walkowiak *et al*. 2001). Blood levels of PCBs in Japanese children of occupationally-exposed parents also showed a strong correlation with length of lactation (Hara 1985). By some estimates, human infants can receive up to 10-12% of their lifetime dose from nursing (Birnbaum and Slezak, 1999).Breast milk samples from 40 first-time mothers from the Pacific Northwest of the U.S. and Canada were analyzed for PBDEs and PCBs (She *et al*. 2007). Total PCBs were calculated by summing values of 82 separate PCB congeners and ranged from 0.049 to 0.415 mg/kg lipid. This is 10-100 times lower than the levels documented in breast milk in the 1980s in a North Carolina study and further evidence that PCBs in U.S. breast milk have declined since PCB production ceased (Pan *et al*. 2009, Zietz *et al*. 2008). PCB in breast milk should not deter women from nursing because studies have shown that even breast milk with PCBs has a net benefit on cognitive and motor development of children compared to formula-fed children (see DOH Recommendation for Breast Feeding).

Sources and Pathways of Human Exposure

PCBs in Food

PCBs in food are the most significant source of exposure for most people. Recent studies on fish indicate concentrations of PCBs can be in the 10 to 100 parts per million in fish (especially freshwater fish). High levels are typically found in top predator fish, in bottom-feeding fish such as carp and large scale suckers, and in fish living near known sources of PCB contamination. Meat and dairy products are generally much lower in PCBs with concentrations in the low parts per billion (see Table 34). A recent analysis of 2001-2004 NHANES data looked at food consumption patterns in a general U.S. population relative to 30 PCB congeners measured in their serum (Xue *et al.* 2014). The study found a strong correlation between serum PCB and reported fish consumption but no measurable correlation with consumption of meat or milk.

PCBs in Freshwater Fish Species from Washington State

PCBs can be highly concentrated in the fish of waters contaminated with even low levels of PCBs. The Washington State Department of Ecology routinely conducts fish tissue monitoring as part of its Washington State Toxics Monitoring Program (WSTMP). Between these two programs, thousands of fish have been sampled from hundreds of sites across Washington State. Figure 27 displays the distribution of total PCB tissue concentrations from fish collected across Washington State from several sources.

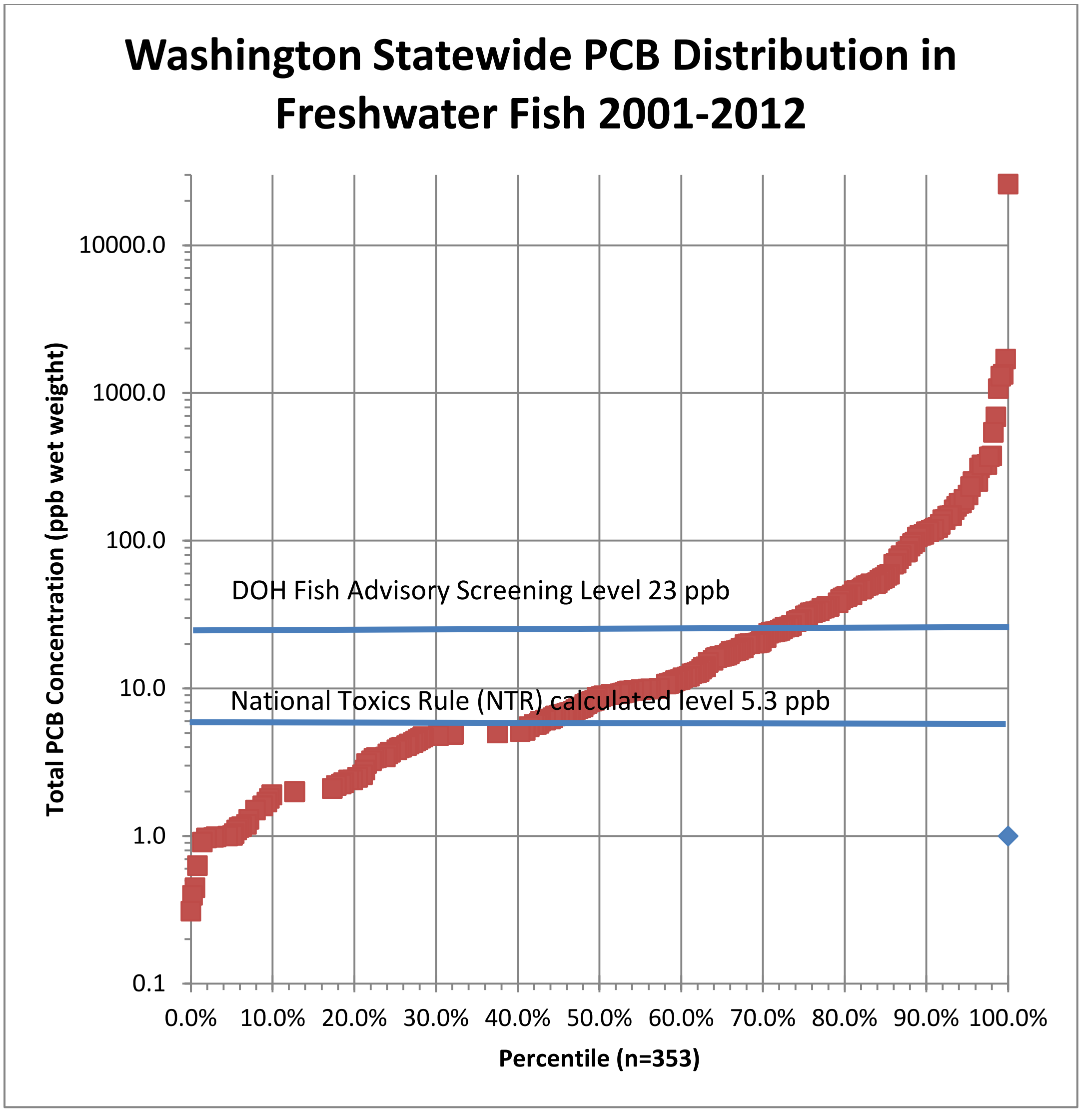


Figure 27. Washington Statewide PCB Distribution in Freshwater Fish Fillets 2001-2012. Data sources: 2001-2010 total PCB fish tissue concentrations extracted from Ecology's EIM database (Seiders 2012), EPA's Upper Columbia River site investigation as reported by Health (WDOH 2012), U.S Department of Energy's 2012 assessment of contaminant data in the Mid-Columbia River, and fish tissue data provided to Health by the U.S. Army Corps of Engineers near Bradford Island and the Bonneville Dam on the Columbia River (unpublished data). NTR and Health screening levels for PCB concentration in fish tissue are displayed for reference.

The data set displayed in Figure 27 includes 353 total PCB values that range from non-detects to greater than 26,000 ppb, with a median of 8.7 ppb. The maximum detection is from a single bass collected near the Bonneville Dam in the Columbia River.

PCBs in Commercially Available Fish in Washington State

Limited data on PCBs in commercially available fish are also available for Washington State. The primary source of this data is a Washington Department of Health 2005 study of contaminants in canned tuna and other frequently consumed store bought fish purchased in

Washington State grocery stores (McBride *et al*. 2005). In this study, PCBs (based on Aroclors concentrations) were detected in store-bought halibut, red snapper, and salmon in at least 10% of the samples collected. Salmon had the highest average PCB concentrations (31.5 ppb PCBs, total Aroclors). Additional data from the Washington State Department of Fish and Wildlife on PCB levels in Puget Sound Chinook and coho salmon were also included for this assessment (WDOH 2006). A comparison of PCB concentrations in store bought and Puget Sound commercially available fish can be seen in Figure 28. Of all fish species, PCB concentrations were highest in Chinook salmon collected in Puget Sound. PCB levels in Chinook salmon returning to Puget Sound waters typically have higher concentrations than coastal salmon or Alaskan Chinook. The higher concentration in Puget Sound Chinook and resident Blackmouth is believed to be due to residence time in areas such as Puget Sound that have greater PCB loads. DOH recommends that women of childbearing age and young children should eat no more than one meal per week of Puget Sound Chinook salmon. Most fish species collected from grocery stores were below Health's general screening level of 23 ppb.

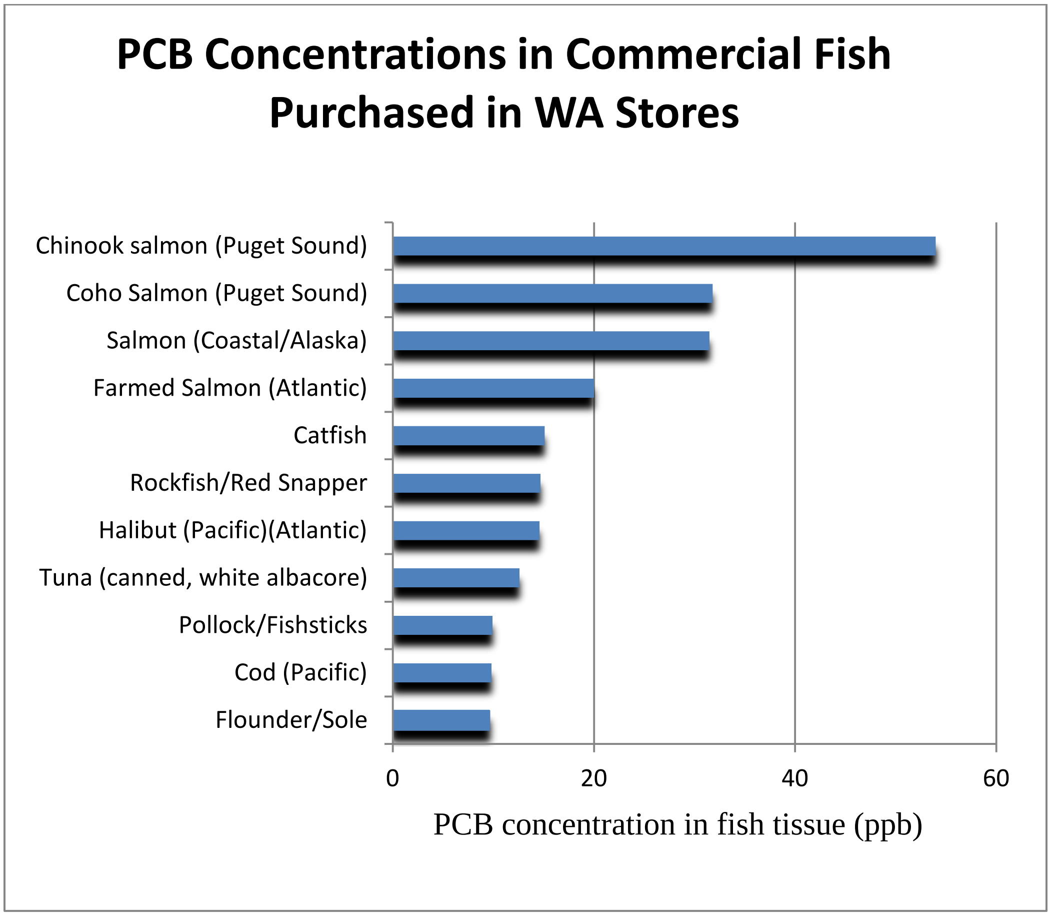


Figure 28. Mean PCB concentrations (total Aroclors) in fish collected from markets and grocery stores in Washington State and from Puget Sound. Data Source: McBride et al. 2005.

Other Dietary Sources of PCBs

Humans may be exposed to small but detectable quantities of PCBs in meat, dairy products, and other foods. PCB concentrations in fish, meat, and dairy products vary widely depending on where they are grown and how they are processed or cooked. Sampling for PCB concentrations in FDA's Market Basket studies between 1991 and 2003 showed PCB levels are far below FDA limits in a variety of prepared dishes. This section summarizes the limited data available from various U.S. and international sources.

The Total Diet Study (TDS), sometimes called the market basket study, is an ongoing FDA program that determines levels of various contaminants and nutrients in foods. http://www.fda.gov/downloads/Food/FoodScienceResearch/TotalDietStudy/UCM184304.pdf. A unique aspect of the TDS is that foods are prepared as they would be consumed (table-ready) prior to analysis, so the analytical results provide the basis for realistic estimates of the dietary intake of these analytes. TDS Market Basket surveys are generally conducted four times each year, once in each of four geographic regions of the countries. Food samples are purchased from supermarkets, grocery stores, and fast food restaurants in three cities in the region and are shipped to a central laboratory. The foods are then prepared table-ready and the three samples are combined to form a single analytical composite for each food. For each survey, samples of food are collected over a 5-week period. Table 32 presents data collected from 1991 through 2004 for PCBs in 26 separate food items. Total PCB concentrations are expressed as Aroclor equivalents, rather than as the sum of congener-specific measurements. Mean PCB concentrations ranged from 0.09 ppb for chicken potpie to 24.4 ppb for salmon.

PCB concentrations in foods from the market basket survey are much lower than previously reported by the Puget Sound Action Team in 2007 and cited by Ecology's Toxics Cleanup Program (Ecology 2012d). PCB levels in foods reported by the Puget Sound Action Team were based on very small sample sizes of one or two. FDA data presented in Table 32 are based on average samples sizes of 40 resulting in more robust, representative PCB levels. The state of origin of the food sampled is not available.

Table 32. Measured PCB Levels as Reported by U.S.FDA

Food Description	Sample Size	Results		
		Concentration (ppb)		Detection Frequency %
		Mean	Maximum	
Chicken potpie, frozen, heated	44	0.09	4	2.3
Candy, caramels	40	0.15	6	2.5
Beef roast, chuck, oven-roasted	44	0.23	10	2.3
Pork roast, loin, oven-roasted	44	0.23	10	2.3
Lamb chop, pan-cooked w/ oil	44	0.23	10	2.3
Chicken, drumsticks and breasts, breaded and fried, homemade	40	0.23	9	2.5
Corn/hominy grits, enriched, cooked	44	0.23	10	2.3
Cornbread, homemade	44	0.23	10	2.3
Biscuits, refrigerated-type, baked	44	0.23	10	2.3
Raisins	44	0.23	10	2.3
English muffin, plain, toasted	44	0.23	10	2.3
Veal cutlet, pan-cooked	40	0.25	10	2.5
Crackers, butter-type	44	0.25	11	2.3
Pork chop, pan-cooked w/ oil	44	0.45	20	2.3
Meatloaf, beef, homemade	44	0.45	20	2.3
Beef (loin/sirloin) steak, pan cooked with added fat	40	0.5	20	2.5
Pancakes made from mix with addition of egg, milk, and oil	40	0.5	20	2.5
Baby food, vegetables and chicken	44	0.68	30	2.3
Brown gravy, homemade	40	0.75	30	2.5
Tuna, canned in oil, drained	40	1.0	40	2.5
Eggs, fried with added fat	40	1.23	39	5.0
Chicken breast, oven-roasted (skin removed)	44	1.36	30	4.5
Popcorn, popped in oil	40	1.7	30	10.0
Butter, regular (salted)	44	3.18	120	4.5
Catfish, pan-cooked w/ oil	4	4.25	17	25.0
Salmon, steaks/fillets, baked	24	24.38	55	91.7

Table 32 summarizes PCB analytical results of food from the Food and Drug Administration's Total Diet Study program. The information pertains to Total Diet Study market baskets 1991-93 through 2003-04. Statistics were calculated using value of zero for results below the detection limit. This document is available on the internet at: http://www.cfsan.fda.gov/~comm/tds-res.html.

In addition to the U.S.FDA information, Arnold Schecter and colleagues at the University of Texas in Dallas have analyzed PCB concentrations in foods in the U.S. over the past 15 years. These studies have focused on common foods in the American diet that were collected throughout the country. The following summarizes those individual studies and a compilation of the data is presented in Table 33.

- Schecter *et al*. (1997) pooled food samples collected from grocery stores across the U.S. and measured 15 different PCB congeners, including eight coplanar PCBs, three mono-ortho PCBs, and four di-ortho PCBs. A total of 90 individual food specimens were pooled into 12 different food types (e.g., cheese, beef) and analyzed for dioxins, dibenzofurans, and PCBs. Based on a conversion of the measured congeners, the authors conclude that PCBs contribute significantly to total TEQ values in eight out of 12 sample types.
- Schecter and Li (1997) measured dioxin-like PCBs in U.S. fast food purchased at five cities across the US. Samples were pooled by type and tested for seven mono- and di-ortho PCBs. Total PCB levels ranged from 0.957 ppb (McDonald’s Big Mac) up to 1.180 ppb (Pizza Hut Personal Pan Supreme with anchovies). The authors estimate that fast food accounts for roughly 16.7-52.7% of the total daily TEQ of dioxin-like compounds.
- Schecter *et al*. (1998) analyzed both cooked and uncooked samples of beef, bacon, and catfish from a supermarket in Binghamton, New York. A total of five cooked, and four uncooked samples of each type of meat were analyzed for dioxins, dibenzofurans, and three dioxin-like PCBs (77, 126, 169). Total PCB concentration for each food type ranged from 1.028 ppb (wet weight) (uncooked hamburger) to 5.370 ppb (cooked bacon). Broiling each type of sample resulted in a 50% decrease on average in total PCDD, PCDF, and coplanar PCB TEQ. However, broiling of hamburger resulted in an increase of total coplanar PCB concentration of 10.4%; broiling bacon resulted in an increase of 75.7% of total coplanar PCB concentration. The authors conclude that final concentrations (pg TEQ/kg) of PCDDs, PCDFs, and coplanar PCBs in broiled foods cannot be accurately predicted from raw samples due to variances in cooking method.
- Schecter *et al*. (2002) analyzed a total of 72 meat baby food samples purchased from grocery stores across the U.S. (Illinois, Nebraska, California, Georgia, New York, Pennsylvania, and Maryland). Three to six samples (200 g each) were purchased from each state, and analyzed for dioxins and three coplanar PCB congeners (77, 126, and 159). Total PCBs for each food sample type range from 0.579 ppb (wet weight) (lamb) to 2.280 ppb (chicken). Converted TEQ concentration for total PCBs for each food type ranged from 17.6 (lamb) to 95.9 (beef). The authors note that for the turkey, beef, lamb, and ham samples, total PCBs contributed more to total TEQ values than did the PCDD/PCDF values.

- Schecter *et al*. (2010) study expanded their previous studies of persistent organic pollutants contamination, including PCBs in composite U.S. food samples collected in Dallas, Texas. The study showed that PCBs were not detected by congener analysis in any meats except hamburger, in any fish except salmon and canned sardines, or in any dairy products or eggs.

Overall, Schecter and colleagues have shown that the PCB levels in foods common in the U.S. are typically low relative to freshwater fish species collected in Washington State. PCB levels in foods other than fish are generally in the low single digit parts per billion range whereas freshwater and marine fish species are generally one, two, and sometimes three orders of magnitude higher. Even when beef, chicken, and pork consumption rates are greater than fish consumption rates, dietary exposure to PCBs is dominated by the consumption of fish.

Table 33. Level of PCBs in U.S. Foods (1994 – 2009)

Location (date)	Type of Sample	PCB congeners	Food (sample size)	Total PCB concentration ppb (wet weight)	Reference
Across U.S. (1995)	Grocery Stores	15 total, including 8 coplanar, 3 mono-ortho, and 4 di-ortho PCB congeners	Beef (5 pooled)	Total coplanar 0.0428 ng/g; mono-ortho 0.344 ng/g; di-ortho 0.593 ng/g **Total 0.980 ppb**	Schecter et al. 1997
			Chicken (4 pooled)	Total coplanar 0.132 ng/g; mono- ortho 0.403 ng/g; di-ortho 0.505 ng/g **Total 1.04 ppb**	
			Pork (5 pooled)	Total coplanar 0.182 ng/g; mono-ortho 0.375 ng/g; di-ortho 0.322 ng/g **Total 0.879 ppb**	
			Hot dog/bologna (2 pooled)	Total coplanar 0.156 ng/g; mono-ortho 1.500 ng/g; di-ortho 1.871 ng/g **Total 3.027 ppb**	
			Eggs (3 pooled)	Total coplanar 0.0006 ng/g; mono-ortho 0.064 ng/g; di-ortho 0.147 ng/g **Total 0.212 ppb**	
			Cheese (5 pooled)	Total coplanar 0.0017 ng/g; mono-ortho 0.240 ng/g; di-ortho 0.342 ng/g **Total 0.584 ppb**	
			Butter (2 pooled)	Total coplanar 0.004 ng/g; mono-ortho 1.150 ng/g; di-ortho 2.080 ng/g **Total 3.23 ppb**	
			Ice cream (5 pooled)	Total coplanar 0.0001 ng/g; mono- ortho and di-ortho ND **Total 0.0001 ppb**	
			Milk (5 pooled)	Total coplanar 0.0004 ng/g; mono and di-ortho ND **Total 0.0004 ppb**	
			Vegan diet (1 pooled)	Total coplanar 0.0002 ng/g; mono-ortho 0.015 ng/g; di-ortho 0.144 ng/g **Total 0.159 ppb**	
Across U.S. (1995)	Fast Food Restaurants	PCBs 105, 118,156,128,138,153, 180	Hamburger, McDonalds Big Mac (5)	mono & di-ortho total 0.957 ppb	Schecter and Li 1997
			Pizza, Pizza Hut Supreme (5)	mono & di-ortho total 1.180 ppb	
			Chicken, KFC Original Recipe (5)	mono & di-ortho total 1.170 ppb	
Binghamton, NY (1996)	Grocery Stores	Coplanar PCBs 77,126, 169	Hamburger, cooked (5)	Mean 1.401; range 1.204-1.601 ppb	Schecter et al. 1998
			Hamburger, uncooked (4)	Mean 1.270; range 1.028-1.736 ppb	
			Bacon, cooked (5)	Mean 2.734; range 1.722-5.370 ppb	
			Bacon, uncooked (4)	Mean 1.556; range 1.205-1.971 ppb	
			Catfish, cooked (4)	Mean 3.188; range 1.945- 3.963 ppb	
			Catfish, uncooked (4)	Mean 4.691; range 2.200-6.387 ppb	
Across U.S. (IL, NE, CA, GA, NY, PA, MD) (1998)	Baby Food Grocery Stores	PCBs 77, 126, 159	Chicken	Range 0.883-0.228 ppb	Schecter et al. 2002
			Turkey	Range 0.144-0.160 ppb	
			Beef	Range 0.150-0.225 ppb	
			Lamb	Range 0.579-0.844 ppb	
			Ham	0.771 ppb	
Dallas, TX (2009)	Supermarkets	PCBs, 52, 101, 118, 138, 153, 180	Hambuger	PCB-153 1.2 ppb; PCB-180 0.21 ppb	Schecter et al. 2010
			Salmon	PCB-52 0.28 ppb; PCB-101 0.51 ppb; PCB-118 0.43 ppb; PCB-138 0.93 ppb; PCB-153 1.21 ppb; PCB-180 0.44 ppb	
			Canned Sardines	PCB-52 0.28 ppb; PCB-101 0.67 ppb; PCB-118 0.80 ppb; PCB-138 1.80 ppb; PCB-153 1.83 ppb; PCB-180 0.49 ppb	
			Bacon	Non-detected	
			Turkey	Non-detected	
			Sausages	Non-detected	
			Ham	Non-detected	
			Chicken breast	Non-detected	
			Roast beef	Non-detected	
			Canned chili	Non-detected	
			Catfish fillet	Non-detected	
			Tilapia	Non-detected	
			Cod	Non-detected	
			Frozen fish sticks	Non-detected	
			Butter	Non-detected	
			American cheese	Non-detected	
			Other cheese	Non-detected	
			Whole milk	Non-detected	
			Yogurt	Non-detected	
			Cream cheese	Non-detected	
			Eggs	Non-detected	

PCB Contribution to Dioxin TEQ in Food

Coplanar PCB congeners act toxicologically like dioxins and contribute to the total dioxin TEQ in foods. The National Academies of Science provided a comprehensive compilation of data on dietary exposure to dioxin and dioxin-like compounds including PCBs (NAS 2003). Estimates of exposure are based on concentrations of dioxins and dioxins-like compounds measured in foods and dietary consumption habits of those foods. The dioxin and PCB food concentration data were based on the U.S. Food and Drug Administration's Total Diet Study (FDA 2006). The NAS report identifies that dietary sources of animal fat are by far the largest source of dioxin exposure to the general population, with 90% of total exposure being due to consumption of food – namely animal products and their associated animal fats (beef, pork chicken, fish, fats (butter), and dairy products. The NAS reported that estimates of the contribution of PCBs to dietary dioxin TEQ range from 37-57% and concluded that 50% was a reasonable estimate (NAS 2003).

EPA's 2000 Draft Dioxin Reassessment (EPA 2000a) summarized the available data on background concentrations in foods for the United States. Using that data and standard assumptions for intake, they developed an estimate of general background exposure to coplanar PCBs. The estimates assume concentrations in food reported as nondetected are present at ½ the detection limit. EPA estimated background exposure to adults in the general population to be 0.64 pg/kg/day for dioxins and furans and 0.34 pg/kg/day for dioxin-like PCBs. Based on EPA's analysis, coplanar PCBs account for approximately one-third of total dioxin-TEQs (Smith and Frohmberg, 2008). See Table 34.

Table 34. Estimates of Background Dietary Exposure to Dioxins and Coplanar PCBs on a Toxic Equivalents (TEQs) Basis.

Chemical	Estimated Exposure Assuming NDs = 0 (pg/kg/day)	Estimated Exposure Assuming NDs = 1/2 DL (pg/kg/day)
Dioxins/Furans TEQs	0.38	0.64
Coplanar PCB TEQs	0.34	0.34
Total TEQ	0.72	0.98
% Contribution of Coplanar PCBs to Total TEQs	47%	35%
EPA RfD for dioxin (non-cancer endpoints)	0.7 pg/kg/d	0.7 pg/kg/d

(Source: Smith and Frohmberg, 2008)
ND = non-detected, DL= Laboratory detection limit

In summary, food and especially fish appear to be major contributors to PCB exposure in the U.S. population. With few exceptions, freshwater fish species have the highest PCB levels. Mean PCB concentration of all Washington state freshwater fish for which Health has issued fish consumption advisories is over 150 times higher than the mean PCB concentration reported in other common food items. Freshwater fish species in Washington are over ten times higher than

PCB concentrations measured in commercially available fish in Washington State stores. Commercially purchased fish PCB levels are also greater than mean PCB concentrations of other non-fish foods tested by a factor of ten (Figure 29). Such comparisons illustrate the relative contribution of freshwater fish species to an individual's dietary PCB exposure, particularly for high fish consumers. Those individuals or groups that rely on freshwater fish species as an important component of their diet are potentially at greater exposure to PCBs and correspondingly at greater health risk.

Dioxin-like PCBs are significant contributors to dietary dioxin burden in the U.S. and the total dioxin burden appears to be at the EPA reference dose for dioxin TEQ.

The PCBs in fish are relatively well studied and this source of exposure has a robust health literature pointing to adverse health impacts. The most vulnerable lifestage to PCB exposure appears to be fetal development. Although U.S. exposures have dropped dramatically since the 1980s, Avid consumers of Puget Sound salmon, freshwater sports fish like bass, and other fish from contaminated waters are still at risk for elevated exposure. Reducing PCB exposure in people will require efforts to reduce PCB levels in freshwater and some marine fish and to mitigate the sources of PCB loading to the waters where they live.

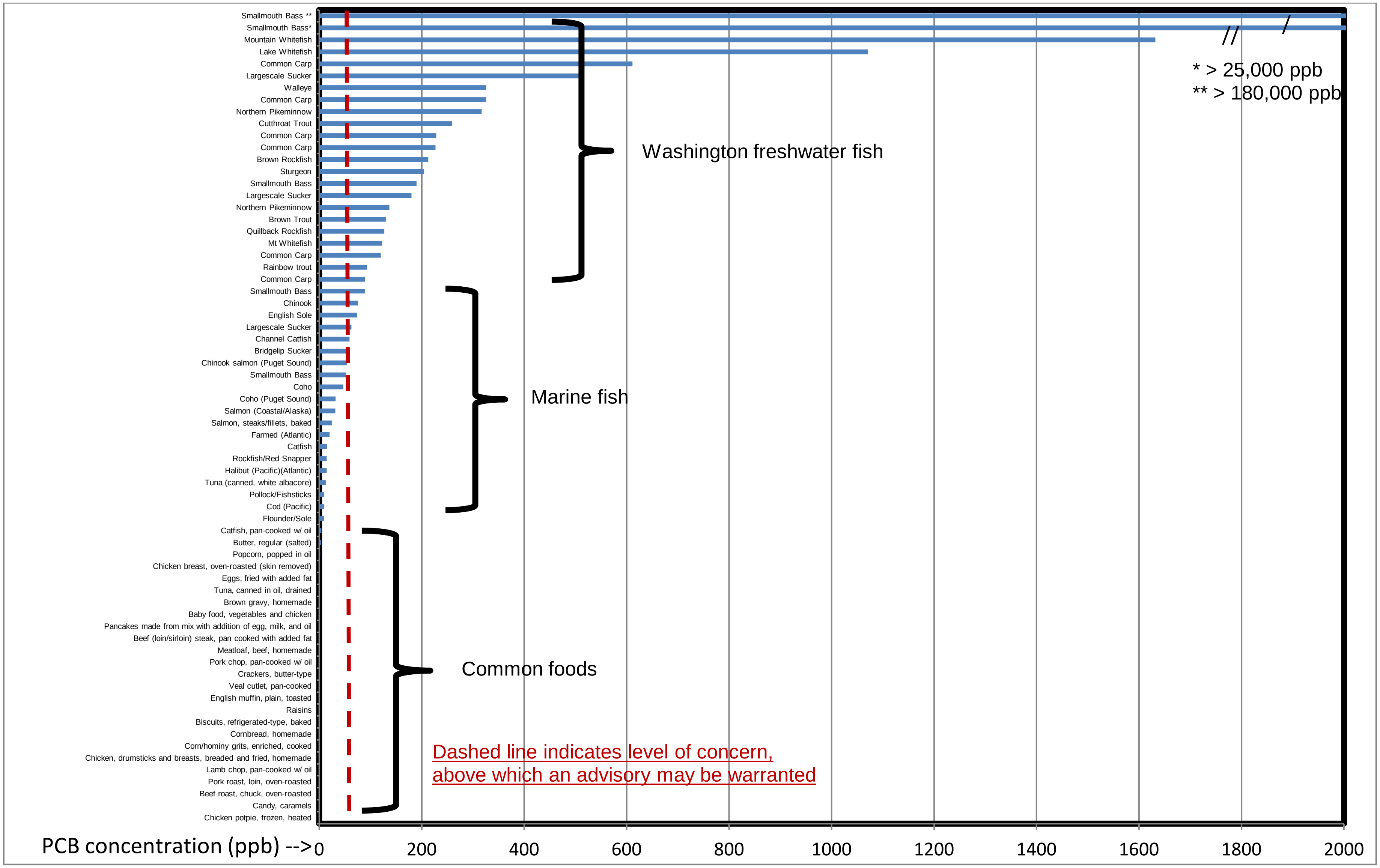


Figure 29. PCB Concentrations (ppb) in Sportcaught Fish Collected in Washington, Commercial Fish Purchased in Washington, & Common Foods

Data sources: WA freshwater fish data 2001-12 in Ecology EIM database, U.S. Dept. of Energy, WA Dept of Health commercial fish study (McBride et al.,2005), FDA Total Diet Study 1991-2006. Only a subset of the state's freshwater fish PCB data are shown to represent those species associated with Health fish advisories based on PCB levels.

PCBs in Ambient Air

PCBs with fewer chlorines can volatilize from water, soil, or contaminated materials and effect local air concentrations (ATSDR 2000, Carlson and Hites 2005, Du *et al*. 2009).They can also be transported long distances by global air currents and have been detected polar research stations where no local sources exist (Choi *et al*. 2008). Heavier PCBs are not volatile but can contaminate air when adhered to demolition dust, wind-blown dust, and airborne particulate. Inhalation was thought to be the primary pathway of occupational exposure to PCBs historically but was largely ignored for general population exposures until recently. PCB air monitoring started in Chicago in 1995 and found surprising PCB concentrations in urban air. Hu *et al*. 2008 analyzed for 209 PCB congeners in Chicago area air and reported an annual average of 0.000835 µg/m^3 (range 0.000075 to 0.0055 µg/m^3). Similar air concentrations results have been reported from the Philadelphia, PA (Du *et al*. 2009) and Cleveland, OH (Basu *et al*. 2009). Air levels at least an order of magnitude lower have been detected in polar regions (Choi *et al*. 2008) and in various remote locations around the Great lakes region (Basu *et al*. 2009).

Only limited air sampling for PCBs has been conducted in Washington State. Bulk air deposition samplers have been used to estimate the load to Puget Sound soils and water surfaces (Ecology 2010d). These results are not adequate for estimating inhalation exposure for health risk assessment because the lighter gas phase PCBs would be largely missed by these samplers.

One EPA pilot study analyzed air samples collected in year 2000 from rural areas of the U.S. for six PCBs that are considered dioxin-like. This study included one site on the Olympic Peninsula in Washington. PCB 118 was the most common dioxin-like PCB detected (0.337 pg/m^3). PCB 105 was detected at 0.115 pg/m^3, PCB 156/7 were detected at 19.7 fg/m^3, 77 was detected at 16 fg/m^3, and PCB 126 and 169 were detected at 1 fg/m^3 or less (EPA 2007).

The reported levels of PCBs in ambient air are generally well below EPA level of human health concern. The maximum PCB levels reported on hot summer days in Chicago was 0.0055 µg/m^3 which is still below the EPA "de minimus" cancer risk estimate for chronic inhalation of evaporated PCB congeners (0.01 µg/m^3).

Congener profiles of PCBs in ambient air differ both from profiles of commercial Aroclors and from congeners that partition to fish. Although the full spectrum of congeners has been detected in ambient air, lightly chlorinated congeners predominate (PCBs 1-52). Lighter congeners are more quickly eliminated from the body and their toxicological properties are less studied. This introduces uncertainty in the exposure and toxicity assessment of the mixture. Norström *et al.* 2010 conducted modelling to predict the contribution to PCB body burden from breathing urban air contaminated with a profile of PCBs similar to those detected in Chicago air. Their model suggests that urban air would not significantly impact the body burden of congeners associated with dietary uptake such as PCB 153, 180, and 183 but could contribute to human body burden of PCB 28, 33, and 52 by as much as 30% depending on the congener (Norström *et al.* 2010).

The toxicological relevance of inhaling congeners in urban air was investigated by Hu *et al.* 2012. They conducted a subchronic rodent inhalation assay with a cocktail of PCBs representing urban air and observed for immune responses, microsomal enzyme induction, cellular toxicity and histopathologic abnormalities. The minimal effects detected are suggestive of mild oxidative stress during the course of treatment.

The toxicological relevance of lighter chlorinated congeners must also consider the impact of metabolites produced once these lighter PCBs are absorbed into the body. For example, some PCB 3 metabolites are genotoxic and have been shown to cause point mutations in rodents (Xie *et al.* 2010, Robertson and Ludewig 2011). There is also limited evidence of tumor initiating activity of PCB 3, 15, 52 and 77 in a rodent model (Espandiari *et al.* 2004). Congeners like PCB 11 may be transformed into metabolizes that contribute to oxidative stress and cellular damage (Zhu *et al.* 2013). This is an active area of research and more study is needed to understand the potential toxicity of lower chlorinated PCBs and their metabolites.

PCBs in Indoor Air (Caulk, Joint Sealants, Lamp Ballasts)

PCBs were used as plasticizers and flame retardants in building materials such as some elastic caulks, joint sealing compounds for brick and masonry buildings, exterior paints, window glazing, ceiling tile coatings, and some floor finishes sold in the 1950-1970s. PCBs were also widely used in fluorescent lighting ballasts installed during this same period. In different investigations since 1980, these materials have been identified as sources of elevated PCB levels in air in schools, office buildings, large apartment complexes, and other buildings. A few examples are listed below.

EPA investigated PCB levels at six unoccupied schools in New York that were scheduled for major renovation or demolition and were suspected of containing PCB sources (EPA 2012c). EPA measured PCBs in air and surface wipes in the buildings and estimated student exposures before and after PCB remediation. EPA estimated doses for an average student were 0.022 µg/kg/day before remediation and 0.007 µg/kg/d after. Estimates of higher student exposure scenarios were 0.041 µg/kg/day before remediation and 0.012 µg/kg/day after. PCB light ballasts and caulk were considered the primary PCB sources in the schools and inhalation the primary exposure route. Remediation reduced estimated exposure by approximately two thirds. EPA conducted congener specific PCB analysis in one of the six schools. Average indoor air concentration of total PCBs in air was 0.50 $\mu g/m^3$, the average TEQ of dioxin-like congeners in air was 0.788 pg/m^3. (EPA 2012c). EPA research associated with this project confirmed that caulk with high levels of PCBs caused elevated PCB in the surrounding air, that light ballasts emit PCBs at normal operating temperatures even when there was no visible liquid leaking, that caulk with low levels of PCBs can be encapsulated to reduce emissions, and that a special treatment system can be effective in removing PCBs from thin surfaces such as wall paint (EPA 2013h). In December 2010, EPA released national guidance recommending that schools remove

all PCB-containing lighting ballasts.
http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/ballasts.htm

Elastic joint sealants containing PCBs were found to be the source of elevated PCBs in indoor air at 29 sampling sites in various public buildings in Switzerland (Kohler *et al*. 2002). In most cases the indoor air levels of PCBs were below 1.50 µg/m^3 but levels up to 4.20 µg/m^3 were detected. As a comparison, this study reported air levels of 13.0 µg/m^3 PCB at an industrial building that formerly produced transformers. PCB congeners 28 and 52, used as indicators for the more volatile PCBs, predominated in all air samples. Dioxin-like PCBs were also measured (primarily PCB 118 and 105) and the TEQ was calculated using WHO 1998 TEFs. Emissions from joint sealants had a consistent ratio of dioxin-like PCBs to total PCBs. Air levels of 1.0 µg/m^3 total PCBs corresponded to a 1.2 pg/m^3 of dioxin-like PCBs. (Kohler *et al*. 2002).

Joint sealants were also the source of PCB contamination in a public building in Germany (Schettgen *et al*. 2012). Investigations included air measurements and biomonitoring of people who worked in the building. Workers from an uncontaminated building served as controls. Median air levels for total PCBs were reported as 1.74 µg/m^3 with a maximum of 4.28 µg/m^3. Exposed workers had significantly higher blood levels of the more volatile PCBs (28, 52, 101 and the dioxin-like congeners 105 and 118) but not heavier PCBs which constitute the bulk of human body burden and are taken up primarily in the diet (PCB 138, 153, or 180). The calculated TEQ for dioxin-like congeners did not differ statistically between the groups. Follow-up monitoring of three people who were removed from the building demonstrated that levels of PCB 28, 52, and 101 declined steadily after removal and that the biological half-lives were 4.5 ± 0.9 years for PCB 28, 1.3 ± 0.1 years for PCB 52, and 2.8 ± 0.7 years for PCB 101 (Schettgen *et al*. 2012). Longer retention of PCB 28 in the body may explain why PCB 52 predominated in air samples but PCB 28 predominated in serum samples.

Liebel *et al*. 2004 reported significantly higher median serum concentrations for PCBs 28, 52, and 101 in 377 children from the contaminated school in Germany compared to 218 students attending an uncontaminated school. There was a significant positive association between years spent at the contaminated school and serum levels of the combined lower chlorinated congeners. Air levels measured in multiple locations over two years in the school building ranged 0.004-0.600 µg/m^3 for PCB 28, 0.038-2.300 µg m^3 for PCB 52, and 0.003-1.100 µg/m^3 for PCB 101. Very little PCB 138, 153 or 180 were detected in air sampling. The authors estimated total PCB in air over the two-year period to be 0.690- 20.80 µg/m^3 (mean 2.044 µg/m^3) based on measurement of six indicator congeners. When PCB congeners associated with dietary intake were considered, there was no statistically significant difference between overall PCB body burden in students from the two schools. Nor was there a detectable difference in a survey of children’s subjective symptoms.

Frederiksen *et al*. 2012 reported that mean PCB air levels in Danish multiunit housing was 1.03 µg/m^3 (range 0.168-3.843 µg/m^3) in apartments that contained PCB in elastic sealants verses a mean of 0.006 µg/m^3 in apartments sealed with PCB-free sealants. PCB sealants contained up 20% (221,680 ppm) PCB and were the primary determinant of indoor PCB levels. A survey of residents about their adherence to advice about minimizing their exposure showed that frequent ventilation, vacuuming, dusting, and floor washing were associated with lower indoor air levels.

In 2009, PCBs were discovered in chipping exterior paint on the former Rainier Brewery in Seattle at concentrations over 10,000 ppm PCB. This 4.5 acre site now houses mixed residential, restaurant, and business spaces. Paint chips were suspected to be the source of elevated PCBs in a nearby stormwater collection area. In 2010, sampling by EPA detected PCBs in indoor air in some office areas (0.010-0.028 µg/m^3) and in an outside stairwell that had been enclosed with the exterior paint intact (0.052 µg/m^3). Sampling also detected PCBs in vacuum dust at concentrations between 1.4-15.6 ppm in residential and office spaces, 3.4-36 ppm in storage and warehouse areas, and 470 ppm in stairwell dust. DOH concluded that there was a very low to insignificant increase in cancer risk associated with the levels detected. Recommendations for mitigation included removing all paint with more than 50 ppm PCB (as required by law), warning occupants to avoid regular use of the external stairwell until remediation could take place, and adopting cleaning techniques that would reduce potential for human exposure (WDOH 2013b).

PCBs can bind to indoor dust and present an inhalation or ingestion pathway for people. Dust intake is associated with higher molecular weight PCBs than air exposures. A 2006 survey of PCBs in residential settings reported median dust concentrations to be 0.200 µg/kg dust (ppb) in 20 Texas homes and 0.260 µg/kg in ten Toronto homes (Harrad *et al.* 2009). Maximum detected was 0.820 µg/kg PCBs in dust. While ingestion of house dust was a minor contributor to adult exposures, it contributed 1-20% of total PCB exposure to toddlers in exposure modelling (Harrad *et al.* 2009). Homes built before 1980 had higher PCB loading in house dust than more recently constructed homes in a large sampling of 415 homes in California (Whitehead *et al.* 2013). A recent study in China reported that house dust levels of PCBs were associated with subtle neurodevelopmental effects in pre-school aged children (Wang *et al.* 2015).

It appears that PCBs in older building materials can elevate PCBs in indoor air and dust and cause higher body burden of certain PCB congeners in the bodies of people living or working in these buildings. In some cases the detected air concentrations were high enough to exceed residential or occupational health guidelines. In the EPA investigation into older schools in New York, indoor air levels frequently exceeded EPA health guidance for schools of 0.70-0.60 µg/m^3 depending on the age of the children present. EPA requires caulk with more than 50 ppm of PCBs to be removed. PCB containing fluorescent light ballasts that remain in service are generally more than 30 years and have exceeded their expected life-span. They are at high risk for over-heating and failing and should be removed and properly disposed.

PCBs in Pigments and Dyes

Residual PCBs in dyes and pigments have been detected in ambient air, food, water, and consumer products. Air monitoring studies of urban air and remote polar air detect PCB 11, occasionally as a major component (Hu *et al.* 2008, Du *et al.* 2009, Basu *et al.* 2009, Choi *et al.* 2008). Consumer product testing has measured residual amounts of PCB 11 and other congener in a variety of colored paper, cardboard, and plastic packaging. (Hu and Hornbuckle 2010, Rodenberg *et al.* 2010). In Washington, PCBs associated with pigments and dyes have been identified in Columbia River water and clams and in a majority of fish sampled in a recent study in the Mid-Columbia. River (McCarthy 2007, Ecology 2005, U.S. Department of Energy 2010)

There is only limited investigation of absorption of PCB 11 into people. In rats, PCB 11 was rapidly absorbed via inhalation, distributed to tissue, and eliminated with half-lives in lung, liver and serum of approximately two hours. A hydroxylated metabolite of PCB 11 was also detected in the rodent liver (Hu et al 2013). Biomonitoring for PCB congeners unique to dyes and pigments (PCB 11) has detected PCB 11 in people. In a recent study, 65% of 85 women in a mid-West had traces of PCB 11 in their blood (Marek *et al* 2013). Three potentially toxic metabolites of PCB 11 have also been detected in human serum (Zhu *et al*. 2013).

There is only limited toxicity information specific to PCB 11. Zhu et al 2013, tested PCB 11 and the 4-hydroxymetabolite detected in human serum for toxicity *in vitro*. In this study, the PCB 11 metabolite suppressed cell growth, created oxidative stress, and resulted in cytotoxicity. Co-administration of antioxidants partially protected against the observed effects. PCB 11 had no effect in the test (Zhu et al 2013). Further study is needed to understand the magnitude of human exposure to PCB 11 and its metabolites as well as their toxicity.

Other Environmental Exposures

Small amounts of PCBs can be found in almost all soil surfaces and sediments. Most soil levels of PCBs are less than 0.010-0.040 µg/kg (ppb) but soil at hazardous waste sites may be much higher. In water, a small amount of PCB may remain dissolved but most tends to stick to organic particles and sediments or evaporate from the water surface (ATSDR 2000).

Direct contact with PCB in old paint, caulk or fluids leaking from capacitors can lead to skin absorption or ingestion of PCBs. It is important to wear protective clothing gloves and respiratory protection if repairing or handling equipment like light ballasts that may have PCBs in them.

Occupational Exposures

Current occupational exposures can come from exposure to leaking electrical equipment made before 1979, from PCB abatement programs, or during demolition or recycling of PCB-contaminated structures and equipment.

Herrick *et al*. (2007), conducted biomonitoring for 54 PCB congeners in a small group of construction workers with a history of removing PCB caulk from buildings in the greater Boston area. The workers had higher proportions of lighter PCB congeners (PCBs 6-74) in their serum than a reference population of men who sought health care in the Boston area. The construction workers as a group had more than five times more PCB 6, 16, 26, 33, 37, 41, 70, 97, and 136 than the referent population. One worker, who was actively involved with removal of PCB products at the time of blood collection, had 25% of his body burden comprised of the lighter PCBs compared to 7% of the PCB serum levels in the referent population.

Wingfors *et al*. 2006 collected blood samples from 36 workers directly involved in abating PCB sealants in Sweden. These were compared in a biomonitoring study to 33 age- and sex-matched construction workers who did not work in the abatement program. The exposed workers had PCB serum levels (sum of 19 congeners) that were twice as high as the controls (mean of exposed workers were 575 ng/g lipid compared to 267 ng/g for the controls). The PCB congener patterns also differed between the workers and the controls, with much higher levels of many less chlorinated PCBs in the exposed workers, compared to the controls. The authors concluded that PCBs 56/60 and 66, were good markers of general occupational exposure; PCB 44, 70, and 110 were good markers for recent occupational exposures; and PCB 153 and 180 reflected background (dietary) exposure. Follow-up samples taken 10 months later showed that serum concentrations of rapidly excreted congeners (PCB 52, 44, 70, and 110) declined after workers were given information about protecting themselves from exposure.

Adequate safeguards are also important during recycling and disposal of PCB containing materials. Electronic waste recycling and disposal practices in China have resulted in elevated exposures in workers, PCB release into nearby soils and rivers, and subsequent contamination of staple foods grown in surrounding areas. (Yang *et al.* 2013, Tue *et al.* 2013, Labunska *et al.* 2015).

Existing Washington State Health Advice

Fish consumption is the primary exposure pathway that most Washingtonians have to many Persistent, Bioaccumulative Toxics (PBTs). Many PBTs such as PCBs, DDT, and mercury are linked to a variety of adverse health effects (e.g. neurological, developmental, immunological, and cancer). The paradox of consuming fish is that it also known to be one of the healthiest forms of protein due in part to the high levels of omega-3 fatty acids that have been associated with a variety of positive health outcomes (e.g. prevention of heart disease, inflammation, arteriosclerosis, and cognitive development). Results from the most recent Behavioral Risk Factor Surveillance System (BRFSS) conducted by DOH indicate that nearly three quarters of the adult general population in Washington State consume fish. Washington State is also the home of numerous federally recognized tribes whose fish consumption rates are often well above that of the general population (Ecology 2013b). Additionally, there are other high fish consuming populations within the state including Asian and Pacific Islanders and sports fishers.

Because of potential exposure to PBTs to fish consuming populations, DOH collaborates with numerous state and federal agencies on the collection and analysis of contaminants in fish. DOH's role is to evaluate fish contaminant levels in fish tissue for potential public health impacts and to convey information on risks and benefits to fish consumers by way of fish advisories. Currently, Washington State has thirteen waterbody specific fish advisories based on PCB levels in tissue. PCBs account for the greatest number of waterbody specific advisories in Washington State and across the country (WDOH 2013a, EPA 1999b).

Table 35 lists those waterbodies and fish species that currently have a fish advisory due to elevated PCB levels.

Table 35. Washington State PCB Fish Advisories

Water Body/Location	Fish Species	Advisory
Green Lake	Common Carp	1 meal per month
Lake Roosevelt	Largescale Suckers	2 meals per month
Lake Washington	Common Carp	Do not eat
	Northern Pikeminnow	Do not eat
	Cutthroat Trout	1 meal per month
	Yellow Perch	1 meal per week
Lower Duwamish River	Resident fish	Do not eat
	Shellfish	Do not eat
	Crab	Do not eat
Lower Columbia – (Bonneville Dam)	Resident fish	Do not eat
Bonneville Dam to McNary Dam	Resident fish	1 meal per week
Okanogan River	Common Carp	1 meal per month
Puget Sound	Chinook	1 meal per week
	Chinook (Blackmouth)	2 meal per month
	English Sole/Flatfish	Varies by location
	Rockfish	Varies by location
Spokane River		
Idaho Border to Upriver Dam	All species	Do not eat
UpRiver Dam to Nine Mile Dam	All species*	1 meal per month
	* Exception: Largescale Suckers	Do not eat
Long Lake (Lake Spokane)	Largescale Suckers, Brown Trout	1 meal per week
	Mountain Whitefish	1 meal per month
Walla Walla River – Lower	Carp	1 meal per month
Walla Walla River – Lower & Upper	Northern Pikeminnow	Do not eat
Wenatchee River	Mountain Whitefish	Do not eat
Yakima River	Common Carp	1 meal per week
Pending Advisories*		
Mid-Columbia	Lake Whitefish	1 meal per month
	Largescale Suckers	2 meals per month
	Sturgeon	2 meals per month
	Common Carp	1 meal per month
	Walleye	2 meals per month
	Bass	2 meals per month
Snake River	Channel Catfish	2 meals per month
	Common Carp	2 meals per month
* preliminary assessment, meal recommendations may change Fish advisories apply to all individuals. Women of childbearing age and young children should pay particular attention.		

Food Preparation and Cooking Advice to Reduce Exposure

Chemical contaminants are not distributed uniformly in fish. Fatty tissues typically concentrate organic chemicals such as PCBs and dioxins more readily than lean muscle tissue (ATSDR 2004). To reduce the level of PCBs in fish, remove the fish skin and visible fat before cooking. Do not use the fat for gravy or sauces. For further information on reducing contaminants such as PCBs in fish, visit http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/ReduceContaminantExposure.

Benefits of Fish Consumption

The primary health benefits of eating fish are well documented for children and adults. Dietary fish is associated with reduction of cardiovascular disease (Yuan *et al*. 2001, Rodriguez *et al*. 1996, Hu *et al*. 2002, Marckmann and Gronbaek 1999, Mozaffarian *et al*. 2003, Simon *et al*. 1995, Burr *et al*. 1989, 1994, Singh *et al*.1997, and Harrison and Abhyankar 2005) and positive pregnancy outcome (Jorgensen *et al*. 2001, Olsen *et al*. 1992, Olsen *et al*. 1995, Olsen and Secher 2002, Carlson *et al*. 1993, 1996, Fadella *et al*. 1996, San Giovanni *et al*. 2000, and Helland *et al*. 2003). Limited data also show a link between fish consumption and a decrease in development of some cancers (SACN 2004, IOM 2007). Additionally, eating fish has been associated with impacts on brain function, including protection against cognitive decline (SACN 2004, IOM 2007).

At present, we know that fish is an excellent protein source that is low in saturated fats, rich in vitamin D, omega-3 fatty acids, and other vitamins and minerals. The health benefits of eating fish are associated with low levels of saturated versus unsaturated fats. Saturated fats are linked with increased cholesterol levels and risk of heart disease while unsaturated fats (e.g., omega-3 polyunsaturated fatty acid) are an essential nutrient. Replacing fish in the diet with other sources of protein may reduce exposure to contaminants but could also result in increased risk for certain diseases (Pan *et al*. 2012). For example, replacing fish with red meat could increase the risk of cardiovascular disease due to the fact that red meat has higher levels of saturated fat and cholesterol (Law, 2000).

DOH fish advisories work to be protective of human health while acknowledging the benefits of eating fish. This is done by recommending decreased consumption of fish known to have high concentrations of contaminants in favor of fish that are lower in contaminants. DOH supports the American Heart Association and the U.S. Food and Drug Administration recommendation of consuming at least two servings (12 oz.) of fish per week as part of a healthy diet.

Health benefits of eating fish deserve particular consideration when dealing with groups that consume fish for subsistence. Removal of fish from the diet of subsistence consumers may have serious health, social, cultural, and economic consequences. In order to decrease the potential risks of fish consumption, these populations are encouraged to consume a variety of fish species, to fish from locations with low contamination, and to follow recommended preparation and cooking methods.

Recommendation for Breast-feeding

DOH recommends that babies be breast fed because breast feeding has many demonstrated health benefits for the developing child and the mother. (Washington State Department of Health website http://www.doh.wa.gov/YouandYourFamily/WIC/BreastfeedingSupport.aspx)

Many investigations have looked for adverse effects associated with PCBs in breast milk and duration of breast feeding. Most studies have shown that prenatal, not postnatal PCB exposure correlates with neurobehavioral effects (Michigan, NC, Patandin *et al*. 1999, Darvill *et al*. 2000). Breast feeding appears to have a net positive effect on neurobevavioral test performance regardless of PCB concentration of the milk (Jacobson *et al*. 1990b).

A Dutch study on PCB and dioxin exposures to children recently found that PCB body burden at 42 months is associated with possible immune deficits. However, when the researchers controlled for length of breast feeding, they found that the negative effect of higher postnatal PCB exposure was counteracted by the positive effect of longer duration of nursing in infancy (Weisglas-Kuperus *et al*. 2000). Using this same cohort, other researchers conducted neurological and cognitive assessments at 42 months and found that breast-fed children performed better than their formula fed counterparts despite higher prenatal and postnatal exposure to PCBs (Lanting *et al*. 1998, Patandin *et al*. 1997 and 1999). Follow-up with these children at 6.5 years showed that effects of prenatal exposure to PCBs on cognitive and motor abilities were still measureable in the formula fed group and not measurable in the breast-fed group (Vreugdenhil *et al*. 2002). Analysis of parental and home characteristics suggested that an advantaged home environment contributed significantly to the resilience of the breast-fed group (Vreugdenhil *et al*. 2002).

Current Regulatory Approaches for PCBs

This chapter describes the existing regulations relevant to PCBs and the activities that generate them at the federal, state, and international levels. It includes a brief summary of many laws and regulations directly related to management of processes that produce PCBs, the production, use, and disposal of products that contain PCBs, and exposure limits and cleanup levels for PCBs themselves. This chapter is not an exhaustive review of all of the regulations pertinent to PCBs.

In many instances, federal laws and regulations delegate the authority for implementing these laws and regulations to state or Tribal governments. In some cases, states adopt laws and promulgate regulations that are more stringent than their federal partners.

Federal Laws & Regulations

Toxic Substances Control Act

15 USC 2601 et seq., Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) of 1976 (15 USC 2601 et seq.) gives EPA the authority to regulate new and existing substances. TSCA gives EPA the authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures. Certain substances are generally excluded from TSCA, including, among others, food, drugs, cosmetics, and pesticides.

TSCA is the primary federal law pertinent to PCBs in the United States. PCBs are regulated by Title I Section 6 of the Act and by EPA implementing regulations, Title 40, Part 761 of the Code of Federal Regulations (CFR). Section 6(e)(2)(A) of TSCA states that "…effective one year after January 1, 1977, no person may manufacture, process, or distribute in commerce or use any polychlorinated biphenyl in any manner other than in a totally enclosed manner." Section 6 of TSCA further prohibited the manufacture of all PCBs by 1979, but allowed the EPA administrator to authorize certain processing, distribution in commerce, and use of PCBs manufactured before 1979 if the Administrator determined that such activity did not present an unreasonable risk of injury to health or the environment. Table 37 summarizes several subparts of TSCA and their contents

Table 36. Subparts of TSCA

Subpart A	General regulations governing PCBs including definitions
Subpart B	Manufacturing, processing, distribution in commerce and use of PCBs and PCB items Prohibitions and exceptions Authorizations including: • Totally enclosed uses (e.g. transformers, capacitors) • Non-totally enclosed uses (including requirements for servicing PCB-containing equipment) • Other uses (carbonless copy paper, research and development, scientific instruments, continued use of porous surfaces contaminated with PCBs)
Subpart C	Marking of PCBs and PCB items
Subpart D	Storage and disposal, including: • PCB disposal requirements • Remediation waste disposal and cleanup levels • Bulk product waste • PCB household waste storage and disposal • PCB decontamination standards and procedures • Storage for disposal
Subpart E	Manufacturing, processing, and distribution in commerce exemptions, including: • Research and development for disposal technologies • Analytical reference samples • 5 ml or less PCB fluids from electrical equipment for analysis •
Subpart F	Transboundary shipments of PCBs for disposal
Subpart G	PCB spill cleanup policy
Subpart J	General records and reports
Subpart K	PCB waste disposal records and reports
Subparts M-R	Sampling requirements for various media and disposal authorizations
Subpart S	Double wash/rinse method for decontaminating non-porous surfaces
Subpart T	Comparison study for validating a new performance-based decontamination solvent

Continued use and disposal of existing PCBs is governed by a framework of controls driven by the form the PCBs take (liquid form, non-liquid form, or multi-phasic, meaning a combination of liquid and non-liquid forms), the amount of PCBs in each form, and the original source of PCBs for media contaminated by a release.

While not a complete summary of all sections in TSCA that pertain to PCBs: below are some important requirements:

- Prohibits of manufacture, sale, and distribution, with exceptions.
- Mandates proper disposal for any PCBs unauthorized for use.
- Does not require testing to find PCB sources, but does require proper use and disposal of identified PCB contaminated items.
    - Many unauthorized uses are therefore not found until a release to the environment has occurred.
- Limits use of PCBs to certain "totally enclosed" uses, such as transformers and capacitors, or concentrations below 50 ppm in bulk product. Various other levels exist for remediation waste and other limited uses, typically with EPA approval.
- Requires that by December 1998, all known transformers containing PCBs >500 ppm be registered with EPA.
    - There is no requirement to determine if transformers contain >500 ppm PCBs, only to register it if it is known to be a PCB Transformer (>500 ppm PCBs).
- Allows many forms of PCB waste to be disposed of as municipal solid waste, which does not require PCBs to be listed on a manifest. Examples include:
    - Small non-leaking PCB capacitors.
    - Plastics (such as plastic insulation from wire or cable; radio, television and computer casings; vehicle parts; or furniture laminates); preformed or molded rubber parts and components; applied dried paints, varnishes, waxes or other similar coatings or sealants; caulking; Galbestos; non-liquid building demolition debris; or non-liquid PCB bulk product waste from the shredding of automobiles or household appliances from which PCB small capacitors have been removed (shredder fluff).
        - Any of these may also be disposed as landfill daily cover or as roadbed under asphalt.
    - Other PCB bulk product waste that leaches PCBs at <10 µg/L of water measured using a procedure used to simulate leachate generation.
    - PCB bulk product waste other than those materials listed above if:
        - The PCB bulk product waste is segregated from organic liquids disposed of in the landfill unit.
        - Leachate is collected from the landfill unit and monitored for PCBs.
- Requires labels identifying electrical equipment containing over 500 ppm PCBs.
- Requires quarterly inspections of PCB transformers containing more than 60,000 ppm PCBs. Transformers with less than 60,000 ppm PCBs and those with appropriate secondary containment must be inspected for leaks at least annually.

- Requires removal or reclassification of high-voltage network PCB-containing transformers to prevent fires. Requires enhanced electrical protection be added on many types of PCB transformers in, or within 30 meters of, commercial buildings.[12]
- Requires EPA authorization for commercial storage of PCBs. Non-Commercial storage does not always require EPA oversight.

TSCA *Rules*

Under TSCA EPA has promulgated 29 rules for the regulation of PCBs. A list of rules, with the associated notices, drafts, etc. can be found on the EPA website at http://www.epa.gov/wastes/hazard/tsd/pcbs/pubs/laws.htm. The current regulations can all be found in the Federal Code of Regulations (CFR) part 761. In general, each rule addresses a specific portion of managing PCBs, such as labeling and spills. Below is some information on three specific regulations.

1. 44 FR 31514 PCBs; Manufacturing, Processing, Distribution in Commerce and Use Bans.

This 1979 rule implemented the ban on PCBs and established 50 ppm PCBs as the general regulatory limit.

2. 49 FR 28172 Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions; Exclusions, Exemptions, and Use Authorizations

EPA promulgated a rule in 1984 for inadvertent generation of PCBs that are not in closed or controlled manufacturing processes (49 FR 28172). EPA found the societal benefit of these products and the cost of not producing PCBs outweighed the risks to human health and the environment from these sources of PCBs. The rule was based on a consensus proposal from the Environmental Defense Fund, Natural Resources Defense Council, and Chemical Manufacturers Association (now known as the American Chemistry Council). It requires that the concentration of inadvertently generated PCBs in products, including recycled paper, must have an annual average of < 25 ppm, with a maximum of 50 ppm. Detergent bars are treated differently as they are consumer products with a high potential for exposure, and are limited to 5ppm (soap and deodorant are regulated by the FDA).

There were several additional criteria in the rule:

- Releases to ambient air must be less than 10ppm.
- Discharges to water must be less than 0.1ppm, except from recyclable paper the limit is 3 ppb total Aroclors.

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[12] Panero, M., Boheme, S., and Muñoz, G. Pollution Prevention and Management Strategies for Polychlorinated Biphenyls in the New York/New Jersey Harbor. February 2005. New York Academy of Sciences, New York, NY. Available at: http://www.nyas.org/WhatWeDo/Harbor.aspx

- All wastes must be disposed of properly. Process wastes with PCB levels > 50 ppm must be disposed of in accordance with TSCA.
- The concentration of monochlorinated biphenyls is discounted by a factor of 50 and dichlorinated biphenyls are discounted by a factor of 5.
- Certification, reporting, and records maintenance.

The numerical limits in the law were set at the Limits of Quantification (LOQs) at the time.

The rule clarifies some overlap between TSCA with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and Federal Food Drug and Cosmetic Act (FFDCA). If a chemical is solely manufactured for a use that is regulated by FIFRA or FFDCA, then that substance is not regulated under TSCA. If only some uses are regulated under FIFRA, then the chemical is regulated under TSCA until it becomes part of an identified pesticide product. However, chemicals used in FDA-regulated products under FFDCA (like a food, food additive, drug, cosmetic, or medical device) are excluded from TSCA jurisdiction.

In 2013 EPA clarified the definition of "excluded PCB Products" to generally allow for the recycling of plastic separated from shredder residue containing < 50 ppm PCBs under specific conditions. The voluntary procedures to prevent the introduction of PCBs in shredder residue are (1) documented source control programs and (2) documented output control. The review was done at the request of the Institute of Scrap and Recycling Industries to clarify whether the plastic material should be managed as an Excluded PCB Product or as a PCB Remediation Waste. This interpretation reiterates EPA's "generic exclusion for processing, distribution in commerce, and use, based on the Agency's determination that the use, processing, and distribution in commerce of products with less than 50 ppm concentration will not generally present an unreasonable risk of injury to health or the environment" (FR Vol. 78, No. 66, April 5, 2013).

3. Several rules on transformers and other electrical equipment have been promulgated. The current regulations are in CFR part 761.

The regulations include several important definitions:

- PCB Transformer (≥500 ppm) *PCB Transformer* means any transformer that contains ≥500 ppm PCBs.
- PCB contaminated (50-500 ppm) *PCB-Contaminated* refers to liquid and non-liquid material containing PCBs at concentrations ≥50 ppm but <500 ppm, and non-porous surface having a surface concentration >10 µg/100 cm^2 but <100 µg/100 cm^2.

  The definitions specifically mention electrical equipment with a very similar definition. *PCB-Contaminated Electrical Equipment* means any electrical equipment including, but not limited to, transformers (including those used in railway locomotives and self-propelled cars), capacitors, circuit breakers, reclosers, voltage regulators, switches (including sectionalizers and motor starters), electromagnets, and cable, that contains PCBs at concentrations of ≥50 ppm and <500 ppm in the contaminated fluid. In the absence of liquids, electrical equipment is PCB-Contaminated if it has PCBs at >10 µg/100 cm^2 and <100 µg/100 cm^2.

- Non-PCB Transformer (<50 ppm) *Non-PCB Transformer* means any transformer that contains less than 50 ppm PCB.

Owners of PCB transformers (≥500 ppm) were required to register their transformers with the EPA by Dec. 28, 1998. Some important points about this requirement:

- There is no requirement to test a transformer to determine if it is a PCB Transformer.
- There is no requirement to register a transformer if the owner takes ownership after 1998.
- There is no requirement to register a PCB-contaminated transformer (50-500ppm PCBs)
- There is no requirement to request a registered transformer be removed from the database if it is physically removed from service.
- Other equipment, such as bushings with ≥ 500 ppm PCBs, are not required to be registered.

While testing for PCBs is not required, the regulations do include PCB concentration assumptions that are based on the age and size of the equipment. The assumptions include:

- Transformers with <3 pounds (1.36 kilograms (kgs)) of fluid, circuit breakers, reclosers, oil-filled cable, and rectifiers whose PCB concentration is not established contain PCBs at <50 ppm.
- Mineral oil-filled electrical equipment that was manufactured before July 2, 1979, and whose PCB concentration is not established is PCB-Contaminated Electrical Equipment (i.e., contains ≥50 ppm PCB, but <500 ppm PCB). All pole-top and pad-mounted distribution transformers manufactured before July 2, 1979, must be assumed to be mineral-oil filled.
- Electrical equipment manufactured after July 2, 1979, is non-PCB (<50 ppm PCBs).
- If the date of manufacture of mineral oil-filled electrical equipment is unknown, any person must assume it to be PCB-Contaminated.
- A transformer manufactured prior to July 2, 1979, that contains 1.36 kg (3 pounds) or more of fluid other than mineral oil and whose PCB concentration is not established, is a PCB Transformer (i.e., ≥500 ppm). If the date of manufacture and the type of dielectric fluid are unknown, any person must assume the transformer to be a PCB Transformer.
- A capacitor manufactured prior to July 2, 1979, whose PCB concentration is not established contains ≥500 ppm PCBs.
- A capacitor manufactured after July 2, 1979, is non-PCB (i.e., <50 ppm PCBs).
- If the date of manufacture is unknown, any person must assume the capacitor contains ≥500 ppm PCBs.

Water Regulations

33 USC 1251 et seq., The Clean Water Act (CWA)

EPA has established water quality criteria for certain compounds that define levels to protect human health and aquatic life. The Clean Water Act and its amendments prohibit discharging pollutants from a point source without a National Pollutant Discharge Elimination System (NPDES) permit. These permits include conditions to protect water quality. EPA authorizes states to issue and monitor compliance with these permits. The Clean Water Act also directs EPA to establish technology-based standards, known as Best Available Technology (BAT) requirements to prevent discharges of harmful amounts of pollutants.

Stormwater from certain industries and municipalities is also considered a point source of pollution that requires NPDES permitting[13]. PCBs from various sources that are deposited on land and washed into storm drains would be regulated under these stormwater permits. EPA's stormwater regulations establish two phases for the stormwater permit program:

- Phase I stormwater permits cover discharges from certain industries, construction sites involving five or more acres, and municipalities with a population of more than 100,000.
- Phase II stormwater permits cover all municipalities located in urbanized areas and construction sites between one and five acres. The EPA rule also requires an evaluation of cities outside of urbanized areas that have a population over 10,000, to determine if a permit is necessary for some or all of these cities.

National Recommended Water Quality Criteria[14]

PCBs are a Priority Pollutant under the CWA. EPA has national recommended water quality criteria for the protection of aquatic life and human health in surface water for about 150 pollutants. These criteria are published pursuant to Section 304(a) of the Clean Water Act and provide guidance to states. For aquatic health the chronic freshwater criterion is 0.014 ug/L and 0.03 ug/L for saltwater. For human health the criteria are 0.000064 ug/L both for the consumption of water and organism and for the consumption of organism only.

National Toxics Rule (40 CFR 131.36).[15]

The National Toxics Rule promulgated chemical-specific numerical criteria for priority toxic pollutants for 14 states to bring them into compliance with requirements of section 303(c)(2)(B)

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[13] Department of Ecology. How is Stormwater Regulated? Available at: http://www.ecy.wa.gov/programs/wq/stormwater/municipal/howregulated.html

[14] US EPA. National Recommended Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/current/index.cfm (accessed 9 June 2011).

[15] US EPA. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliances. 57 FR 60848. Available at: http://water.epa.gov/lawsregs/rulesregs/ntr/index.cfm (accessed 21 Oct 2013).

of the CWA. This rule became effective in 1993. The criterion for PCBs for both freshwater and marine water is 0.00017 ug/L, which has a fish tissue equivalent of 5.304 ug/kg.

42 USC 300f et seq., Safe Drinking Water Act (SDWA)

The Safe Drinking Water Act specifies water quality standards for drinking water. The National Primary Drinking Water regulations under the SDWA apply to public water systems with at least 15 service connections or more than 25 individuals for more than 60 days per year.

The SDWA sets two drinking water standards. The Maximum Contaminant Level Goal (MCLG) is a non-enforceable health goal. The Maximum Contaminant Level (MCL) is the legally enforceable standard. Water systems must reduce levels of the contaminant as close to the MCLG as feasible, considering technology, treatment techniques, and costs. For PCBs the MCLG is zero and the MCL is 0.0005 mg/L (ppm)[16]

Air Regulations

42 USC 7401, Clean Air Act and Amendments

PCBs are regulated under Section 112 of the Clean Air Act as Hazardous Air Pollutants (HAPs).

Regulation under Section 112 of the Clean Air Act requires major sources of HAPs to meet standards based on Maximum Achievable Control Technology (MACT). These standards must require the maximum degree of emission reduction that the EPA determines to be achievable by each particular source category. Different criteria for MACT apply for new and existing sources. For existing major sources, MACT is defined as the technology used to control emissions at the top 12% of facilities within the same source category. Eight to nine years after MACT is implemented, EPA is required to conduct a residual risk analysis. If the "residual risk" for a source category does not protect public health with "an ample margin of safety," the EPA must promulgate health-based standards for that source category to further reduce HAP emissions.

PCBs are one of several substances listed in Section 112(c)(6) of the Clean Air Act, which requires EPA to “list categories and subcategories of sources assuring that sources accounting for not less than 90 per centum of the aggregate emissions of each such pollutant are subject to standards.” EPA published this listing in a Federal Register notice in June 1997.[17] Various forms of waste incineration were identified as the primary industrial source categories emitting PCBs.

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[16] US EPA. List of Contaminants & their MCLs. Available at: http://water.epa.gov/drink/contaminants/index.cfm#List (accessed 9 June 2011).

[17] Notice of draft source category listing for section 112(d)(2) rulemaking pursuant section 112(c)(6) requirements. 62 FR 119 (20 June 1997). p. 33625 - 33638.

Waste, Hazardous Substance & Cleanup Regulations

42 USC 6901 et seq., Resource Conservation and Recovery Act (RCRA)

Under the authority of the Resource Conservation and Recovery Act of 1976, EPA implements regulations pertaining to solid waste, hazardous waste and underground storage tanks (40 CFR parts 239-299).

Hazardous wastes are managed under RCRA from their point of generation to their proper disposal or treatment. There are three means under RCRA of identifying if a waste is hazardous: (1) if the waste is specifically listed as hazardous, (2) if it exhibits hazardous characteristics, as determined by a Toxicity Characteristic Leaching Procedure (TCLP) test or 3) exhibits the characteristics of ignitability, corrosivity or reactivity.

Wastes are given waste codes based on their sources or specific properties. D codes are for characteristic wastes. P and U waste codes are assigned to discarded chemical products. F codes are for non-specific and K codes are for specific industrial sources.

Standards for the Management of Used Oil (40 CFR Part 279)[18] include management standards for generators, transporters, processors, burners, and marketers of used oil containing PCBs at less than 50 ppm. Used oil containing more than 50 ppm is regulated under TSCA (40 CFR part 761).

RCRA allows EPA to permit facilities to Treat, Store and Dispose of hazardous waste. Additionally, RCRA grants EPA the authority to require cleanup of any releases of hazardous waste to the environment from a permitted or interim status facility through the RCRA Corrective Action Program. RCRA cleanup sites regularly also have PCB contamination. Generally these sites come under both programs for approval of the waste cleanup.

42 USC Part 103, Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

CERCLA, passed in 1980, is the primary federal authority used to regulate and cleanup historic hazardous waste sites. The statute and implementing regulations establish procedures for the long-term remediation of such sites, but also provides authority to clean up hazardous waste sites in need of immediate action. The law has subsequently been amended, by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and the Small Business Liability Relief and Brownfields Revitalization Act of 2002.

Under CERCLA Section 103, releases of hazardous substances are required to be reported to the National Response Center if they exceed the Reportable Quantity (RQ) for that substance, which

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[18] US EPA. Standards for the Management of Used Oil. 40 CFR Part 279. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_07/40cfr279_07.html (accessed 10 June 2011).

is 1 pound for PCBs.[19] CERCLA implements TSCA as an Applicable or Relevant and Appropriate Requirements (ARAR), without need for separate approval under TSCA for PCB waste disposal.

42 USC Part 116, Emergency Planning and Community Right-to-Know Act (EPCRA)

EPCRA, or SARA Title III, is intended to protect public health and the environment from hazards posed by toxic chemicals by providing information about the presence of toxic chemicals in communities. The Act, passed in 1986, creates the annual hazardous chemical inventory as well as the toxics release inventory (TRI).

Under Section 302 of EPCRA, facilities that manufacture, process or use chemicals on the list of Extremely Hazardous Substances (EHSs) must report the presence of those chemicals above a certain quantity, known as the Threshold Planning Quantity (TPQ).

Section 313 of EPCRA establishes the Toxics Release Inventory (TRI). Under the TRI, the release or waste management of toxic chemicals by certain industries must be reported if the quantity of a chemical that is manufactured, processed, or otherwise used during the calendar year exceeds the reporting threshold. For most TRI chemicals, the thresholds are 25,000 pounds manufactured or 10,000 pounds otherwise used.[20] The reporting threshold for PBTs is lower and is 10 lbs for PCBs.

Worker & Product Safety Regulations

84 USC 1590 et seq., Occupational Safety and Health Act (OSHA)

The Occupational Safety and Health Act allows the Occupational Safety and Health Administration (OSHA) to set protective regulatory limits on the amount or concentration of a substance in the air in workplaces. These limits, called Permissible Exposure Limits (PELs) are based on an average exposure over an 8 hour workday, or a Time-Weighted Average (TWA).[21] OSHAs PEL is 1,000 µg/m^3 for PCBs containing 42% chlorine (CAS 53469-21-9) and 500 µg/m^3 for compounds containing 54% chlorine (CAS 11097-69-1). The PELs include "skin" to refer to the contribution to overall exposure through skin. These are based on the prevention of liver injury in exposed workers.

The National Institute for Occupational Safety and Health (NIOSH) recommends a 10-hour TWA of 1 µg/m^3 based on the minimum reliable detectable concentration and the potential

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[19] US EPA. List of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Section 112(r) of the Clean Air Act. EPA 550-B-01-003. October 2012. Available at: http://www.epa.gov/emergencies/tools.htm#lol (accessed 21 October 2013).

[20] US EPA. List of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Section 112(r) of the Clean Air Act. EPA 550-B-01-003. October 2012. Available at: http://www.epa.gov/emergencies/tools.htm#lol (accessed 21 October 2013).

[21] Occupational Safety and Health Administration. Permissible Exposure Limits (PELs). Available at: https://www.osha.gov/dsg/topics/pel/ (accessed 21 October 2013).

carcinogenicity of PCBs.[22] The NIOSH Recommended Exposure Limit (REL) was based on reproductive effects in animal models, carcinogenic effects, and prevention of liver injury. NIOSH also recommends that all workplace exposures be reduced to the lowest feasible level.

Washington State Laws and Regulations

Water Regulations

Chapter 90.48 RCW Water Pollution Control

Chapter 173-200 WAC Water quality standards for groundwaters of the state of Washington.

This regulation is intended to protect current and future beneficial uses of groundwater from deleterious effects, prevent degradation of waters of outstanding value, and actively maintain the higher quality of waters that exceed water quality criteria.

Chapter 173-201A WAC Water quality standards for surface waters of the state of Washington.

This regulation institutes narrative and numeric criteria for surface water quality, an anti-degradation policy, and use-based protection measures.

Chapter 70.142 RCW Chemical Contaminants and Water Quality

This law allows the State Board of Health to establish standards for allowable concentrations of chemical contaminants in public water supplies.

Chapter 246-290 WAC Water quality standards for groundwaters of the state of Washington

This regulation establishes regulatory requirements applicable to public drinking water supplies.

Multiple Statutes – Chapters 90.48, 70.105D, 90.70, 90.52, 90.54 and 43.21 RCW

Chapter 173-204 WAC, Sediment Management Standards

Enacted in 1991, this chapter establishes marine, low salinity and freshwater surface sediment management standards. The purpose of this chapter is to reduce health threats to humans and biological resources resulting from surface sediment contamination.[23]

Air Regulations

Chapter 70.94 RCW Washington Clean Air Act

The Washington Clean Air Act authorizes the Department of Ecology to develop and implement regulations that are needed to control air pollution.

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[22] Polychlorinated Biphenyls (PCBs). Current Intelligence Bulletin 45 (1986) http://www.cdc.gov/niosh/docs/86-111/ (accessed 21 October 2013)

[23] WAC 173-204-320. Table 1, Marine Sediment Quality Standards. Available at: http://apps.leg.wa.gov/wac/default.aspx?cite=173-204-320 (accessed 10 June 2011).

Chapter 173-460 WAC Controls for new sources of toxic air pollutants

Under this chapter, Ecology reviews new sources of toxic air pollutants and establishes emission control requirements that are needed to prevent air pollution that may impact human health and safety. This chapter, enacted in 1991, requires new sources to implement Best Available Control Technology for toxics (BACT). The owner or operator of a new toxic air pollutant source must also conduct an Acceptable Source Impact Level (ASIL) analysis for toxic air pollutants. When performing these assessments, the owner/operator must quantify the amount of toxic air pollutant likely to be emitted from the new source and estimate ambient air concentrations that might result from those emissions. Ambient air concentrations are estimated using air quality models. The model air concentrations are then compared to regulatory screening values (ASIL). If the modeled concentration exceeds the ASIL screening levels, the owner/operator must perform a comprehensive review using a more sophisticated model and, if necessary, apply additional emission controls. Violators may be subject to enforcement actions, civil penalties and/or criminal charges such as gross misdemeanor. Twelve PCB congeners and general PCBs (CAS 1336-36-3) are regulated as Toxic Air Pollutants (TAPs).[24]

Waste, Hazardous Substance & Cleanup Regulations

Multiple Statutes - Chapter 70.105 RCW and parts of chapters 70.105A, 70.105D and 15.54 RCW

Chapter *173-303 WAC, Dangerous Waste Regulations*

These regulations meet the requirements of the Federal Resource Conservation and Recovery Act (RCRA) and the Department of Ecology is authorized by the US EPA to implement RCRA within the state. Therefore, all the requirements identified under RCRA are also part of the state’s dangerous waste regulations. In addition, this chapter also contains specific state-only dangerous waste requirements for any waste generated or disposed of within the state. The dangerous waste regulations require a generator of dangerous waste to designate that waste according to the regulations and follow the associated requirements for waste of that designation.

Washington State has specific requirements that pertain to toxicity and persistent criteria. Halogenated organic compounds like PCBs are considered persistent in the dangerous waste regulations.

WAC 173-303-100(5) requires waste to be evaluated for mammalian and aquatic toxicity and WAC 173-303-100(5)(b)(i) provides a process to designate a specific waste stream based upon the toxicity of the individual components. In this evaluation, toxicity must be considered with other waste constituents to determine if the waste stream designates as a state-only toxic waste

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[24] WAC 173-460-450. Table of ASIL, SQER and de minimis emission values. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-460-150 (accessed 10 June 2011).

and assigned the waste codes of WT02 as dangerous waste or WT01 as EHW (extremely hazardous waste).

In Washington State, PCB waste may be regulated as a state criteria dangerous waste or as a state listed dangerous waste. The Washington dangerous waste regulations separate wastes into four categories:

- Characteristic wastes.
- Criteria wastes.
- Discarded chemical products.
- Non-specific and specific industrial sources.

Wastes are given waste codes based on their sources or specific properties as discussed in the Federal Regulations section on RCRA. W codes are for state-only wastes.

PCBs as a state criteria dangerous waste

Since PCBs meet the definition of Halogenated Organic Compound (WAC 173-303-040), wastes containing PCBs (other than state listed PCB wastes discussed below) must be evaluated for state persistence. This requirement has been in place since early adoption of the State’s Dangerous Waste Regulations in 1982. At 100ppm PCB, a waste would be considered a persistent dangerous waste (waste code WP02). A few examples of PCB persistent waste include: caulking, tar and rubber stripping at airport runways. If the PCB concentration exceeds 10,000 ppm (waste code WP01), the waste is recognized as an extremely hazardous waste pulling on additional requirements and/or prohibitions on the management of that waste.

PCBs as a state listed dangerous wastes

To address the management of the most problematic PCB wastes- liquid PCBs in transformers, bushings and capacitors- RCW 70.105.105 gives the authority to Ecology to regulate PCBs as a dangerous waste. In 1985, Ecology amended its Dangerous Waste Regulations to include certain PCB wastes (waste code WPCB). This is a source specific group of waste products that only applies to discarded transformers, capacitors or bushings containing 2 ppm PCB or greater (except when drained of all free flowing liquid) and to the following wastes generated from the salvaging, rebuilding, or discarding of transformers, capacitors or bushing at 2 ppm PCB or greater: cooling and insulation fluids, cores, and core papers.

Exclusions

1) -071(3)(k). PCB exclusion. One may manage a state only PCB waste under specific TSCA regulations instead of the state Dangerous Waste regulations. The waste would become excluded from the state Dangerous Waste regulations. Often, listed-WPCB dangerous wastes are managed under this exclusion.

2) -073 “Special waste exclusion”. If the waste meets the definition of special waste (WAC 173-303-040), then some listed WPCB wastes and some state only persistent criteria waste (due to PCB) can be managed this way.

Chapter 70.95I RCW Used oil recycling

Used oil is conditionally regulated under the dangerous waste regulations as long as 1) it is not contaminated with chlorinated solvents or PCBs and 2) it is managed appropriately. If used oil is not contaminated, it may be recycled or burned for energy recovery. Used oil with 2 ppm or greater PCBs is prohibited from being managed as used oil under the Dangerous Wastes used oil regulations when burned for energy recovery. WAC 173-303-515 contains management standards for used oil.

This statute requires local governments to include an element in their hazardous waste plans enumerating how they will collect used oil. It also requires used oil recycling containers and educational information about used oil to be provided at any business that sells above 1,000 gallons of lubricating oil to consumers (500 gallons in a city with an approved used oil recycling element in their hazardous waste plan).

Chapter 70.105D RCW Hazardous Waste Cleanup – Model Toxics Control Act

Chapter 173-340 WAC, Model Toxics Control Act – Cleanup

Chapter 70.105D RCW establishes the framework and authority for the development of a program dealing with the cleanup of sites contaminated with toxic chemicals. The MTCA Cleanup Regulation, issued in 1991, establishes procedures and standards for the identification, investigation and cleanup of facilities contaminated with hazardous wastes.

MTCA provides several methods for setting cleanup standards. Under MTCA Method A, pre-calculated protective cleanup levels are available in tables within the regulation for use at relatively simple sites.

Method B is the universal method for determining cleanup levels for all media at all sites. A target cancer risk level of one in one million (10^{-6}) is used when calculating cleanup levels under Method B. Toxicity equivalency factor (TEF) methodology (Van Den Berg *et al*. 2006) may also be used to evaluate the toxicity of PCBs, where the mixture is considered a single hazardous substance.[25]

Method C cleanup levels are established when cleanup levels established under Method A or B may be impossible to achieve or may cause greater environmental harm.

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[25] Department of Ecology. Evaluating the Toxicity and Assessing the Carcinogenic Risk of Environmental Mixtures Using Toxicity Equivalency Factors. Available at: https://fortress.wa.gov/ecy/clarc/FocusSheets/tef.pdf (accessed 16 June 2011).

Chapter 173-360 WAC, Underground Storage Tank Regulations

The Department of Ecology implements Chapter 90.76 RCW, Underground Storage Tanks, in order to protect human health and the environment from leaking underground storage tanks containing petroleum and other regulated substances. No underground storage tank systems, within the parameters of this chapter's scope, may operate without a valid permit. This chapter sets forth performance standards for underground storage tanks. Tanks must be monitored and owners and operators are required to comply fully with testing and inspection. Releases into the surrounding environment must be immediately reported to Ecology and appropriate cleanup and containment measures must be taken. Under most circumstances, MTCA cleanup standards apply to the remediation of releases from leaking underground storage tanks. This chapter was adopted in 1990 and violators face fines of up to $5,000 dollars per day per violation.

Worker & Product Safety Regulations

Chapter 49.17 RCW Washington Industrial Safety and Health Act

Chapter 296-841 WAC Airborne Contaminants

This chapter specifies Permissible Exposure Limits (PELs) of 1,000 $\mu g/m^3$ for PCBs containing 42% chlorine (CAS 53469-21-9) and 500 $\mu g/m^3$ for compounds containing 54% chlorine (CAS 11097-69-1) that mirror the federal OSHA requirements (see Federal Regulations).

They also specify Short-Term Exposure Limits (STEL) of 3,000 $\mu g/m^3$ for PCBs containing 42% chlorine (CAS 53469-21-9) and 1,500 $\mu g/m^3$ for compounds containing 54% chlorine (CAS 11097-69-1). STELs refer to 15 minute exposure periods.

Taxes

Chapter 82.21 RCW Hazardous substance tax – model toxics control act

Chapter 458-20-252 WAC Hazardous substance tax and petroleum product tax

PCBs are taxed under the Hazardous Substance Tax.

This law places a tax on the first possession of hazardous substances in Washington. The Department of Ecology determines which substances are subject to the tax. The tax applies to petroleum products, pesticides, and certain chemicals. There are currently over 8,000 different hazardous substances identified as being subject to the tax. The tax rate is .007 of the wholesale value of the product. Funds are distributed to the Department of Ecology to help clean up, manage and prevent solid and hazardous waste in the state of Washington.[26] The tax does not apply to components or contaminants, such as inadvertently generated PCBs in other products.

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[26] Washington State Department of Revenue. Hazardous substance tax. Available at: http://dor.wa.gov/content/findtaxesandrates/othertaxes/tax_hazard.aspx

The tax applies to

- Petroleum products.
- Substances designated as hazardous under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA – see Federal Regulations).
- Any pesticide product required to be registered under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA – see Federal Regulations).
- Other substances or categories of substances designated by Ecology.

Select Regulations in Other US Jurisdictions

Maine

http://www.mainelegislature.org/legis/statutes/38/title38sec419-B.html

This law requires public utilities to remove transformers with more than 50 ppm PCBs. There are earlier deadlines for transformers within 100 feet surface water, elementary school or secondary school.

Select International Regulations

Most countries have prohibited the commercial manufacturing of PCBs.

Stockholm Convention[27]

The Stockholm Convention on Persistent Organic Pollutants is a global treaty that aims to protect human health and the environment from the effects of persistent organic pollutants. The Convention has a range of control measures to reduce and, where feasible, eliminate the release of POPs. The Convention also aims to ensure the sound management of stockpiles and wastes that contain POPs.

The Convention was signed in 2001 and entered into force in 2004. The US is a signatory, but has not ratified the Convention, so is not a Party to it.

PCBs are one of the 12 initial POPs under the Stockholm Convention. The parties to the Convention are required to eliminate the use of PCBs in existing equipment by 2025 and ensure environmentally sound waste management of them by 2028. Each country is expected to develop inventories and identify contaminated sites. To help stakeholders achieve the goals in the Stockholm Convention they created the PCB Elimination Network (PEN) as a voluntary

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[27] http://chm.pops.int/Home/tabid/2121/mctl/ViewDetails/EventModID/871/EventID/407/xmid/6921/Default.aspx

collaborative arrangement to promote and facilitate information exchange to support the obligations of Stockholm Convention on environmentally sound management of PCBs. Canada

Sweden

In addition to banning the use of PCBs, Sweden has required inventorying buildings with PCB-contaminated materials, such as caulk, and removing them[28]. The initial program in 1980 was voluntary, with information to homeowners and voluntary work by the Ecocycle Council to inventory and remediate buildings. In 2007 an ordinance passed to make owners required to inventory and remediate structures built or renovated between 1956 and 1973 (when PCBs in open applications were banned in Sweden). Working at the local city level, the inventories have mostly been completed and the remediation is expected to be finished by 2016.

Canada

PCBs were never manufactured in Canada and most PCBs used in Canada were imported from the US. Like the US, Canada banned the import, manufacture, and sale of PCBs in 1977 and allowed PCB equipment to be used until the end of its service life in the original regulation. The release of PCBs to the environment was made illegal in 1985.

One significant difference between US and Canada regulations is that Canada does not regulate mono- and di-chlorinated biphenyls[29]. PCBs with more than 2 chlorines are on Schedule 1 of the Toxics Substances list in Canada.

The Canadian Environmental Protection Act (CEPA) covers PCB Regulations.[30] Many of the regulations are similar to TSCA, such as a general limit of 50 ppm. One major difference is the Canadian regulations set deadlines for the phase-out of PCBs in use:

- Dec. 31, 2009 for equipment containing more than 500 ppm PCBs
- Dec. 31, 2009 for equipment containing 50-500 ppm PCBs within 100 meters of a drinking water plant, food or feed processing plant, school, hospital, or care center
- Dec. 31, 2025 for other equipment containing 50-500 ppm PCB
- Dec. 31, 2025 for light ballasts and pole-top electrical transformers

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[28] Johansson, Niklas. PCBs in Schools: International Experience: Inventory, Remediation, and Outcomes. EPA webinar series PCBs in Schools Session II. April 28, 2014.

[29] http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=0DA2924D-1&wsdoc=4ABEFFC8-5BEC-B57A-F4BF-11069545E434 (accessed 13 July 2014).

[30] SOR/2008-273 available at http://www.ec.gc.ca/bpc-pcb/default.asp?lang=En&n=663E7488-1 (accessed 21 October 2013).

Economic analysis

Cost Estimates of Various PCB Reduction Methods

Chapter 173-333 WAC, the Persistent Bioaccumulative Toxic Chemical rule, requires Ecology to follow a specific process while developing Chemical Action Plans (CAPs). Specifically, Chapter 173-333-420(1) (f) (iii) (B) requires Ecology to consider the potential economic and social impacts of implementing the recommendations within the CAPs. In this section, we present estimates for the likely costs associated with the recommendations within the polychlorinated biphenyls (PCBs) CAP. The majority of the initial costs would accrue to Ecology because of the amount of scoping and research necessary to grasp the extent of PCB contamination in the state of Washington.

Economic analysis, like all analytical exercises, depends on the quantity and quality of data. As described throughout the document, PCBs are ubiquitous in the environment, which dictates that the scope of activities taken to reduce PCBs involve the combined efforts of public and private actors across numerous sectors of the economy throughout Washington. To the greatest extent possible given data limitations, we estimated costs to Ecology and the entities directly impacted by the recommended actions.

As expected, we lack data on various processes involved in remediating PCB-contaminated buildings, equipment, and habitats. In some cases, representative data is not available. In other cases, we determined that systemic attributes of entities affected by the recommendations, especially public and quasi-public entities, hindered our ability to reasonably assume that past costs serve as a basis for future costs. We determined that a scarcity of data in some areas required us to consider certain figures as anecdotal that fail to describe what an average entity in Washington affected by the recommendations might face. When we faced questions concerning the availability or reliability of data, we proceeded with a qualitative analysis. That is, we focused more on identifying the variables that drive the costs to those affected by recommendations.

As evident from the recommendations below, we anticipate building databases concerning PCBs based upon data submitted from entities and collected by Ecology. This new data would enable us to revisit the qualitative cost estimates presented in this section. Accordingly, it is important to remember that qualitative analysis is suggestive as opposed to representative.

The economic analysis section proceeds with a statement of each recommendation, specific goals, related background, and analysis of likely costs.

Historic PCB-Containing Building Materials

1. Identify PCB-containing lamp ballasts in schools and other public buildings. Encourage replacement with more energy efficient PCB-free fixtures.

Goal: Remove remaining PCB lamp ballasts from schools and other publicly owned buildings.

Prior to 1979, PCBs were widely used in fluorescent lamp ballasts, including those in use at schools and other public buildings. The pre-1979 ballasts have likely outlived their useful lives and are at high risk for failing (dripping, smoking, and catching fire). Ballast failures can expose children and others that frequently use public school buildings to concentrated PCB oils and elevated PCBs in the air.

There is no easily accessible source of information on how many buildings are of the age and construction type likely to have PCB-containing light ballasts. Because children are more sensitive to PCBs and school buildings are typically publicly owned, Ecology recommends prioritizing public schools. The first step towards implementing this recommendation is to conduct a survey of the 295 school districts in Washington to identify how many of the approximately 9,000 school buildings are likely to have PCB-containing light ballasts. Other public buildings will be surveyed as time and resources allow. Ecology would use the survey results to construct a database with information on construction and renovation dates and activities of schools (and other public buildings if possible). Ecology would first use the database to identify schools where PCB-containing light ballasts are likely still in use. Lamp ballasts with PCBs can then be identified through visual inspection.

Ecology anticipates that this recommendation would require an additional FTE at Environmental Specialist 3 (ES3) level. One FTE at ES3 level would cost $90,931 annually. We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of $5,709 annually, or $2.74 per hour
- Travel costs of $1,394 annually, or $0.67 per hour
- Equipment costs of $1,131 annually, or $0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

Ecology envisions this person would split time between working towards this recommendation (0.75 FTE) and working towards Recommendation 5 (0.25 FTE). Because the staff person would work on two goals, we estimate the cost based on the time spent (.75 FTE) on this recommendation as $68,198 annually. Ecology anticipates that work on this recommendation could span two years (FY2016- FY2017) for a total estimated cost of $136,396.

We do not have confident cost estimates for replacing light ballasts in schools or other public buildings. Estimating the cost of replacing the light ballasts to school districts is not possible without knowing how many schools might contain PCB-containing light ballasts, the condition of the light ballasts, and the extent of the problem within each building. However, replacing old, potentially dangerous light ballasts not only reduces the risk of exposure for children and others that use the school buildings frequently, it also reduces energy costs. Accordingly, it makes sense to combine PCB removal with initiatives to increase energy efficiency rather than create a new program just for removal of PCB-containing ballasts.[31]

Public money should be used to remove PCB-containing lamp ballasts from schools and other public buildings. Schools with PCB-containing lamp ballasts will be provided with information about the importance of removing these ballasts and referred to the Office of the Superintendent of Public Instruction (OSPI) (or Washington State Department of Health and other available resources) to replace these fixtures with more energy-efficient lighting. Ecology has requested $200,000 in public money to assist with some of this work.

2. Develop and promote best management practices to contain PCBs in building materials currently in use and those slated for remodel or demolition.

Goal: Reduce exposure to people from PCBs in historic building materials and prevent PCBs in building materials from getting into stormwater.

Historically, PCBs were used at high levels in some caulks and paints. Studies in other areas have shown the widespread occurrence of PCB-containing caulk in buildings from about 1950-1980, especially masonry buildings. Smaller sampling efforts in Washington support this conclusion.[32] Accordingly, developing best management practices and other materials to provide guidance for renovation and demolition of buildings that contain PCB materials would help to prevent the release of PCBs into the environment.

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[31] Since 2009, the Legislature has provided money to the Office of the Superintendent of Public Instruction (OSPI) and the Department of Commerce to support energy efficiency measures in schools and other public buildings. If the grant programs are not funded, the legislature could establish a fund to help offset the costs of replacing PCB-containing lamp ballasts.

[32] For example, studies suggest that buildings with PCB-containing materials exist in the Duwamish basin. In addition, source tracing from cleanup efforts in Tacoma revealed PCBs in sidewalk and building caulk.

The first step toward preventing PCBs in building materials from getting into the environment is to compile, compose, and distribute information concerning best management practices for containment of PCB-containing materials. Based on available data in Washington, other government programs, and scientific literature, Ecology would develop BMPs for containing PCBs to prevent exposure during the life of the building and during remodeling or demolition. Ecology should also provide education and outreach on BMPs to local governments and those in the building trades.

Ecology estimates that developing BMPs would require an additional FTE of an Environmental Specialist 3 (ES3) for a three-year period. We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). One FTE at ES3 would cost $90,931 annually. Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of $5,709 annually, or $2.74 per hour
- Travel costs of $1,394 annually, or $0.67 per hour
- Equipment costs of $1,131 annually, or $0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

While working on the BMPs, Ecology would also work to compile existing information into a PCB Source Control Guidance Manual to aid Local Source Control work. A number of urban waters programs around the northwest have performed PCB source identification work. However, to date, the lessons learned from each of these programs have not been synthesized and summarized for the benefit of future pollution prevention efforts at the state and local levels.

Ecology estimates that work on the best management practices and source control manual would last approximately three years (FY2016-FY2018) and result in total staff costs of $272,793.

3. Assess schools and other public buildings for the presence of PCB-containing building materials.

Goal: Reduce children's exposure to PCB-containing building materials.
Goal: Prevent PCBs in building materials from getting into stormwater.

Many buildings constructed prior to the ban of PCBs include materials, such as caulk, paint, and light ballasts that often contain high levels of PCBs. Industrial buildings, including schools, are more likely to contain PCB-contaminated materials than residential buildings. Other states have found high levels of PCB contamination in schools. Because children are more sensitive to PCBs and school buildings are typically publicly owned, Ecology recommends assessing public schools for possible PCB contamination first and expanding the effort to include other buildings, as appropriate.

To our knowledge, school districts in Washington have not systematically tested schools for PCBs. Schools built prior to 1980 are more likely to contain material with PCBs. The first step in assessing public school buildings that contain PCB material is to construct a centralized database based on information provided by school districts. The database would contain information on the date of construction and dates of renovation for each school building in Washington. The database would serve as a mechanism to identify schools, based on construction date, that require testing for PCBs. Initial testing would include visual inspections and then physical testing where appropriate. Ecology would use the database and test results to determine the scope of the problem in Washington and plan accordingly. A similar approach would be used to assess other public buildings once the assessment of schools is complete, and as resources allow.

Ecology estimates that the person retained to compile information on PCB light ballasts in schools would compile the database for building materials, as well. Ecology anticipates that two Environmental Specialist 3 (ES3) positions in other recommendations will merge tasks in FY2018:

- The 0.75 FTE at Environmental Specialist 3 (ES3) level at $68,198 annually would spend two years (FY2016-FY2017) focusing on light ballasts (Recommendation 1).
- The 0.25 FTE at the ES3 level at $22,733 annually would spend two years (FY2016-2017) focusing on electrical equipment (Recommendation 5).
- These positions would shift their database efforts to include other building materials at schools.

Ecology anticipates that work on this recommendation could span four years (FY2018- FY2021) for a total estimated cost of $363,724.

We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of $5,709 annually, or $2.74 per hour
- Travel costs of $1,394 annually, or $0.67 per hour
- Equipment costs of $1,131 annually, or $0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

Ecology understands the time and budget constraints facing school districts across the state. However, this recommendation would not require school districts to generate new reports or information. We assume that school districts have information concerning construction and renovation of school buildings from routine recordkeeping, operations, and maintenance documents. Therefore, we do not expect a cost to school districts to submit documents to Ecology for the database beyond minimal expenditures of time and resources to submit records to Ecology.

After compiling the database and conducting initial testing, Ecology would work with school districts to plan and coordinate remediation efforts at schools that have PCB-contaminated materials. There is no one size fits all approach to remediation projects for buildings containing PCBs (Environmental Health & Engineering, 2012). Depending on the extent of contamination, schools decide whether to pursue abatement (reducing the amount of PCBs in building materials permanently) or mitigation (controlling exposure) procedures. Regardless of the remediation technique, schools would need to work with local health agencies, Ecology, and EPA to meet removal criteria and follow hazardous waste regulations.

Estimating the cost of remediating school buildings in Washington is not possible without knowing the scope (number of schools and extent of remediation needed) of the problem. The number of school buildings and extent of work necessary to bring a building in compliance would determine bids from contractors and others involved in remediation activities. In addition, remediation activities generally involve mandated testing procedures, extensive planning, feasibility studies, and permitting requests. School districts might also have to explore temporarily relocating students during the initial testing/cleanup stage (depending on age of building and likelihood of PCB contamination). Because of the extensive nature of remediation projects, we feel that a database is appropriate to enable Ecology and school districts to narrow the scope, identify economies of scale, and prioritize remediation projects.

As mentioned above, systemic attributes of public entities make some estimates less reliable. We consider the process school districts use to price construction projects such a structural constraint. Generally, available data suggests that the cost of remediating PCB-contaminated school buildings depends on the extent of contamination and approach used by schools (abatement or mitigation) to address the problem. To our knowledge, no state has addressed PCB contamination in schools in a comprehensive manner. It appears that most schools learn of PCB contamination by miscellaneous tests conducted prior to unrelated renovation work, and must react quickly to bring exposure levels below EPA guidelines. This creates immediate financial stress on local/state agencies responsible for public health, school facilities, etc. Further, school districts face unique budget constraints and absorb costs differently than owners of private buildings.

Schools generally face administrative procedures (feasibility studies, budget requests, and limited window for large remediation projects) that increase the overall cost of projects. However, it is difficult to compare how school districts determine costs for certain projects, especially when comparing school districts in different regions or states. School districts in Washington form cost estimates based on the needs of schools here in Washington. In sum, existing estimates of remediation projects based solely on PCB contamination are too limited to provide a meaningful basis for comparison, at this point.

Acknowledging the above limitations, though, illustrates the need for Ecology to identify the scope of the problem here in Washington. We found estimates for remediation work at five schools in New York and two schools in Massachusetts. Estimates from remediation projects at the five public schools in New York City ranged from $3.2 million to $3.6 million (2014$) per school depending on the techniques (abatement or mitigation) used to address the PCB-contaminated areas (TRC, 2011). In 2010, an elementary school in Lexington, MA found PCB-contaminated material. The school had to close for a week while workers performed testing required by the EPA and performed preliminary cleanup work. Feasibility studies suggested that officials faced temporary solutions ranging from $3.0 million to $4.6 million (2014$) to relocate students while remediating the school (Goddard, 2010). Ultimately, officials decided to replace the school with a new $40 million building (Parker, 2014). A different school in Westport, MA also found PCB material and encountered initial costs in excess of $3 million (Wagner, 2014). Currently, the school faces additional costs ranging from $1.8 million to $7.75 million (2014$) (CGKV Architects, 2013) to remediate the PCB-contaminated material. Again, we consider the estimates from New York and Massachusetts more suggestive than representative. That said, the expenses incurred by the school districts in New York City and Massachusetts, along with the extent of activity required to remediate the structures, indicate a need to determine the scope of the problem by compiling construction dates and preliminary testing of high risk schools here in Washington.

Current Manufacturing Processes

4. Learn more about what products contain PCBs and promote the use of processes that don’t inadvertently generate PCBs.

Goal: Reduce newly generated PCBs in manufacturing processes.

Unpermitted non-point releases, such as from consumer products, are becoming increasingly important to control in order to reduce total PCB delivery. In 1982, EPA identified 70 manufacturing processes that are likely to inadvertently generate PCBs, but little else is known about this potentially large source of uncontrolled PCBs. More information is known about PCBs in pigments and dyes, which are a known source of PCBs in the environment and a problem for paper recyclers in Washington. Ecology recommends adding additional staff and funding to determine the extent of inadvertently generated PCBs in consumer products.

To accomplish the goal of reducing newly generated PCBs in manufacturing processes, Ecology would work with EPA, manufacturers, and other partners to identify products that inadvertently contain PCBs and explore available alternatives. Ecology would test identified products, and provide relevant results to the Department of Enterprise Services (DES) to assist with implementing new purchasing policies that provide a preference for products that do not contain PCBs. Ecology would also work with the Department of Health and DES to develop a focus sheet to educate purchasers and vendors in the state supply chain about the prevalence and incidence of products that inadvertently contain PCBs and concisely outlines the problem and its potential impacts.

Learning more about processes that inadvertently generate PCBs would require 1 FTE of a Natural Resource Scientist 3 (NRS3) at $116,641. We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of $5,709 annually, or $2.74 per hour
- Travel costs of $1,394 annually, or $0.67 per hour
- Equipment costs of $1,131 annually, or $0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

Ecology anticipates that the NRS3 would test approximately 100 products a year. Ecology anticipates that the employee retained to perform the product testing would continue to work on this issue on an ongoing basis, with costs from FY2016 through FY2021 totaling $699,846. Additionally, at $1,000 per test, Ecology estimates annual testing costs of $100,000.

In addition to testing for PCBs, we also estimated the cost of investigating alternate processes in chemical manufacturing, to prospectively replace processes that produce PCBs as a byproduct. Specifically, we estimated the cost of initiating an alternatives assessment process for pigments and dyes, based on the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide.

Ecology anticipates that producing such an "Alternatives Assessment" would cost $470,000 in FY2016, which includes hiring a consultant. Ecology plans to engage business and other concerned stakeholders to participate in the alternatives assessment process. If there are currently no alternatives that do not generate PCBs, Ecology would engage Green Chemistry Northwest or a similar institution to develop alternative processes.

Historic Electrical Equipment

5. Survey owners of historic electrical equipment, including transformers and large capacitors.

Goal: Confirm estimates of EPA-regulated electrical equipment with more than 500 parts per million (ppm) PCBs, learn what is known about electrical equipment with the PCBs greater than 2 ppm, and find out when such electrical equipment is estimated for replacement.

Electrical equipment, such as transformers and capacitors, used by utility and large non-utility industrial sites are the primary historical use of PCBs. Concentrations of PCBs in many pieces of electrical equipment are high compared to other sources, so relatively rare leaks and spills can release a significant amount of PCBs into the environment. Ecology recommends a survey of the 61 utilities and other sites that provide electricity to construct a recent and relevant database of electrical equipment that contains PCBs in Washington.

We anticipate that this recommendation would most likely affect utilities and large non-utility entities that provide electrical transmission (operate transformers or large capacitors) on site. The nature of electricity and the regulatory status of utilities presents unique challenges regarding this recommendation. Electricity is difficult to store, impossible to substitute, and a necessity to most consumers and businesses. Accordingly, each utility in the state enjoys a natural monopoly in the transmission of electricity to end users within a defined area. In exchange for monopoly status, various regulatory agencies set prices administratively based on costs incurred by utilities. The process of setting prices administratively makes it difficult, if not impossible, for us to determine the cost of individual projects and to determine how the utilities absorb costs. Regulations also require utilities to provide electricity on demand that makes a recommendation to test all existing equipment difficult to undertake without potentially disrupting service. In sum, from a practical perspective, a recommendation for further testing could prove cost prohibitive to utilities and consumers.

Prior to the ban on PCBs, manufacturers of transformers, capacitors, and other electrical equipment used oil-containing PCBs as a coolant within the housing of utility equipment. Since the ban on PCBs took effect in the United States, utilities and owners of electrical equipment have worked to identify and replace equipment that contains PCBs. According to a report submitted by the Utility Solid Waste Activities Group (USWAG, 2010) to the EPA, utilities across the country have reduced the use of equipment containing PCBs through normal maintenance and replacement procedures. A similar statement by the Northwest Public Power

Association (2010), extensive discussions with representatives from various utilities, and local news reports (Kramer, 2014), suggest that utilities across Washington have also replaced many units that contain PCBs. Currently, however, no reporting requirement exists to verify the claims of utility and a non-utility users of electrical equipment concerning retirement of equipment that contains PCBs.

Ecology believes that surveying the state's utilities and compiling a centralized database based on past, present, and future efforts by owners of electrical equipment is within reason and at minimal cost to the owners of electrical equipment. Because electrical equipment that might contain PCBs are part of a complex transmission system that requires significant time and resources to maintain, Ecology assumes that owners of electrical equipment maintain records that form the basis of routine maintenance schedules. Over the past 15 years, increased demand for energy and the interconnectedness of the electrical grid has changed the regulatory environment in such a way that providers of electricity at all levels of the transmission process must maintain certain levels of service at all times. In addition, utilities upgrade old and inefficient transmission equipment (often the equipment that might also contain PCBs) to increase efficiency and output. The need to maintain a consistent supply of energy and increase profitability, where possible, necessitates that utilities maintain extensive records. Therefore, we assume that utilities and other large non-utility owners know which pieces of equipment have PCBs or may have PCBs based on the age of the equipment.

Because the utilities have taken action to address the use of equipment that contains PCBs, Ecology believes establishing a database of current equipment containing PCBs would require minimal effort and cost to Ecology and users and electrical equipment. The survey of electrical equipment would not include small capacitors. The survey would not require additional testing or disposal of equipment by a certain date. The survey would ask owners to report what they know about detectable levels of PCBs in their equipment, using the industry standard detection level that is currently 2 parts per million (ppm), and detail when they expect all the equipment to be replaced based on their current maintenance practices. A statewide inventory will allow the state to confirm current inventories and target efforts to prevent releases of PCBs from this equipment.

Ecology anticipates that the FTE assigned to collect data on PCBs in public schools (Recommendation 1) would also assemble and enter data on electrical equipment. Ecology envisions this person would split time between working towards this recommendation (.25 FTE on this goal) and working towards Recommendation 1.

One FTE at Environmental Specialist 3 (ES3) level would cost $90,931 annually. We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of $5,709 annually, or $2.74 per hour
- Travel costs of $1,394 annually, or $0.67 per hour
- Equipment costs of $1,131 annually, or $0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

Because the staff person would work on two goals, we estimate the cost based on the time spent (.25 FTE) on this recommendation as $22,733 annually. Ecology anticipates that work on this recommendation could span two years (FY2016-FY2017) for a total estimated cost of $45,466.

Multi-Source

6. Expand environmental monitoring to identify any new areas requiring cleanup.

Goal: Find areas with highly concentrated PCBs and clean them up to prevent the wider release of PCBs.
Goal: Find out more about the distribution of PCBs in Washington to prioritize future actions.

Ecology should expand environmental monitoring of water, fish tissue, and sediment to identify PCB hot spots, such as the recently found historical landfill of electrical equipment on Bradford Island in the Columbia River. Historical disposal practices at Bradford Island near Bonneville Dam on the Columbia River contaminated resident fish with high levels of PCBs. Levels were high enough to prompt Oregon and Washington to issue a joint fish consumption advisory for select species from Bonneville Dam upstream to McNary Dam. A number of fish sampling efforts in the Columbia basin (CRITFC, Hanford Corridor Study and Ecology's Freshwater Fish Contaminant Monitoring Program) found other areas (mid-Columbia and Snake River) with elevated levels of PCBs and a number of hydroelectric facilities.

To our knowledge no work has been done to identify sources of contaminants in these areas. The proposed monitoring would conduct sampling to determine if contaminant sources exist in areas with a focus on hydroelectric facilities. Ecology may also use mapping and historical information on the location of potential sites, such as landfills, industrial sites, railroad switching yards, etc., to find potential sites. Newly identified sites would receive priority for clean up using existing procedures. In addition to identifying new hot spots, Ecology would continue its trend monitoring to show changes in PCBs in the environment and biota over time.

Air deposition is a potentially significant pathway for PCBs to move into the environment. Ecology proposes to investigate monitoring air deposition to assess the relative importance of this pathway.

Ecology estimates that the workload generated by Recommendation 6 would require the addition of three FTE. Ecology estimates that it would take 1 FTE Natural Resource Scientist 3 (NRS3) to identify new hot spots and implement necessary testing procedures. In addition, Ecology estimates that effectively monitoring hot spots would require an Environmental Specialist 2 (ES2) FTE to provide support for testing. The addition of one FTE at NRS3 level would cost \$116,641 annually, and one FTE at the ES2 level would cost \$79,513 annually. To monitor air deposition, Ecology would require an additional FTE at the Environmental Specialist 3 (ES3) level to conduct the air monitoring tests. The ES3 would cost \$90,931 annually.

We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of \$5,709 annually, or \$2.74 per hour
- Travel costs of \$1,394 annually, or \$0.67 per hour
- Equipment costs of \$1,131 annually, or \$0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

Ecology anticipates that the work of the NRS3 toward this recommendation would take 3 years, with assistance from the ES2 for 2 years. Ecology anticipates that testing to identify potential hot spots would result in lab costs of \$87,192 annually for two years. Ecology anticipates that the work of the ES3 to monitor air disposition would take two years, and anticipates testing costs of \$37,967 annually for two years to monitor air deposition.

Table 37 summarizes the costs associated with this recommendation.

Table 37. Summary of the costs associated with Recommendation 6.

	FY 2016	**FY 2017**	**FY 2018**
Hot spot monitoring			
1 FTE NRS3	\$116,641	\$116,641	\$116,641
1 FTE ES2	\$79,513	\$79,513	
Hot spot testing	\$87,192	\$87,192	
Air monitoring			
1 FTE ES3	\$90,931	\$90,931	
Air testing	\$37,967	\$37,967	

7. Conduct a public educational campaign.

Goal: Provide information to residents about ways they can minimize exposure.
Goal: Raise awareness of the problems associated with current and past production of PCBs.
Goal: Educate residents to identify and address possible household sources of PCBs.

To reach the goal of raising public awareness for PCBs, Ecology and the Department of Health would work together to help residents, people who fish, schools, local governments and businesses understand the risks associated with PCB exposure and ways to reduce risks, including the availability of safer alternatives.

The public educational campaign will include perspectives on public health risks and information on where exposures to PCB are most likely. It will also include advice on how individuals can minimize their own exposures to PCBs. The campaign will include where to look for potential sources of PCBs in households, such as in old appliances, electrical equipment, and building materials. It will also teach the public how to safely remove and dispose of these materials to prevent PCB releases.

Ecology anticipates that this recommendation would require the addition of 1 FTE Communication Consultant 3 (CC3) to develop and disseminate information to businesses, purchasing agents, vendors, residents, fishers, schools, and local governments describing the hazards associated with exposure to PCBs and resources available to address the problem. This FTE would cost $92,957 each year. This work includes promotion of BMPs for containment and demolition of buildings containing PCB laden materials.

We employed Washington State employee pay grades at step H (DOP, 2014) and standard overhead cost assumptions used for legislative fiscal notes and related estimation (Ecology, 2013). Wages include the following adjustments for overhead expenses (per FTE):

- Benefits of 33.0 percent of salary
- Goods and services of $5,709 annually, or $2.74 per hour
- Travel costs of $1,394 annually, or $0.67 per hour
- Equipment costs of $1,131 annually, or $0.54 per hour
- Agency administrative overhead of 32.25 percent of salaries and benefits (Agency administrative overhead FTEs are included at 0.15 FTE per direct FTE, and are identified as Fiscal Analyst 2 and IT Specialist 2.)

Ecology anticipates that the community awareness work would continue on an ongoing basis. Estimated costs for this recommendation from FY2016 through FY2021 are $557,742.

8. Conduct a study on which PCB congeners are present in Washington residents

Goal: Learn more about PCB congeners to which Washington residents are exposed
Goal: Find out more about the distribution of PCBs in Washington to prioritize future actions

Within available resources, the Department of Health should conduct bio-monitoring of Washington residents for PCBs including PCB 11 and other inadvertently produced PCBs associated with dyes, pigments, and printing inks. Researchers would use the data to better understand 1) the extent of total human exposure from multiple potential pathways and 2) the relative contribution of these congeners to human body burden of PCBs. In addition, the data would enable researchers to estimate the statewide distribution of PCBs in Washington residents, which would provide a better baseline than national data given the elevated levels of PCBs in local fish populations and relatively high fish consumption in a number of Washington communities and regions.

Ecology believes that this sort of bio-monitoring falls within criteria already established under existing DOH programs. Accordingly, we do not anticipate new costs with this recommendation.

Summary of Economic Impacts

Table 38 presents estimated costs to Ecology to implement the recommendations above.

Table 38. Estimated costs to Ecology to implement recommendations

Recommendation		FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
1	0.75 FTE (ES3) to survey and assess lamp ballasts in schools.	$68,198	$68,198				
2	1 FTE (ES3) to develop and promote BMPs.	$90,931	$90,931	$90,931			
3	1 FTE (ES3) to assess schools for PCB-containing building materials.			$90,931	$90,931	$90,931	$90,931
4	Conduct an alternatives assessment for pigments and dyes.	$470,000					
	1 FTE (NRS3)	$116,641	$116,641	$116,641	$116,641	$116,641	$116,641

	to look for sources of PCBs in products.						
	Lab costs for product testing.	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
5	0.25 FTE (ES3) to survey owners of electrical equipment.	$22,733	$22,733				
6	1 FTE (NRS3) to identify environmental hot spots.	$116,641	$116,641	$116,641			
	1 FTE (ES2) to assist with monitoring.	$79,513	$79,513				
	Environmental monitoring/ lab analysis.	$87,192	$87,192				
	1 FTE (ES3) for air monitoring	$90,931	$90,931				
	Sampling/lab analysis for air monitoring stations.	$37,967	$37,967				
7	1 FTE (CC3) to conduct an education campaign.	$92,957	$92,957	$92,957	$92,957	$92,957	$92,957
Total		**$1,373,704**	**$903,704**	**$608,101**	**$400,529**	**$400,529**	**$400,529**
All estimates in (2014 $)							
ES2 = Environmental Specialist 2							
ES3 = Environmental Specialist 3							
NRS3 = Natural Resource Scientist 3							
CC3 = Communications Consultant 3							

Ecology does not anticipate that these initial recommendations would increase compliance costs for affected firms or public entities.

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Appendices

Appendix A. List of 209 PCB Congeners (EPA, 2003)

CASRN	Congener Number	IUPAC Name
1336-36-3		Polychlorinated biphenyl (PCB)
2051-60-7	1	2-Chlorobiphenyl
2051-61-8	2	3-Chlorobiphenyl
2051-62-9	3	4-Chlorobiphenyl
13029-08-8	4	2,2'-Dichlorobiphenyl
16605-91-7	5	2,3-Dichlorobiphenyl
25569-80-6	6	2,3'-Dichlorobiphenyl
33284-50-3	7	2,4-Dichlorobiphenyl
34883-43-7	8	2,4'-Dichlorobiphenyl
34883-39-1	9	2,5-Dichlorobiphenyl
33146-45-1	10	2,6-Dichlorobiphenyl
2050-67-1	11	3,3'-Dichlorobiphenyl
2974-92-7	12	3,4-Dichlorobiphenyl
2974-90-5	13	3,4'-Dichlorobiphenyl
34883-41-5	14	3,5-Dichlorobiphenyl
2050-68-2	15	4,4'-Dichlorobiphenyl
38444-78-9	16	2,2',3-Trichlorobiphenyl
37680-66-3	17	2,2',4-Trichlorobiphenyl
37680-65-2	18	2,2',5-Trichlorobiphenyl
38444-73-4	19	2,2',6-Trichlorobiphenyl
38444-84-7	20	2,3,3'-Trichlorobiphenyl
55702-46-0	21	2,3,4-Trichlorobiphenyl
38444-85-8	22	2,3,4'-Trichlorobiphenyl
55720-44-0	23	2,3,5-Trichlorobiphenyl
55702-45-9	24	2,3,6-Trichlorobiphenyl
55712-37-3	25	2,3',4-Trichlorobiphenyl
38444-81-4	26	2,3',5-Trichlorobiphenyl
38444-76-7	27	2,3',6-Trichlorobiphenyl
7012-37-5	28	2,4,4'-Trichlorobiphenyl
15862-07-4	29	2,4,5-Trichlorobiphenyl
35693-92-6	30	2,4,6-Trichlorobiphenyl
16606-02-3	31	2,4',5-Trichlorobiphenyl

38444-77-8	32	2,4',6-Trichlorobiphenyl
38444-86-9	33	2,3',4'-Trichlorobiphenyl
37680-68-5	34	2,3',5'-Trichlorobiphenyl
37680-69-6	35	3,3',4-Trichlorobiphenyl
38444-87-0	36	3,3',5-Trichlorobiphenyl
38444-90-5	37	3,4,4'-Trichlorobiphenyl
53555-66-1	38	3,4,5-Trichlorobiphenyl
38444-88-1	39	3,4',5-Trichlorobiphenyl
38444-93-8	40	2,2',3,3'-Tetrachlorobiphenyl
52663-59-9	41	2,2',3,4-Tetrachlorobiphenyl
36559-22-5	42	2,2',3,4'-Tetrachlorobiphenyl
70362-46-8	43	2,2',3,5-Tetrachlorobiphenyl
41464-39-5	44	2,2',3,5'-Tetrachlorobiphenyl
70362-45-7	45	2,2',3,6-Tetrachlorobiphenyl
41464-47-5	46	2,2',3,6'-Tetrachlorobiphenyl
2437-79-8	47	2,2',4,4'-Tetrachlorobiphenyl
70362-47-9	48	2,2',4,5-Tetrachlorobiphenyl
41464-40-8	49	2,2',4,5'-Tetrachlorobiphenyl
62796-65-0	50	2,2',4,6-Tetrachlorobiphenyl
68194-04-7	51	2,2',4,6'-Tetrachlorobiphenyl
35693-99-3	52	2,2',5,5'-Tetrachlorobiphenyl
41464-41-9	53	2,2',5,6'-Tetrachlorobiphenyl
15968-05-5	54	2,2',6,6'-Tetrachlorobiphenyl
74338-24-2	55	2,3,3',4-Tetrachlorobiphenyl
41464-43-1	56	2,3,3',4'-Tetrachlorobiphenyl
70424-67-8	57	2,3,3',5-Tetrachlorobiphenyl
41464-49-7	58	2,3,3',5'-Tetrachlorobiphenyl
74472-33-6	59	2,3,3',6-Tetrachlorobiphenyl
33025-41-1	60	2,3,4,4'-Tetrachlorobiphenyl
33284-53-6	61	2,3,4,5-Tetrachlorobiphenyl
54230-22-7	62	2,3,4,6-Tetrachlorobiphenyl
74472-34-7	63	2,3,4',5-Tetrachlorobiphenyl
52663-58-8	64	2,3,4',6-Tetrachlorobiphenyl
32284-54-7	65	2,3,5,6-Tetrachlorobiphenyl
32598-10-0	66	2,3',4,4'-Tetrachlorobiphenyl
73575-53-8	67	2,3',4,5-Tetrachlorobiphenyl
73575-52-7	68	2,3',4,5'-Tetrachlorobiphenyl

60233-24-1	69	2,3',4,6-Tetrachlorobiphenyl
32598-11-1	70	2,3',4',5-Tetrachlorobiphenyl
41464-46-4	71	2,3',4',6-Tetrachlorobiphenyl
41464-42-0	72	2,3',5,5'-Tetrachlorobiphenyl
74338-23-1	73	2,3',5',6-Tetrachlorobiphenyl
32690-93-0	74	2,4,4',5-Tetrachlorobiphenyl
32598-12-2	75	2,4,4',6-Tetrachlorobiphenyl
70362-48-0	76	2,3',4',5'-Tetrachlorobiphenyl
32598-13-3	77	3,3',4,4'-Tetrachlorobiphenyl
70362-49-1	78	3,3',4,5-Tetrachlorobiphenyl
41464-48-6	79	3,3',4,5'-Tetrachlorobiphenyl
33284-52-5	80	3,3',5,5'-Tetrachlorobiphenyl
70362-50-4	81	3,4,4',5-Tetrachlorobiphenyl
52663-62-4	82	2,2',3,3',4-Pentachlorobiphenyl
60145-20-2	83	2,2',3,3',5-Pentachlorobiphenyl
52663-60-2	84	2,2',3,3',6-Pentachlorobiphenyl
65510-45-4	85	2,2',3,4,4'-Pentachlorobiphenyl
55312-69-1	86	2,2',3,4,5-Pentachlorobiphenyl
38380-02-8	87	2,2',3,4,5'-Pentachlorobiphenyl
55215-17-3	88	2,2',3,4,6-Pentachlorobiphenyl
73575-57-2	89	2,2',3,4,6'-Pentachlorobiphenyl
68194-07-0	90	2,2',3,4',5-Pentachlorobiphenyl
68194-05-8	91	2,2',3,4',6-Pentachlorobiphenyl
52663-61-3	92	2,2',3,5,5'-Pentachlorobiphenyl
73575-56-1	93	2,2',3,5,6-Pentachlorobiphenyl
73575-55-0	94	2,2',3,5,6'-Pentachlorobiphenyl
38379-99-6	95	2,2',3,5',6-Pentachlorobiphenyl
73575-54-9	96	2,2',3,6,6'-Pentachlorobiphenyl
41464-51-1	97	2,2',3,4',5'-Pentachlorobiphenyl
60233-25-2	98	2,2',3,4',6'-Pentachlorobiphenyl
38380-01-7	99	2,2',4,4',5-Pentachlorobiphenyl
39485-83-1	100	2,2',4,4',6-Pentachlorobiphenyl
37680-73-2	101	2,2',4,5,5'-Pentachlorobiphenyl
68194-06-9	102	2,2',4,5,6'-Pentachlorobiphenyl
60145-21-3	103	2,2',4,5',6-Pentachlorobiphenyl
56558-16-8	104	2,2',4,6,6'-Pentachlorobiphenyl
32598-14-4	105	2,3,3',4,4'-Pentachlorobiphenyl

70424-69-0	106	2,3,3',4,5-Pentachlorobiphenyl
70424-68-9	107	2,3,3',4',5-Pentachlorobiphenyl
70362-41-3	108	2,3,3',4,5'-Pentachlorobiphenyl
74472-35-8	109	2,3,3',4,6-Pentachlorobiphenyl
38380-03-9	110	2,3,3',4',6-Pentachlorobiphenyl
39635-32-0	111	2,3,3',5,5'-Pentachlorobiphenyl
74472-36-9	112	2,3,3',5,6-Pentachlorobiphenyl
68194-10-5	113	2,3,3',5',6-Pentachlorobiphenyl
74472-37-0	114	2,3,4,4',5-Pentachlorobiphenyl
74472-38-1	115	2,3,4,4',6-Pentachlorobiphenyl
18259-05-7	116	2,3,4,5,6-Pentachlorobiphenyl
68194-11-6	117	2,3,4',5,6-Pentachlorobiphenyl
31508-00-6	118	2,3',4,4',5-Pentachlorobiphenyl
56558-17-9	119	2,3',4,4',6-Pentachlorobiphenyl
68194-12-7	120	2,3',4,5,5'-Pentachlorobiphenyl
56558-18-0	121	2,3',4,5',6-Pentachlorobiphenyl
76842-07-4	122	2,3,3',4',5'-Pentachlorobiphenyl
65510-44-3	123	2,3',4,4',5'-Pentachlorobiphenyl
70424-70-3	124	2,3',4',5,5'-Pentachlorobiphenyl
74472-39-2	125	2,3',4',5',6-Pentachlorobiphenyl
57465-28-8	126	3,3',4,4',5-Pentachlorobiphenyl
39635-33-1	127	3,3',4,5,5'-Pentachlorobiphenyl
38380-07-3	128	2,2',3,3',4,4'-Hexachlorobiphenyl
55215-18-4	129	2,2',3,3',4,5-Hexachlorobiphenyl
52663-66-8	130	2,2',3,3',4,5'-Hexachlorobiphenyl
61798-70-7	131	2,2',3,3',4,6-Hexachlorobiphenyl
38380-05-1	132	2,2',3,3',4,6'-Hexachlorobiphenyl
35694-04-3	133	2,2',3,3',5,5'-Hexachlorobiphenyl
52704-70-8	134	2,2',3,3',5,6-Hexachlorobiphenyl
52744-13-5	135	2,2',3,3',5,6'-Hexachlorobiphenyl
38411-22-2	136	2,2',3,3',6,6'-Hexachlorobiphenyl
35694-06-5	137	2,2',3,4,4',5-Hexachlorobiphenyl
35065-28-2	138	2,2',3,4,4',5'-Hexachlorobiphenyl
56030-56-9	139	2,2',3,4,4',6-Hexachlorobiphenyl
59291-64-4	140	2,2',3,4,4',6'-Hexachlorobiphenyl
52712-04-6	141	2,2',3,4,5,5'-Hexachlorobiphenyl
41411-61-4	142	2,2',3,4,5,6-Hexachlorobiphenyl

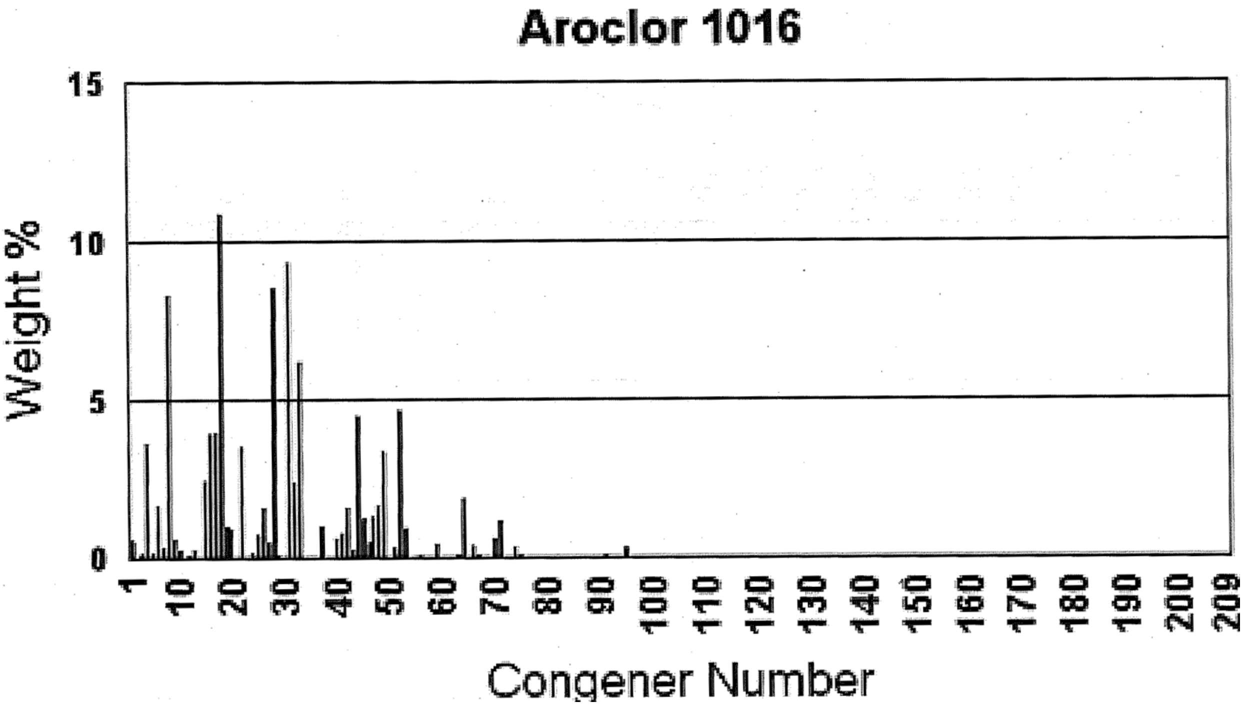
68194-15-0	143	2,2',3,4,5,6'-Hexachlorobiphenyl
68194-14-9	144	2,2',3,4,5',6-Hexachlorobiphenyl
74472-40-5	145	2,2',3,4,6,6'-Hexachlorobiphenyl
51908-16-8	146	2,2',3,4',5,5'-Hexachlorobiphenyl
68194-13-8	147	2,2',3,4',5,6-Hexachlorobiphenyl
74472-41-6	148	2,2',3,4',5,6'-Hexachlorobiphenyl
38380-04-0	149	2,2',3,4',5',6-Hexachlorobiphenyl
68194-08-1	150	2,2',3,4',6,6'-Hexachlorobiphenyl
52663-63-5	151	2,2',3,5,5',6-Hexachlorobiphenyl
68194-09-2	152	2,2',3,5,6,6'-Hexachlorobiphenyl
35065-27-1	153	2,2',4,4',5,5'-Hexachlorobiphenyl
60145-22-4	154	2,2',4,4',5,6'-Hexachlorobiphenyl
33979-03-2	155	2,2',4,4',6,6'-Hexachlorobiphenyl
38380-08-4	156	2,3,3',4,4',5-Hexachlorobiphenyl
69782-90-7	157	2,3,3',4,4',5'-Hexachlorobiphenyl
74472-42-7	158	2,3,3',4,4',6-Hexachlorobiphenyl
39635-35-3	159	2,3,3',4,5,5'-Hexachlorobiphenyl
41411-62-5	160	2,3,3',4,5,6-Hexachlorobiphenyl
74472-43-8	161	2,3,3',4,5',6-Hexachlorobiphenyl
39635-34-2	162	2,3,3',4',5,5'-Hexachlorobiphenyl
74472-44-9	163	2,3,3',4',5,6-Hexachlorobiphenyl
74472-45-0	164	2,3,3',4',5',6-Hexachlorobiphenyl
74472-46-1	165	2,3,3',5,5',6-Hexachlorobiphenyl
41411-63-6	166	2,3,4,4',5,6-Hexachlorobiphenyl
52663-72-6	167	2,3',4,4',5,5'-Hexachlorobiphenyl
59291-65-5	168	2,3',4,4',5',6-Hexachlorobiphenyl
32774-16-6	169	3,3',4,4',5,5'-Hexachlorobiphenyl
35065-30-6	170	2,2',3,3',4,4',5-Heptachlorobiphenyl
52663-71-5	171	2,2',3,3',4,4',6-Heptachlorobiphenyl
52663-74-8	172	2,2',3,3',4,5,5'-Heptachlorobiphenyl
68194-16-1	173	2,2',3,3',4,5,6-Heptachlorobiphenyl
38411-25-5	174	2,2',3,3',4,5,6'-Heptachlorobiphenyl
40186-70-7	175	2,2',3,3',4,5',6-Heptachlorobiphenyl
52663-65-7	176	2,2',3,3',4,6,6'-Heptachlorobiphenyl
52663-70-4	177	2,2',3,3',4,5',6'-Heptachlorobiphenyl
52663-67-9	178	2,2',3,3',5,5',6-Heptachlorobiphenyl
52663-64-6	179	2,2',3,3',5,6,6'-Heptachlorobiphenyl

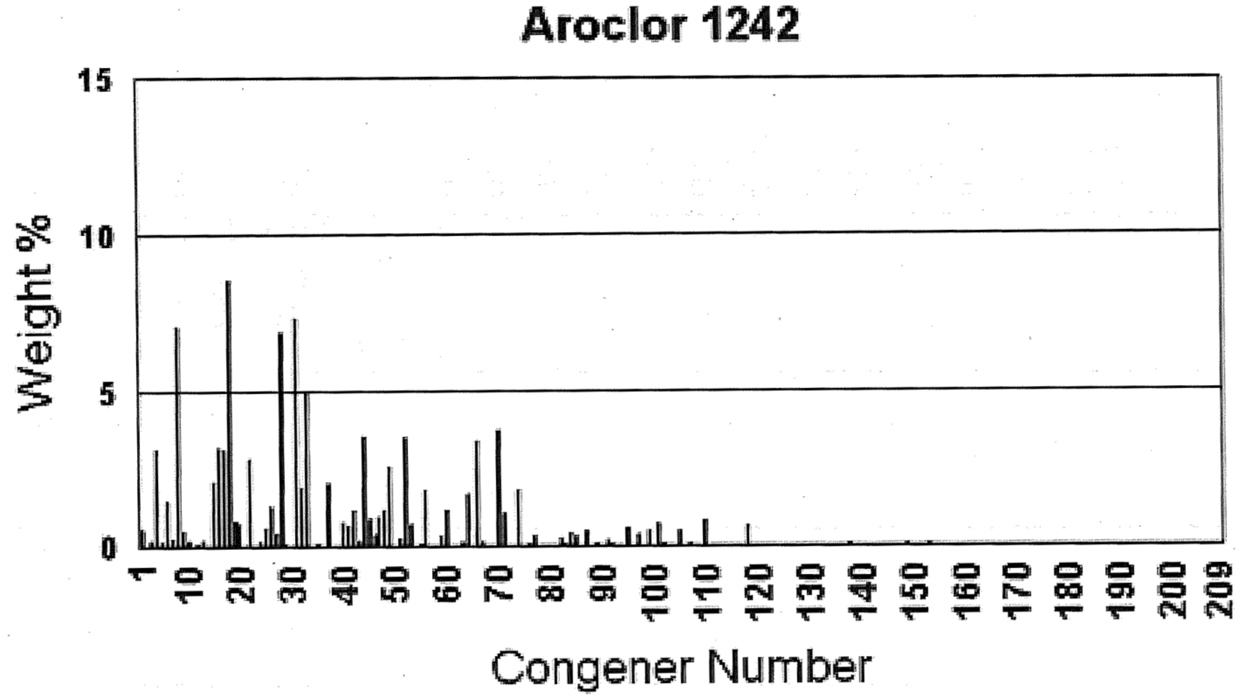
35065-29-3	180	2,2',3,4,4',5,5'-Heptachlorobiphenyl
74472-47-2	181	2,2',3,4,4',5,6-Heptachlorobiphenyl
60145-23-5	182	2,2',3,4,4',5,6'-Heptachlorobiphenyl
52663-69-1	183	2,2',3,4,4',5',6-Heptachlorobiphenyl
74472-48-3	184	2,2',3,4,4',6,6'-Heptachlorobiphenyl
52712-05-7	185	2,2',3,4,5,5',6-Heptachlorobiphenyl
74472-49-4	186	2,2',3,4,5,6,6'-Heptachlorobiphenyl
52663-68-0	187	2,2',3,4',5,5',6-Heptachlorobiphenyl
74487-85-7	188	2,2',3,4',5,6,6'-Heptachlorobiphenyl
39635-31-9	189	2,3,3',4,4',5,5'-Heptachlorobiphenyl
41411-64-7	190	2,3,3',4,4',5,6-Heptachlorobiphenyl
74472-50-7	191	2,3,3',4,4',5',6-Heptachlorobiphenyl
74472-51-8	192	2,3,3',4,5,5',6-Heptachlorobiphenyl
69782-91-8	193	2,3,3',4',5,5',6-Heptachlorobiphenyl
35694-08-7	194	2,2',3,3',4,4',5,5'-Octachlorobiphenyl
52663-78-2	195	2,2',3,3',4,4',5,6-Octachlorobiphenyl
42740-50-1	196	2,2',3,3',4,4',5,6'-Octachlorobiphenyl
33091-17-7	197	2,2',3,3',4,4',6,6'-Octachlorobiphenyl
68194-17-2	198	2,2',3,3',4,5,5',6-Octachlorobiphenyl
52663-75-9	199	2,2',3,3',4,5,5',6'-Octachlorobiphenyl
52663-73-7	200	2,2',3,3',4,5,6,6'-Octachlorobiphenyl
40186-71-8	201	2,2',3,3',4,5',6,6'-Octachlorobiphenyl
2136-99-4	202	2,2',3,3',5,5',6,6'-Octachlorobiphenyl
52663-76-0	203	2,2',3,4,4',5,5',6-Octachlorobiphenyl
74472-52-9	204	2,2',3,4,4',5,6,6'-Octachlorobiphenyl
74472-53-0	205	2,3,3',4,4',5,5',6-Octachlorobiphenyl
40186-72-9	206	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl
52663-79-3	207	2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl
52663-77-1	208	2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl
2051-24-3	209	Decachlorobiphenyl

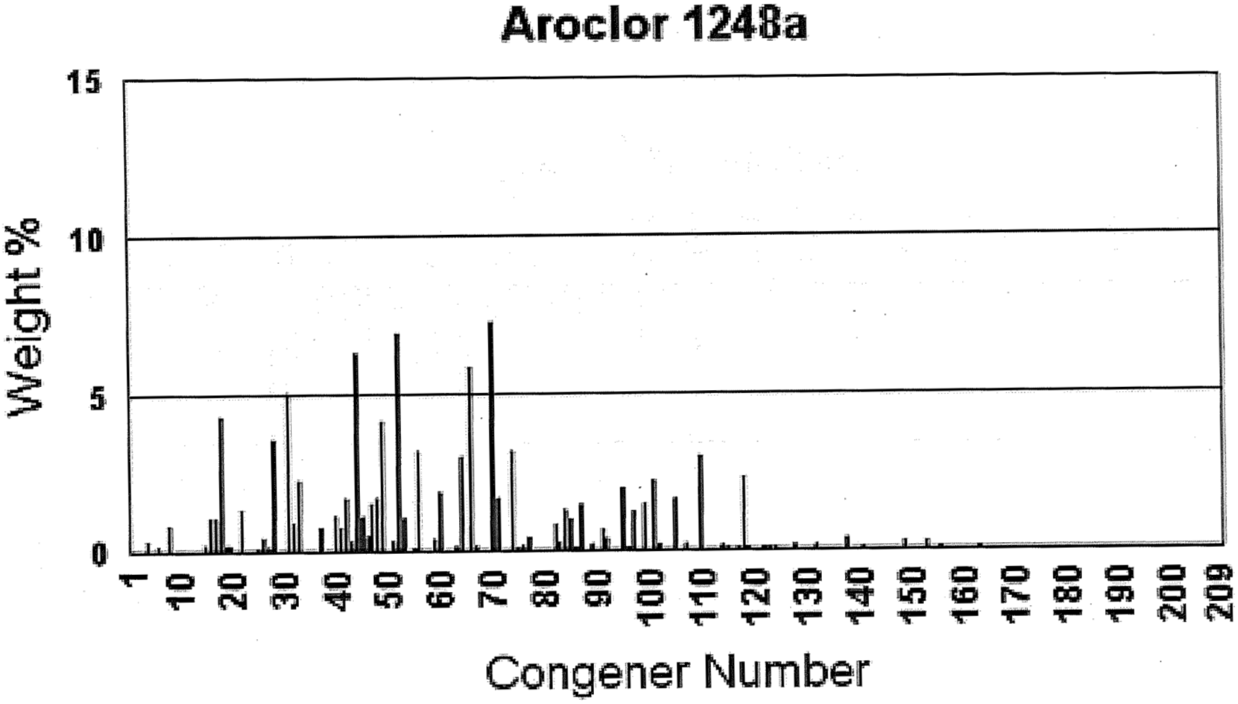
Appendix B. PCB Mixtures and Trade Names (EPA 2013d)

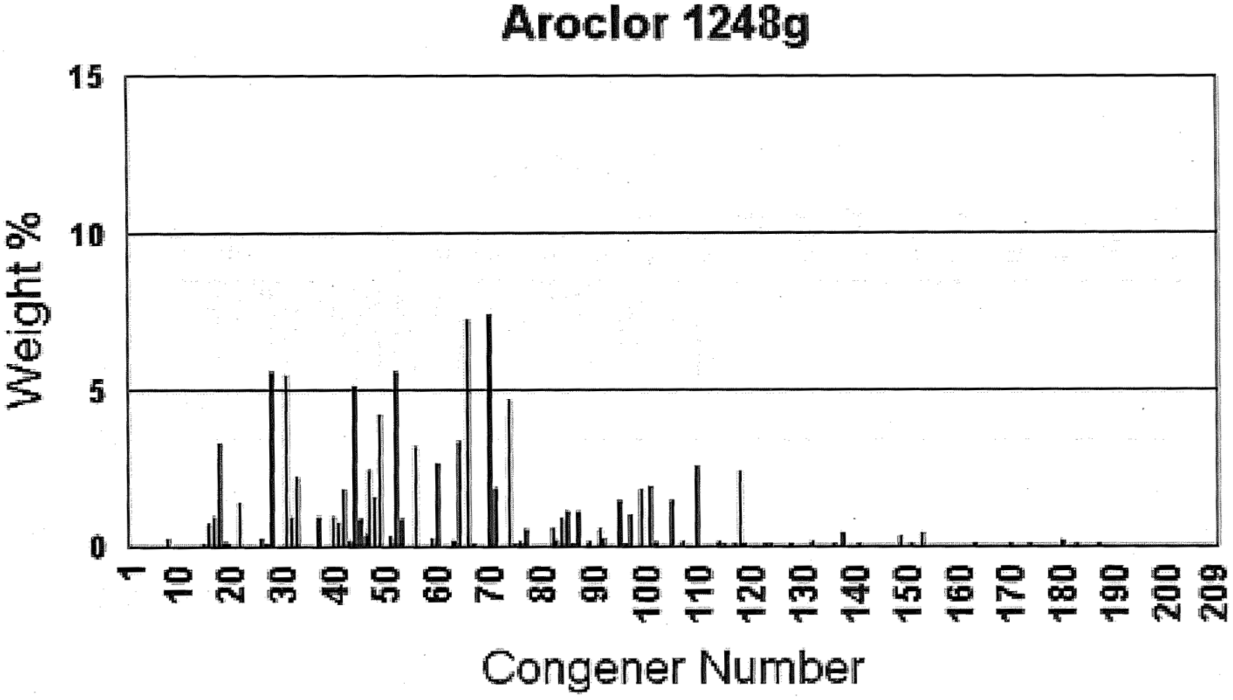
- Acector
- Adkarel
- ALC
- Apirolio
- Apirorlio
- Arochlor
- Arochlors
- Aroclor
- Aroclors
- Arubren
- Asbestol
- ASK
- Askael
- Askarel
- Auxol
- Bakola
- Biphenyl, chlorinated
- Chlophen
- Chloretol
- Chlorextol
- Chlorinated biphenyl
- Chlorinated diphenyl
- Chlorinol
- Chlorobiphenyl
- Chlorodiphenyl
- Chlorphen
- Chorextol
- Chorinol
- Clophen
- Clophenharz
- Cloresil
- Clorinal
- Clorphen
- Decachlorodiphenyl
- Delor
- Delorene
- Diaclor
- Dicolor
- Diconal
- Diphenyl, chlorinated
- DK
- Duconal
- Dykanol
- Educarel
- EEC-18
- Elaol
- Electrophenyl
- Elemex
- Elinol
- Eucarel
- Fenchlor
- Fenclor
- Fenocloro
- Gilotherm
- Hydol
- Hyrol
- Hyvol
- Inclor
- Inerteen
- Inertenn
- Kanechlor
- Kaneclor
- Kennechlor
- Kenneclor
- Leromoll
- Magvar
- MCS 1489
- Montar
- Nepolin
- No-Flamol
- NoFlamol
- Non-Flamol
- Olex-sf-d
- Orophene
- PCB
- PCB's
- PCBs
- Pheaoclor
- Phenochlor
- Phenoclor
- Plastivar
- Polychlorinated biphenyl
- Polychlorinated biphenyls
- Polychlorinated diphenyl
- Polychlorinated diphenyls
- Polychlorobiphenyl
- Polychlorodiphenyl
- Prodelec
- Pydraul
- Pyraclor
- Pyralene
- Pyranol
- Pyroclor
- Pyronol
- Saf-T-Kuhl
- Saf-T-Kohl
- Santosol
- Santotherm
- Santothern
- Santovac
- Solvol
- Sorol
- Soval
- Sovol
- Soltol
- Terphenychlore
- Therminal
- Therminol
- Turbinol

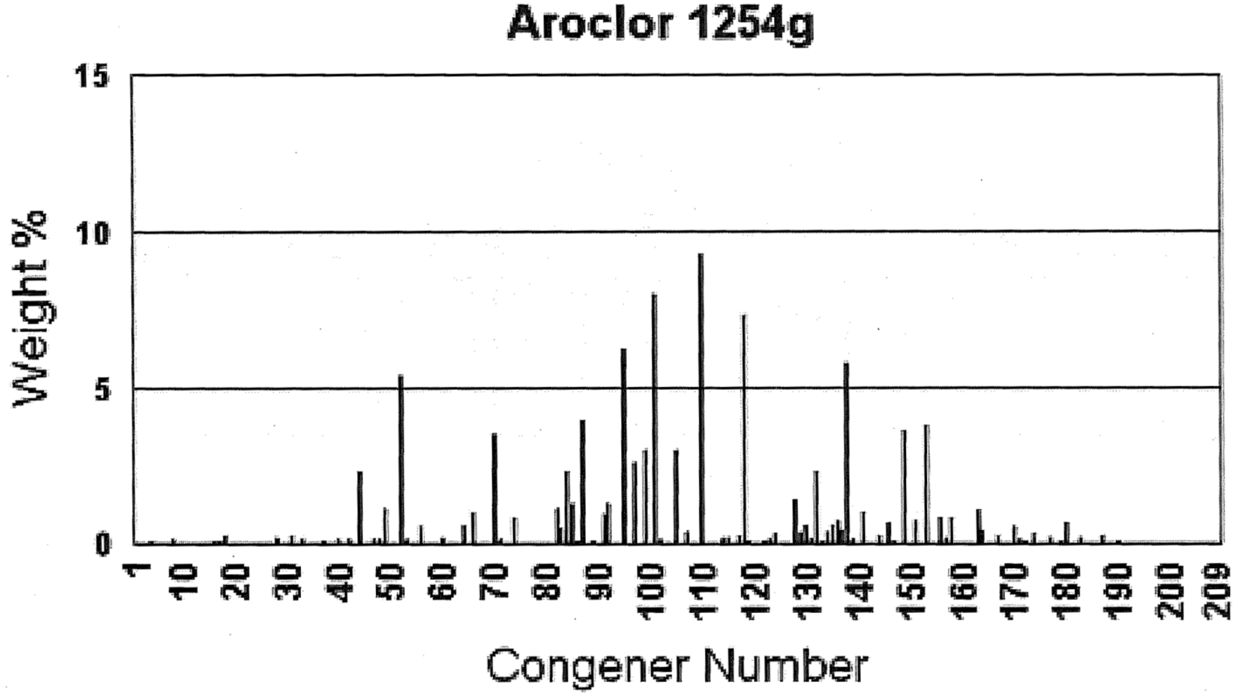
Appendix C. Distribution of Aroclor mixtures (EPA, 2013d)



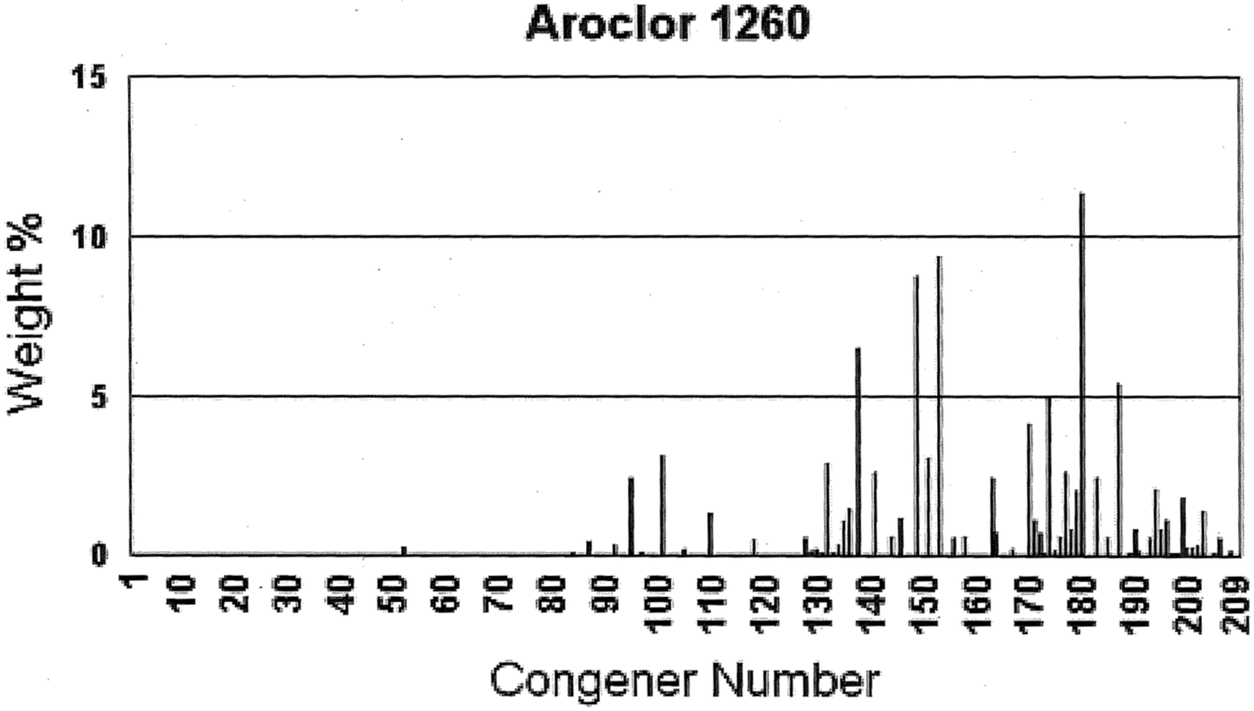



Aroclor 1248a
Weight %
0
5
10
15
1
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
209
Congener Number


Aroclor 1248g
Weight %
0
5
10
15
1
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
209
Congener Number



Aroclor 1254g



Aroclor 1260

Appendix D. Chemical Processes that have the Potential to Generate PCBs

The following was transcribed from EPA rulemaking records from "Polychlorinated Biphenyls (PCBs); Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions: Exclusions, Exemptions and Use Authorizations" Doc No. OPTS-62032. This was transcribed for Panero *et al*. (2005).

Chlorinated Compounds Produced Using Direct Chlorination	Chlorinated Compounds Produced Using Chlorinated Feedstocks	Non-chlorinated Compounds Produced Using Chlorinated Feedstocks	IPPPEU No.
Petroleum Feedstock: BENZENE			
Chlorinated benzenes	Chloronitrobenzenes	Phenol	8
Chlorinated phenols	Dichloronitrobenzenes	Aniline	9
Hexachlorocyclohexane	Dichloroanilines	o-Phenylenediamine	28
Chloranilines	Chlorinated methyl phenols	o-,p-Nitroanilines	29
Trichloroanilines	Chlorophenyl phenylethers	Diphenylamine	34
	Chlorinated benzidines	Acetanilide	17
Petroleum Feedstock: ETHYLENE			
Mono, di-chloroacetic acid	Ethyl chloroacetate	Glycine	108
Sodium chloroacetate	Vinyl chloride	Cyanoacetic acid	111
Chlorinated ethanes	Vinylidene chloride	Sodium, carboxymethyl cellulose	112
Chlorinated ethylenes	Bis (2-chloroethyl) ether	Ethyl cellulose	118
Ethylene chlorohydrin	Chlorinated acetophenones	Ethylene diamine	134
Chlorinated, fluorinated ethanes	Choline chloride	Aminoethylethanolamine	135
Chlorinated, brominated ethylenes	Hexachlorobutadiene	Mono-, di-, and triethylene glycol ethers	150
Chlorinated, fluorinated ethylenes		Tetramethylethylene diamine	(3341)
Chlorinated acetaldehyde			
Chlorinated acetyl chloride			
Hexachlorobenzene			
Petroleum Feedstock: METHANE			
Chlorinated methanes	Chlorinated, fluorinated methanes	Carbon tetrabromide	162
Phosgene	Chlorinated, brominated methanes	Carbon tetrafluoride	(812)
Tetrachloroethane	Bis (chloromethyl) ether		
Chlorodifluoroethane (?)	Cyanuric chloride		
Perchloromethyl mercaptan (?)	Trichloroethylene		
Cyanogen chloride			

Chlorinated Compounds Produced Using Direct Chlorination	Chlorinated Compounds Produced Using Chlorinated Feedstocks	Non-chlorinated Compounds Produced Using Chlorinated Feedstocks	IPPPEU No.
Petroleum Feedstock: NAPHTHALENE			
Chloronaphthalenes			
Tetrachlorophthalic anhydride			
Petroleum Feedstock: PARAFFINS			
n-Propyl chloride		n-Propylamine	231
Carbon tetrachloride		Butyronitrile	232
Perchloroethylene		Amyl amines	243
Hexachloroethane		Amyl alcohols	244
Amyl chlorides		Amyl Mercaptans	245
Chloroprene		Benzophenone	249
Hexachlorocyclopentadiene		Linear alkylbenzenes	(2417)
Methallyl Chloride			
Petroleum Feedstock: PROPYLENE			
Dichlorohydrin	Epichlorohydrin	Isopropylphenols	272
Chloranil	Bis (2-chloroisopropyl) ether	Propylene oxide	280
Propylene chlorohydrin		Anisols	302
Chlorinated propanes		Allyl alcohol	317
Chlorinated propylenes		Glycerol	318/319
		Propyl amines	(1446)
Petroleum Feedstock: TOLUENE			
Benzyl chloride	Benzoyl chloride	Benzyl alcohol	334
Benzyl dichloride		Benzyl amine	335
Benzyl trichloride		Benzamide	337
Chlorotoluenes		Toluenesulfonamide	358
Chlorobenzaldehyde		Benzoyl peroxide	(495)
Chlorobenzoic acids & esters			
Chlorobenzoyl chlorides			
Toluenesulfonyl chloride			
Chlorobenzotrichlorides			

*The IPPEU No. refers to the process description in the 1977 EPA summary (EPA, 1977). Those numbers bracketed by parentheses refer to the OCPDB numbers in the 1980 EPA summary (EPA, 1980)

Appendix E. Reported Products with Inadvertently Generated PCBs

Manufacturers are required to report inadvertent generation of PCBs to EPA. Below is a summary table of the 77 reports received from 1994 to present. See the Regulations section for explanation of the requirement and "discounted."

Date	Reporter	Product	Concentration or amount	Category
4/13/1995	Sun Chem. Corp	2-Naphthalenecarboxylic acid, 4-[(2,5-dichlorophenyl) azo]-3-hydroxy, a dye precursor		pigments and dyes
2/11/2004	Clariant	imported dyes		pigments and dyes
6/13/2005	Clariant	imported dyes		pigments and dyes
5/19/2011	Clariant	imported dyes		pigments and dyes
7/29/1994	Ciba-Geigy Pigments Division	CBI		pigments and dyes
12/28/1994	Ciba-Geigy Pigments Division	CBI		pigments and dyes
12/29/1994	DIC Trading	3 pigments		pigments and dyes
6/22/1995	Ciba-Geigy Pigments Division	CBI		pigments and dyes
7/25/1995	Cappelle	4 pigments		pigments and dyes
7/2/1996	Uhlich Color Co	CI Pigment Orange 24		pigments and dyes
7/15/1996	Ciba-Geigy Pigments Division	CBI		pigments and dyes
8/16/1996	Engelhard	CI Pigment Violet 23	19.6 ppm	pigments and dyes
8/23/1996	Cappelle	CI Pigment Yellow 170		pigments and dyes
9/27/1996	UMC (United Mineral and Chem)	CI Pigment Green 7		pigments and dyes
1/13/1997	Zeneca	7 pigments		pigments and dyes
7/29/1996	CDR Pigments and Dispersions	6 pigments		pigments and dyes
6/18/1997	Fabricolor	12 pigments		pigments and dyes
7/1/1997	BASF	13 pigments		pigments and dyes
8/18/1997	Ciba Pigments Division	CBI for several pages		pigments and dyes
10/21/1997	Mil International	5 pigments		pigments and dyes
1/6/1998	Sun Chem. Corp	4 pigments		pigments and dyes
10/26/1997	Mil International	4 pigments		pigments and dyes
5/15/1998	Mil International	5 pigments		pigments and dyes
7/20/1998	Ciba Pigments Division	CBI		pigments and dyes
10/23/1998	Ciba Pigments Division	CBI		pigments and dyes
2/2/1999	Lansco Colors	7 pigments		pigments and dyes
7/15/1999	Ciba Colors	CBI		pigments and dyes

	Division			
7/31/1999	Sun Chem. Corp	CBI		pigments and dyes
2/2/2000	Ciba Colors Division	CBI		pigments and dyes
5/23/2000	Ciba Colors Division	CBI		pigments and dyes
8/31/2000	Ciba Colors Divison	CBI		pigments and dyes
9/8/2000	Avecia	7 pigments		pigments and dyes
11/22/2000	Mil International	7 pigments		pigments and dyes
12/13/2000	Ciba Colors Division	CBI		pigments and dyes
3/30/2001	Ciba Colors Division	CBI		pigments and dyes
5/4/2001	Magruder Color Co	3 pigments		pigments and dyes
6/1/2001	Sun Chem. Corp	9 pigments		pigments and dyes
7/18/2001	Ciba Colors Division	CBI		pigments and dyes
4/8/1994	PCL Group	Copper Phthalocyanine Blue		pigments and dyes
10/17/2001	Ciba Colors Division	CBI		pigments and dyes
1/25/2002	Ciba Colors Division	CBI		pigments and dyes
3/27/2002	Mil International	8 pigments		pigments and dyes
4/29/2002	Ciba Coating Effects	CBI		pigments and dyes
8/6/2002	Ciba Coating Effects	CBI		pigments and dyes
8/28/2002	Sun Chem. Corp	CBI		pigments and dyes
11/5/2002	Ciba Coating Effects	CBI		pigments and dyes
6/13/2003	Ciba Coating Effects	CBI		pigments and dyes
10/16/2003	Ciba Coating Effects	CBI		pigments and dyes
4/2/2004	Ciba Coating Effects	CBI		pigments and dyes
7/6/2004	Ciba Coating Effects	CBI		pigments and dyes
7/6/2004	Ciba Coating Effects	CBI		pigments and dyes
8/8/2005	Sun Chemical	CBI		pigments and dyes
5/25/2006	Cappelle	CI Pigment Yellow 17		pigments and dyes
1/30/1995	GE Silicones	CBI	<2.5 ppm discounted, total discounted quantity <1.1 lbs	silicones
1/30/1996	GE Silicones	CBI	<1.1 ppm discounted, total discounted quantity <0.9 lbs	silicones

1/24/1997	GE Silicones	CBI	<1.5 ppm discounted, total discounted quantity <0.6 lbs	silicones
1/24/1997	GE Silicones	CBI	<1.3 ppm discounted, total discounted quantity <0.53 lbs	silicones
2/25/1999	GE Silicones	CBI	<1.5 ppm discounted, total discounted quantity <0.8 lbs	silicones
2/7/2000	GE Silicones	CBI	<1.7 ppm discounted, total discounted quantity <0.5 lbs	silicones
3/13/2001	GE	CBI	<1.9 ppm discounted, total discounted quantity <0.7 lbs	silicones
5/28/2002	GE	CBI, adding hydrolyzed phenylchlorosilanes and phenylchlorosilanes	total discounted quantity < 0.83 lbs	silicones
4/30/1997	ABB	electrical capacitors	3.9 ppm, 134 liters	Unique
6/24/1994	Nagase America	2,4,6-TCPH (2,4,6-Trichlorophenylhydrazine)	9-12 ppm	Unique
11/30/1995	PHT International	2,6-Dichloro-4-Nitro Aniline		Unique
3/17/1998	ISK Biosciences	CBI, Chlorothalonil production		Unique
5/15/2001	PPG Industries	trichlorobenzene (TCB)		Unique
8/17/2012	Future Fuel	pesticide intermediate		Unique
4/7/1997	Elf Atochem		4 and 5 ppm	Unknown
2/18/2000	CBI	CBI		Unknown
6/13/2001	CBI	CBI		Unknown
2/4/2003	CBI	CBI		Unknown
CBI	CBI	CBI		Unknown
5/31/2011	CBI	CBI		Unknown
9/11/2012	CBI	CBI, 220 kg shipment		Unknown
8/23/2004	Formosa Plastics		up to 215-255 ppm, 143 lbs	vinyl chloride
6/24/1996	Geon		740 lbs PCB/ 62,676,000 lbs chemical feedstocks	vinyl chloride
11/13/1997	Dow			vinyl chloride

Appendix F. Washington PCB transformers in EPA database

We attempted to contact the registrants to find out about the current whereabouts of the registered transformers. While owners of PCB transformers (> 500 ppm PCBs) were required to register with the EPA, the EPA is not required to update the database.

Company	City	Contact	Transformer street address	Trans. City	Trans. Zip code	No. of Trans.	Weight (kg)	Current whereabouts
Puget Sound Energy	Bellevue	John Rork	Talcott Avenue & Columbia Street	Olympia	98501	3	7	In use
Puget Sound Energy	Bellevue	John Rork	14401 278th Avenue NE	Duval	98019	2	5	In use
Puget Sound Energy	Bellevue	Lea Boyle	14401 188th Avenue NE	Redmond	98052	2	4.52	In use
Puget Sound Energy	Bellevue	John Rork	S 173rd & 43rd Avenue S	Renton	98055	0	0	
Puget Sound Energy	Bellevue	John Rork	2211 Nevada Street	Bellingham	98225	0	0	
Puget Sound Energy	Bellevue	John Rork	24810 156th Avenue SE	Kent	98025	0	0	
Puget Sound Energy	Bellevue	John Rork	Hodgedon & Garfield Streets	Tenino	98589	0	0	
Puget Sound Energy	Bellevue	John Rork	70th Street E & Myers Road	Bonney Lk	98390	0	0	
Puget Sound Energy	Bellevue	John Rork	Dolarway Road	Ellensburg	98922	0	0	
Puget Sound Energy	Bellevue	John Rork	Jackson & Main Streets	Cle Elum	98922	0	0	
Puget Sound Energy	Bellevue	John Rork	19319 Electron Road	Orting	98360	0	0	
Puget Sound Energy	Bellevue	John Rork	W. side of Stottlemeyer Road	Poulsbo	98370	0	0	
Puget Sound Energy	Bellevue	John Rork	40801 268th Avenue SE	Enumclaw	98022	0	0	
Puget Sound Energy	Bellevue	John Rork	N. Tapps Highway & Vandermark Road	Auburn	98002	0	0	
Puget Sound Energy	Bellevue	John Rork	SE 80th Street & 246 Avenue SE	Issaquah	98027	0	0	
Puget Sound Energy	Bellevue	John Rork	13635 SE 26th	Bellevue	98004	0	0	
Puget Sound Energy	Bellevue	John Rork	3975 E. Highway 525	Langley	98260	0	0	
Puget Sound Energy	Bellevue	John Rork	1274 Thompson Road	Anacortes	98221	0	0	
Puget Sound Energy	Bellevue	John Rork	2857 S. 221st	Des Moines	98148	0	0	
Puget Sound Energy	Bellevue	John Rork	12251 Mt Baker Highway	Glacier	98244	0	0	

Puget Sound Energy	Bellevue	John Rork	7537 Portal Way	Ferndale	98248	0	0	
Puget Sound Energy	Bellevue	John Rork	13635 NE 80th	Redmond	98052	0	0	
Puget Sound Energy	Bellevue	John Rork	9512 Pacific Highway SE	Lacey	98503	0	0	
Puget Sound Energy	Bellevue	John Rork	9221 Wilows Road NE	Redmond	98502	0	0	
Puget Sound Energy	Bellevue	John Rork	34717 21st Avenue SW	Federal Way	98003	0	0	
Puget Sound Energy	Bellevue	John Rork	1035 Stevenson Avenue	Enumclaw	98022	0	0	
Puget Sound Energy	Bellevue	John Rork	Hanford Road & Centralia Steam Plt	Centralia	98531	0	0	
Puget Sound Energy	Bellevue	John Rork	South of I-90 between Exits 37 & 38	Snoqualmie	98065	0	0	
Puget Sound Energy	Bellevue	John Rork	Corner of Central Valley Road & Bucklin	Bremerton	98310	0	0	
Puget Sound Energy	Bellevue	John Rork	20th Street E & 169th Avenue E (2111)	Sumner	98340	0	0	
Western Washington University	Bellingham	Gayle Shipley	Commissary 781 25th St.	Bellingham	98225	0	0	
SDS Lumber Co	Bingen	Ronald Schultz	South Side BNSF RR	Bingen	98605	2	2138	Unknown
Kimberly-Clark Worldwide	Everett	Jim Ketchum	2600 Federal Ave.	Everett	98201	0	0	
Grays Harbor Paper L.P.	Hoquiam	Richard Johnston	801 23rd St.	Hoquiam	98550	5	50932	In use
Reynolds Metals Company	Longview	H.S. Hays	4029 Industrial Way	Longview	98632	0	0	
Washington Veneer	Omak	Joe Atwood	1100 Eighth Ave.E.	Omak	98841	7	12412	Unknown
PUD. No. 1 of Clallam Co	Port Angeles	Quimby Moon	1936 West 18th Street	Port Angeles	98362	4	505	Disposed of
City of Port Angeles	Port Angeles	Mark Shamp	321 E. Fifth Street	Port Angeles	98362	1		Disposed of
PUD. No. 1 of Clallam Co	Port Angeles	Quimby Moon	1936 West 18th Street	Port Angeles	98363	1	100	Disposed of
PUD No. 1 of Clallam Co	Port Angeles	Quimby Moon	1936 West 18th Street	Port Angeles	98363	1	68	Disposed of
Port Townsend Paper Corporation	Port Townsend	John M. Recht	100 Mill Hill Rd	Port Townsend	98368	0	0	
City of Richland	Richland	Wayne Collop	806 Thayer Drive	Richland	99352	2	45	Disposed of
US Dept of Energy Richland Oper. Office	Richland	B.J. Dixon	200 East Area	Richland	99352	1	137	Unknown
Energy Northwest	Richland	J.P. Chasse	HPCS Diesel Generator Rm, Nuclear Plant #2, N. Power Plant Loop	Blank	Blank	0	0	
Entercom Communications	Seattle	Martin Hadfield	910 Lone Oak Road	Longview	Blank	0	0	

Corp								
Total Reclaim, Inc	Seattle	Craig Lorch	2200 Sixth Avenue South	Seattle	98134	1	215	Disposed of
Seattle City Light	Seatle	Karen Dinehart	Laurelhurst Lane and 51st	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	4502 NE 41st Street	Seattle	98124	3	182	Disposed of
Seattle City Light	Seattle	Karen Dinehart	Bellevue Ave E & E. John	Seattle	98124	3	160	Disposed of
Seattle City Light	Seattle	Karen Dinehart	2826 NW Market Street	Seattle	98124	2	114	Disposed of
Seattle City Light	Seattle	Karen Dinehart	7710 35th Avenue, SW	Seattle	98124	1	68	Disposed of
Seattle City Light	Seattle	Karen Dinehart	6730 24th Avenue, NW	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen. Dinehart	1414 NW Leary Way	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	7750 28th Ave NW	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	1405 NW 65th Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	8032 15th Avenue NW	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	3209 NW 65th Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	2333 W Boston Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	2100 SW Andover Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	35th Ave SE & SW Genessee	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	5601 23rd Avenue SW	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	1605 SW Holden Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	3405 SW Graham Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	4118 SW Morgan Street	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	9370 52nd Avenue S	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	1stE/Of Earl Ave NW, S/SI NW 90th	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	1stN/Of S Holden,E/SI Rainier AveS	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	1stS/Of W Bertona,E/SI 21st Ave W	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	48th NE & 47th NE	Seattle	98124	0	0	
Seattle City Light	Seattle	Karen Dinehart	51st Ave NE & NE 41st Street	Seattle	98124	0	0	
Inland Power and Light	Spokane	Todd Hoffman	10110 W. Hallett Road	Spokane	99014		1,249.00	
Avista Utilities	Spokane	Clarice	various locations	Blank	Blank	157	16,434.	Disposed of

		Robertson					00	
Avista Corporation	Spokane	Clarice Robertson	Onion Creek Road	Colville	Blank	0	0	
Avista Corporation	Spokane	Clarice Robertson	SE corner of Rockwell and Monroe Streets	Spokane	Blank	0	0	
Tacoma Power	Tacoma	Russell Post	418 Gershick Rd	Silver Creek	98585	10	830	Disposed of
Tacoma School District #10	Tacoma	Margaret Ohlson	111 North E Street	Tacoma	98403	1	358	In use
Tacoma School District #10	Tacoma	Margaret Ohlson	2502 North Orchard	Tacoma	98406	1	358	In use
Pioneer Americas, Inc./Chlor Alkali Co. Inc.	Tacoma	Karl Iams	605 Alexander Ave.	Tacoma	98421	0	0	
TransAlta of Calgary	Alberta	Roger Carter	913 Big Hanaford Rd	Centralia	98531	42	34731	Disposed of

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF THE REGIONAL
ADMINISTRATOR

February 24, 2015

Ms. Adriane Borgias
Spokane River Regional Toxics Task Force
Washington State Department of Ecology
4601 North Monroe Street
Spokane, Washington 99205-1295

Dear Ms. Borgias:

Thank you for your October 23, 2013, letter on behalf of the Spokane River Regional Toxic Task Force to Jim Jones, Assistant Administrator for the Environmental Protection Agency's Office of Chemical Safety and Pollution Prevention, and Cynthia Giles, Assistant Administrator for EPA's Office of Enforcement and Compliance Assurance, regarding the water quality challenges presented by polychlorinated biphenyls. I apologize for the delay in my response on behalf of the Agency, but your letter raises some particularly challenging issues for us. Specifically, your letter notes the potential problems from the release of inadvertently generated PCBs from products such as pigments, and requests that the EPA take two actions to address the problems. First, you ask that the EPA initiate enforcement of the existing prohibition on the imports of inadvertently generated PCBs at concentrations at or above 50 parts per million and, second, that EPA revise its regulations to eliminate all manufacture or import of inadvertently generated PCBs.

The EPA agrees with the Task Force on the importance of reducing PCBs in the environment and the need to look at all potential sources. The EPA participates on the Task Force and supports the collaborative approach being taken to reduce PCB sources in advance of completing a TMDL. Having approved the Spokane Tribe's water quality standards, the EPA understands the issues of concern associated with very low levels of PCBs and the challenges of meeting those standards.

Your request that the EPA initiate enforcement of the regulations regarding inadvertently generated PCBs raises very complex issues. Excluded Manufacturing Processes and the resulting products are excluded from the otherwise applicable statutory bans as long as certain requirements are met, including reporting those processes and products to the EPA and maintaining concentrations under specified limits. Given your request, we examined the potential for increased compliance and enforcement activity to address possible violations of these regulations and found a number of significant challenges. These challenges include the nature of the regulations, the EPA's ability to identify possible non-compliers, the resources necessary to implement an effective enforcement initiative, and the potential of any such initiative to effectively reduce PCB levels to meet water quality standards. Thus, an enforcement initiative targeted specifically at the regulations for inadvertently generated PCBs is not a promising approach.

Revising current regulations to reduce inadvertently generated PCBs presents both policy and scientific challenges. Before proposing more stringent regulations on the inadvertent generation of PCBs in pigments, the EPA would seek to further understand the complexities and contributions of not only PCB-11, but also other congeners that may be present in the Spokane River. At present, there are not sufficient data to assess such PCB congeners. However, in a step toward addressing this deficiency, the EPA has requested that toxicity testing on PCB-11, a congener identified to be incorporated into yellow pigments, be conducted through the National Toxicology Program at the National Institute of Environmental Health Sciences.

Excluded Manufacturing Processes and associated products may generate or contain a variety of inadvertently generated PCB congeners other than PCB-11. There are Toxicity Equivalence Factors (TEFs) established for the dioxin-like congeners, but, prior to revising TSCA regulations or the EPA's recommended water quality criteria for PCBs, the EPA would want to rely on additional toxicity information for many of the non-dioxin-like individual congeners. The aggregation of PCB congeners may in some instances be problematic for risk assessment because the toxicity of different PCB congeners varies and a fixed water quality concentration for total PCBs may not adequately represent the variable toxicity of the various congeners actually present in a particular water body. While the EPA is not proposing to undertake a comprehensive analysis of the remaining PCB congeners, we are examining the characterization of PCBs in water bodies. As stated above, characterizing individual PCB congeners' contribution to risk presents challenges. Therefore, the aggregation of all PCBs in the EPA's recommended water quality criteria for PCBs (i.e., expressed as total PCBs) is one topic we are discussing.

We note that states have taken the initiative to assess toxicity of specific chemicals in the past. One example is the toxicity criteria program managed by California's Office of Environmental Health Hazard Assessment. This process may be a reasonable approach that Washington can take to address the allowable amounts of specific PCB congeners generated inadvertently.

As you know, the EPA intends to propose to restrict and/or eliminate many of the remaining authorized uses of higher-concentration liquid PCBs. These remaining uses are the largest reservoir of commercial mixtures (Aroclors) that contain the dioxin-like PCBs for which there have been health concerns for decades. While these proposed changes will not address the inadvertently generated non-dioxin-like PCBs identified in your letter, the EPA believes this effort will help to reduce potential exposure and risk from remaining dioxin-like PCB uses.

One potentially promising strategy to address PCBs inadvertently produced in products is Green Chemistry. The EPA has provided funding to Ecology to establish a Green Chemistry Center and is a member of the Advisory Board for the Center. The Green Chemistry Center plans to host a workshop later this year on PCBs inadvertently produced in inks and pigments, perhaps leading to improvements in the production and use of PCB-free inks and pigments.

I understand that, having not heard back from the EPA in so long, you recently requested a meeting with the EPA senior managers to discuss these issues. If you still would like to meet after you and the other members of the Task Force have had a chance to review this response, I would be happy to assist in getting the meeting organized. Please feel free to contact me or have your staff contact Tom Eaton, Director of our Washington Operations Office at (360) 753-8086 or by email at eaton.thomas@epa.gov if you still wish to proceed with the meeting.

Thank you again for your letter, and again, I apologize for the delay. I look forward to continuing our work together and protecting human health and the environment.

Sincerely,

for

Dennis J. McLerran
Regional Administrator

cc: Wendy Cleland-Hamnett, Director, OPPT
Susan Shinkman, Director, OCE
Ken Kopocis, Deputy Assistant Administrator, OW
Ed Kowalski, Director, OCE, Region 10
Lauris Davies, Associate Director, OCE, Region 10
Dan Opalski, Director, OWW, Region 10
Kate Kelly, Director, AWT, Region 10

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
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Seattle, WA 98101-3140

OFFICE OF
WATER AND WATERSHEDS

September 5, 2014

Don Essig
Idaho Department of Environmental Quality
1410 N. Hilton
Boise, Idaho 83706

RE: EPA comments on Idaho's Discussion Paper #5 Anadromous Fish

Dear Don:

EPA appreciates the opportunity to provide comments on the discussion paper, which the Idaho Department of Environmental Quality (DEQ) provided at the July 23, 2014 negotiated rulemaking meeting. This discussion paper considers some of the issues regarding inclusion or exclusion of anadromous fish in the derivation of a fish consumption rate in Idaho. In our comments, we would like to note that we are discussing inclusion of fish that migrate in the consumption rate. EPA assumes that Idaho already intends to include species that ordinarily migrate but cannot because of physical barriers (e.g., dams) in their fish consumption rate. Whenever salmon are referred to in this comment letter, EPA is referring to salmon that can physically migrate.

EPA found Idaho's discussion paper to be quite comprehensive and well written. However, EPA believes the paper would have been strengthened by incorporating some of the issues analysis that Washington and Oregon did when considering the inclusion of anadromous species in the FCR. These issues are largely those associated with the uncertainties referred to later in these comments. The discussion paper also does not accurately describe the basis for EPA's subsistence default fish consumption rate of 142 g/day, implying it is solely derived from the 99th percentile of the general population (p. 4 under 'EPA's Position'). While EPA's recommendation corresponds to this percentile, the subsistence default rate was developed from a number of consumption estimates for subsistence fishers based on subsistence-fisher specific surveys. The subsistence default rate corresponds to a high-end (>90th percentile) consumption rate for a subsistence fisher population, as evidenced in particular by the 1994 CRITFC Survey. Although it also corresponds to the 99th percentile of the USDA's Continuing Survey of Food Intake by Individuals (CSFII) 1994-96, it was not derived from this data and the CSFII was not the basis for the selection of the 142.4 g/day value.

Although water quality criteria are developed by states and tribes on a local basis, the overall function of the water quality criteria is to support maintenance of appropriate water quality throughout the United States. Individuals should be able to safely consume the amount of fish they wish to and utilize water resources from any location within the U.S. Therefore, it is EPA's policy that consumption of freshwater and estuarine fish, regardless of source, should be used to develop water quality criteria for the protection of human health.

There are a number of uncertainties to consider in evaluating the inclusion of anadromous species, such as migrating salmon, in the FCR used to compute human health water quality criteria. Although EPA has, on a national basis, considered salmon to be largely a marine species, there is uncertainty as to the body burden of contaminants that salmon acquire in fresh water. Further, the marine food web that adult salmon rely upon is potentially affected by contaminant sources regulated under the Clean Water Act. The importance of considering these uncertainties is magnified by the fact that large amounts of salmon are consumed by tribal members and others in Idaho with associated contaminant exposures and consequent health risks. Yet another source of uncertainty is the market basket preferences of consumers. Individuals desiring to consume fish generally will vary in the species they consume. To protect the public in the face of these uncertainties, EPA believes that salmon should be included in the fish consumption rate used to derive human health water quality criteria in Idaho. Specifically, EPA believes that including salmon at a discounted rate (Option 2) or not including salmon at all (Option 3) would not be appropriate in Idaho.

There are additional arguments for including salmon in the fish consumption rate for chemicals regulated on the basis of their non-cancer toxicity. For these chemicals, EPA considers overall contaminant exposures in determining what allowable exposures are via fish consumption and drinking water ingestion. Specifically, the allowable exposure via fish consumption and drinking water should equal the total allowable exposure minus the exposure from other sources. EPA generally implements this consideration via the "relative source contribution" (RSC) term. The RSC is the fraction of the reference dose (e.g. the allowable daily intake) that can be allocated to fish consumption and water ingestion after considering the dose contributed by other routes of exposure. Though EPA guidance has stated that the primary approach for dealing with exposure to contaminants in salmon should be via reducing the RSC, it is difficult to do this using data because the necessary information is not always available. An alternate, acceptable approach to reducing the RSC is to fully include salmon consumption in the fish consumption rate. Assuming that Idaho would use the fish consumption rate to address exposure to contaminants found in anadromous fish, EPA believes that neither Option 2 nor Option 3 are appropriate.

EPA also has attempted to develop a cohesive regional perspective as it works with states and tribes to develop and/or update human health water quality criteria. Given that Washington and Oregon, which are downstream of Idaho, are considering including or have included salmon in their fish consumption rate, implementation of human health water quality criteria throughout the Pacific Northwest would be facilitated by uniformly including salmon in the fish consumption rate for Idaho. For all of the aforementioned reasons, EPA believes that salmon should be fully included in the fish consumption rate used to develop Idaho's human health water quality criteria.

We look forward to continued work with DEQ on this effort and are available if you would like to discuss our comments further. Please contact Lon Kissinger (206-553-2115) or myself (206-553-1834) if you have any questions.

Sincerely,

Lisa Macchio
Water Quality Standards Coordinator

ACWA Monitoring, Standards & Assessment Committee Call
Wednesday, April 17, 2013

Subject: Discussion on EPA's new FAQ: *Human Health Ambient water Quality Criteria and Fish Consumption Rates Frequently Asked Questions*: http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/upload/hhfaqs.pdf

Comments from Washington & Idaho:

Cheryl Niemi, Washington Department of Ecology, cnie461@ecy.wa.gov
Don Essig, Idaho Department of Environmental Quality, don.essig@deq.idaho.gov

Overall comment:

Several states are dealing with development of human health criteria as they revise standards. Washington and Idaho are both starting the process and are dealing with particularly complex issues because of abundance of fisheries for anadromous fish, subpopulations that consume large amounts of anadromous and local fish and shellfish, a lack of state-specific data on the fish and shellfish consumption patterns of the general population, and a very motivated and concerned set of stakeholders who all have important interests to address. In addition, in Idaho and Washington there have been recent communications with EPA Region 10 that indicate that EPA is considering development of regional guidance or other decision-making processes on human health criteria development that could seriously affect the ability of the states to make the risk management decisions that have historically and appropriately been made by states – decisions on such issues as risk levels and fish consumption rates. This had led to an uncertain rule-making environment, and a real concern that EPA might develop guidance that could act as rule. Launching this FAQ into such a highly charged environment, without the benefit of state review and consideration of the issues being addressed in state rule-makings, is of significant concern.

Specific comments:

In the left column below is a copy of the EPA FAQ. The FAQ is divided below into a table format to facilitate discussion of individual Question/Response topics. State comments/concerns with the information in the FAQ are in the right column. Specific comments in each section are numbered across the columns to clarify the linkage between highlighted FAQ language and state comments/concerns.

Document Title:
Human Health Ambient water Quality Criteria and Fish Consumption Rates
Frequently Asked Questions
[Note: the answers below reflect existing EPA policy and guidance, as articulated in the 2000 Human Health Methodology]

Abbreviations:
HHC – Human health criteria, WQS = water quality standards, SDWA = Safe Drinking Water Act, CWA = Clean Water Act, RSC = Relative Source Contribution, MCLG = Maximum Contaminant level Goal, MCL = Maximum Contaminant Level

EPA FAQ Language	State Comment/concern
This guidance does not have a disclaimer.	EPA's new FAQ on multiple discharger variances (EPA-820-F-13-012, March 2013) contains some introductory language that clarifies the role of that FAQ – explaining that it is guidance and not rule. A similar disclaimer is desirable for this Fish Consumption Rate FAQ (EPA variance FAQ language below): ***DISCLAIMER*** *These Frequently Asked Questions (FAQs) do not impose legally binding requirements on the EPA, states, tribes or the regulated community, nor do they confer legal rights or impose legal obligations upon any member of the public. The Clean Water Act (CWA) provisions and the EPA regulations described in this document contain legally binding requirements. These FAQs do not constitute a regulation, nor do they change or substitute for any CWA provision or the EPA regulations.* *The general description provided here may not apply to a particular situation based upon the circumstances. Interested parties are free to raise questions and objections about the substance of these FAQs and the appropriateness of their application to a particular situation. The EPA retains the discretion to adopt approaches on a case-by-case basis that differ from those described in these FAQs where appropriate. These FAQs are a living document and may be revised periodically without public notice. The EPA welcomes public input on these FAQs at any time.*

Q1. What is the goal of the human health ambient water quality criteria?	**Comment 1.**
Clean Water Act (CWA) section 303(c)(2)(A) requires that water quality standards (WQS) protect "public health or welfare, enhance the quality of the water and serve the purposes of [the Act]." CWA section 101(a)(2) establishes as a national goal "water quality which provides for protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable." EPA has interpreted the "fishable" language in section 101(a)(2) to refer not only to protecting water quality so the fish and shellfish thrive, but when caught they can also be safely eaten by humans. Thus, to be consistent with section 101(a)(2),the applicable criteria for such "fishable" designated uses must not only protect the aquatic organisms themselves, but also protect human health through consumption of fish and shellfish.1 1 See memorandum from Geoffrey H. Grubbs and Robert H. Wayland (October 2000) posted at http://water.epa.gov/scitech/swguidance/standards/upload/2000_10_31_standards_shellfish.pdf EPA's recommended 304(a) water quality criteria to protect these "fishable" designated uses, and accompanying risk assessment methodologies, reflect the longstanding interpretation that a designated use consistent with the goals of the Act means that State and Tribal waters should support safe consumption of fish and shellfish. EPA has consistently implemented the Clean Water Act to ensure that the total rate of consumption of freshwater and estuarine fish and shellfish (including estuarine species harvested in near coastal waters) reflects consumption rates demonstrated by the population of concern. In other words, EPA expects that the standards will be set to enable residents to safely	Suppression effects are a very sensitive topic for many groups in the Pacific Northwest, and it is difficult to apportion the amount of suppression caused by different factors. Unfortunately the concepts of *availability* of fish and *contamination* of fish get mixed up. Some specific language here that speaks directly to the possible causes of suppression, and then directly pinpoints the suppression linked to contamination, would be useful for readers. It would also be helpful to acknowledge the difficulty in accurately quantifying suppression.

consume from local waters the amount of fish they would normally consume from all fresh and estuarine waters (including estuarine species harvested in near coastal waters). EPA does not necessarily expect all consumers to eat only fish from a single State, but individuals or groups should be able to do so without concern for their health. (see **comment 1** at right)It is also important to avoid any suppression effect that may occur when a fish consumption rate for a given subpopulation reflects an artificially diminished level of consumption from an appropriate baseline level of consumption for that subpopulation because of a perception that fish are contaminated with pollutants. This approach is consistent with a principle that every State does its share to protect people who consume fish and shellfish that originate from multiple jurisdictions. In addition, the goal of water quality criteria for human health is to protect people from exposure to pollutants through fish and water over a lifetime, and the goal of a State's designated use should be that the waters are safe to fish in the context of the total consumption pattern of its residents. Likewise, because people are expected to continue consuming fish and shellfish throughout their lifetime regardless of where they live, and this consumption leads to similar exposure to pollutants, it is appropriate to derive protective human health criteria in State and Tribal water quality standards assuming a lifetime of exposure. Although the human health ambient water quality criteria (AWQC) are based on chronic health effects data (both cancer and noncancer effects), the criteria are intended to also be protective against adverse effects that may reasonably be expected to occur as a result of elevated acute or short-term exposures.	

Q2. What does the fish consumption rate (FCR) indicate in the calculation for human health ambient water quality criteria? The FCR indicates the amount of fish and shellfish in kilograms consumed by a person each day. For the purposes of human health ambient water quality criteria, the fish and shellfish to be reflected in the FCR include all of the fish and shellfish consumed that are species found in fresh and estuarine waters (including estuarine species harvested in near coastal waters). (see **comment 1** at right)Because the overall goal of the criteria is to allow for a consumer to safely consume from local waters the amount of fish they would normally consume from all fresh and estuarine waters, the FCR does include fish and shellfish from local, commercial, aquaculture, interstate, and international sources. It is not necessary for the FCR to include fish and shellfish species designated as marine species, as that exposure is addressed by relative source contribution (see question 4 for more detail). However, partitioning of fish and shellfish into the different habitats in order to develop a FCR can only be done where sufficient data are available for this to be done in a scientifically defensible manner. For example, if a State were to determine through scientifically collected data that its citizens consumed 25 grams of fish and shellfish per day where 5 grams came from marine fish, 5 grams came from a local fresh water stream (see comment 1 at right) 5 grams came from a neighboring state's fresh waters, 5 grams came from international imports of estuarine shellfish, and 5 grams came from aquaculture of a freshwater species, then the FCR would be 20 grams per day. Only the marine fish component would be excluded from the FCR (see discussion below on relative source contribution). (see **comment 2** at right) All of the other components represent the amount of fish and shellfish that could	**Comment 1.** If the overall goal is to allow consumers to safely consume freshwater and estuarine fish resources from local waters, then including all the fish and shellfish consumed from interstate and international sources does not make sense. The amount of consumption associated with the commercial availability of these sources does not necessarily reflect the amount of fish or shellfish that are, were, or might be attainable in local waters. For instance, a person from a state with no marine coastline might eat large amounts of prawns and bivalves harvested in a foreign country and purchased at the supermarket. This consumption does not reflect exposures from local waters or the fishery resources that would naturally be there. This consumption should be considered during the development of the RSC (if data are available to document contaminants in these new fishery sources (such as mercury in tuna)), but not in the overall FCR. Aquaculture resources are complex. Many types of aquaculture are practiced. Some types are almost completely dependent on the local waters for support (e.g. oyster industry), others use a mixture of in-situ exposure of local water and commercial or proprietary feed stock (e.g. net pens), and still others use upland facilities with waters piped to the facility in a manner analogous to industrial water use and combined with commercial or proprietary feed stock (upland facilities raising tilapia). The first type of aquaculture venture could closely fit the definition of locally harvested resources, the second is more ambiguous, and the third is more similar to an industrial operation and not a local waterbody harvest issue. Including all resources from aquaculture in the FCR does not take the complexity of these different types of exposure sources into account. The different sources merit further discussion to

be taken and consumed from local waters if the consumer chose to do so.	determine whether they should be included in the FCR and when they should be considered for development of the RSC. **Comment 2.** The last sentence states that all of the "*components represent the* <u>*amount of fish and shellfish that could be taken and consumed from local waters if the consumer chose to do so*</u>*.*" This does not make sense. The international and national market for fisheries has created a market situation where people who previously would have little harvest available locally could (by eating commercially available non-local fish or shellfish) enhance their consumption to levels that would more closely mirror locally supported consumption patterns in areas with locally abundant fishery resources – but do not mirror the "*amount of fish and shellfish that could be taken and consumed from local waters if the consumer chose to do so.*"
Q3. How is the exposure to a pollutant due to marine fish consumption accounted for in the human health ambient water quality criteria? Human health ambient water quality criteria are to account for all sources of exposure to the pollutants for which they are developed. The exposure to pollutants from marine fish and shellfish species that are not included in the fish consumption rate should be accounted for in the relative source contribution (RSC) when setting criteria for threshold non-carcinogens and non-linear carcinogens.	**No comment.**

Q4. What does the relative source contribution (RSC) indicate in the calculation for the human health ambient water quality criteria? The relative source contribution component of the human health ambient water quality criteria (AWQC) calculation for threshold non-carcinogens and non-linear carcinogens allows a percentage of the reference dose’s exposure to be attributed to ambient water and freshwater and estuarine fish consumption (including estuarine species harvested in near coastal waters) when there are other potential exposure sources. (see **comment 1** at right) The rationale for this approach is that for pollutants exhibiting threshold effects, the objective of the AWQC is to ensure that an individual’s total exposure from all sources does not exceed that threshold level. The RSC includes, but is not limited to, exposure to a particular pollutant from marine fish consumption (not included in the fish consumption rate), non-fish food consumption (fruits, vegetables, and grains), dermal exposure, and respiratory exposure. In the absence of scientific data, the application of the EPA’s default value of 20 percent RSC in calculating 304(a) criteria or establishing State or Tribal water quality standards under Section 303(c) will ensure that the designated use for a water body is protected. (see **comment 2** at right – boldface added) This 20 percent **default for RSC can only be replaced where sufficient data are available to develop a scientifically defensible alternative value**. If appropriate scientific data demonstrating that other sources and routes of exposure besides water and freshwater/estuarine fish are not anticipated for the pollutant in question, then (see **comment 3** at right – boldface added) the RSC **may be raised to the appropriate level, based on the data, but not to exceed 80 percent.** The 80 percent ceiling accounts for the	**Comment 1.** The 20%/80% RSC approach in the EPA 2000 guidance was developed as part of a process to “harmonize” the SDWA and the CWA. See EPA 2000 (bottom of page 1-5): *“Another reason for the 2000 Human Health Methodology is the need to bridge the gap between the differences in the risk assessment and risk management approaches used by EPA’s Office of Water for the derivation of AWQC under the authority of the CWA and Maximum Contaminant Level Goals (MCLGs) under the Safe Drinking Water Act (SDWA). Three notable differences are the treatment of chemicals designated as Group C, possible human carcinogens under the 1996 proposed cancer guidelines, the consideration of non-water sources of exposure when setting an AWQC or MCLG for a noncarcinogen, and cancer risk ranges.”* The SDWA MCLG derivation procedures use a 20%80% approach. Applying this RSC range to CWA HHC provides some harmonization between the two Acts, but does not take into account that the MCLG is not a regulatory level (it is a goal), and that the CWA human health criteria (HHC) are regulatory levels enforced both as ambient concentrations in the water body (303(d) listing process and through NPDES permit limits.) Under the SDWA the MCLG is modified to create an at-tap regulatory level (the maximum contaminant level - MCL) by taking into account factors such as available treatment and available analytical methods. Here is an example for nitrate taken from EPA’s website (boldface added) at http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm that gives some explanation of how MCLs are developed from MCLGs:

fact that some sources of exposure may be unknown. In cases where an 80 percent RSC is used, 20 percent of the exposure is reserved for unknown sources. Although the 20 percent RSC has not been consistently applied to national 304(a) criteria recommendations for non-carcinogenic pollutants, where there are inconsistencies between the 2000 Human Health Methodology recommendation and implementation in criteria, the Human health Methodology should prevail and the 20 percent RSC applied. EPA is moving to complete implementation of this guidance in existing 304(a) criteria.	*"The MCLG for nitrate is 10 mg/L or 10 ppm. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for nitrate, called a maximum contaminant level (MCL), at 10 mg/L or 10 ppm.* ***MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation."*** NPDES permitting tools can sometimes accommodate some of these considerations during implementation, but final limits must always be based on the HHC. The larger reason why the MCLG does not mirror the HHC is that the MCLG is not in itself a level that must be attained, while the HHC is always a level that must be attained in ambient waters. The roll-out of this difference is apparent with the application of the 303(d) program, the requirement for allocation of loads, and subsequent permitting requirements found at 40 CFR 122.4(i) and the Pinto Creek decision (http://cdn.ca9.uscourts.gov/datastore/opinions/2007/10/03/0570785.pdf . In this context, the HHC themselves are strong regulatory numbers that drive resource intensive programs. This is important because the risk management/policy decision to use a RCS of 20% to 80% in the MCLG itself has no regulatory outcome – it simply provides a backdrop for development of the MCL. The risk management/policy decision to use a 20% to 80%

	RSC in HHC development directly affects a regulatory value with potentially large economic consequences (see Pinto Creek decision). We believe this background discussion is relevant because maybe the risk management/policy decision to use the SDWA RSCs to harmonize with the CWA HHC should be reconsidered now that states have had time to examine more fully the EPA 2000 guidance. The decision to try to harmonize the development of the MCLG and the CWA HHC may be like trying to harmonize apples and oranges: both are fruit – both are different from each other. Different regulatory programs address the same chemicals and effects in different ways in order to fulfill the requirements of enabling legislation, regulations, and local needs. Applying a default assumption (RSC = 20% to 80%) that might have no affect on a regulatory level (the MCL) from one program, to another program (NPDES) where the assumption can drive huge resource and compliance issues (through requirements to meet HHC in ambient waters) does not necessarily make sense. Trying to harmonize programs or regulatory levels seems like a good idea on the surface, but trying to harmonize programs or regulatory levels that are not completely analogous is not necessarily a good idea. An alternative to using the 20%-80% range would be to apply 100% as the RSC. 100% has been the RSC value traditionally incorporated into HH criteria development for the non-carcinogens, unless additional data to identify other exposure pathways are available (e.g., the new mercury HH criteria). Maybe this is the way to go until this issue has had more discussion. An inherent assumption in how the RSC for HHC is developed is that all other sources of the contaminant are

	required to be considered in the exposure scenario, and the HHC get the "left over" part of the reference dose. This results in the odd situation where, as the contribution of a contaminant from water becomes less and less important (a smaller part of the RfD allowed in water), the HHC get more and more stringent – in effect becomes a bigger and bigger driver for more restrictive limits. Because other regulatory programs (e.g., FDA action levels and food tolerances, SDWA MCLs, Superfund clean-ups) target lower levels of protection, the CWA program is at the mercy of the regulatory levels set in other programs, and is expected to "clean-up" the waters that are allowed higher levels of pollution than these other sources (even when these other sources may be ongoing sources even after their regulatory requirements have been fulfilled). It would be interesting to have a broader national discussion on how the RfD for any individual chemical is allocated among different regulatory programs. Maybe it would make more economic sense, and more opportunities might be available, to try to cut down the levels of contaminants allowed in other regulatory programs (that are based on cost, feasibility, etc.) so that the CWA criteria could focus only on the designated uses and CWA-regulated pollution sources within the geographic jurisdiction of each state. **Comment 2.** This reads like rule language instead of guidance. **Comment 3.** This reads like rule language instead of guidance.
Q5. Should an RSC also be applied to carcinogens? In the case of carcinogens based on linear low-dose extrapolation, the AWQC is determined with respect to the *incremental* lifetime risk posed by a substance's presence in water, and is not being set	**Comment 1.** This statement in the FAQ causes confusion about who has the responsibility for making risk management decisions with regard to both risk level and FCR: EPA regions or the states? It would be useful for EPA to include a statement in

with regard to an individual's total risk from all sources of exposure. Thus, the AWQC represents the water concentration that would be expected to increase an individual's lifetime risk of carcinogenicity from exposure to the particular pollutant by no more than one chance in one million, regardless of the additional lifetime cancer risk due to exposure, if any, to that particular substance from other sources. For human health criteria, this exposure pathway considers consumption of freshwater and estuarine fish and shellfish (as described in the responses to Q1 and Q2) and drinking water ingestion. (see **comment 1** at right) EPA recommends that the incremental cancer risk from these exposure pathways not exceed more than 1 in 1,000,000 or 1 in 100,000 for the general population, nor exceed more than 1 in 10,000 for any sensitive sub-population (such as those who may consume a great deal more fish because of a subsistence lifestyle). States and tribes may consider adjusting the risk level according to guidance in the 2000 Human Health Methodology (and mentioned above), particularly if exposure to "other" sources besides water and fish is determined to be significant.	this FAQ similar to its statement in the 2000 Human Health methodology that: *"EPA believes that ambient water quality criteria inherently require several risk management decisions that are, in many cases, better made at the State, Tribal, or regional level."* This issue is particularly important, in an immediate sense, for Washington and Idaho. Both states have been told by EPA Region 10 that the Region is considering developing "region-specific" guidance (or some other framework to look at approvable criteria) on HHC, including risk levels and FCRs. The states have also been told that Region 10 thinks "the Oregon outcome was the right outcome." The Oregon outcome included risk management decisions, appropriately made by that state, for a FCR that included salmon consumption and application of that rate to a state-determined risk level. Washington and Oregon are concerned that development of regional guidance will usurp the risk management decisions appropriately and historically made by states, and instead have them made by EPA. If this is the approach then the issue of "rule-by-guidance" becomes important.
Q6. Could a state include a component of marine fish consumption in their FCR for deriving human health criteria? Yes, a state may include consumption of marine species in the FCR. (see **comment 1** at right) Coastal States and authorized Tribes that believe accounting for total fish consumption (i.e., freshwater/estuarine and marine species) is more appropriate for protecting the population of concern may do so. In the instance	**Comment 1.** As discussed above in the comments on Q2, commercial markets make marine fishery resources available to consumers in all states. Inland states may have just as much, or even maybe more, fish of marine origin sold in their markets than coastal states. This seems to be analogous to the inclusion of consumption of imported fish/shellfish from waters outside the US in the FCR used to calculate criteria. However, as

where the FCR includes freshwater, estuarine and all marine fish consumption, EPA recommends that states adjust the RSC estimate to reflect a greater proportion of the reference dose being attributed to water intake and the marine-inclusive FCR exposures. Including marine fish in the fish consumption rate may be particularly appropriate if a large proportion of fish consumption for the population to be protected consists of marine fish (such as salmon) and this exposure is clearly documented. Including marine fish in the fish consumption rate for criteria calculations would provide some calculations that are more stringent than those that don't include marine fish consumption, particularly for chemicals that are highly bioaccumulative.	discussed above, it seems that there is still much to discuss around the use, in HHC development, of commercially acquired fishery resources and resources from marine waters that are outside the jurisdictional boundaries of states. A serious national public policy discussion needs to take place about what we are trying to achieve by including non-local fish in the basis for water quality criteria that are going to be used to regulate local waters.
Q7. When fish consumption exposure is represented by a distribution of values, what are the appropriate percentiles to choose? In general, EPA considers protection of the general population to be represented by the 90th percentile of a total exposure distribution utilizing a "per capita" fish consumption distribution. If present in the state, subsistence fishers should be considered on a site specific basis. EPA has recommended the 99th percentile of a per capita fish consumption distribution as a surrogate for subsistence fishers, which corresponded to a range of average consumption estimates from actual surveys for subsistence fishers. (see **comments 1** at right) An analysis of protectiveness of the criteria for the general population, recreational fishers and subsistence fishers should be included in the criteria documentation.	**Comment 1.** We think it is clear from the EPA 2000 guidance, as reiterated in this FAQ, that final criteria development should be underlain by clear statements on risk management decisions made by the states and on the levels of risk/protection that are provided by new HHC. As stated at left, that clarity should apply to "the general population, recreational fishers and subsistence fishers." Note: Idaho's request for assistance in planning and/or conducting a survey of the general population of Idaho was recently refused by EPA. Given this FAQ direction, we would like greater clarification from EPA on why they were not supportive given their statement highlighted at left.

Draft Environmental Impact Statement on Two Joint State and Tribal Resource Management Plans for Puget Sound Salmon and Steelhead Hatchery Programs

July 2014

NOAA
FISHERIES
West Coast Region

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Puget Sound Hatcheries Draft EIS

Appendix K

Chemicals Used in Hatchery Operations

Table of Contents

Hatchery operations routinely use a variety of chemicals to maintain a clean environment for the production of disease-free fish. These chemicals and safe handling requirements for the chemicals are described in this appendix. A brief description of commonly used chemicals in hatchery facilities and operations is provided below. In addition, a literature review is provided describing the potential for toxic contaminants in salmon and steelhead. This appendix provides information in support of Environmental Impact Statement (EIS) Subsection 3.7, Human Health, and EIS Subsection 4.7, Human Health.

1.0 Commonly Used Hatchery Chemicals

Common chemicals used in hatchery operations are disinfectants, therapeutics, anesthetics, pesticides and herbicides, and feed additives.

1.1 Disinfectants

Disinfectants are primarily used to clean equipment throughout hatchery facilities and may also be used to treat fish diseases. Hatchery facility workers are typically exposed to these chemicals through skin contact or inhalation during cleaning activities. However, Federal and state occupational safety and health programs (e.g., Occupational Safety and Health Act [OSHA], Washington State Industrial Safety and Health Act [WISHA]) ensure safe workplaces and require personal protective equipment and procedures (e.g., gloves, use of proper ventilation procedures, and/or respiratory protection in enclosed spaces). Following directions on product labels and using other hatchery-specific safety measures reduces chemical exposure to safe levels. Some common disinfectants used in hatchery operations are described below.

- **Chlorine (sodium hypochlorite).** Sodium hypochlorite is used for cleaning tanks and equipment and is the active component in chlorine. This compound may also be used to destroy fish fry that are infected with a disease.
- **Chloramine T.** Chloramine T is used for disinfecting tanks and equipment, and the treatment of bacterial gill diseases in salmon and steelhead. The active component is chlorine.
- **Formalin.** Formalin is a saturated aqueous solution of formaldehyde. It is used as a general disinfectant and is effective against fungal or parasitic infections.
- **Hydrogen peroxide.** Hydrogen peroxide is used as a general disinfectant and is effective against fish parasites (e.g., sea lice).
- **Iodophor.** Iodophor is a form of stabilized iodine employed as a general disinfectant. It is used to disinfect fish eggs and is effective against some bacteria and viruses.

- **Quaternary ammonium compounds (Hyamine).** Ammonium compounds or topical disinfectants are used to remove parasites from fish and have detergent and antibacterial properties.

1.2 Therapeutics

Therapeutics, which include antibiotics, are chemicals or veterinary medicines designed to be effective against parasitic, bacterial, or viral infections in fish. The most commonly used therapeutics in salmon and steelhead hatchery operations are:

- **Amoxicillin.** Amoxicillin is generally used as a veterinary antibiotic.
- **Erythromycin.** Erythromycin is generally used as a veterinary antibiotic.
- **Florfenicol.** Florfenicol is generally used as a veterinary antibiotic.
- **Oxytetracycline (terramycin).** Terramycin is widely used as an antibiotic. Oxytetracycline may be applied orally in fish feed or as a bath and is effective against a wide range of bacteria.
- **Potassium permanganate.** Potassium permanganate is primarily used as a bath treatment for fungal infections of finfish. It may also be used to alleviate acute oxygen shortage and to remove organic contaminants in fish ponds.
- **Penicillin.** Penicillin is generally used as a veterinary antibiotic.
- **ROMET®.** ROMET® is typically applied in fish feed and used to control a variety of bacterial infections.
- **Sulfamethazole trimethoprim.** Sulfamethazole trimethoprim is generally used as a veterinary antibiotic.
- **Vaccines.** Vaccines are generally used to treat viral diseases. There are a variety of vaccines available to treat animals in aquaculture. Salmon may be given vaccines to treat furunculosis, vibriosis, or yersiniosis. These vaccines are generally not considered a potential risk for human health since viral diseases of fish are typically not pathogenic to humans (World Health Organization [WHO] 1999), and the potential for exposure is minimal. The primary exposure pathway tends to be through accidental needle-stick injury (Douglas 1995; Leira and Baalsrud 1997).

Therapeutics typically are only applied when fish health specialists have determined that a disease is present in fish rearing in hatcheries. Human exposure to these chemicals typically would occur through skin contact by hatchery workers during application of the compound or through accidental needle pricks during vaccinations. However, Federal and state occupational safety regulations (e.g., Occupational Safety and Health Act of 1970 [29 United States Code [USC] 651 et seq.]) are in place to prevent these types of accidents.

Outside of the use of therapeutic chemicals in the workplace, there are two primary environmental concerns with the use of therapeutics in hatchery facility operations:

1. Therapeutic substances are not 100 percent absorbed by the fish and may be excreted into the holding water (Texas Agricultural Extension Service 1994; Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection [GESAMP] 1997; Milewski 2001). Government agencies typically do not regulate disposal of chemicals in fish waste products; therefore, there is a potential for these chemicals to enter the environment surrounding the hatcheries (Texas Agricultural Extension Service 1994; GESAMP 1997; Milewski 2001). Federal Clean Water Act and state surface water regulations prevent the discharge of chemicals at concentrations that may pose a threat to human health. However, water quality regulations currently do not exist for all veterinary products, medicines, or their by-products when incompletely metabolized. The environmental persistence of therapeutic substances varies, and some may degrade in a few hours to a few months (GESAMP 1997). Antibiotics used at hatcheries have been detected in receiving waters downstream of aquaculture operations (Boxall et al. 2004; Pouliquen et al. 2009; Martinez-Bueno et al. 2009). Moreover, studies suggest these compounds may persist in sediments (Pouliquen et al. 2009; Martinez-Bueno et al. 2009).

   Therapeutics are typically applied infrequently and at low doses (GESAMP 1997). The use of therapeutics is governed by the Federal Drug Administration (FDA) through the Animal Medicinal Drug Use Clarification Act of 1994 (21 Code of Federal Regulations [CFR] 530), which does not permit extra-label use of drugs that are administered through feed (MacMillan et al. 2006). Currently, the volume of therapeutics released from hatcheries and the potential risks associated with these releases are unknown. Concentrations that have been reported in receiving waters near fish farms and hatcheries in other parts of the United States and in Europe are usually well below those toxic to fish and invertebrates (Boxall et al. 2004). It is expected that limited use of veterinary medicines following label instructions in U.S. fish hatcheries poses minimal risk to human health and the environment (GESAMP 1997; MacMillan et al. 2006), although locally high concentrations could occur depending on the nature of the receiving environment.

2. The use of antibiotics may increase the potential for the development of resistance in certain strains of bacteria (Burka et al. 1997; GESAMP 1997; WHO 1999). Therefore, overuse of antibiotics could render them ineffective for control of some bacteria. Resistant bacteria that infect fish have the potential to transfer resistant genetic material to bacteria that infect non-fish organisms (e.g., humans). Genetic bacterial resistance may occur by the movement of plasmids (i.e., genetic elements independent of the chromosome) between bacteria. This type of transfer has been demonstrated in a number of microorganisms (Burka et al. 1997; GESAMP 1997; WHO 1999; Cabello 2006). Therefore, the improper use of antibacterial antibiotics may cause resistance in bacterial pathogens that can infect humans (Burka et al. 1997; GESAMP 1997; WHO 1999; Cabello 2006). The use of therapeutics is governed by the FDA through the Animal Medicinal Drug Use Clarification Act of 1994 (21 CFR 530), which does not permit therapeutics for uses not specified in the drug's label (MacMillan et al. 2006). Adhering to this regulation and drug label recommendations minimizes the potential for the development of antibiotic resistance.

1.3 Anesthetics

Anesthetics are commonly used to immobilize fish during egg or milt collection, to calm fish during transportation, or during treatment with other therapeutics. They are typically applied or used at low concentrations and, thus, represent a low risk to human health (GESAMP 1997) when handled using general safety precautions (i.e., Federal OSHA or state WISHA regulations) and following label requirements. Some common anesthetics used in hatchery operations are:

- **Benzocaine.** Benzocaine is used during egg or milt stripping or during preparation for transport.
- **Tricaine methanesulfonate (MS-222).** MS-222 is used as a general sedative and applied as a bath in the holding tanks.

1.4 Pesticides and Herbicides

A wide variety of aquatic pesticides and herbicides is used in hatchery facility operations to protect fish from parasites and remove nuisance organisms, weeds, or algae. Due to their toxicity, a number of these chemicals are not approved for use in the United States. For hatcheries, pesticides and herbicides are typically highly toxic and are used in small concentrations to control algae growth or aquatic weed growth. Commonly used algaecides approved for use in the United States may contain various forms of copper. Some common aquatic herbicides include dichlobenil, diquat, endothall, fluridone, glyphosate, 2,4-dichlorophenoxyacetic acid, and 2-butoxyethyl ester. These products may be hazardous to human health if prolonged or accidental exposure (i.e., inhalation, ingestion, or dermal contact) occurs because these compounds may be toxic at certain concentrations. Some of these products have bacteria as the active ingredient (e.g., Microbe Lift and Liquid Live Micro-organism) rather than a chemical ingredient to reduce the growth of pests. These products are typically less toxic to human health than synthetic chemicals. Safety measures on the product label and the material safety data sheet (MSDS) provide directions for proper use and applications. These safety measures, along with Federal OSHA and state WISHA regulations, serve to limit human exposure to potentially hazardous concentrations.

1.5 Feed Additives

While in hatchery facilities, hatchery-origin fish are fed with commercial diets containing fish oil and fish meal that can be from sources anywhere in the world. These feeds are known sources of toxic contaminants (Jacobs et al. 2002a; Carlson and Hites 2005; Maule et al. 2007; Johnson et al. 2010). The potential risk to human health from these contaminants is discussed further in Subsection 3.7.2, Toxic Contaminants in Hatchery-origin Fish.

Hatcheries may also use fish food that is supplemented with a variety of dietary additives. Fish raised and released from hatcheries are only fed (including dietary additives) while they are juveniles, which differs from fish raised in aquaculture farms that consume feeds and additives throughout their life. These additives may consist of artificial or natural pigments, fish oils, and/or vitamins. For example, astaxanthin and canthaxanthin are carotenoids commonly used in aquaculture to artificially color the flesh of salmon during the later stages of growth, since farm-raised fish tend to be less colorful than hatchery- or natural-origin fish. Vitamin C and Vitamin E are widely used to enhance the disease resistance of fish stocks. Exposure to feed additives from hatchery-origin fish is considered to be of low risk to human health because the concentrations used in hatcheries are typically below levels that would result in adverse health effects (GESAMP 1997).

1.6 Miscellaneous Chemicals

A variety of other chemicals are typically used at salmon and steelhead hatcheries. These chemicals are considered nonhazardous and, when used within the product label requirements and following OSHA regulations, are not expected to pose a risk to human health.

- **Anhydrous (3thyl) alcohol.** Ethyl alcohol is one of two chemicals used in a solution used to check the fertilization of eggs.
- **Lime (Type S).** Lime is widely used to neutralize acidity and increase total alkalinity of grow-out ponds.

- **Salt (sodium chloride).** Salt can be used to remove parasites or prevent stress during transport of fish.
- **Sodium thiosulfate.** Sodium thiosulfate is used to neutralize chlorine and iodophor prior to discharging wastewater.

2.0 Toxic Contaminants in Hatchery-origin Fish

Seafood consumption by humans is generally promoted due to the nutritional value of fish products. For example, fish contain elevated levels of omega-3 fatty acids, which are considered beneficial to the cardiovascular system (Mayo Clinic 2014). However, concerns have been raised that farm-raised and hatchery-origin fish may contain toxic contaminants (WHO 1999; Easton et al. 2002; Jacobs et al. 2002a; Jacobs et al. 2002b; Hites et al. 2004) that pose a health risk to consumers. Sources of contaminants in fish include chemicals or therapeutics, contamination of the nutritional supplements or feeds, and/or contamination of the environment where the fish are reared or released (Easton et al. 2002; Jacobs et al. 2002a; Jacobs et al. 2002b; Hites et al. 2004; Carlson and Hites 2005; Johnson et al. 2007; Maule et al. 2007; Kelly et al. 2008; Johnson et al. 2010). The contaminants of primary concern are those that are persistent in the environment and are known to accumulate in the tissues of fish (e.g., methylmercury, dioxins, dichlorodiphenyltrichloroethane [DDT] and its metabolites, or polychlorinated biphenyls [PCBs]) (Easton et al. 2002; Jacobs et al. 2002a; Jacobs et al. 2002b; Hites et al. 2004; Johnson et al. 2007; Maule et al. 2007; Kelly et al. 2008; Johnson et al. 2010).

Commercial diets fed to farm-raised and to hatchery-origin fish are known sources of toxic contaminants. Contaminant concentrations (e.g., pesticides, PCBs) measured in farm-raised fish are higher than in natural-origin fish (Hites et al. 2004; Hamilton et al. 2005), and the use of commercial feed in hatchery facilities may also contribute to higher concentrations of organic pollutants in hatchery-reared fish compared to their natural-origin counterparts (Johnson et al. 2007).

Hites et al. (2004) found that farm-raised salmon contained substantially more chemical pollutants than fish caught in the wild. This study suggested that these pollutants were originating from fish pellets that contain the dried and compressed body parts and toxicants from several whole fish, which they compared to a natural-origin salmon that eats a few bites of a single fish. In recent studies completed by Johnson et al. (2007), high concentrations of both PCBs and DDTs, comparable to those observed in farmed salmon, were found in juvenile hatchery-origin Chinook salmon. The authors attributed this effect in part to high body fat levels in hatchery-reared juveniles, which facilitates the uptake of lipid soluble contaminants, but concluded that there was too little information on contaminant concentrations in different lots of feed and in fish from different hatcheries, and concentrations were potentially too variable to determine how fish feed affects contaminant levels in hatchery-origin fish. The authors stated that more comprehensive sampling of fish and feed from hatcheries would be needed to determine the extent of the problem in the Pacific Northwest (which includes the project area). In a more recent study (Johnson et al. 2010), subyearling Chinook salmon were sampled from eight hatcheries that release juvenile salmon into the Columbia River. Concentrations of PCBs and DDTs were found to be lower than those reported from previous studies (i.e., in Johnson et al. 2007), and were generally comparable to levels observed in juvenile salmon from minimally contaminated rural estuaries. Contaminant concentrations were higher in the earlier study, in part, because the fish sampled were older and larger than those sampled in the more recent study, but the differences could also be related to differences in contaminant concentrations in feed or in the hatchery environment.

Various investigations have examined the amount of organic contaminants in commercial fish feeds, and found elevated levels of PCBs, polycyclic aromatic hydrocarbons [PAHs], and pesticides (Easton et al. 2002; Jacobs et al. 2002a; Jacobs et al. 2002b; Hites et al. 2004; Neergaard 2004; Carlson and Hites 2005). In a study of contaminants in fish feeds used at National Fish Hatcheries, Maule et al. (2007) found contaminants present, although generally at lower concentrations than those reported by the investigators cited above. The U.S. Geological Survey (USGS) and U.S. Fish and Wildlife Service (USFWS) have continued studying contaminants in feeds and fish (USGS 2012) at several Federal hatcheries in the USFWS Pacific Region to 1) evaluate and compare overall contaminant levels, 2) identify temporal differences in contaminant levels found in various feed forms, 3) evaluate contaminant levels and bioaccumulation rates of different commercial diets in various life-stage history classes, 4) assess the re-distribution of contaminants during smoltification, and 5) simulate the release of fish from a hatchery by fasting fish and monitoring the mobilization and re-distribution of contaminants.

Another potential source of contaminants for hatchery-origin fish includes construction materials found within hatcheries. For example, PCBs identified in fish from the Leavenworth National Fish Hatchery in the Columbia River basin were found to be related to the paint lining fish tanks (Cornwall 2005). Some hatchery facilities in Puget Sound were constructed in the early to mid-1900s and may contain chemicals in historical building materials (e.g., paint) that are banned in current materials. Other sampling for toxic substances is ongoing at national fish hatcheries (Cornwall 2005), and the U.S. Environmental Protection Agency's (EPA's) National Pollutant Discharge Elimination System (NPDES) general permit for Federal and tribal facilities requires hatcheries to include information on painted and caulked surfaces that regularly contact process water when they apply for general permit coverage (EPA 2009). While the potential for exposure of hatchery-raised fish to contaminants in building materials exists, further incidents have not been reported.

While hatchery-origin fish may contain chemicals of concern, the risks to humans from consumption of contaminants in hatchery-origin fish remain uncertain. The potential for human exposure to contaminants in fish is directly tied to the frequency of consuming fish (EPA 1999). Thus, consumer groups that eat large amounts of fish may have a higher potential for exposure to contaminants. Current information on consumption patterns suggests that some groups of people may consume greater quantities of fish than the general population (often termed subsistence consumers) (EPA 1999; ODEQ 2008; Ecology 2013). However, information is not available to determine what proportion of the diet of subsistence consumers comes from hatchery-origin or farm-raised fish. In addition, not all the contaminants in hatchery-origin fish are derived from hatchery facilities and their operation.

Migrating and rearing salmon and steelhead encounter and accumulate additional contaminants in the rivers, estuaries, and oceans that they inhabit (Missildine et al. 2005; Johnson et al. 2007). It is unknown what proportion of contaminants present in hatchery-origin fish originates from hatcheries and what proportion originates after release. It is also unknown whether those contaminant levels pose a risk to human health. Johnson et al. (2010) suggested that the greatest accumulation of contaminants in the bodies of hatchery-origin juvenile salmon that feed and rear in urban areas occurs after the fish are released from hatcheries. In contrast, for juvenile hatchery-origin fish that are released into relatively uncontaminated rural areas, hatcheries can be a primary source of contaminants. Contaminants accumulated during hatchery rearing would probably contribute very little to concentrations of contaminants in returning adult salmon, since concentrations acquired only during the relatively short juvenile rearing period would be diluted as the fish grew larger to adulthood. Studies suggest that, for returning adult salmon, most of the contaminants present in their bodies are acquired during their time at sea (Kelly et al. 2007; Cullon et al. 2009; O’Neill and West 2009). An exception would be resident Chinook salmon that rear in Puget Sound (about 4 percent of Chinook salmon releases), and may carry a heavier load of contaminants than other salmon that spend more time at sea. Outside of resident Chinook salmon, there is no available information that demonstrates hatchery-origin fish have a greater proportion of contaminates than natural-origin fish, and thus, it is assumed that hatchery-origin salmon and steelhead do not present a greater threat of contamination than natural-origin salmon and steelhead. The Washington Department of Fish and Wildlife currently monitors toxic contaminants in fish and other organisms, as a member of the Puget Sound Ecosystem Monitoring Program.

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CAAP
General Permit
Permit No.: MTG130000

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

CONCENTRATED AQUATIC ANIMAL PRODUCTION GENERAL PERMIT

AUTHORIZATION TO DISCHARGE UNDER THE

MONTANA POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with Montana Water Quality Act, Title 75, Chapter 5, Montana Code Annotated (MCA), and the Federal Water Pollution Control Act (the "Clean Water Act"), 33 U.S.C. 1251 et. seq., applicants issued an authorization letter for this Fish Farm General Permit, are permitted to discharge wastewater effluent from fish farms and hatcheries to state waters in accordance with effluent limitations, monitoring requirements and other conditions set forth herein.

A written authorization letter from the Department is required before an applicant is authorized to discharge under the Fish Farm General Permit.

This permit shall become effective: **July 1, 2011**.

This permit and the authorization to discharge shall expire at midnight: **June 30, 2016**.

COPY

FOR THE MONTANA DEPARTMENT
OF ENVIRONMENTAL QUALITY

Jenny Chambers

Jenny Chambers, Chief
Water Protection Bureau
Permitting and Compliance Division

Issuance Date: July 1, 2011

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Cover Sheet--Issuance and Expiration Dates

I. EFFLUENT LIMITATIONS, MONITORING REQUIREMENTS, & OTHER CONDITIONS

A. Specific Effluent Limitations

Effectively immediately upon issuance of an authorization under this general permit and lasting for the duration of the permit, the following effluent limitations apply to all fish farm facilities covered by this general permit.

1. All facilities must develop and implement a Best Management Practices (BMP) plan to minimize the discharge of hatchery wastes to state waters. The plan shall be developed and submitted to the Department for review and approval, postmarked within 90 days of the date on the authorization letter. Thereafter the plan shall be updated annually and a copy, dated and signed by the facility manager, shall be kept onsite and be available for inspection. The plan must include the minimum requirements described in Part I.C.

2. There shall be no discharge of polychlorinated byphenyls (PCBs) in excess of 0.00065 µg/L in any sample. Analytical results less than the required reporting value (RRV) of 1 µg/L shall be reported as zero on the DMR and will be considered in compliance with this limit.

3. Drug and chemical use shall be limited to those approved by the Food and Drug Administration for use in aquaculture in accordance with label requirements. Pesticides must be registered for use in Montana by the Montana Department of Agriculture. Any extra-label use of approved drugs and chemicals or use of unapproved drugs and chemicals will require case-by-case approval by the Department prior to the discharge to state waters. All drug and chemical use shall be documented in the annual BMP plan.

4. Any additional requirements specified in the authorization letter.

B. Self-Monitoring Requirements

Upon the effective date of this permit, the following constituents shall be monitored at the frequency and with the type of measurement indicated; samples or measurements shall be representative of the volume and nature of the monitored discharge.

Discharge monitoring shall be conducted at the end of pipe, prior to discharge to the receiving water. Samples from multiple discharge pipes shall be flow proportioned and composited prior to analysis.

Parameter	Frequency	Type(1)	RRV
Flow Rate (gpm)	Monthly (2)	Instantaneous	NA
PCBs µg/L	Semi-Annual	Grab	1 µg/L
Fish Food Fed (lbs/day)	Daily (3)	Measured	NA
Total Suspended Solids(4) (mg/L)	Semi-Annual	Grab	1 mg/L

(1) See the definitions in Part I.A. of the permit.
(2) Both the average flow during the monitoring period and the highest average monthly flow shall be reported. Flow rate may be established via either influent or effluent flow.
(3) Both the average daily feeding rate during the monitoring period and the maximum daily feeding rate shall be reported
(4) TSS monitoring is only required at facilities with production greater than or equal to 20,000 pounds per year

All monitoring shall be reported semi-annually on Discharge Monitoring Report (DMR) forms (EPA No. 3320-1).

All monitoring shall be conducted during the month of maximum feeding within the monitoring period.

C. Best Management Practices Plan

The BMP plan shall be developed and implemented as described in Part I.A. The plan shall include, at a minimum, the following:

1. A written plan for the efficient feeding of fish in the facility that will maximize feed conversion and minimize the amount of metabolic wastes and uneaten food produced, and still allow the achievement of production goals. This plan could include, but is not limited to, the following: projected annual production, feeding methods that will be used, appropriate record-keeping of feed consumption, feed storage and handling methods, and any other means employed to minimize waste solids.

2. A description and schedule of cleaning and maintenance activities that will minimize the amount of waste discharged at any one time. This must include, at a minimum,

the weekly cleaning of raceways, unless otherwise approved for a specific fish species' rearing requirements in an approved BMP plan. Records of raceway cleaning must be maintained on site.

3. A description, including dosage rates, total quantity used, and calculated concentrations, of all drugs and chemicals that will be used routinely in hatchery operations.

Facilities that produce 20,000 pounds or more of fish per year shall be subject to the following requirements and prohibitions:

4. As part of the BMP plan each facility shall record and maintain on site records of the total pounds of food fed for the previous calendar year, the total weight gain of all fish in the facility the previous calendar year, and the corresponding feed conversion ratio (FCR). FCRs may be calculated for individual lots of fish, providing all fish produced are accounted for.

5. Sweeping accumulated solids from raceways or ponds to state waters without treatment is prohibited.

6. Practices such as the removal of dam boards or standpipes in raceways or ponds, which allow accumulated solids to discharge to state waters without treatment, are prohibited.

7. The BMP plan must include a description of the methods for cleaning accumulated wastes from settling basins of other treatment units. The plan must also address the disposal of the wastes in such a manner that they will not reach state waters.

Facilities that produce 100,000 pounds, or more, of fish per year are also subject to the specific federal ELG limits of 40 CFR 451 as follows:

(a) Solids control. The permittee must:

1. Employ efficient feed management and feeding strategies that limit feed input to the minimum amount reasonably necessary to achieve production goals and sustain targeted rates of aquatic animal growth in order to minimize potential discharges of uneaten feed and waste products to water of the U.S.
2. In order to minimize the discharge of accumulated solids from settling ponds and basins and production systems, identify and implement procedures for routine cleaning of rearing units and off-line settling basins, and procedures to minimize any discharge of accumulated solids during the inventorying, grading, and harvesting of aquatic animals in the production system.
3. Remove and dispose of aquatic animal mortalities properly on a regular basis to prevent discharge to state waters, except in cases where the permitting authority authorizes such discharge in order to benefit the aquatic environment.

(b) Materials storage. The permittee must:

1. Ensure proper storage of drugs, pesticides, and feed in a manner designed to prevent spills that may result in the discharge of drugs, pesticides, or feed to state waters.
2. Implement procedures for properly containing, cleaning and disposing of any spilled material.

(c) Structural maintenance. The permittee must:

1. Inspect the production system and the wastewater treatment system on a routine basis in order to identify and promptly repair any damage.
2. Conduct regular maintenance of the production system and the wastewater treatment system in order to ensure that they are properly functioning.

(d) Recordkeeping. The permittee must:

1. In order to calculate representative feed conversion ratios, maintain records for aquatic animal rearing units documenting the feed amounts and estimates of the numbers and weight of aquatic animals.
2. Keep records documenting the frequency of cleaning, inspections, maintenance and repairs.

(e) Training

1. In order to ensure the proper clean-up and disposal of spilled material adequately train all relevant facility personnel in spill prevention and how to respond in the event of a spill.
2. Train staff on the proper operation and cleaning of production and wastewater treatment systems including training in feeding procedures and proper use of equipment.

II. MONITORING, RECORDING AND REPORTING REQUIREMENTS

A. Reporting Requirements

All required monitoring shall be reported on a Discharge Monitoring Report (DMR), postmarked no later than the 28th day of the month following the monitoring period. Submit completed DMR forms and all reports to the following address:

Montana Department of Environmental Quality
Water Protection Bureau
P.O. Box 200901
Helena, Montana 59620-0901
Phone: (406) 444-3080

B. Monitoring Procedures

Monitoring must be conducted according to test procedures approved under Part 136 Title 40 of the Code of Federal Regulations, unless other test procedures have been specified in this permit.

C. Additional Monitoring by Permittee

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit the results of such monitoring shall be included in the DMR form. Such increased frequency shall be indicated.

D. Record Retention

All records and information resulting from the monitoring activities required by this permit shall be retained for a minimum of three (3) years, or longer if requested by the Department.

E. Noncompliance Notification

If for any reason, the permittee does not comply with or will be unable to comply with any effluent limitation specified in this permit, the permittee shall notify as soon as possible by phone and provide the Department with the following information, in writing, within five (5) days of becoming aware of such condition:

1. A description of the discharge and cause of noncompliance; and
2. The period of noncompliance including exact dates and times, or if not corrected, the anticipated time the noncompliance is expected to continue, and steps being taken to reduce, eliminate and prevent recurrence of the non-complying discharge.

F. Inspection and Entry

The permittee shall allow the head of the Department or the Regional Administrator, or an authorized representative, upon the presentation of credentials and other documents as may be required by law, to:

1. Enter upon the permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this permit;

2. Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;

3. Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and,

4. Sample, or monitor at reasonable times for the purpose of assuring permit compliance, any substances or parameters at any location.

III. COMPLIANCE RESPONSIBILITIES

A. Duty to Comply

The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Act and is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or for denial of a permit renewal application. The permittee shall give the Department advance notice of any planned changes at the permitted facility or of an activity, which may result in permit noncompliance.

B. Penalties for Violations of Permit Conditions

The Montana Water Quality Act provides that any person who violates a permit condition of the Act is subject to civil or criminal penalties not to exceed $25,000 per day of such violation. Any person who willfully or negligently violates permit conditions of the Act is subject to a fine of not more than $50,000 per day of violation, or by imprisonment for not more than 2 years, or both. Except as provided in permit conditions on Part III.G of this permit, "Bypass of Treatment Facilities" and Part III.H of this permit, "Upset Conditions", nothing in this permit shall be construed to relieve the permittee of the civil or criminal penalties for noncompliance.

C. Need to Halt or Reduce Activity not a Defense

It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

D. Duty to Mitigate

The permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit, which has a reasonable likelihood of adversely affecting human health or the environment.

E. Toxic Pollutants

The permittee shall comply with effluent standards or prohibitions established under Section 307(a) of the Act for toxic pollutants within the time provided in the regulations that establish those standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

F. Changes in Discharge of Toxic Substances

Notification shall be provided to the Department as soon as the permittee knows of, or has reason to believe:

1. That any activity has occurred or will occur which would result in the discharge, on a routine or frequent basis, of any toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels":

    a. One hundred micrograms per liter (100 μg/*l*);

b. Two hundred micrograms per liter (200 μg/*l*) for acrolein and acrylonitrile; five hundred micrograms per liter (500 μg/*l*) for 2,4-dinitrophenol and for 2-methyl-4, 6-dinitrophenol; and one milligram per liter (1 mg/*l*) for antimony;

c. Five (5) times the maximum concentration value reported for that pollutant in the permit application in accordance with 40 CFR 122.21(g)(7); or,

d. The level established by the Department in accordance with 40 CFR 122.44(f).

2. That any activity has occurred or will occur which would result in any discharge, on a non-routine or infrequent basis, of a toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels":

   a. Five hundred micrograms per liter (500 μg/*l*);

   b. One milligram per liter (1 mg/*l*) for antimony:

   c. Ten (10) times the maximum concentration value reported for that pollutant in the permit application in accordance with 40 CFR 122.21(g)(7); or,

   d. The level established by the Department in accordance with 40 CFR 122.44(f).

IV. GENERAL REQUIREMENTS

A. Planned Changes
The permittee shall give notice to the Department as soon as possible of any planned physical alterations or additions to the permitted facility. Notice is required only when the alteration or addition could significantly change the nature or increase the quantity of pollutant discharged. This notification applies to pollutants, which are not subject to effluent limitations in the permit.

B. Anticipated Noncompliance
The permittee shall give advance notice to the Department of any planned changes in the permitted facility or activity, which may result in noncompliance with permit requirements.

C. Permit Actions
This permit may be modified, revoked and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance, does not stay any permit condition.

D. Duty to Reapply
If the permittee wishes to continue an activity regulated by this permit after the expiration date of the authorization to discharge, the permittee must apply for and obtain a new authorization. The request must be submitted at least 180 days before the anticipated operation date. A new application must be submitted with the correct application fee after the fifth year of operation and shall be submitted within 180 days before the anticipated operation date.

E. Duty to Provide Information
The permittee shall furnish to the Department, within a reasonable time, any information which the Department may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee shall also furnish to the Department, upon request, copies of records required to be kept by this permit.

F. Other Information
When the permittee becomes aware that it failed to submit any relevant facts in a permit application, or submitted incorrect information in a permit application or any report to the Department, it shall promptly submit such facts or information.

G. Signatory Requirements
All applications, reports or information submitted to the Department shall be signed and certified.

1. All permit applications shall be signed as follows:

a. For a corporation: by a responsible corporate officer;

b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively;

c. For a municipality, State, Federal, or other public agency: by either a principal executive officer or ranking elected official.

2. All reports required by the permit and other information requested by the Department shall be signed by a person described above or by a duly authorized representative of that person. A person is considered a duly authorized representative only if:

   a. The authorization is made in writing by a person described above and submitted to the Department, and,

   b. The authorization specified either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of plant manager, operator of a well or a well field, superintendent, position of equivalent responsibility, or an individual or position having overall responsibility for environmental matters for the company. (A duly authorized representative may thus be either a named individual or any individual occupying a named position.)

3. Changes to authorization. If an authorization under Part IV.G.2 of this permit is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of Part IV.G.2 of this permit must be submitted to the Department prior to or together with any reports, information, or applications to be signed by an authorized representative.

4. Certification. Any person signing a document under this section shall make the following certification:

> "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

H. Penalties for Falsification of Reports

The Montana Water Quality Act provides that any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance shall, upon conviction be punished by a fine of not more than $25,000 per violation, or by imprisonment for not more than six months per violation, or by both.

I. Availability of Reports

Except for data determined to be confidential under 40 CFR Part 2, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Department. As required by the Clean Water Act, permit applications, permits and effluent data shall not be considered confidential.

J. Oil and Hazardous Substance Liability

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under Section 311 of the Clean Water Act.

K. Property or Water Rights

The issuance of this permit does not convey any property or water rights of any sort, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of federal, state or local laws or regulations.

L. Severability

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

M. Transfers

This permit cannot be transferred to a new permittee. A new owner or operator of a facility must apply according to the application procedures in Part IV.D of this permit 30 days prior to taking responsibility for the facility.

N. Fees

The permittee is required to submit payment of an annual fee as set forth in ARM 17.30.201. If the permittee fails to pay the annual fee within 90 days after the due date for payment, the Department may:

1. Impose an additional assessment consisting of 15% of the fee plus interest on the required fee computed at the rate established under 15-31-510(3), MCA; or

2. Suspend the processing of the application for a permit or authorization or, if the nonpayment involves an annual permit fee, suspend the permit, certificate, license

or other authorization for which the fee is required. The Department may lift the suspension at any time up to one year after the suspension occurs if the holder has paid all outstanding fees, including all penalties, assessments and interest imposed under this subsection.

O. Reopener Provisions

This permit may be reopened and modified (following proper administrative procedures) to include the appropriate effluent limitations (and compliance schedule, if necessary), or other appropriate requirements if one or more of the following events occurs:

1. Water Quality Standards: The water quality standards of the receiving water(s) to which the permittee discharges are modified in such a manner as to require different effluent limits than contained in this permit.

2. TMDL or Wasteload Allocation: TMDL requirements or a wasteload allocation is developed and approved by the Department and/or EPA for incorporation in this permit.

3. Water Quality Management Plan: A revision to the current water quality management plan is approved and adopted which calls for different effluent limitations than contained in this permit.

4. Toxic Pollutants: A toxic standard or prohibition is established under Section 307(a) of the Act for a toxic pollutant which is present in the discharge and such standard or prohibition is more stringent than any limitation for such pollutant in this permit.

V. DEFINITIONS

1. "**Department**" means the Montana Department of Environmental Quality (MDEQ).

2. A "**grab**" sample, for monitoring requirements, is defined as a single "dip and take" sample collected at a representative point in the discharge stream.

3. An "**instantaneous**" measurement, for monitoring requirements, is defined as a single reading, observation, or measurement.

4. A "**mixing zone**" means a limited area of a surface water body or aquifer where initial dilution of a discharge takes place and where water quality changes may occur. Also recognized as an area where certain water quality standards may be exceeded.

5. "**Non-degradation**" means the prevention of a significant change in water quality that lowers the quality of high-quality water for one or more parameters. Also, the prohibition of any increase in discharge that exceeds the limits established under or determined from a permit or approval issued by the Department prior to April 29, 1993.

6. The term "**TMDL**" means the total maximum daily load limitation of a parameter, representing the estimated assimilative capacity for a water body before other designated uses are adversely affected. Mathematically, it is the sum of wasteload allocations for point sources, load allocations for non-point and natural background sources, and a margin of safety.

7. The **"receiving stream"** means the river, stream, or creek, which receives the wastewater discharge from the facility.

FRESHWATER

DRAFT Comparison: Washington National Toxic Rule (NTR) criteria versus Oregon Human Health Criteria

Grouped by: ➡

More protective criteria could result in new permit limit where detected	More protective criteria non-detect in effluent sample	New criteria	Equal or less protective than current NTR criteria

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Blue values = less protective

NTR Chem #	Chemical Name (Non-Carcinogens / Carcinogens)	CAS #	NTR Criterion Water and Organisms (µg/L) based on 6.5 Grams/Day	Oregon Criterion Water and Organisms (µg/L) based on **175 grams/day** Includes updated RSCs, RfDs, Cancer Slope Factors, and other modifications specific to Hg & As	Is Oregon's revised criterion is more protective?	Percent decrease between WA & OR Criteria	Priority Pollutant Scan Data Detection From preliminary data as presented in Policy Forum #3. (Ecology staff are in the process of reviewing all available effluent datasets to determine if any other chemicals have been detected in discharge.)	EPA method number	Detection Level (DL) (µg/L)	Quantitation Level (QL) (µg/L)
77	1,4-Dichlorobenzene	106467	**397**	**16**	Yes	**96%**	Detected	624	4.4	17.6
1	Antimony	7440360	**14**	**5.1**	Yes	**63%**	Detected	200.8	0.3	1
68	Bis(2-Ethylhexyl) Phthalate	117817	**1.8**	**0.20**	Yes	**89%**	Detected and Quantified	625	0.1	0.5
14	Cyanide	57125	**698**	**130**	Yes	**81%**	Detected	335.4	5	10
79	Diethyl Phthalate	84662	**22,631**	**3,800**	Yes	**83%**	Detected	625	1.9	7.6
36	Methylene Chloride	75092	**4.7**	**4.3**	Yes	**8%**	Detected	624	5	10
9	Nickel	7440020	**607**	**140**	Yes	**77%**	Detected and Quantified	200.8	0.1	0.5
38	Tetrachloroethylene	127184	**0.80**	**0.24**	Yes	**70%**	Detected and Quantified	624	1	2
39	Toluene	108883	**6,765**	**720**	Yes	**89%**	Detected and Quantified	624	1	2
119	Total Polychlorinated Biphenyls (PCBs)	multiple CAS #	**0.00017**	**0.0000064**	Yes	**96%**	Detected w/ non- 40 CFR 136 methods	1668C	~ 30pg/L	~50 pg/L
			0.00017	**0.0000064**	Yes	**96%**	--	608	0.25	0.5
37	1,1,2,2-Tetrachloroethane	79345	**0.17**	**0.12**	Yes	**30%**	--	624	1.9	2
42	1,1,2-Trichloroethane	79005	**0.61**	**0.44**	Yes	**27%**	--	624	1	2
29	1,2-Dichloroethane	107062	**0.38**	**0.35**	Yes	**9%**	--	624	1	2
85	1,2-Diphenylhydrazine	122667	**0.040**	**0.014**	Yes	**65%**	--	1625B	5	20
76	1,3-Dichlorobenzene	541731	**397**	**80**	Yes	**80%**	--	624	1.9	7.6
32	1,3-Dichloropropene	542756	**10**	**0.30**	Yes	**97%**	--	624	1	2
16	2, 3, 7, 8-TCDD Dioxin	1746016	**0.000000013**	**0.00000000051**	Yes	**96%**	--	1613B	1.3E-06	0.000005

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55	2,4,6-Trichlorophenol	88062	**2.1**	**0.23**	Yes	**89%**	--	625	2	4
46	2,4-Dichlorophenol	120832	**93**	**23**	Yes	**75%**	--	625	0.5	1
49	2,4-Dinitrophenol	51285	**70**	**62.0**	Yes	**11%**	--	625	1	2
82	2,4-Dinitrotoluene	121142	**0.11**	**0.084**	Yes	**24%**	--	609/625	0.2	0.4
48	2-Methyl-4,6-Dinitrophenol	534521	**13**	**9.2**	Yes	**31%**	--	625/1625B	1	2
78	3,3'-Dichlorobenzidine	91941	**0.039**	**0.0027**	Yes	**93%**	--	605/625	0.5	1
110	4,4'-DDD	72548	**0.00083**	**0.000031**	Yes	**96%**	--	608	0.025	0.05
109	4,4'-DDE	72559	**0.00059**	**0.000022**	Yes	**96%**	--	608	0.025	0.05
108	4,4'-DDT	50293	**0.00059**	**0.000022**	Yes	**96%**	--	608	0.025	0.05
17	Acrolein	107028	**321**	**0.88**	Yes	**100%**	--	624	5	10
18	Acrylonitrile	107131	**0.059**	**0.018**	Yes	**70%**	--	624	1	2
102	Aldrin	309002	**0.00013**	**0.0000050**	Yes	**96%**	--	608	0.025	0.05
103	alpha-BHC	319846	**0.0039**	**0.00045**	Yes	**88%**	--	608	0.025	0.05
58	Anthracene	120127	**9,567**	**2,900**	Yes	**70%**	--	625	0.3	0.6
19	Benzene	71432	**1.2**	**0.44**	Yes	**63%**	--	624	1	2
59	Benzidine	92875	**0.00012**	**0.000018**	Yes	**85%**	--	625	12	24
60	Benzo(a)Anthracene	56553	**0.0028**	**0.0013**	Yes	**54%**	--	625	0.3	0.6
61	Benzo(a)Pyrene	50328	**0.0028**	**0.0013**	Yes	**54%**	--	610/625	0.5	1

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62	Benzo(b)Fluoranthene	205992	**0.0028**	**0.0013**	Yes	**54%**	--	610/625	0.8	1.6
64	Benzo(k)Fluoranthene	207089	**0.0028**	**0.0013**	Yes	**54%**	--	610/625	0.8	1.6
104	beta-BHC	319857	**0.014**	**0.0016**	Yes	**88%**	--	608	0.025	0.05
66	Bis(2-Chloroethyl)Ether	111444	**0.031**	**0.020**	Yes	**36%**	--	611/625	0.3	1
67	Bis(2-Chloroisopropyl) Ether	108601	**1,389**	**1,200**	Yes	**14%**	--	625	0.3	0.6
20	Bromoform	75252	**4.3**	**3.3**	Yes	**23%**	--	624	1	2
21	Carbon Tetrachloride	56235	**0.25**	**0.10**	Yes	**61%**	--	624/601 or SM6230B	1	2
107	Chlordane	57749	**0.00057**	**0.000081**	Yes	**86%**	--	608	0.025	0.05
22	Chlorobenzene	108907	**677**	**74**	Yes	**89%**	--	624	1	2
23	Chlorodibromomethane	124481	**0.41**	**0.31**	Yes	**25%**	--	624	2	2
73	Chrysene	218019	**0.0028**	**0.0013**	Yes	**54%**	--	610/625	0.3	0.6
80	Dimethyl Phthalate	131113	**313,000**	**84,000**	Yes	**73%**	--	625	1.6	6.4
74	Dibenzo (a,h) Anthracene	53703	**0.0028**	**0.0013**	Yes	**54%**	--	625	0.8	1.6
111	Dieldrin	60571	**0.00014**	**0.0000053**	Yes	**96%**	--	608	0.025	0.05
81	Di-n-Butyl Phthalate	84742	**2,715**	**400**	Yes	**85%**	--	625	0.5	1
115	Endrin	72208	**0.76**	**0.024**	Yes	**97%**	--	608	0.025	0.05
116	Endrin Aldehyde	7421934	**0.76**	**0.030**	Yes	**96%**	--	608	0.025	0.05
33	Ethylbenzene	100414	**3,120**	**160**	Yes	**95%**	--	624	1	2

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86	Fluoranthene	206440	**296**	**14**	Yes	**95%**	--	625	0.3	0.6
87	Fluorene	86737	**1,276**	**390**	Yes	**69%**	--	625	0.3	0.6
117	Heptachlor	76448	**0.00021**	**0.0000079**	Yes	**96%**	--	608	0.025	0.05
118	Heptachlor Epoxide	1024573	**0.00010**	**0.0000039**	Yes	**96%**	--	608	0.025	0.05
88	Hexachlorobenzene	118741	**0.00075**	**0.000029**	Yes	**96%**	--	612/625	0.3	0.6
89	Hexachlorobutadiene	87683	**0.44**	**0.36**	Yes	**19%**	--	625	0.5	1
90	Hexachloro-cyclopentadiene	77474	**240**	**30**	Yes	**88%**	--	1625B/625	0.5	1
91	Hexachloroethane	67721	**1.9**	**0.29**	Yes	**85%**	--	625	0.5	1
92	Indeno (1,2,3-cd) Pyrene	193395	**0.0028**	**0.00130**	Yes	**54%**	--	610/625	0.5	1
34	Methyl Bromide	74839	**48**	**37**	Yes	**24%**	--	624/601	5	10
95	Nitrobenzene	98953	**17**	**14**	Yes	**19%**	--	625	0.5	1
96	N-Nitrosodimethylamine	62759	**0.00069**	**0.00068**	Yes	**1%**	--	607/625	2	4
98	N-Nitrosodiphenylamine	86306	**5.0**	**0.55**	Yes	**89%**	--	625	0.5	1
53	Pentachlorophenol	87865	**0.28**	**0.15**	Yes	**47%**	--	625	0.5	1
54	Phenol	108952	**20,905**	**9,400**	Yes	**55%**	--	625	2	4
100	Pyrene	129000	**957**	**290**	Yes	**70%**	--	625	0.3	0.6
12	Thallium	7440280	**1.7**	**0.043**	Yes	**98%**	--	200.8	0.09	0.36
120	Toxaphene	8001352	**0.00073**	**0.000028**	Yes	**96%**	--	608	0.24	0.5

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DRAFT Comparison: Washington National Toxic Rule (NTR) criteria versus Oregon Human Health Criteria

Grouped by: ➡	More protective criteria could result in new permit limit where detected	More protective criteria non-detect in effluent sample	New criteria	Equal or less protective than current NTR criteria

NA = Not Applicable
NC = Not Calculated
Red values = **more protective**
Blue values = **less protective**

NTR Chem #	Chemical Name Non-Carcinogens Carcinogens	CAS #	NTR Criterion Water and Organisms (µg/L) based on **6.5** Grams/Day	Oregon Criterion Water and Organisms (µg/L) based on **175 grams/day** Includes updated RSCs, RfDs, Cancer Slope Factors, and other modifications specific to Hg & As	Is Oregon's revised criterion is more protective?	Percent decrease between WA & OR Criteria	Priority Pollutant Scan Data Detection From preliminary data as presented in Policy Forum #3. (Ecology staff are in the process of reviewing all available effluent datasets to determine if any other chemicals have been detected in discharge.)	EPA method number	Detection Level (DL) (µg/L)	Quantitation Level (QL) (µg/L)
43	Trichloroethylene	79016	**2.7**	**1.4**	Yes	**48%**	--	624	1	2
44	Vinyl Chloride	75014	**2.0**	**0.023**	Yes	**99%**	--	624/SM6200B	1	2
	1,2,4,5-Tetrachlorobenzene	95943	NC	**0.11**	Yes	NA	--			
101	1,2,4-Trichlorobenzene	120821	NC	**6.4**	Yes	NA	--	625	0.3	0.6
31	1,2-Dichloropropane	78875	NC	**0.38**	Yes	NA	--	624	1	2
40	1,2-Trans-Dichloroethylene	156605	NC	**120**	Yes	NA	--	624	1	2
	2,4,5-TP	93721	NC	**10**	Yes	NA	--			
	2,4,5-Trichlorophenol	95954	NC	**330**	Yes	NA	--			
	2,4-D	94757	NC	**100**	Yes	NA	--	6640B		
47	2,4-Dimethylphenol	105679	NC	**76**	Yes	NA	--	625	0.5	1
71	2-Chloronaphthalene	91587	NC	**150**	Yes	NA	--	625	0.3	0.6
45	2-Chlorophenol	95578	NC	**14**	Yes	NA	--	625	1	2
56	Acenaphthene	83329	NC	**95**	Yes	NA	--	625	0.2	0.4
	Barium	7440393	NC	**1,000**	Yes	NA	--	200.8	0.5	2
70	Butylbenzyl Phthalate	85687	NC	**190**	Yes	NA	--	625	0.3	0.6
	Chloromethyl ether, bis	542881	NC	**0.000024**	Yes	NA	--			
6	Copper	7440508	NC	**1,300**	Yes	NA	--	200.8	0.4	2

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	Dinitrophenols	25550587	NC	62	Yes	NA	--			
	Hexachlorocyclo-hexane,	608731	NC	0.0014	Yes	NA	--			
	Methoxychlor	72435	NC	100	Yes	NA	--	6630B&C and D3086-90		
8b	Methylmercury	22967926	NC	0.040 mg/kg	Yes	NA	--			
	Nitrates	14797558	NC	10000	Yes	NA	--			
	Nitrosamines	35576911	NC	0.00079	Yes	NA	--			
	N-Nitrosodibutylamine	924163	NC	0.005	Yes	NA	--			
	N-Nitrosodiethylamine	55185	NC	0.00079	Yes	NA	--			
97	N-Nitrosodi-n-Propylamine	621647	NC	0.0046	Yes	NA	--	607/625	0.5	1
	N-Nitrosopyrrolidine	930552	NC	0.016	Yes	NA	--			
	Pentachlorobenzene	608935	NC	0.15	Yes	NA	--			
10	Selenium	7782492	NC	120	Yes	NA	--	200.8	1	1
13	Zinc	7440666	NC	2,100	Yes	NA	--	200.8	0.5	2.5
41	1,1,1-Trichloroethane	71556	NC	NC	No	NA	--	624	1	2
28	1,1-Dichloroethane	75343	NC	NC	No	NA	--	624	1	2
30	1,1-Dichloroethylene	75354	**0.057**	230	No	NA	--	624	1	2
83	2,6-Dinitrotoluene	606202	NC	NC	No	NA	--	609/625	0.2	0.4

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25	2-Chloroethylvinyl Ether	110758	NC	NC	No	NA	--	624	1	2
50	2-Nitrophenol	88755	NC	NC	No	NA	--	625	0.5	1
52	3-Methyl-4-Chlorophenol	59507	NC	NC	No	NA	--	625	1	2
69	4-Bromophenyl Phenyl Ether	101553	NC	NC	No	NA	--	625	0.2	0.4
72	4-Chlorophenyl Phenyl Ether	7005723	NC	NC	No	NA	--	625	0.3	0.5
51	4-Nitrophenol	100027	NC	NC	No	NA	--	625	0.5	1
57	Acenaphthylene	208968	NC	NC	No	NA	--	625	0.3	0.6
15	Asbestos	1332214	**7,000,000**	**7,000,000 fibers/L**	No	NA	--			
112	alpha-Endosulfan	959988	**0.93**	**8.5**	No	NA	--	608	0.025	0.05
2	Arsenic (inorganic)	7440382	**0.017**	**2.1**	No	NA	--			
63	Benzo(ghi)Perylene	191242	NC	NC	No	NA	--	610/625	0.5	1
3	Beryllium	7440417	NC	NC	No	NA	--	200.8	0.1	0.5
113	beta-Endosulfan	33213659	**0.93**	**8.5**	No	NA	--	608	0.025	0.05
65	Bis(2-Chloroethoxy) Methane	111911	NC	NC	No	NA	--	625	5.3	21.2
4	Cadmium	7440439	NC	NC	No	NA	--	200.8	0.05	0.25
24	Chloroethane	75003	NC	NC	No	NA	--	624/601	1	2
26	Chloroform	67663	**5.7**	**260**	No	NA	Detected and Quantified	624 or SM6210B	1	2
5a	Chromium III	16065831	NC	NC	No	NA	--			

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5b	Chromium VI	18540299	NC	NC	No	NA	--	3500-Cr EC	0.3	1.2
106	delta-BHC	319868	NC	NC	No	NA	--	608	0.025	0.05
27	Dichlorobromomethane	75274	**0.27**	**0.42**	No	NA	--	624	1	2
84	Di-n-Octyl Phthalate	117840	NC	NC	No	NA	--	625	0.3	0.6
114	Endosulfan Sulfate	1031078	**0.93**	**8.5**	No	NA	--	608	0.025	0.05
105	gamma-BHC (Lindane)	58899	**0.019**	**0.17**	No	NA	--	608	0.025	0.05
93	Isophorone	78591	**8.4**	**27**	No	NA	--	625	0.5	1
7	Lead	7439921	NC	NC	No	NA	--	200.8	0.1	0.5
	Manganese	7439965	NC	NC	No	NA	--	200.8	0.1	0.5
8a	Mercury (freshwater)	7439976	**0.14**	NC	No	NA	Detected and Quantified			
35	Methyl Chloride	74873	NC	NC	No	NA	--			
94	Naphthalene	91203	NC	NC	No	NA	--	625	0.3	0.6
99	Phenanthrene	85018	NC	NC	No	NA	--	625	0.3	0.6
11	Silver	7440224	NC	NC	No	NA	--	200.8	0.04	0.2

Control of Toxic Chemicals in Puget Sound

Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011

Publication No. 11-03-055

DEPARTMENT OF
ECOLOGY
State of Washington

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Control of Toxic Chemicals in Puget Sound

Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011

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November 2011

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Abstract

The Washington State Department of Ecology and other agencies initiated a multi-phase project in 2006, the Puget Sound Toxics Loading Analysis (PSTLA), to evaluate sources of toxic chemicals entering Puget Sound. The analysis focused on an abbreviated list of chemicals that were known to, or threaten to, harm the Puget Sound Ecosystem. The study included an assessment of major delivery pathways such as surface water runoff, groundwater, publicly-owned treatment works (POTWs), and direct air deposition. An assessment of the relative hazards posed by target chemicals was also performed.

The overall goal of PSTLA is to provide technical information to help develop toxic chemical control strategies for the Puget Sound basin. This report is a synthesis of information generated on (1) chemical releases from human-caused sources, (2) the rates of chemical loading through various pathways, and (3) a basin-wide hazard evaluation for chemicals of concern.

For most of the chemicals addressed, the rate of loading to Puget Sound was estimated to be one to three orders of magnitude lower than the rate of release from human-caused sources. In most cases, surface runoff was found to contribute the largest loads to Puget Sound, typically accounting for more than one-half of the total loads from all environmental pathways combined. Loads delivered through POTWs were generally the smallest among the pathways assessed, typically accounting for less than 10% of the total loading for each of the chemicals addressed.

Results of the hazard evaluation suggest that the following chemicals are most likely to be found at concentrations where effects are documented or at levels above criteria used to protect aquatic organisms and consumers of aquatic organisms:

- copper
- mercury
- polychlorinated biphenyls (PCBs)
- polychlorinated dioxins and furans (PCDD/Fs)
- the pesticide DDT (and its metabolites DDD and DDE)
- polycyclic aromatic hydrocarbons (PAHs)
- bis(2-ethylhexyl) phthalate (DEHP)

Results of the hazard evaluation were coupled with information on chemical sources and loading to suggest priorities for source control among the chemicals assessed. Recommendations are provided for source control strategies, and data needs are identified.

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Independent third-party peer review was conducted by Tetra Tech, Research Triangle Park, NC.

Executive Summary

Background and Approach

The Washington State Department of Ecology (Ecology) and other agencies initiated the Puget Sound Toxics Loading Analysis (PSTLA) in late 2006 to provide scientific information that could be used to guide decisions about how best to direct and prioritize resources and strategies for controlling toxic chemicals in the Puget Sound basin. The primary focus of PSTLA was to estimate toxic chemical loading to Puget Sound through major pathways such as surface water runoff, publicly-owned treatment works (POTWs), and direct air deposition.

PSTLA used a phased approach to develop technical information on toxics chemicals in the Puget Sound basin.

- Phases 1 and 2 relied on existing data to estimate chemical loadings and identify the most important delivery pathways.
- Phase 3 studies included collection of new monitoring data to fill data gaps identified during earlier phases.

Other important components of the project included:

- Assessing pharmaceuticals and personal care products in wastewater treatment plants.
- Assessing persistent organic pollutants in three guilds of marine species.
- Developing numerical models for polychlorinated biphenyls (PCBs) in Puget Sound.
- Developing a framework for a toxicant-based biological monitoring system.
- Preparing a report on the estimated release of chemicals from human-caused (anthropogenic) sources.

The present *Assessment Report* aims to synthesize information from all phases of the PSTLA, focusing primarily on the Phase 3 loading studies. Since information on loading and delivery pathways, primary chemical sources, and other PSTLA studies may not by itself be sufficient to meet the overall goal of PSTLA, a screening-level hazard evaluation of selected chemicals was conducted and included in this report. The hazard evaluation provides information about the relative risk of toxic effects posed by selected chemicals at observed concentrations in the Puget Sound basin. The information provides a scientific basis to develop a source control strategy for toxic chemicals in the Puget Sound Basin, and to prioritize actions.

The report is organized in a chemical-by-chemical fashion. For each of the selected chemicals addressed in the report, the major ongoing anthropogenic sources are discussed and release rates are estimated, an assessment of loading to Puget Sound and major pathways is presented, and the results of the hazard evaluation for the specific chemical are discussed. These elements are expressed by asking the following questions about toxic chemicals in the Puget Sound basin:

- Where do they come from?
- How much is being delivered?
- What delivery pathways contribute to the loading?
- What is the relative toxic hazard posed by these chemicals at observed concentrations?

In order to focus source control actions, a lines-of-evidence approach was developed to identify (1) chemicals with large ongoing anthropogenic releases from primary sources (does not include natural sources or legacy pollution, *and* (2) a relatively high potential to elicit effects based on the results of the hazard evaluation and regionally important biological-effects data. Combining information on chemical releases and loadings with the relative potential for effects provides for a more robust prioritization of possible future source control efforts. Recommendations for filling data gaps are also included.

The PSTLA focused on an abbreviated list of chemicals of concern (COCs). This list was developed during Phase 1 of the project based on observed harm or the threat of harm to the Puget Sound ecosystem. There is a wide range of chemicals in the Puget Sound basin for which we lack environmental information, and yet the chemicals may have the potential to cause biological or ecological harm. In addition, there is a large degree of uncertainty about the sources, pathways, and hazards for the chemicals that have been addressed. Therefore, this assessment should be viewed as the starting point for developing a larger toxic chemical control strategy in which a much broader spectrum of chemicals is considered.

Summary of Major Findings

Sources, Loads, and Pathways

COCs (listed in Table ES-1) were selected as the core group of chemicals analyzed in PSTLA studies (1) based on a documented history of their presence in Puget Sound and their capacity to harm or threaten the Puget Sound ecosystem and (2) to ensure that a broad variety of delivery pathways would be represented. While there is general consensus that a much larger number of potentially harmful chemicals are released to Puget Sound, the identification and evaluation of all of these chemicals were beyond the scope of the PSTLA projects.

To remain consistent with other PSTLA projects, the geographical scope of this *Assessment Report* includes Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits.

Chemical loads were calculated for most of the major pathways identified during the initial phase of the PSTLA effort. These include surface water runoff, POTWs, atmospheric deposition directly to marine waters, and direct groundwater discharge. Table ES-1 summarizes the estimated quantities of COCs released in the Puget Sound basin and the loads delivered to Puget Sound. Although these estimates are based on the best available information, releases and loads for some COCs remain incomplete or reflect high levels of uncertainty. In particular, air deposition and groundwater loading data are unavailable for many of the organic COCs.

In general, the load of metals to Puget Sound is approximately an order of magnitude lower than the total release from ongoing anthropogenic sources. Arsenic is an exception, apparently due to a high level of enrichment from natural sources.

For organic chemicals, loads are generally one to three orders of magnitude lower than releases from ongoing anthropogenic sources. The comparatively large differences between release and loading rates for organics may simply reflect the fewer number of pathways assessed for some organics. Closer agreement between anthropogenic releases and loads for metals may also be due in part to natural enrichment which contributes to the loads. Historic releases may also be a factor in loading of both metals and organic compounds.

Table ES-1. Toxic Chemical Releases and Loading in the Puget Sound Basin (metric tons/year).

COC	Total Release in the Puget Sound Basin[a]	Major Sources	Total Load to Puget Sound[b,c]	Major Pathway(s)
Arsenic	0.8	Industrial air emissions. CCA-treated wood leaching. Roofing material leaching.	14 – 25	Surface Runoff
Cadmium	1.0	Roofing material leaching.	0.05 – 0.53	Groundwater Atm. Deposition
Copper	180 - 250	Pesticides use on urban lawns and gardens.[d] Residential plumbing component leaching. Brake pad abrasion. Roofing material leaching. Vessel anti-fouling paint leaching.	33 – 80[e]	Surface Runoff
Lead	520	Ammunition and hunting shot use. Loss of fishing sinkers and wheel weights. Roofing material leaching. Aviation fuel combustion.	3.6 – 12	Surface Runoff
Mercury	0.5	Consumer product improper disposal. Crematoria and industrial air emissions.	0.11 – 0.37	Surface Runoff
Zinc	1,500	Roofing material leaching. Vehicle tire abrasion.	140 - 200	Surface Runoff
Total PCBs	2.2	Electrical equipment spills and leakage.[d] Residential trash burning. Building sealant (caulk) volatilization and abrasion.	0.003 – 0.02	Surface Runoff
Total PBDEs	0.7	Furniture, computer monitors, and other components of residential and commercial indoor environments.	0.028 – 0.054	Atm. Deposition POTWs
PCDD/Fs	0.000009[f]	Backyard burn barrels.	NA	NA
Total DDT	NA	NA	0.0025 – 0.032	Surface Runoff
Total PAHs	310	Woodstoves and fireplace combustion emissions. Vehicle combustion emissions. Creosote-treated piling, railroad ties, and utility poles.	0.19 – 1.0[e]	Groundwater Surface Runoff
DEHP	17	Polymer (primarily PVC) off-gassing. Industrial, commercial, and institutional air emissions. Roofing material leaching.	2.0 – 3.2	Surface Runoff
Triclopyr	150	Herbicide use on crops and golf courses.	0.64 – 0.69	Surface Runoff
Nonylphenol[g]	0.18	Industrial, commercial, and institutional air emissions.	0.023 – 0.024	Surface Runoff
Petroleum	9,300	Motor oil drips and leaks. Used oil improper disposal. Gasoline spillage during fueling.	330 – 500	Surface Runoff
Oil & Grease[h]	NA	NA	8,500 – 11,000	Surface Runoff

NA=Not analyzed

[a] Includes the Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits.

[b] Includes the Puget Sound and the U.S. portions of the Straits of Georgia and Juan de Fuca.

[c] Range of all pathways combined expressed as the sum of the 25th percentile values for each pathway – sum of the 75th percentile values for each pathway.

[d] Estimate is highly uncertain.

[e] Does not include estimated direct releases to marine waters (54 metric tons/yr for PAHs and 26 metric ton/yr for copper).

[f] Expressed as Toxic Equivalents (TEQs).

[g] Sources were not fully assessed.

[h] Category includes all hexane extractable material

The relationships between rates of initial release, rates of loading to Puget Sound, and the major delivery pathways are discussed for each COC. For most COCs, it is clear that a simple assessment of overall release from primary sources will not translate to levels measured in the environment. The type, mechanism, and setting of a chemical release are important factors governing their presence in environmental pathways. For instance, large quantities of polycyclic aromatic hydrocarbons (PAHs) are potentially released from creosote-treated railroad ties and utility poles throughout the basin, but the mechanisms and settings of release (volatilization and near-field leaching primarily to soil) do not translate to elevated concentrations of PAHs in surface runoff. In contrast, estimated zinc releases from major sources such as roof materials and vehicle tires occur in manners and settings (leaching from precipitation, abrasion to roadway surfaces) that result in substantial entrainment of zinc to surface waters.

For the majority of COCs, surface runoff contributed the largest loads to Puget Sound, typically accounting for more than one-half of the total loads from all pathways combined. Surface runoff from commercial/industrial land covers typically had the highest concentrations. However, agricultural areas produced the highest concentrations for several metals. Loading calculations were strongly influenced by the areas occupied by different land cover types. As a result, the largest loads were typically from forested areas (occupying 83% of all land cover), even though COC concentrations in forest areas were often the lowest among land covers or below reporting limits.

Loads delivered directly to the Puget Sound marine environment through groundwater were estimated using literature values for COC concentrations and discharge estimates. Groundwater loads were estimated to be an order of magnitude lower than surface runoff for most COCs. Exceptions were PAH loads, which were similar to surface water, as well as cadmium, gasoline, and diesel fuel, which had low to non-detectable surface water loads. Like surface runoff, load calculations for groundwater were strongly influenced by methods used to estimate concentrations from non-detected values.

Atmospheric deposition directly to marine waters was an important loading pathway for polybrominated diphenyl ethers (PBDEs) and high molecular weight PAHs. PBDEs was the only COC for which direct deposition from air appeared to be the largest delivery pathway to Puget Sound. COC flux from the atmosphere was comparatively high at a monitoring station located in a high-density urban area with nearby commercial, industrial, and major roadway contaminant sources.

POTWs generally accounted for less than one-tenth of the delivery to Puget Sound for each of the COCs assessed. Exceptions were diethylhexyl phthalate (DEHP, a.k.a. bis(2-ethylhexyl) phthalate) and PBDEs, the latter of which had POTW loads larger than those in surface runoff. POTW loads for other chemicals not specifically addressed in this report, such as pharmaceuticals, are expected to be much higher in POTWs than in other delivery pathways.

Hazard Evaluation

To assess the relative hazards, observed environmental concentrations of COCs in various environmental media (surface water, sediment) were compared to available data on biological effects or to established criteria to protect aquatic life and consumers of aquatic organisms.

Evaluations were conducted for the following categories:

- Direct hazards to aquatic life through surface water exposure
- Direct hazards to benthic organisms through sediment exposure
- Direct hazards to aquatic life based on tissue residue levels
- Hazards to wildlife based on ingestion of prey, water, and sediment
- Hazards to human health through fish/seafood consumption

The results of these comparisons were grouped into three broad “level of concern” categories: Priority 1 level of concern, Priority 2 level of concern, or unknown (U) level of concern. Results were classified as Priority 1 when the upper end of a set of observed concentrations (e.g. 90th percentile values) exceeded the lower end of a set of effects concentrations (e.g. 10th percentile values), or exceeded selected threshold values such as water quality criteria. A Priority 2 level of concern was assigned in cases where the upper end of a set of observed concentrations was below the lower end of a set of effects concentrations or other threshold values. In cases where there were not sufficient data to make a meaningful comparison, results were assigned a U.

The hazard evaluation has several limitations that should be considered prior to acting on the results. In particular, the hazard evaluation is not a risk assessment but is instead designed to assess the *relative* level of concern of COCs *across the entire Puget Sound basin*. Although a COC may be assigned Priority 2 or U for a particular sub-category, this should not be interpreted to mean there are no hazards associated with that COC. All of the COCs evaluated pose some level of concern for Puget Sound. Locally, concentration hot spots may exist near major sources and may cause localized toxicity to aquatic organisms or lead to violations of standards that would not necessarily be emphasized in this broad regional assessment. To address this shortcoming in the hazard assessment, a limited review was conducted of regionally important biological effects information.

Results of the hazard evaluation showed that all of the COCs except lead are a Priority 1, where sufficient data were available for evaluation, for at least one of the categories evaluated. There were not sufficient data to conduct evaluations for PBDEs, triclopyr, nonylphenol, or petroleum. PCBs is the only COC assigned a Priority 1 for all five categories evaluated.

COC concentrations in surface waters and sediments – particularly freshwater – resulted in the most COCs assigned Priority 1. Tissue residue effects, wildlife, and human health evaluations generally resulted in fewer COCs receiving a Priority 1 assignment. However, only bioaccumulative chemicals were evaluated for these latter categories.

In addition to the hazard evaluation, reviews of regionally important biological-effects data showed that levels of the following chemicals found in the Puget Sound basin result in documented or potentially adverse effects to a variety of aquatic organisms:

- copper
- mercury
- PCBs
- PBDEs
- polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs)
- dichlorodiphenyltrichloroethane (DDT) and metabolites DDD and DDE
- PAHs

Priorities for Source Control Actions

A lines-of-evidence approach was used to move further toward a goal of deciding how best to prioritize actions and resources for controlling toxic chemicals in the Puget Sound basin. This lines-of-evidence approach considers information on the four major components of the assessment (sources, loading, pathways, and the relative hazards), but the approach mostly relies on COC sources and the relative hazards posed by COCs as determined by the hazard evaluation and review of other regional studies.

This approach adopts the rationale that chemicals with the greatest potential to elicit toxic effects at existing concentrations should be an important factor in determining the priority for source control efforts. Priority was also given to COCs for which we have large opportunities for source control. This reflects the extent to which there are existing regulatory actions to control releases, such as bans, management of materials, or other permanent actions which reduce releases to the environment. Given the uncertainty associated with individual estimates of releases or loadings, this lines-of-evidence approach provides a supportable rationale for establishing relative priorities for control actions.

Opportunities for source control are considered large where the major sources of a COC have not been addressed by control actions; where some of the major sources have been addressed, opportunities may be considered medium. In cases where actions have been implemented to control and reduce all or most of the major sources and this appears to have resulted in low rates of loading to Puget Sound, the opportunities for controlling a COC are considered small. This assessment relies principally on the *Sources Report* (Ecology, 2011) with limited input by Ecology staff and management to gauge the opportunities for source control; the assessment was not intended to be a detailed review of management initiatives. Table ES-2 summarizes major sources for each COC and possible opportunities for reducing those sources.

Based on the lines-of-evidence approach, copper, PAHs, DEHP, and petroleum sources were rated as have the highest priority for early actions. The reasoning for this determination is as follows:

- A substantial portion of the fresh and marine water copper data observed basin-wide falls within concentrations where effects have been documented (including reduced olfactory function in salmonids). Copper is released in large quantities from a variety of sources which appear to translate to substantial loads to the Puget Sound ecosystem. The use of copper in pesticide applications and the release of copper from roofing materials are sources which warrant further investigation. In addition, the effectiveness of recent legislation to limit copper in brake pads and vessel anti-fouling paint should be evaluated.
- A number of individual PAHs surpass (do not meet) freshwater sediment guidelines and human health criteria. In addition, a variety of studies have demonstrated links between PAH exposure and adverse effects to regionally relevant aquatic species. There appear to be numerous opportunities for control actions, primarily for combustion sources and for creosote-treated wood.

- Observed DEHP concentrations in both freshwater and marine environments exceed (do not meet) criteria for protection of benthic species and human health. Substantial amounts of DEHP are released in the Puget Sound basin, much of which occurs initially through releases to air from off-gassing of plasticized polymers and point-source air emissions. Several non-polymer uses of DEHP may also provide opportunities for source reduction.
- The relative hazard posed by petroleum in the Puget Sound basin was not able to be evaluated due primarily to the lack of biological-effects data and the absence of criteria to protect aquatic organisms, wildlife, or human health. However, some of the COCs addressed in this assessment are components of petroleum and may be released in substantial quantities along with the release of petroleum. In particular, substantial releases of PAHs are estimated to be released from petroleum. The major sources of petroleum are diffuse, such as motor oil drips and leaks and minor gasoline spillage during vehicle fueling, and therefore offer ample opportunities for reduction efforts.

Several COCs were found to be a Priority 1 level of concern based on the hazard evaluation but were not determined to be among the highest priorities for reduction actions since the major sources have been addressed through regulatory programs or other efforts. For instance, mercury poses a relatively high hazard to freshwater and marine aquatic organisms and wildlife based on doses calculated from observed data. However, many of the historical regional sources of mercury to the Puget Sound basin have been eliminated or are being addressed by the Mercury Chemical Action Plan (Ecology and WDOH, 2003). Similarly, PCBs are a Priority 1 level of concern for all hazard evaluation categories, but PCBs have been banned for decades, the major sources (use in electrical equipment) are highly regulated, and current loads to Puget Sound appear to be small.

Although the systematic prioritization approach identified four COCs for early actions, other factors should be considered to determine the need and feasibility for developing control and reduction strategies for other COCs. For instance, PBDEs are ubiquitous environmental contaminants, and although voluntary actions and bans have removed major PBDE formulations from new consumer products, much of the PBDEs produced historically may remain in consumer products and commercial office products and these potentially represent substantial diffuse ongoing sources. The hazard evaluation was not able to adequately assess the relative hazards associated with PBDEs due to a lack of environmental standards, although there is evidence in the available literature to suggest this COC may pose a hazard at observed concentrations.

Additional research is needed to assess the relative hazards posed by PBDEs and other COCs for which there are only limited environmental data. By the same token, COCs with limited source information should be further evaluated to assess additional opportunities for source control.
Of the COCs addressed in this report, PBDEs and nonylphenol were the COCs that should receive top attention for further research on potential hazard as well as possible opportunities for source control.

Table ES-2. Summary of Possible Actions to Reduce COCs in the Environment.

COC	Opportunities for Source Control	Major Ongoing Anthropogenic Sources	Possible Actions for Reductions
Arsenic	Medium	Industrial air emissions	Maintain existing permit controls.
		CCA-treated wood leaching	Continue ban for most non-structural uses.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
Cadmium	Medium	Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
Copper	Large	Pesticides use on urban lawns and gardens	More data needed on actual pesticide use.
		Residential plumbing component leaching	Continue to implement Lead and Copper Rule.
		Brake pad abrasion	Continue to implement legislation enacted to reduce source.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
		Vessel anti-fouling paint leaching	Continue to implement legislation enacted to reduce source.
Lead	Small	Ammunition and hunting shot use	Implement CAP and enforce existing regulations.
		Loss of fishing sinkers and wheel weights	Implement CAP and enforce existing regulations.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
		Aviation fuel combustion	Implement CAP and enforce existing regulations.
Mercury	Medium	Consumer product improper disposal	Continue to implement CAP and enforce existing regulations.
		Crematoria and industrial air emissions	Continue existing permit limits.
Zinc	Large	Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
		Vehicle tire abrasion	Investigate source where it poses local concern.
Total PCBs	Small	Electrical equipment spills and leakage	Continue programs for management and disposal.
		Residential trash burning	Continue enforcing existing ban.
		Building sealant (caulk) volatilization and abrasion	Investigate source where it poses local concern.
Total PBDEs	Medium	Furniture, computer monitors, and other components of residential and commercial indoor environments	Enforce ban on new products but consider control actions to reduce the release from existing products.
PCDD/Fs	Small	Backyard burn barrels	Continue enforcing existing ban.
Total DDT	Small	None apparent	Investigate source where it poses local concern.
Total PAHs	Large	Woodstoves and fireplace combustion emissions	Continue change out programs, investigate catalysts/capture devices, promote alternatives to wood heat.
		Vehicle combustion emissions	Anti-idling programs, continue/expand engine retrofits for private section engines, enforce existing vehicle controls.
		Creosote-treated piling, railroad ties, and utility poles	Control actions needed, gather information to identify highest priority areas.
DEHP	Large	Polymer (primarily PVC) off-gassing	Gather additional information on extent of releases.
		Industrial, commercial, and institutional air emissions	Maintain existing permit controls.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
Triclopyr	Medium	Herbicide use on crops and golf courses	More data needed on pesticide use.
Nonylphenol	Unknown	Industrial, commercial, and institutional air emissions	More information needed on emissions from these sources and unidentified releases.
Petroleum	Large	Motor oil drips and leaks Used motor oil improper disposal	Expand existing education/workshop programs.
		Gasoline spillage (minor) during fueling	Possible opportunity for source control, but more data needed on extent of releases.

Bold=Recommended as priority for near-term actions based on lines-of-evidence approach.

Recommendations

Broad recommendations are provided below. These are intended to guide development of a long-term strategy to reduce toxic threats to Puget Sound. The reader is directed to the main body of the report for more detailed results of this assessment that should provide further direction towards specific chemical control actions and further source/pathway investigations.

While this report identifies sources of toxic chemicals entering Puget Sound and recommends ways to reduce this contamination, these recommendations should be prioritized and balanced alongside current efforts and regulatory programs that already keep millions of pounds of business-generated COCs safely managed.

In 2010 the U.S. Environmental Protection Agency selected Ecology to lead the development and implementation of a long-term toxic chemical control strategy for Puget Sound. Results from the PSTLA will be a key piece of information to help design and implement actions to reduce threats from the most important sources of toxic chemicals to the Puget Sound ecosystem. Ecology will use funding from a National Estuary Program grant to implement priority actions under this long-term toxics control strategy.

Major recommendations from this assessment can be summarized as follows:

- A variety of diffuse (nonpoint) sources appear to account for the majority of contaminant releases in the Puget Sound basin. In addition, surface water runoff during storms was identified as the major delivery pathway for most contaminants. High priority should be given to (1) implementing control strategies to prevent the initial release of contaminants and (2) reducing or treating stormwater inputs.

- Vehicles and vehicle-related activities represent an important source of a number of contaminants. Examples include: copper and zinc from brake and tire wear, PAHs from fuel combustion, and petroleum from motor oil drips and leaks as well as refueling operations. Source control strategies should be developed around reducing contaminant inputs from vehicles.

- Runoff and leaching from roofing materials were estimated to be a major source of several metals, particularly cadmium, copper, and zinc. Roof runoff may also be a substantial source of DEHP. Field investigations should be conducted to gauge the accuracy of this information, and if warranted, alternative assessments should be considered for this source category.

- Developed lands (commercial/industrial, agricultural, and residential) had higher concentrations of COCs compared to undeveloped forest land. Source control strategies should focus on identifying and controlling contaminant releases from existing and new developments.

- This assessment focused on a short list of contaminants that were known to, or threaten to, harm the Puget Sound ecosystem. Data are needed on the spatial distribution and impacts from a much wider range of potential contaminants (e.g. pharmaceuticals and personal care products, brominated flame retardants, nanomaterials) in the basin.

- Businesses in Washington that routinely handle large amounts of COCs should be inspected on a routine basis; once every three years appears to be a reasonable schedule.

Examples of other recommendations are provided below:

- One of the largest potential releases of copper is due to the urban lawn and garden use of products containing copper. Due to the lack of good pesticide-use information, there is a high degree of uncertainty surrounding this conclusion. Additional information is needed to determine release rates for this potentially important source of copper.

- Wood-burning stoves and fireplaces along with vehicle emissions were identified as some of the largest sources of PAHs in the Puget Sound watershed. Regional air programs should continue to pursue abatement programs to reduce wood smoke emissions and vehicle emissions.

- Creosote-treated wood represented approximately one-third of the PAHs released to the Puget Sound basin. In particular, direct release to Puget Sound occurs from treated pilings in marine (salt) water. Programs such as the Department of Natural Resources Marine Piling Removal program should be supported to reduce the release of PAHs from marine pilings and bulkheads.

- More information is needed to help distinguish natural and legacy sources of contaminants in environmental pathways such as surface water runoff. This will help gauge the feasibility and effectiveness of actions taken to reduce releases of chemicals from contemporary anthropogenic (human-caused) releases.

- Resources should be provided for local source control programs that identify and prevent the release of contaminants on a local scale.

Introduction

Background

The Puget Sound Basin covers more than 43,400 square kilometers (16,800 square miles) of land and water (Hart Crowser et al., 2007) and is home to 4.5 million people (U.S. Census Bureau, 2010) including large urban metropolitan centers such as Seattle and Tacoma (Figure 1). Although large urban and industrial areas have developed along the shores of Puget Sound and near the mouths of major rivers – particularly on the east side of the central Sound – much of the shoreline and the watershed remains undeveloped and the bulk of the upland basin is forest.

During the past 150 years, humans and their activities have released a wide variety of chemicals into Puget Sound and its surrounding watershed, many of which are toxic to humans and aquatic organisms. Due to its fjord-like structure and shallow sills, the entry of deep oceanic water into Puget Sound is restricted, which reduces flushing of the inland marine and estuarine waters (PSAT, 2007). As a result, toxic chemicals (toxicants) and other pollutants may accumulate in some inlets and embayments of Puget Sound, increasing their exposure to aquatic organisms.

While the marine waters of Puget Sound may be the ultimate sink for many of the toxic chemicals released in the basin, it is universally recognized that freshwater streams, rivers, and lakes in the basin may be at risk from contamination as toxic chemicals travel from their points of initial release to the Puget Sound. The health of Puget Sound ultimately depends on the health of its upland watershed, particularly since one of its most ecologically important and iconic organisms – pacific salmon – rely on the upland watersheds for some of their most vulnerable stages of life.

For several decades the loading of toxicants to Puget Sound has been recognized as a serious problem and has been documented in a number of reviews (e.g. Dexter et al., 1981; Romberg et al., 1984; PSWQA, 1986; PTI, 1991; PSAT, 2003; Redman et al., 2006). These reviews have primarily focused on identifying chemicals of concern (COCs), concentrations in marine sediments, and effects to aquatic organisms, but generally provided only conjecture about delivery pathways.

Puget Sound Toxics Loading Analysis

In December 2005, Governor Christine Gregoire and the Washington Legislature launched the Puget Sound Initiative, a comprehensive effort by local, state, federal, and tribal governments; business, agriculture and environmental communities; scientists; and the public to restore, protect, and preserve the Sound by 2020. Among the top recommendations put forth by the original Puget Sound Partnership (Partnership) in 2006 was to make the reduction of toxic chemicals entering Puget Sound waters a primary objective for the long-term agenda.

The Washington State Department of Ecology (Ecology) and other agencies responded to the original Partnership's "reducing toxics" recommendation by initiating the Puget Sound Toxics Loading Analysis (PSTLA). Phase 1 of PSTLA was an initial estimate of toxicant loading to Puget Sound through various pathways such as surface runoff and direct air deposition. The analysis relied on readily accessible data to estimate chemical loading to the marine basin, and the authors of the report acknowledged that there remained a number of significant gaps in determining an accurate toxics budget for the Sound (Hart Crowser et al., 2007). However, the Phase 1 study satisfied its primary goal of identifying data gaps and needs for additional studies, and informed the Puget Sound Action Agenda (PSP, 2008), the plan for restoring Puget Sound.

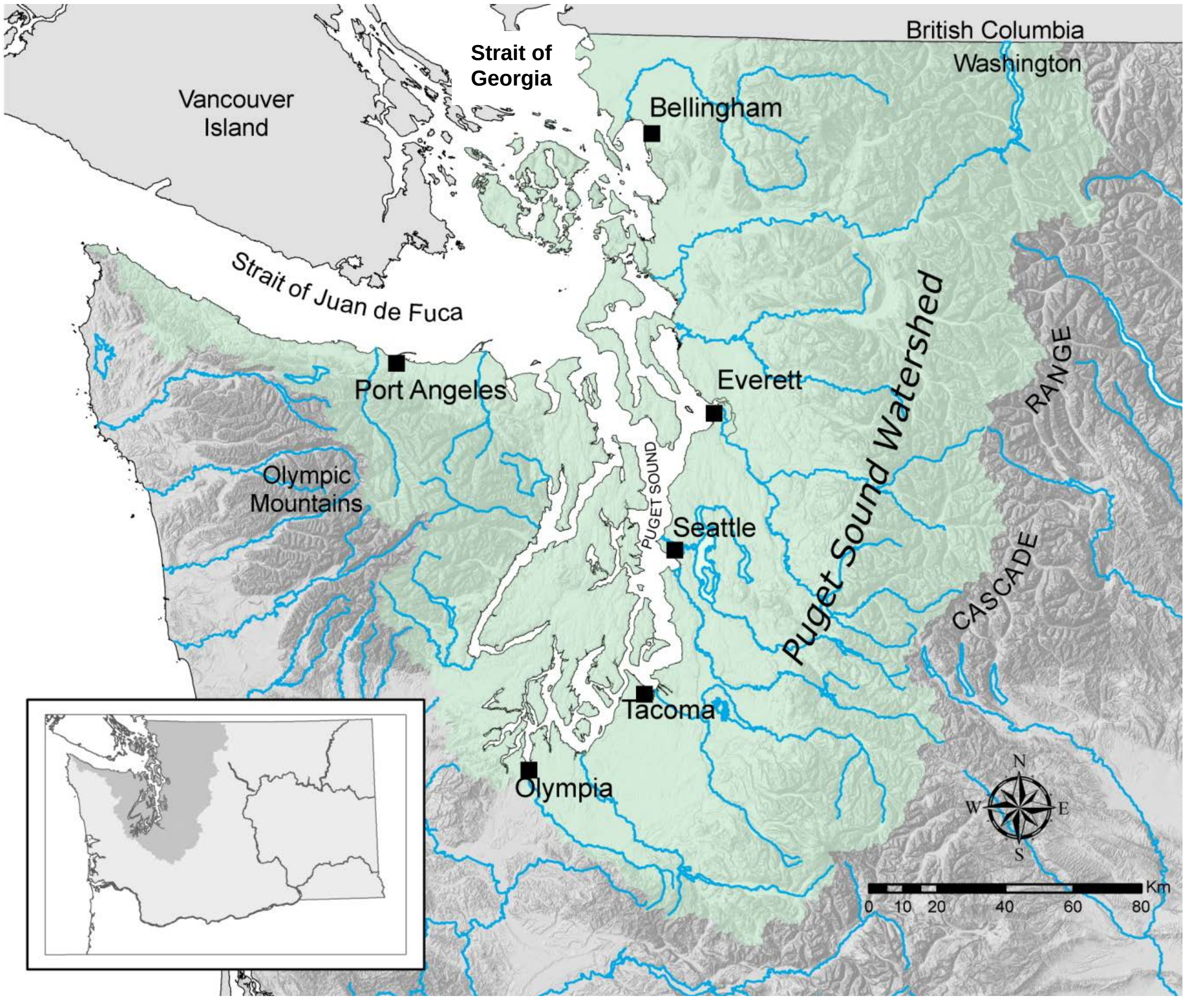


Figure 1. Watershed area for Puget Sound and the U.S. Portion of the Strait of Georgia and the Strait of Juan de Fuca.

The Partnership's Action Agenda re-iterated the conclusion that toxic chemical contamination is one of the largest problems facing Puget Sound, and a number of recommendations were developed to tackle various aspects of this complex problem. Although many of the recommendations were centered on implementation (e.g. programmatic, education, policy), the Partnership also recognized the need to gain a more thorough understanding of the problem as it currently exists. This need was expressed in the Action Agenda as Priority C.1.1.10: *Continue scientific work to better understand the sources of toxics, as well as transport and fate in the Puget Sound ecosystem, to better refine reduction strategies. This includes the toxic loadings assessments.*

In keeping with recommendations from the Action Agenda, two additional phases of PSTLA projects were mapped out:

- Phase 2 PSTLA studies were generally designed to refine loading estimates obtained during the Phase 1 effort and relied on readily available information much like the Phase 1 study.
- Phase 3 represented a departure from the earlier approaches in that nearly all of the Phase 3 projects included a sampling component so that refinements would include up-to-date and region-specific data.

In general, PSTLA projects were designed to assess the loading, sources, and to some degree, the impacts of toxic chemicals in Puget Sound. But the bulk of the PSTLA effort has been devoted to studying the delivery of toxicants through various pathways, such as direct atmospheric deposition, surface water runoff, and water exchange at the ocean boundary.

Purpose

The overall goal of PSTLA is to provide scientific information that will help guide decisions about how best to direct and prioritize resources and strategies for controlling toxic chemicals in the Puget Sound basin.

The purpose of this *Assessment Report* is to (1) distill the data and information generated by the PSTLA projects into a single document and (2) provide conclusions about toxic chemicals and their sources that can be used by those developing strategies to control toxic chemicals in Puget Sound.

The *Assessment Report* does not address all threats to Puget Sound. The issues regarding cleanup and restoration of Puget Sound are complicated and multi-faceted. For every pound of toxic chemicals released to Puget Sound by people, cars, households, etc., Washington businesses produce and handle hundreds to thousands times the amount of these chemicals, both in the form of chemical products and hazardous waste. While the *Assessment Report* identifies sources of pollution entering Puget Sound and recommends priorities to address this contamination, these recommendations should be balanced alongside current efforts that already keep millions of pounds of business-generated chemicals safely managed.

In 2010 the U.S. Environmental Protection Agency (EPA) selected Ecology to lead development and implementation of a long-term toxic chemical control strategy for Puget Sound. Results from the PSTLA will be a key component to (1) identify the most significant sources and delivery pathways of toxic chemicals and (2) prioritize reduction efforts to reduce threats from toxic chemical to the Puget Sound ecosystem. Ecology will use funding from a National Estuary Program grant to implement priority actions under the toxics control strategy.

Scope, Approach, and Organization of the Report

Many projects are included under the umbrella of the PSTLA, as shown in Figure 2. Appendix A provides additional information on PSTLA project subject matter, authorship, and completion status. All completed PSTLA reports are posted on the PSTLA internet homepage: www.ecy.wa.gov/programs/wq/pstoxics/index.html.

This *Assessment Report* focuses primarily on the PSTLA Phase 3 loading studies and draws on information provided in other PSTLA studies where appropriate. Since information on loading and delivery pathways, primary chemical sources, and other PSTLA-derived data may not by itself be sufficient to meet the overall goal of PSTLA, a screening-level hazard evaluation of selected chemicals was conducted and included in the *Assessment Report*. The hazard evaluation provides information about the relative risk of toxic effects posed by selected chemicals at observed concentrations in the Puget Sound basin.

This *Assessment Report* is organized in a chemical-by-chemical fashion. For each of the selected chemicals addressed in the report, the major ongoing anthropogenic sources are discussed, an assessment of loading to Puget Sound and major pathways is presented, and the results of the hazard evaluation for the specific chemical is discussed. These elements may be re-phrased as the following questions for specific toxic chemicals in the Puget Sound basin:

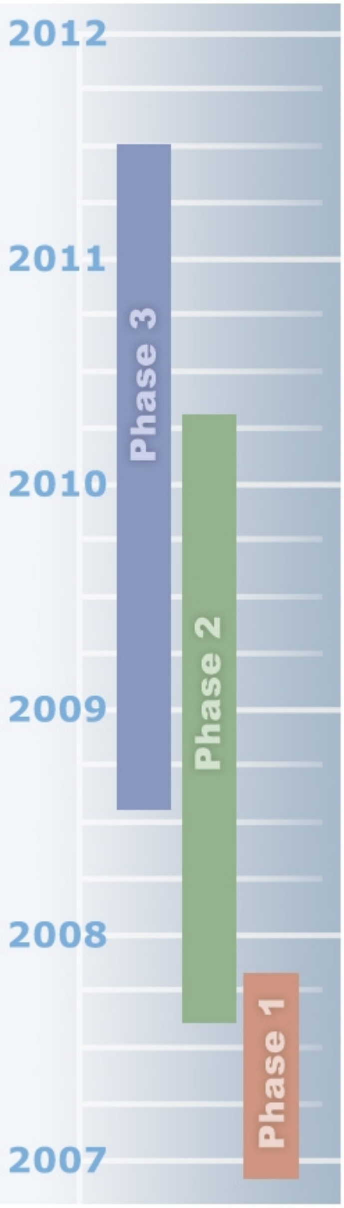
- Where do they come from?
- How much is being delivered to Puget Sound?
- What delivery pathways contribute to the loading?
- What is the relative toxic hazard posed by these chemicals at observed concentrations?

Figure 3 shows the major elements considered for this *Assessment Report*. As mentioned previously, loading estimates from different pathways come primarily from the PSTLA Phase 3 loading studies. Loading information from PSTLA Phases 1 and 2, as well as additional information on chemical transport and attenuation, may be used to supplement the PSTLA Phase 3 loading studies.

The PSTLA Phase 3 report on primary sources provides estimates of ongoing anthropogenic releases of selected chemicals. For each chemical addressed in this *Assessment Report*, the information on loading rates and pathways is discussed in context of their ongoing releases from primary sources (i.e. how these chemicals get in the environment in the first place).

As mentioned previously, the hazard evaluation provides information about the relative risk of toxic effects posed by selected chemicals at observed concentrations in the Puget Sound basin. The hazard evaluation was not produced as a separate project; it was conducted specifically for this Assessment Repot to enhance and supply additional context to the information on loading, pathways, and sources of toxic chemicals.

The major components used for this *Assessment Report* are described in more detail in subsequent sections. The reader should be aware that the *Assessment Report* does not consider these components exclusively. For instance, additional information on bioaccumulative chemicals in three guilds of marine organisms (West et al., 2011a and b; Noel et al., 2011) are used to provide additional context to the hazard evaluation for specific chemicals.



Phase 3: Targeting Priority Toxic Sources

Phase 3 Projects:

3A: Toxic Chemical Loadings via Surface Runoff
3B: Modeling Surface Runoff in Two Pilot Watersheds
3C: Evaluate Air Deposition
3D: Toxic Chemicals in Marine Waters and from Ocean Exchange
3E: Numerical Models and Scenarios
3F: Priority Pollutant Scans for POTWs
3G: Primary Sources of Toxic Chemicals
3H: Pharmaceuticals and Personal Care Products (PPCPs)
3J: Persistent Organic Pollutants in Three Guilds of Pelagic Marine Species from the Puget Sound
3K: Assessment Report
3L: Groundwater Discharge Directly to Puget Sound

Phase 2: Improved Loading Estimates

Phase 2 Projects:

2A: Loadings from Surface Runoff and Roadways
2B: Loadings from Dischargers of Municipal and Industrial Wastewater
2C: Bioaccumulation Model Estimates of Toxics from Sediments
2D: Water Column Data for Puget Sound and its Ocean Boundary
2E: Support for a Human Health Risk Assessment
2F: Numerical Models for Polychlorinated Biphenyls in Puget Sound
2G: Biological Observing System (TBiOS) for Toxics in Puget Sound

Phase 1: Initial Estimate of Toxic Chemical Loadings to Puget Sound

Phase 1 Project:

1A: Initial Toxics Loading Estimates

Figure 2. Timeline and Complete List of All PSTLA Projects.

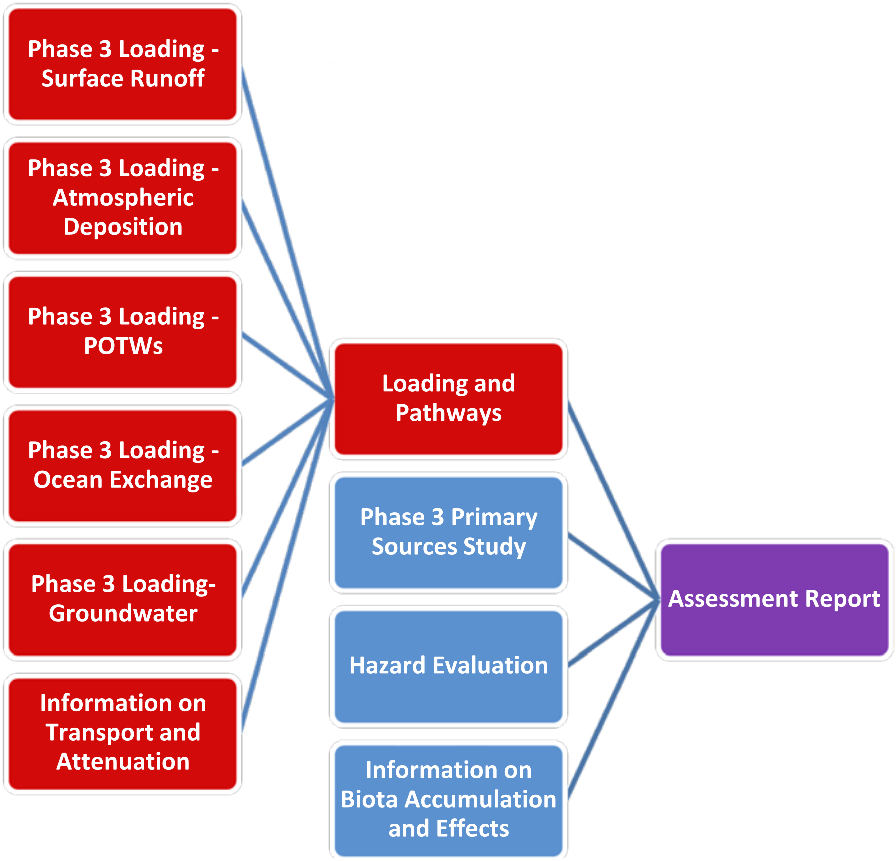


Figure 3. Elements Incorporated into the Assessment Report.

Selection of Chemicals

While there is general consensus that a large number of potentially harmful chemicals may be present in Puget Sound, the identification and evaluation of all chemicals was beyond the scope of the PSTLA projects. In order to focus on a group of chemicals that are known to be important and likely represent at least some of the most important ones in Puget Sound, the chemicals addressed in this *Assessment Report* are the chemicals of concern (COCs) first selected during the initial phase of the PSTLA.

The COCs were selected by a Chemicals of Concern Workgroup that had been convened to recommend a list of chemicals based on previous work and using best professional judgment. The workgroup sought to choose chemicals that had a documented history of presence in Puget Sound and "… that harm or threaten to harm the Puget Sound ecosystem and those that represent, or serve as an indicator for, a particular class of chemicals." The COCs list was developed to ensure that a broad variety of delivery pathways would be represented.

The workgroup settled on a list of chemicals that largely mirrored those identified by the then-lead agency for Puget Sound (Puget Sound Action Team; Redman et al., 2006). These chemicals became the core group of chemicals analyzed for the subsequent loading studies, although a few chemicals were excluded for particular studies while other studies included chemicals beyond the COCs.

The COCs are as follows:

- Arsenic
- Cadmium
- Copper
- Lead
- Mercury
- Zinc
- Polychlorinated biphenyls (PCBs)
- Polybrominated diphenyl ethers (PBDEs)
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs)
- Dichlorodiphenyltrichloroethane (DDT) and metabolites DDD and DDE
- Low molecular weight polycyclic aromatic hydrocarbons (LPAHs)
- High molecular weight polycyclic aromatic hydrocarbons (HPAHs)
- Carcinogenic polycyclic aromatic hydrocarbons (cPAHs)
- Diethylhexyl phthalate (DEHP, a.k.a. bis(2-ethylhexyl) phthalate)
- Triclopyr
- Nonylphenol
- Oil and petroleum hydrocarbons

It is possible that this list of COCs represents only a small subset of those chemicals that may be impacting Puget Sound. Any conclusions drawn from the assessment of these COCs should not signify that other chemicals may not be of equal or greater concern.

Geographical Study Area

The geographical study area addressed in this *Assessment Report* is Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits (Figure 1). This is consistent with all of the land-based PSTLA loading projects (e.g. Hart Crowser et al., 2007; Envirovision et al., 2008a), except the groundwater loading analysis which excludes loads from the western Strait of Juan de Fuca.

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Puget Sound Toxics Loading Analysis (PSTLA) Projects

The bulk of COC data analysis in this report is contained in the Chemical-Specific Assessments section. The COC data analyzed in the Chemical-Specific Assessments section are primarily from the PSTLA studies. The following section summarizes the PSTLA studies used for these analyses in order to familiarize the reader with the subject and scope of the studies conducted under PSTLA. For more detailed information, the reader is advised to review the Chemical-Specific Assessments section or the original PSTLA studies which are referenced in the following section and are available online at www.ecy.wa.gov/programs/wq/pstoxics/index.html.

Loading Projects

PSTLA Phase 3 loading studies are described in the following sub-sections. PSTLA Phase 1 and 2 projects that were conducted to estimate COC loading are not included because their goal was generally to focus information for the development of the more refined Phase 3 loading studies. Aside from a few possible exceptions, the Phase 3 loading studies contain the best PSTLA loading data available.

Surface Water Runoff

Description

The Phase 3 study on COCs and other chemicals in surface water runoff (Herrera, 2011) was the primary off-shoot of the Phase 1 and 2 loading studies which identified surface runoff as the principal delivery pathway for most COCs. Like the other loading studies conducted under PSTLA, the surface runoff study was essentially a modeling effort which included the collection of sampling data to provide input data for the model used to estimate surface runoff loads of COCs.

The primary objective of the surface runoff study was to quantify the annual loading of COCs to Puget Sound through surface runoff, defined as the water flowing over the surface of the land at some point, including stream baseflow, stormwater, and groundwater discharging to surface waters. In addition to calculating COC mass loading to Puget Sound, the surface runoff study also provided data on chemical concentrations in surface runoff among different land cover types (commercial/industrial, residential, agricultural, and forests) and during different streamflow regimes (baseflow and storm flow).

Four sub-basins from the each of the representative land covers (commercial/industrial, residential, agricultural, and forests) were sampled twice during baseflow and six times during storm flow conditions between October 2009 and July 2010. Sampling was limited to stream sub-basins in the Snohomish River and Puyallup River watersheds for logistical reasons. Samples were analyzed for the entire list of COCs (except PCDD/Fs) as well as additional chemicals such as phthalates, semi-volatile organic compounds, pesticides, herbicides, and nutrients (Appendix B). Continuous stream discharges (flows) were recorded during the study period. The complete results of the chemistry and discharge data are included in the surface runoff report (Herrera, 2011).

The COC concentration data obtained from sampling were coupled with stream gauging data and converted to annual unit-area loads (e.g. kg COC/km^2) specific for a land cover and flow regime (baseflows or storm flows). The land area of the entire Puget Sound basin was assigned one of the four land covers, and the unit-area COC loads computed from study results were assigned to the corresponding land cover. Using this "scale-up" methodology, COC loads for the Puget Sound basin were calculated for both storm flows and baseflows.

Summary of Major Findings

The surface runoff project team found that PAHs, phthalates, semi-volatile organic compounds, pesticides, herbicides, and petroleum hydrocarbons were rarely detected or not detected at all. PCBs and PBDEs were detected in a majority of samples; however, only a few individual chemicals from each of these classes were commonly present. Most nutrients and six of the 15 metals evaluated in this study were detected in nearly all the samples. The frequency of detection and concentrations for most chemicals was generally higher for samples collected during storm flows than baseflow samples, a pattern generally consistent among all land cover types.

Since COC concentrations were typically higher during storm events, the increased discharge during storm events amplified the COC loads compared with baseflow loads. As a result, storm flow unit-area loads were much larger than baseflow unit-area loads for most chemicals. This suggests that environmental chemicals are mobilized during storm events; otherwise increased storm flows would simply dilute chemical concentrations and loads would remain the same regardless of discharge.

Although the surface runoff study demonstrated that chemicals are mobilized during storm events, it is unclear to what extent chemicals are transported to the stream corridors versus re-mobilization of chemicals residing in the stream corridors (e.g. sediments). It is likely that both circumstances occur to varying degrees, and may depend largely on the chemical in question.

COCs were generally detected more frequently and at higher concentrations in the commercial/industrial sub-basins compared to the other land cover types with a few exceptions; metals were occasionally detected more frequently and at higher concentrations in the agricultural areas. Metals aside, agricultural and residential areas had roughly the same level of chemical detection frequencies and concentration. Streams sampled in forested areas had the lowest overall concentrations as well as frequency of COC detection.

In general, COC unit-area loading rates for the four land cover types generally showed the same pattern as concentrations (commercial/industrial > agricultural ≥ residential > forest). However, since approximately 83.4% of the land base in the Puget Sound basin is forested and only 0.8% is commercial/industrial land cover, absolute loads from forested areas dominate the overall loading from surface runoff.

As with any study designed to extrapolate large values from a limited sample set, there are a number of uncertainties associated with the results. The low frequencies of detection for many organic COCs were particularly troubling since summary statistics for concentrations were required for calculation of loads. This required substitution methods for non-detected values within a concentration dataset, with one-half of the reporting limit typically used to substitute for non-detected results. Appendix B shows the method used to establish representative COC values for datasets with non-detected values. The result is that COC concentrations used to derive loads were determined largely by reporting limit values rather than measured concentrations.

The use of unit-area loads to compute basin-wide loading has the potential to introduce bias to the final load estimates. The unit-area load method assumes that all of a single land cover type (e.g. agricultural) in the Puget Sound basin delivers the same COC load regardless of the runoff volume (the runoff volume method was applied in the Phase 2 surface runoff estimates). This essentially has the effect of dampening the load signal from forest areas where the percentage of total runoff volume is even greater than the area. At the same time, loads from commercial/ industrial areas (and agricultural areas for some COCs) may be higher using the unit-area load method compared with loading calculations that use precipitation-driven runoff volumes. However, the overall effect of the unit-area load methodology results in lower absolute loads for the Puget Sound basin due to the diminished contribution of the forest loads.

Atmospheric Deposition

Description

The study of COCs atmospherically deposited directly to the surface of the Puget Sound marine waters (Brandenberger et al., 2010) was conducted based on recommendations from the Phase 1 report which concluded that PBDE and PAH loads delivered through this pathway may be comparable or greater than from surface runoff. The Phase 1 report also noted that there were few data to assess atmospheric deposition loads, and that what little data that existed was two decades old. There were no efforts among the Phase 2 projects to improve air depositions loads.

In order to obtain estimates of air deposition loads to Puget Sound, the project team designed a sampling network of seven locations geographically dispersed around Puget Sound that represented a variety of possible air pollution influences and precipitation patterns. One station was located in a high-density urban area of Tacoma with numerous potential industrial and roadway influences; a companion station was located in a nearby undeveloped area to assess the influence of highly localized air deposition.

Sampling was conducted at two-week intervals over the course of 14 months during 2008 – 2009. The funnel-type sampling devices used for the study collected bulk samples (dry + wet deposition) and were not designed to distinguish between dry and wet deposition. However, the large number (19) of discrete sampling events permitted a partial evaluation of differences between dry and wet deposition since sampling spanned wet and dry seasons.

Samples collected from the bulk deposition collectors were analyzed for the COC metals, PCBs, PBDEs, HPAHs, and cPAHs (Appendix B). Additional analyses were conducted for PAH markers and anhydrosugars in order to conduct analyses of PAH sources. Once COC concentrations from a sample were obtained, fluxes (e.g. ng COC/m^2/day) were calculated based on the sample volumes, funnel area, and elapsed collection time.

Using the COC fluxes, three scenarios were used to estimate total annual loads to Puget Sound:

1. The first scenario applied summary statistics derived from all of the pooled results to the entire marine surface.
2. The second scenario used location-specific deposition results and applied them to geographically associated marine compartments based on the Puget Sound Box Model (Pelletier and Mohamedali, 2009).
3. The third scenario used the same method as for the second scenario, but further divided the loading into dry and wet seasons.

The three scenarios for calculating annual loads from atmospheric deposition produced similar results, and the authors of the air deposition study did not explicitly state a preference for any particular scenario. Loading estimates from the third scenario are used for the present report because (1) values typically fell between estimated loads derived from the other scenarios, and (2) loads calculated for both dry and wet deposition could provide useful information for further analysis, much the same way baseflow and storm flow data from the surface runoff study are able to be evaluated independently.

Summary of Major Findings

All of the COCs analyzed were detected at all stations, and fluxes and loads were calculated based on summary statistics computed for each COC at each location. The high-density urban station in Tacoma had COC fluxes much higher than most other stations – an order of magnitude higher in most cases – including the nearby companion station. This finding supports the view that strong air deposition signals may be highly localized, particularly in high-density urban areas. Seasonal differences suggest a higher rate of wet deposition for metals, while the opposite appears to be the case for PBDEs. There does not appear to be any effect on seasonality for PAHs, although biomarker fluxes suggest a larger proportion of PAHs deposited during the winter originates from biofuel (e.g. firewood) combustion.

Users attempting to interpret results of the air deposition study should be aware of several limitations. The difficulties of attempting to extrapolate atmospheric deposition of chemicals across a large area using a limited sampling coverage are evident. As noted by the authors of the study (Brandenberger et al., 2010), the sampling coverage was able to capture only one location with elevated deposition rates due to highly localized conditions. Perhaps more important, mercury aside, there are few data on which to compare the results of the study. Most comparable data were collected 20 years prior to this study, and advances in analytical methods, increases in population, and emissions reduction efforts have all occurred during the intervening years. The current COC fluxes are much lower than those reported during the early 1990s.

Users of the data should also be aware that the method for handling non-detected PBDE congeners (14 were analyzed) was different from methods used in other loading studies. The method detection limit was used to replace each non-detect congener result during the summation of individual congeners to derive a total PBDE sum. The authors of the study acknowledged this resulted in a conservative (upward) bias of the results. This bias appears to result in fluxes (and resulting loads) on the order of 50% higher than those derived from using summing methods which substitute a zero for non-detected congeners when calculating a total PBDE sum.

In contrast to the non-detect substitution method described for PBDEs, non-detected PCB congeners were substituted with a zero, unless no congeners were detected for a sample, in which case one-half the highest method detection limit among congeners was used as the result. This likely resulted in a downward bias of the results. Appendix B shows the method used to establish representative COC values for datasets with non-detected values.

Publicly-Owned Treatment Works (POTWs)

Description

The Phase 3 project to assess COC loading through POTWs (Ecology and Herrera, 2010) was conducted based on recommendations from the Phase 1 report and results of a Phase 2 study of discharge data from POTWs and industrial wastewater discharges (Envirovision et al., 2008b). Both the Phase 1 and 2 studies found a limited amount of data which could be used to calculate reliable load estimates and recommended collection of additional data in order to refine an assessment of loading.

In order to estimate loads from POTWs, ten facilities were sampled during two events each. Sampling was conducted during February and July 2009 to represent wet and dry seasons, respectively. The POTWs were selected to represent varying types of treatment process, size, and source of wastewater, and were geographically distributed around the Puget Sound region. To obtain load estimates, the project team computed summary statistics for representative COC concentrations then multiplied concentrations by the average annual volume of treated wastewater discharged from all of the 96 POTWs in the Puget Sound basin.

Samples collected from POTWs were analyzed for the COCs (except arsenic, cadmium, mercury, and PCDD/Fs) as well as additional chemicals such as phthalates, semi-volatile organic compounds, pesticides, and herbicides (Appendix B). Few of these chemicals are routinely monitored by POTW operators.

Summary of Major Findings

Most classes of chemicals were detected in POTW effluent, and loads were calculated for all of the COCs analyzed except DDT, cPAHs, nonylphenol, triclopyr, and oil/petroleum. To obtain load estimates, the project team computed summary statistics for representative COC concentrations then multiplied concentrations by the average annual volume of treated wastewater discharged from all of the 96 POTWs in the Puget Sound basin. Due to the limited number of sampling events and atypical weather during the sampling period, the project team was not able to assess any seasonal variations in loadings.

Like the other loading studies, methods for handling non-detected results were required in order to obtain representative COC concentrations for datasets that contained a combination of detected and non-detected results. The POTW project team used the regression-on-order statistical analysis to calculate summary COC concentration statistics rather than simple substitution with one-half of the reporting limit. Perhaps more importantly, no loads were calculated for chemicals that had less than 50% overall frequency of detection. This appears to have introduced a downward bias in basin-wide loading estimates when compared with loading estimates that would have been obtained using the same non-detect substitution methodology that was applied in the surface runoff study. Appendix B shows the method used to establish representative COC values for datasets with non-detected values.

The absolute Puget Sound COC loads were calculated based on discharge volumes from 96 POTWs in the Puget Sound basin, yet not all of these POTWs discharge directly to the marine waters of Puget Sound. Efforts to distinguish POTW loads from surface runoff loads potentially run the risk of double-counting surface runoff loads if surface water sampling is conducted downstream of a POTW outfall. However, none of the surface runoff sampling stations were located downstream of POTW outfalls, and therefore distinct COC loads can be attributable to POTWs and surface runoff based on the methodologies used in the respective projects.

Ocean Exchange and Major Tributaries

Description

Ecology’s study of chemical load exchange at the ocean boundary (Gries and Osterberg, 2011) was originally conceived to provide chemical input data for the Puget Sound Box Model (Pelletier and Mohamedali, 2009) after a review of existing data (Serdar, 2008) found the available data were inadequate for the model. The ocean exchange project was designed with a number of marine water column stations to provide calibration data for the box model. The study design was later expanded to include measurements of chemical concentrations in the five rivers having the greatest annual discharges to Puget Sound in order to assess the relationships between river COC concentrations and those in corresponding inland marine waters.

The final sample design for the project included shallow and deep water sampling at three ocean boundary stations (eastern Strait of Juan de Fuca and Haro Strait), marine water at four locations representing the Main, Whidbey, South Sound, and Hood Canal basins, and freshwater and suspended particle sampling near the mouths of the Skagit, Snohomish, Nooksack, Stillaguamish, and Puyallup Rivers. Samples collected from freshwater and marine waters were analyzed for the COCs (except mercury, PCDD/Fs, and triclopyr; oil and petroleum was analyzed in freshwater only) as well as additional chemicals such as phthalates, semi-volatile organic compounds, and chlorinated pesticides (Appendix B).

The exchange of chemical loads at the ocean boundary was calculated by using concentrations in the deep water boundary stations to represent inflow to Puget Sound, and chemical concentrations from the Main, Whidbey, and Hood Canal basin sites to represent water flowing out of Puget Sound. The concentrations representing the inflow and outflow were then multiplied by the known volumes of water flowing in and out of Puget Sound, respectively.

Summary of Major Findings

The study found metals, PCBs, and PBDEs at detectable concentrations in the marine water column, but other COCs were either not detected or detected at such low frequencies that load estimates were not calculated.

Metals, PCBs, and PBDEs were found at detectable concentrations in the water column of rivers, but other COCs were either not detected or detected at such low frequencies that load estimates were not calculated. However, PAHs and DEHP were detected at high frequencies in suspended particles (sampled once in each river versus three water sampling events for each river).

Due to the inherent variability of chemical loads carried by rivers due to constantly shifting stage and conditions, the authors (project team) did not feel that annual loading estimates were supportable based on three sampling events. However, instantaneous daily loads were calculated and reported based on the river discharges recorded during the sampling events.

Uncertainties and limitations of the ocean exchange and major tributaries project were due more to assumptions about hydrology than difficulties associated with handling non-detected laboratory results. Perhaps the largest assumption used by the project team is that COC concentrations at deep water locations in the eastern Strait of Juan de Fuca and Haro Strait represent those flowing into Puget Sound, and COC concentrations from various Puget Sound locations represent concentrations in the outflow. Recommendations were made to improve the assessment of chemical exchange by sampling at more representative boundary locations, namely Admiralty Inlet (sill) and Deception Pass.

Aside from PBDEs, there was little need for the project team to adopt a method for calculating summary statistics for datasets containing non-detects. For PBDEs, the method of substituting a non-detect result with one-half of the estimated quantitation limit was adopted (Appendix B).

PBDE results also showed a very high degree of variability during the study, particularly for marine waters. The project team was unable to provide an explanation for the high degree of variability, but they did note that there was no evidence of sample contamination.

Groundwater

Description

The 2007 Phase 1 report included a specific recommendation for the development of loading estimates for *direct* groundwater discharge to Puget Sound. Although the authors of the Phase 1 report (Hart Crowser et al., 2007) acknowledged the potential for the groundwater pathway to contribute significant toxic chemical loads at the local scale, this pathway was not addressed at | a basin-wide scale. In light of the low mobility characteristics of many of the COCs and the assumed contaminant attenuation capacity of subsurface sediments, the transport of toxic chemicals to Puget Sound via direct groundwater discharge was generally considered to represent a comparatively minor component of the overall loading to Puget Sound marine waters, but this assumption had not been confirmed by a formal technical analysis.

The Phase 1 report recommendation to conduct a sampling-based groundwater loading assessment was not carried forward to a Phase 3 project. Instead, a loading study was conducted using readily available data to address the absence of data on COC loading through a direct groundwater pathway (Pitz, 2011). The study produced estimates of upper-bound (worst-case) mass loads of COCs delivered annually to Puget Sound through the groundwater pathway. The reader should note that i*ndirect* groundwater contributions of toxic chemicals to freshwater streams and rivers draining to Puget Sound are assumed to be represented in the load estimates developed for the surface runoff pathway (Herrera, 2011).

A substantial majority of the chemistry data used for the groundwater loading analysis was from industrial or commercial sites or from facilities that are known or suspected to have point-source-related toxic contamination, typically sampled in response to the Model Toxics Control Act (MTCA) or state Dangerous Waste regulations. Additional sources of data were also found to represent un-impacted (i.e. ambient) groundwater, but these datasets were small compared to the amount of data from impacted areas since most of the COCs are not typically analyzed during routine groundwater monitoring. Only data collected within 500 meters of the marine shoreline were used to derive representative COC concentrations for load calculations.

In an attempt to minimize potential bias from the high proportion of data from contaminated sites, groundwater data were divided into three categories: impacted areas, urban ambient areas, and non-urban ambient areas. Data from each category were pooled separately, and representative concentrations from each category were derived for loading estimates. Fluxes were then calculated by multiplying by the discharge (flow) for each shoreline segment by the COC concentration representing the groundwater data category for the associated 500-m buffer. This approach reduced the groundwater discharge associated with impacted areas to approximately 1% of the overall volume, while non-urban ambient areas discharged approximately 75% of the groundwater.

Sufficient groundwater data were generally available for metals but comparatively scarce for organic compounds. In particular, data on PCBs, PBDEs, PCDD/Fs, triclopyr, and nonylphenol were not sufficient to derive usable representative concentrations for groundwater.

Summary of Major Findings

The groundwater loading analysis found that COC loads from ambient areas generally exceed loads from impacted areas as a result of the comparatively high flow volume in ambient areas. This is similar to the dominant effect that forest land has on absolute COC loads as reported in the surface runoff study. For many of the PAHs, however, the highly elevated concentrations in groundwater from impacted areas more than compensated for lower flows, resulting in comparatively high PAH loads from impacted areas.

Users of the groundwater loading data should be aware of the many limitations and assumptions used in the report. It is an initial effort to calculate direct groundwater loads and has not benefited from the refinement process used for some of the other loading projects. The author (Pitz, 2011) found a low frequency of detection for nearly all of the COCs, and therefore the concentrations used for loading are largely driven by non-detected values (and the substitution methods used to handle non-detects). Appendix B shows the method used to establish representative COC values for datasets with non-detected values. Complex decision processes were developed to derive COC concentration for use in loading computations. Even the discharge volume estimates used to calculate loads, typically a consistent factor in loading studies for other pathways, ranged by an order of magnitude.

In addition to the limitations and assumptions discussed above, there are also uncertainties about the mobility and attenuation of COCs in groundwater. The groundwater loading study does not attempt to account for attenuation – an additional reason the results represent upper-bound estimates – but instead assumes that the COCs will migrate to the marine boundary in the same concentrations measured in upland groundwater. These and other uncertainties and limitations are thoroughly documented in the groundwater loading report (Pitz, 2011).

Other Projects

Inventory of COC Releases from Primary Sources

Description

In recognition that loading analyses by themselves may not provide adequate information to help Ecology, the Puget Sound Partnership, and others to develop and implement a toxics reduction and control strategy, an inventory of COC releases was undertaken by Ecology as part of the PSTLA Phase 3 effort. This sources inventory, referred hereto after as the *Sources Report* (Ecology, 2011), was conducted with the objectives of (1) identifying major ongoing anthropogenic sources of COCs in the Puget Sound basin and (2) estimating the quantities in which they are released into the environment.

The *Sources Report* focused specifically on the release of COCs from their primary sources. The term *source* was strictly defined as *the object or activity from which a COC is initially released to environmental media or released in a form which can be mobilized and transported in an environmental pathway* (Ecology, 2011). The term *primary source* was used to distinguish the initial release of a COC from a secondary release, such as mobilization of a chemical from a toxic cleanup site.

Examples of releases from primary sources include copper and zinc released from tire and brake pad wear, PAHs formed and released from combustion sources, and motor oil released from vehicle drips and leaks. The *Sources Report* did not estimate releases from secondary or natural sources.

All COCs except DDT were addressed in the *Sources Report*. The quantity of COCs released to the environment from approximately 110 primary sources was estimated from available information; no sampling was conducted for the project.

Summary of Major Findings

The study found that petroleum is released in the largest quantity among COCs, followed by zinc which is the only additional COC released at a rate greater than 1,000 metric tons (t) per year.

Lead, PAHs, and copper are released at rates greater than 200 t/yr, and triclopyr is released at a rate over 100 t/yr. Approximately 30 t/yr of phthalates are released, but the organic chemicals PCBs, PBDEs, PCDD/Fs, and nonylphenol, as well as the metals mercury, arsenic, and cadmium, are generally released at rates near 1 t/yr or less. A summary of release estimates for all COCs is included as Appendix C.

While the *Sources Report* provides only rough estimates for many of the COC release rates, useful information about the relative magnitude of releases from each source is contained in the report. The *Sources Report* also discusses how COCs are released from their sources, providing insight into their transport and fate in the environment following release.

The study of COC releases from primary sources was limited in its ability to provide refined estimates of COC releases, and the authors (project team) were not able to consider all sources of COCs to the Puget Sound environment. The release estimates were based on many assumptions and limited data in many cases. However, these assumptions and associated uncertainties are documented in the report.

Evaluation of Fate and Transport Mechanisms

Description

Understanding the behavior, transport, and fate of chemicals following their initial release from primary sources is a key element in developing strategies for controlling chemicals at their source as well as along their transport pathways following release. The transport and fate of chemicals in the environment is complex, particularly in the upland environment where various media and management practices can affect chemical concentrations, loads, sequestration, and removal. In order to better understand the transport and fate of chemicals in the environment, staff at the U.S. Geological Survey (USGS; Paulson et al., 2011-Draft) conducted an evaluation of transport and fate for copper released from several of the major sources identified in the *Sources Report* (Ecology, 2011). The evaluation of fate and transport mechanisms was not conducted as a discrete PSTLA project but instead was done specifically to enhance this *Assessment Report*. Upon its completion, it will be included as an amendment to this report.

The authors (Paulson et al., 2011-Draft) of the transport and fate evaluation used a mass-balance case study approach to examine factors affecting copper attenuation following release from roof runoff, brake pads, and vehicle tires. Using information from the *Sources Report*, the authors calculated the mass of copper released annually from these sources in two small urban watersheds in King County, Washington. The annual mass of copper discharged from these watersheds was estimated from historical sampling data for the streams comprising the respective watershed outlets. Finally, the authors incorporated information on the types of copper release, the likely locations of the releases, watershed characteristics including best management practices, and stream and water quality characteristics to provide possible explanations for copper attenuation.

The initial scope of this project included a proposal to conduct a similar evaluation for PCB and PBDE transport and fate. However, the lack of data on these chemicals in urban streams and stormwater precluded the authors' ability to conduct an evaluation for these chemicals using a case study mass-balance approach.

Summary of Findings

Findings of the copper transport and fate evaluation suggested that less than 10% of the copper mass estimated to be released in the watersheds was discharged at the respective watershed outlets. It appeared that the retention of copper in the watersheds was largely governed by the limited amount of water volume discharged from the watershed at the surface outlet; only about 15% of the estimated storm precipitation for each watershed was discharged at the surface outlets. The authors speculated that the retention of copper was due to infiltration into groundwater, trapping of particles by lawns, grassy road-side ditches, road shoulders and road right-of-ways, retention in the many structures installed in the watershed, and settling of particles in vegetated channels in low-gradient portions of the watersheds. Some of the copper released in the watersheds may have been removed by street sweeping, but this portion was likely minor.

The movement of copper by a variety of transport mechanisms through a variety of pathways was discussed by the authors of the fate and transport report (Paulson et al., 2011-Draft), although most of the information provided was speculative due to a lack of data for the multiple environmental media components required for an exhaustive evaluation. In cases where there were available data, the information did not always yield clear conclusions regarding copper transport and fate. For instance, data on copper analyzed from road surfaces resulted in divergent lines of evidence as to whether copper released from brake pads remains on the road surfaces or alternatively is suspended in air and blown away from the roads. This example underscores the complexity and difficulties in understanding the behavior, transport, and fate of chemicals at a small scale.

Hazard Evaluation for COCs in the Puget Sound Basin

The hazards posed by different COCs are not simply associated with the quantities released to the environment or loaded to Puget Sound, but are rather more appropriately evaluated by assessing their concentrations in various media. To assess the relative hazards posed by COCs, Ecology consulted with the ecological toxicology assessment team at King County Natural Resources and Parks to design and conduct a hazard screening of COCs in the Puget Sound basin. The hazard evaluation was not conducted as a discrete PSTLA project but instead was done specifically to enhance this *Assessment Report*.

To evaluate hazards potentially posed by COCs in the Puget Sound basin, King County used a methodology in which readily available observed environmental data for each COC were compiled then compared to concentrations where effects are documented, or to criteria established to protect aquatic life or consumers of aquatic organisms. These comparisons do not attempt to estimate absolute hazards but instead provide a rough discriminator of relative hazards among COCs using a specified methodology. A similar approach was used in a survey conducted several years earlier to evaluate endocrine disrupting chemicals in King County surface waters (King County, 2007).

The hazard evaluation was conducted for the following categories:

- Direct hazard to aquatic life through surface water exposure
- Direct hazard to benthic organisms through sediment exposure
- Direct hazard to aquatic life based on tissue residue levels
- Hazard to wildlife based on ingestion of prey, water, and sediment
- Hazard to human health through fish/seafood consumption

The results of these comparisons were grouped into three broad "level of concern" categories: a Priority 1 level of concern, a Priority 2 level of concern, or unknown (U) level of concern due to lack of sufficient data for an assessment. Results were classified as a Priority 1 when high observed concentrations (e.g. 90th percentile values) exceeded low effects concentrations (e.g. 10th percentile values), selected criteria, or other threshold values. A Priority 2 level of concern was assigned in cases where high observed concentrations were below threshold values. In cases where there were not sufficient data to make a meaningful comparison, results were assigned a U. Appendix D-1 details the thresholds used for comparisons and the minimum data required for the comparisons.

Environmental COC concentrations used for the hazard evaluation were obtained from a number of data sources including Ecology's Environmental Information Management (EIM) system, King County Laboratory Information Management System, USGS data obtained from their online database, the National Oceanic and Atmospheric Administration (NOAA) mussel watch program, and ENVVEST data from the U.S. Department of Defense. Data from the PSTLA Phase 3 Ocean Exchange, Pelagic Fish, and Surface Runoff studies were included among the observed data compilations. Due to the complexities associated with handling non-detects, only detected values were used to represent observed environmental COC concentrations for each of the media assessed.

Effects concentrations were obtained from a variety of sources. For surface waters, effects data were obtained from EPA's ECOTOX database for surface water. Freshwater and marine sediment data were compared to Washington State's Sediment Quality Standards (2003 Floating Percentile values for freshwater). Effects resulting from fish and invertebrate tissue burdens were evaluated using data from the Lower Duwamish Waterway Group and the Lower Willamette Group Remedial Investigation Baseline Ecological Risk Assessments. Wildlife hazards were evaluated by comparing daily COC doses through various exposure routes with daily doses where effects have been demonstrated. National Toxics Rule criteria were used as a basis for evaluating human health hazards.

The hazard evaluation has several limitations that should be considered prior to acting on the results. In particular, the hazard evaluation is not a risk assessment but is instead designed to assess the *relative* level of concern of COCs *across the entire Puget Sound basin*. Although a COC may be assigned Priority 2 or U, this should not be interpreted to mean there are no hazards associated with that COC. Locally, concentration hot spots may exist near major sources, and may cause localized toxicity to aquatic organisms or lead to violations of standards. Finally, no attempt was made to evaluate hazards due to multiple COC exposures.

Details of the methodology and assumptions used for the hazard evaluation are in Appendix D-1. This includes rules for assigning COCs to Priority Levels for each media or receptor evaluated. Additional sections of Appendix D include box plots of the observed and effects concentrations and tabular summaries of the data and the results.

Puget Sound Box Model

Description

The Puget Sound Box Model study was developed as a tool to predict concentrations of PCBs in water, sediment, and biota of Puget Sound (Pelletier and Mohamedali, 2009). Three separate existing models were linked to achieve this task:

- A model to predict the circulation and transport of between regions of Puget Sound and between surface and deep layers of the water column.
- A contaminant fate and transport model to predict water and sediment concentrations of PCBs in response to external loading and internal processes.
- A food web bioaccumulation model to predict PCBs in Puget Sound biota in response to water and sediment concentrations.

Summary of Findings

Based on model outputs, concentrations of PCBs in sediments and biota were found to be very sensitive to external loading. However, the authors found that conclusions about increasing or decreasing trends in Puget Sound PCB mass could not be made due to the wide range in uncertainties regarding current external loading rates.

The median estimates of PCB loading used for the model showed slight increases in the total PCB mass for Puget Sound. However, the model was conducted using available information at the time and did not benefit from data collected during Phase 3 studies that may have aided in model calibration.

Persistent Organic Pollutants in Three Guilds of Marine Species

Description

Investigations of persistent organic pollutants (POPs) in three guilds of marine species were comprised of three separate studies carried out by Washington Department of Fish and Wildlife (WDFW), NOAA, and Fisheries and Oceans Canada. POPs were analyzed in plankton (West et al., 2011a), pelagic fish (West et al., 2011b), and harbor seals (Noël et al., 2010).

Previous studies have suggested that some pelagic species may accumulate higher levels of POPs from the water column and other pelagic components of the food web than from contaminated bottom sediment. In addition, pelagic fish are considered to be the primary source of POPs to southern resident killer whales. The overall goal of the studies on POPs in marine species was to assess where geographically the POPs enter the pelagic food web from stormwater and the atmosphere, the pathways of POPs within the pelagic food web, and the sources of POPs to species occupying the highest trophic levels (marine mammals, seabirds, and humans). The data from these studies were also intended to be used to refine the Puget Sound Box Model (Pelletier and Mohamedali, 2009).

For the plankton study, investigators analyzed phytoplankton (and other organisms and particles retained in a 20-micron net) and three species of krill which graze on phytoplankton (primarily *Euphausia pacifica*, but also *Thysanoessa spinifera* and *T. raschii).* Samples were obtained from numerous locations around Puget Sound during 2009. Phytoplankton and krill were analyzed for PCBs, PBDEs, PAHs, chlorinated pesticides, and ancillary parameters to assist with interpretation of the results.

In the study of pelagic fishes, researchers analyzed Pacific hake (*Merluccius productus*), which are an important prey item for harbor seals, and walleye pollock (*Theragra chalcogramma*). These species consume a variety of zooplankton such as the krill analyzed in the phytoplankton study, as well as small pelagic forage fishes. Hake or pollock were collected from a number of locations representing six hydrologically distinct waterbodies and one urbanized embayment during 2009. All fish were analyzed whole for PCBs, PBDEs, chlorinated pesticides, and ancillary parameters to assist with interpretation of the results.

The harbor seal (*Phoca vitulina*) study consisted of sampling 24 pups from four widely dispersed locations in Puget Sound. Investigators collected blood, fur, and skin/blubber biopsy samples from the pups. Skin/blubber samples were analyzed for PCBs, PCDD/Fs, PBDEs, chlorinated pesticides, and mercury. Hair and blood samples were analyzed for a variety of parameters to assess the feeding ecology, contaminant trends over space, and effects on their health.

Summary of Findings

For the plankton study, PCBs, PBDEs, DDTs, and PAHs in both particulate organic matter and krill exhibited a correlation with urban waters, and for PCBs and PBDEs in particular, concentrations were lower in less developed, more ocean-influenced basins. This suggests that urban waters represent areas where POPs enter the pelagic food chain.

Although PAHs are known to be metabolized and therefore do not accumulate in tissues of aquatic vertebrates (they were not analyzed for the companion fish and harbor seal studies), the authors of the plankton study found high levels of PAH accumulation in both phytoplankton and krill compared to other POPs. They also noted that a potentially significant implication of this finding was that pacific herring, a primary predator of krill in Puget Sound, exhibited significant exposure to PAHs possibly pointing to krill as a major contaminant transfer pathway. Another finding regarding PAHs was the relatively high concentrations in phytoplankton from non-urbanized basins, and in particular from samples collected near marinas, ferry terminals, or shoreline roadways. This suggests that shoreline development may play an important role in PAH transfer to the pelagic food web.

Patterns of PCB, PBDE, and chlorinated pesticide accumulation similar to plankton were found by authors of the pelagic fish study. Greater size- and lipid-specific accumulations of these chemicals were observed in Pacific hake from more developed basins compared to those with less development. As pointed out by the authors, the lipid-weighted PCB concentrations in Pacific hake were similar to Pacific herring and higher than in Chinook salmon, all species consumed by harbor seals. However, harbor seals may selectively prey on larger hake, which are typically females and have lower lipid and PCB concentrations, potentially making Pacific herring a greater overall contaminant transfer pathway than hake.

Results of the harbor seal study indicated that Hood Canal (south) seal pups were the least contaminated overall. Pups from the Main Basin of Puget Sound had the highest PCB and mercury levels. PBDE levels from all locations were similar, except Hood Canal which had the lowest concentrations. There was no discernible geographical trend in chlorinated pesticide levels, and PCDD/Fs were detected so infrequently that it was difficult to distinguish trends, although concentrations from the South Sound (east) basin were highest.

The authors of the harbor seal study note that several indicators suggest that the health of harbor seals may be impaired due to the contaminant exposure, particularly PCBs. These indicators include both threshold values based on effects and developed to protect marine mammals, as well as the health indicators measured during the study. They also noted that, while PCB exposure and accumulation may pose health risks to harbor seals, concentrations in seals have decreased appreciably during the 2000s.

There appear to be similarities in contaminant accumulation among the three studies conducted on POPs in marine organisms, and some inferences can be drawn from the results. For instance, there is a consistent geographical pattern seen in PCB concentrations across all species, which indicates the greatest exposure occurs in the Main Basin or embayments therein (e.g. Elliott Bay). However, at the time of this writing there has been no assessment of the results considered as a whole to: (1) Evaluate the consistencies in geographical patterns and (2) Assess the trophic transfer of contaminants between plankton and hake, and between hake and harbor seals. This may be best accomplished through updates and refinements to the Puget Sound Box Model.

A Toxics-Focused Biological Observing System for Puget Sound

Description

The concept of a toxics-focused biological observing system (TBiOS) was developed by authors from NOAA Fisheries, WDFW, and University of California (UC) Davis as a framework for assessing and monitoring toxic chemicals in Puget Sound through biological components (e.g. accumulation, responses, effects) rather than simply monitoring toxic chemicals through the more conventional analysis of water and sediments (Johnson et al., 2010a). Examples of recent research showing adverse effects to aquatic organisms from contaminant exposure are provided. The authors point out that biological monitoring would allow us to evaluate the impacts of toxic chemicals, the effectiveness of efforts to reduce toxic chemicals, effects to the ecosystem and the food web, and the effects of toxic chemical exposure coupled with other stressors.

As proposed, TBiOS would have three major components:

- Region-wide monitoring of toxic chemicals to assess large-scale geographical or temporal trends.
- Localized effectiveness monitoring to assess the impact of local source control or cleanup efforts.
- Diagnostic studies that would help uncover biological effects caused by toxic chemicals and develop monitoring tools to measure these effects.

The authors propose general ideas for the type and scale of monitoring and assessment programs that might be conducted under TBiOS. These programs would be a combination of new initiatives and building upon existing programs, such as the Puget Sound Assessment and Monitoring Program (PSAMP).

Benefits of TBiOS would include:

- Identifying toxic chemical-associated injury to the Puget Sound ecosystem, including the geographic extent and severity of the problem.
- Increasing our understanding of how toxic chemicals move through the Puget Sound ecosystem and accumulate in shellfish, fish, wildlife, and consumers of these organisms.
- Guiding our toxics reduction strategy efforts by helping to identify those watersheds where contaminants are the greatest problem and help us focus where detailed evaluations are most needed.
- Helping us evaluate the effectiveness of regional and localized toxics reductions strategies and actions.
- Establishing cause-and-effect linkages between toxicant exposure and biological impacts.
- Helping develop and establish more protective water quality and sediment guidelines.

Bioaccumulation from Sediments

Description

The study on bioaccumulation modeling was conducted to predict the concentrations of toxic chemicals in organisms resulting from specific concentrations in Puget Sound sediments (Ecology and Environment, 2009). In particular, the model was applied to the organic chemical criteria of Washington’s Sediment Quality Standards (SQS). Since the model can also predict water column concentrations, surface water concentrations were predicted to provide comparisons with surface water criteria.

The model used for this effort was based on the Condon bioaccumulation model (Condon, 2007) which was developed to predict PCBs in biota from the Strait of Georgia, and therefore was deemed (with some modifications) adaptable for Puget Sound. This was the same model used as the food-web bioaccumulation component of the Puget Sound Box Model (Pelletier and Mohamedali, 2009; described above) to predict PCB concentrations in biota. The report documents modifications made to the Condon model to accommodate chemicals other than

PCBs, and in some cases, specimens in addition to those used by Condon (e.g. herring and salmon). PCBs, PAHs, and DEHP were the only COCs analyzed for the sediment bioaccumulation study.

Summary of Findings

Results of the modeling exercise showed that, at SQS levels in sediment, predicted water concentrations of PCBs and several PAHs may not be protective of human health, marine organisms, and piscivorous wildlife (PCBs only). Several non-COC organic chemicals were also predicted to be found at non-protective concentrations in water.

The authors of the report conclude that the model provides insights into the behavior and transfer of contaminants in the food web. However, they note the vast complexity of food-web modeling and caution users to consider the numerous assumptions and uncertainty before applying this or other generalized models, particularly if the model may be used for regulatory and management decisions.

Pharmaceuticals and Personal Care Products in POTWs

Description

The study of pharmaceuticals and personal care products (collectively referred to as PPCPs) was a screening-level effort carried out by Ecology and EPA Region 10 staff during 2008 (Lubliner et al., 2010). The study consisted of analyzing one-day composite samples of influent, effluent, and sludge from four POTWs in the Puget Sound region and one POTW in Hayden, Idaho. All of the plants had different processes for treatment of wastewater, with two plants employing secondary treatment and three plants employing tertiary treatment for nitrogen and phosphorus removal.

The screening-level of PPCPs was conducted due to concerns emerging from recent studies (cited in Lubliner et al., 2010) documenting PPCP presence in the aquatic environment and the possibility PPCPs may lead to effects which are not widely understood or have not been investigated. Since POTWs are a major step along the pathway from consumer use to release in the environment, the study sought to generate information about the effectiveness of POTWs in removing these chemicals. The study analyzed 72 PPCPs, 27 hormones and steroids, and 73 semi-volatile organic chemicals. PAHs, DEHP, and nonylphenol were the only COCs among the analytes selected for the PPCP study.

Summary of Findings

The authors of the study found that PPCPs are detected routinely in municipal wastewater and that their removal in POTWs varies by chemical and treatment process. Approximately one-fifth to one-half of the analytes were reduced to levels below reporting limits in the effluent. Overall, the combination of enhanced biological nutrient removal and filtration processes was found to provide the greatest PPCP removal effectiveness, although the authors note that this treatment process is employed by relatively few POTWs in the Puget Sound basin.

As for the COCs analyzed, DEHP was found in all influent samples, and concentrations were greatly reduced in all but one of the POTW effluents. Nonylphenol (4-nonylphenol) was rarely detected in POTW influent or effluent. None of the 16 PAHs analyzed were detected in either influent or effluent samples, although indeno(1,2,3-cd) pyrene was selected as one of the few target analytes for biosolids and was detected in three-quarters of the samples analyzed.

Chemical-Specific Assessments

Arsenic

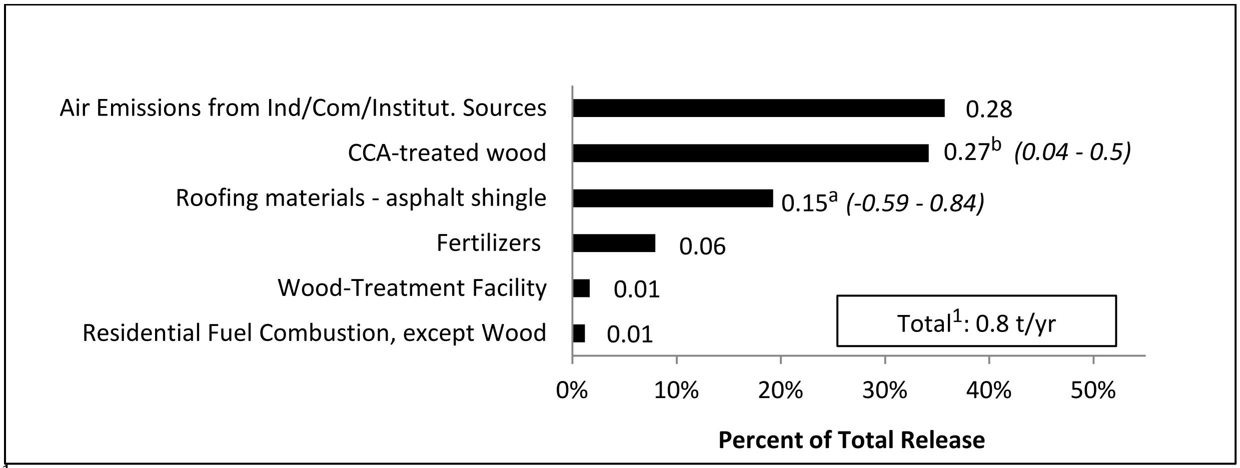
Arsenic is a naturally occurring element in the earth's crust and is nearly always detectable at concentrations >0.1 ug/l in water and >100 ug/kg (dw) in sediments from freshwater and marine environments (PTI, 1991; Serdar, 2008; Hallock, 2010; Appendix D). Toxicity in water varies due to pH and redox potential (Eisler, 1988a).

Historically, approximately 70% of the global arsenic emissions are from anthropogenic sources, with the remaining 30% due to weathering of soils and rock (Moore and Ramamoorthy, 1984). In the Puget Sound region, historical releases may have occurred due to uses of arsenic compounds as pesticides as well as releases from large industrial sources. The Asarco Smelter in Tacoma emitted arsenic for decades and may have resulted in large swaths of the Puget Sound area with elevated arsenic (PTI, 1991; San Juan, 1994).

Major Releases from Primary Sources

An inventory of primary arsenic sources suggests that approximately 0.8 metric tons (t) is released annually from anthropogenic sources in the Puget Sound basin (Ecology, 2011). The largest current source of arsenic to the environment is point-source air emissions, accounting for approximately one-third of the total release (Figure 4).

There is a large amount of uncertainty around estimates of arsenic released from roof runoff and CCA-treated wood, sources which combined account for about one-half of anthropogenic arsenic released in the Puget Sound basin. For other sources – fertilizer application, a wood treatment facility that releases arsenic primarily to surface water, and residential fuel use (excluding wood) – arsenic releases are relatively minor.



[1] Sum of best estimates. Best estimates are either the mean, mid-point, median, or most reasonable estimate for each source.

[a] Mean

[b] Mid-point of range

Figure 4. Total Arsenic Release in the Puget Sound Basin (values shown are t/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for arsenic loading were obtained from PSTLA loading studies and are included in Table 1. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Table 1. Total Arsenic Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	0.06	0.43	0.79
Air Deposition	0.25	0.35	0.54
Surface Runoff	13.5	16.9	23.4
POTWs	NA	NA	NA
Ocean Exchange (b)	-28	-23	-24

(a) Lowest, highest, and mid-point of estimated loads
(b) Negative values indicate a net outflow at the ocean boundary
NA=not analyzed

Estimated groundwater loads of arsenic range by an order of magnitude (0.06 – 0.8 t/yr). The range in estimates is due primarily to differences in flows used to establish the possible range of loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude.

Arsenic was not measured in POTWs for the Phase 3 loading study. Phase 1 estimates suggest that arsenic loads from industrial wastewater are potentially substantial (0.2 – 14.6 t/yr; Hart Crowser et al., 2007), but this is based on a limited dataset and is far in excess of industrial discharge of arsenic reported in the Toxics Release Inventory (TRI) (0.01 t/yr total) (Ecology, 2011). In contrast, Phase 1 estimates for arsenic loading via municipal wastewater were based on a small set of non-detected sample results, and the load estimates appear to be unrealistically small (0 – 1 kg/yr). Due to the unreliability of the arsenic loads discharged through wastewater treatment, estimates from this pathway were not included in Table 1.

The deposition of atmospheric arsenic directly to the marine waters of Puget Sound is approximately 0.25 – 0.54 t/yr, based on fluxes ranging from 0.06 – 0.65 $ug/m^2/d$. Median arsenic fluxes are generally ≤ 0.2 $ug/m^2/d$, except for one location within a high-density urban (Tacoma) area including a nearby pulp mill, metal refiners, other industrial activities, and in close proximity to major roadways including interstate highways. Fluxes at this location are consistently several times higher than at other locations.

Surface runoff loads for arsenic are estimated to be approximately 13.5 – 23.4 t/yr for the entire Puget Sound basin based on the surface runoff study. Nearly all (97%) of the total arsenic was in the dissolved form during baseflows; the fraction of dissolved arsenic decreased during storm flows to 74% of the total. Arsenic concentrations observed across base and storm flows were found to significantly correlate with total suspended solids (TSS) in residential and forest areas, partly due to a seasonal first-flush episode in the forested sub-basins.

Forested areas had much lower arsenic concentrations than other land covers. Commercial/ industrial and agricultural land covers had the highest arsenic concentrations, approximately double those in residential areas and four-fold higher than forests during baseflows. For all of the land covers, arsenic concentrations decreased during storm events, particularly in commercial basins.

Overall, there appears to be a net export of arsenic out of the Puget Sound due to exchange of marine waters, although total arsenic concentrations in the incoming marine waters (1.44 – 1.52 ug/l; 25th -75th percentile) are slightly higher than concentrations in the outgoing marine waters (1.36 – 1.49 ug/l). Total net export was 24 – 28 t/yr based on an inflow of 842 – 889 t/yr and an outflow of 870 – 913 t/yr.

The net sum of arsenic loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is -14, -5.3, and 0.7 t/yr, respectively. Under estimates at the 25th and median levels, there is a net export of arsenic out of Puget Sound due to the large mass exchanged at the ocean boundary. Estimates at the 75th percentile suggest that a net outflow at the ocean boundary is balanced by loads from the watershed and from air deposition.

Arsenic loading from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) is shown as ranges (25th -75th percentiles) and median for each pathway in Figure 5. Each pathway represented as a contribution to the total load is displayed in Figure 6.

Total arsenic loading from the major pathways assessed is 14 – 25 t/yr. Surface runoff accounts for the largest pathway (95% – 98%), followed by air deposition (2%). Groundwater potentially accounts for up to 3% at the upper end of the estimated range, but this value should be viewed with caution since it is based on literature values of arsenic in wells and variable estimates of groundwater flow. At the lower end of the load range, arsenic in groundwater is estimated to account for <1% of the load to Puget Sound. The loading studies failed to provide estimates of arsenic loading through POTWs, and earlier estimates (Envirovision et al., 2008b) provide little information on which to base reasonable load estimates.

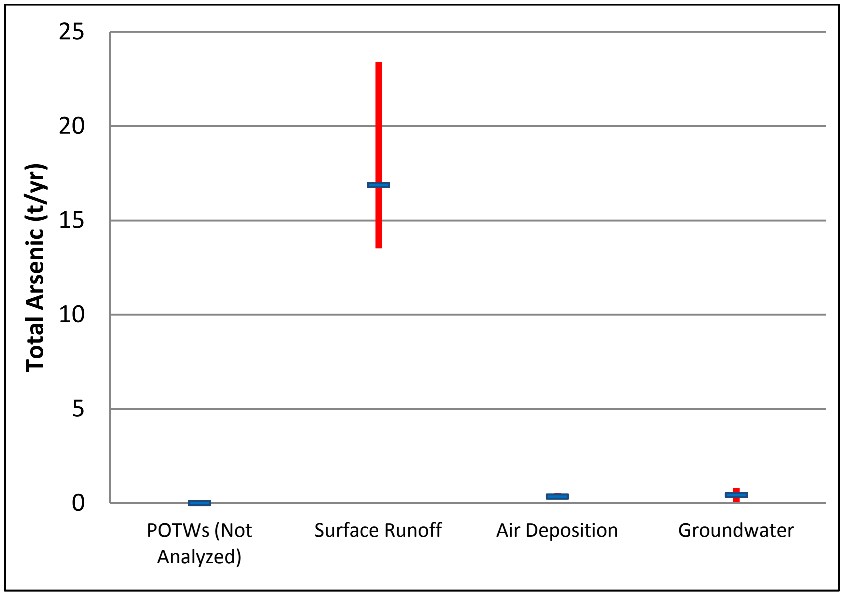


Figure 5. Range (25th - 75th percentiles) and Median Total Arsenic Loads to Puget Sound from Each Major Delivery Pathway.

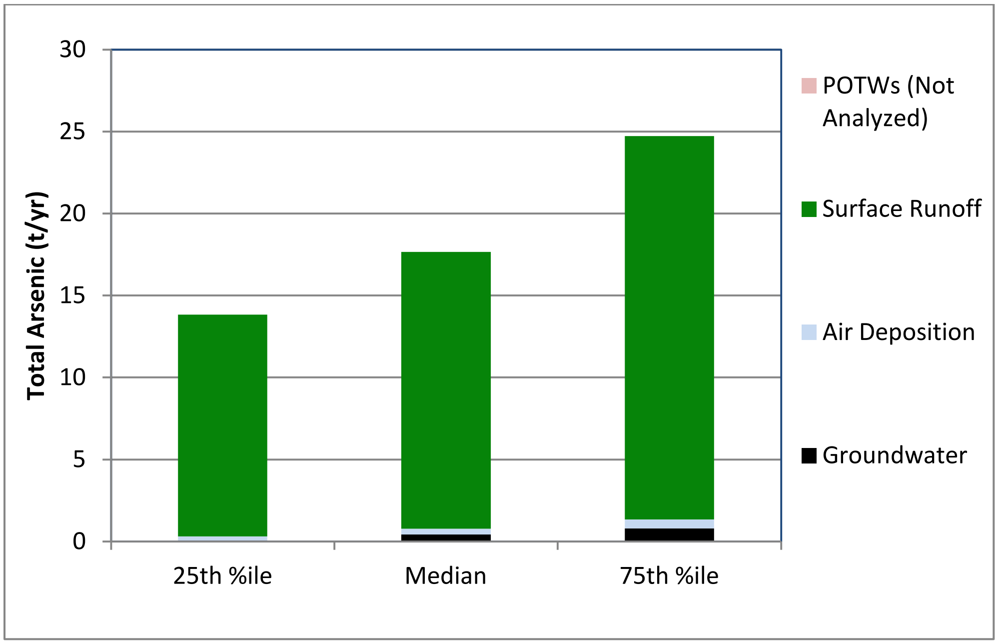


Figure 6. Total Arsenic Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of arsenic transport and fate following release suggests that much of the arsenic will be transported to Puget Sound through surface runoff. Direct deposition to marine waters from atmospheric deposition and loading through direct groundwater discharges appear to be only a small portion of overall loading.

Although not all anthropogenic sources of arsenic were assessed in estimates of primary releases, the total release of arsenic was only a small fraction (3 - 6%) of estimated loads delivered from major controllable pathways. Total arsenic initially emitted to the air (0.3 t/yr) is similar to air deposited on the marine waters (0.25 – 0.54 t/yr), although estimates for releases are for the entire Puget Sound basin and it is not known what portion of the air releases in the basin are transported out of the airshed and what portion of deposited arsenic is imported from outside airsheds.

The inventory of anthropogenic releases suggests that little arsenic is released directly to road surfaces or released through leaching by precipitation. Leaching of arsenic from CCA-treated wood, asphalt shingle roofs, and leaching or mobilization of arsenic-containing agricultural fertilizers only accounts for approximately 0.5 t/yr. In contrast, surface runoff loads range from 13.5 – 23.4 t/yr.

Arsenic loads in surface runoff during baseflow and storm flow conditions are roughly equal, and arsenic concentrations in streams from all land covers decline during storm events. This suggests little enrichment of streams by arsenic mobilized during storms. Instead, stormwater delivered to streams appears to simply dilute the baseflow levels of arsenic. This may indicate that arsenic originates primarily from groundwater.

Ongoing releases of anthropogenic sources of arsenic appear to be minimal, suggesting that a high proportion of the load is due to natural sources or historical releases which reside in the aquatic freshwater environment. Large historical sources of arsenic in the region include the Asarco Smelter in Tacoma which emitted arsenic for decades and may have resulted in large swaths of the Puget Sound area with elevated arsenic (PTI, 1991; San Juan, 1994).

Hazard Evaluation

The hazard evaluation indicates that arsenic is a Priority 2 or unknown level of concern for the categories assessed except for freshwater sediment (Table 2). There were few or no effects data available to adequately compare observed concentrations to surface water effects or human health criteria. Hazard due to tissue residue effects and effects to wildlife were not evaluated.

The limited set of freshwater effects for dissolved arsenic is three orders of magnitude above the 90th percentile value for dissolved arsenic in freshwater (approx. 2 ug/l) and two orders of magnitude below the chronic and acute water quality criteria.

Table 2. Summary of Hazard Evaluation for Arsenic.

Surface Water		**Total N**	**FOD**	**90th %ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	4,528	85%	No/INS	U
	Nearshore Marine	43	93%	INS	U
	Offshore Marine	58	91%	No/INS	U
Sediment		**Total N**	**FOD**	**90th %ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	623	82%	Yes	Priority 1
	Nearshore Marine	399	70%	No	Priority 2
	Offshore Marine	372	84%	No	Priority 2
Tissue Residue Effects		**Total N**	**FOD**	**90th %ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th %ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Freshwater	a	>99%	INS	U
	Nearshore Marine	a	100%	INS	U
	Offshore Marine	a	100%	INS	U

Yellow highlight indicates Priority 1 Level of Concern
FOD=Frequency of detection
INS=Insufficient observed data available for comparison to effects data
U=Unknown level of concern due to lack of sufficient data for adequate comparison
[a] N = 8 for freshwater fish, 11 for nearshore marine bivalves, 2 for nearshore marine invertebrates, 2 for offshore marine bivalves, and 0 for all other categories

Median arsenic concentrations in both freshwater and marine sediments are below the lowest guidelines or standards. However, in freshwater sediments the 90th percentile (approx. 40 mg/kg dw) of observed arsenic concentrations exceed the floating percentile SQS concentration. More than 25% of observed concentrations exceed the Canadian threshold effect level (TEL) and the consensus-based threshold effects concentration (TEC), more than 10% of values exceed the Canadian probable effects level (PEL) and the consensus-based probable effects concentration (PEC), and 5% of observed freshwater arsenic concentrations are at the floating percentile cleanup screening level (CSL).

In marine sediments, arsenic concentrations are nearly all (>95%) well below established guidelines and standards (including the SQS) except for the Canadian TEL which is exceeded by arsenic more than 25% of the observed concentrations in both nearshore and offshore sediments.

Arsenic hazards to human health were difficult to assess due to the paucity of data on inorganic arsenic, the form of arsenic for which the NTR has established criteria. No data were available for inorganic arsenic in edible freshwater fish or invertebrates. In marine waters, the few available data on inorganic arsenic in edible tissues (2 samples each for nearshore invertebrates and offshore fish, 11 samples for nearshore bivalves) all exceed (did not exceed) the NTR criteria. However, due to the small sample size available for assessment and lack of any data for one or more seafood categories, the overall human health level of concern for marine seafood was assigned an unknown level of concern.

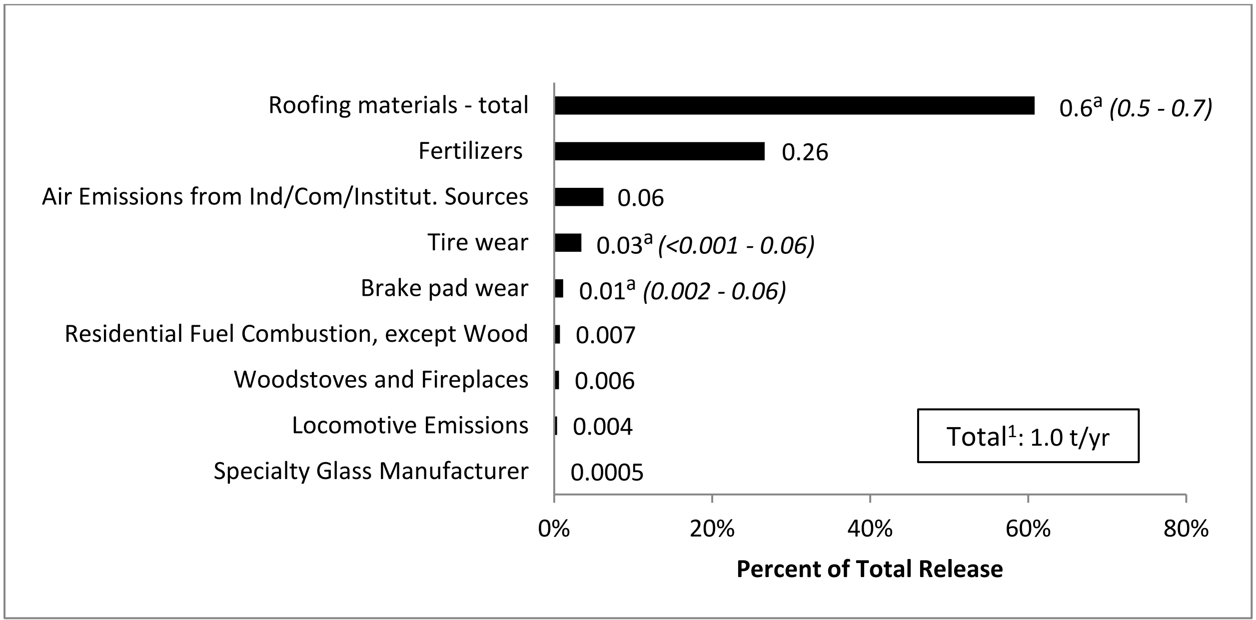
Cadmium

Cadmium is a heavy metal naturally occurring in the earth's crust and is nearly always detectable at concentrations >0.01 ug/l in water and >50 ug/kg (dw) in sediments from freshwater and marine environments (PTI, 1991; Serdar, 2008; Hallock, 2010; Appendix D). Environmental levels of cadmium have been increased above natural levels due largely to manufacturing-related releases, combustion of fossil fuels, and the use of phosphorus fertilizers. Historically, the largest source of cadmium contamination was associated with waste from the now-defunct Asarco smelter in Tacoma (PTI, 1991).

Major Releases from Primary Sources

An inventory of primary cadmium sources suggests that approximately 1.0 metric tons (t) is released annually from anthropogenic sources in the Puget Sound basin. The largest current source of cadmium to the environment appears to be leaching of cadmium from roofing material (Figure 7). Approximately 0.6 t/yr is released from rooftops, with 0.4 t/yr from asphalt composite shingles, 0.14 from built-up roofs, and a small fraction (0.03 t) from metal roofs.

Release from fertilizers accounts for most of the remainder of cadmium release (0.26 t/yr, 27% of total). Road-related sources such as tire and brake pad wear account for approximately 4% of the total release (0.04 t/yr). Comparatively little cadmium is released from industrial sources, with only a single facility reporting fugitive air releases during the previous ten years. Other air releases include locomotives and residential fuel use, but combined, these sources account for only about 6% of the total cadmium release.



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

[a] Mean

Figure 7. Total Cadmium Release in the Puget Sound Basin (values shown are t/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for cadmium loading were obtained from PSTLA loading studies and are included in Table 3. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loading through other pathways was estimated from field studies specifically designed to estimate loads.

Table 3. Total Cadmium Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	0.012	0.22	0.43
Air Deposition	0.031	0.052	0.074
Surface Runoff (b)	0.01	0.01	0.02
POTWs	NA	NA	NA
Ocean Exchange	3.2	2.9	3.9

(a) Lowest, highest, and mid-point of estimated loads
(b) Surface runoff loads based on storm flows only; not detected in any land covers during baseflows and in commercial/industrial areas only during storm flows
NA=not analyzed

The estimated range of groundwater cadmium loads is large (0.012 – 0.43 t/yr). The range in estimates is due primarily to differences in flows used to establish the possible range of loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude. Cadmium was not measured in POTWs for the Phase 3 loading study. Phase 1 estimates suggest that cadmium loads through industrial wastewater may range from 0.02 to 0.9 t/yr (Hart Crowser et al., 2007), but this is based on a limited dataset and exceeds the industrial discharge of cadmium reported in the TRI by one to three orders of magnitude (Ecology, 2011). Phase 1 estimates for cadmium loading via municipal wastewater were based on a small set of non-detected sample results, and the load estimates appear to be small (1 – 4 kg/yr).

The deposition of atmospheric cadmium directly to the marine waters of Puget Sound is approximately 0.031 – 0.074 t/yr, based on fluxes ranging from 0.007 – 0.11 $ug/m^2/d$. Median cadmium fluxes were generally <0.02 $ug/m^2/d$, except for one location within a high-density urban (Tacoma) area including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. Cadmium fluxes at this location were elevated three- to four-fold above fluxes at other locations.

Surface runoff loads for cadmium are estimated to be approximately 0.01 – 0.02 t/yr for the entire Puget Sound basin based on the surface runoff study. Total cadmium was not detected in baseflow samples, although dissolved cadmium was detected in 13% of baseflow samples. Dissolved cadmium was also detected at a higher frequency than total cadmium in storm flow samples (34% and 8%, respectively). In either case, cadmium was detected at such low rates that estimates to calculate loads in surface waters were driven by the analytical reporting limits, and no estimate was derived for baseflow loads.

No cadmium was detected in surface runoff from residential or forested areas. Total cadmium was only detected in commercial/industrial areas – largely as a result of a seasonal first-flush episode – but the overall low frequency of detection was low (27%). However, dissolved cadmium was detected at a high rate in commercial/industrial areas (87%) and a more moderate rate in agricultural land covers (34%).

Overall, there appears to be a large net import of cadmium through exchange at the ocean boundary compared to other load pathways, although this estimate is based on very limited data. Total cadmium concentrations (25th -75th percentile) in the incoming marine waters are 0.091 – 0.097 ug/l, and total cadmium concentrations in the outgoing marine waters are 0.072 – 0.077 ug/l. Total net import was 3.2 – 3.9 t/yr based on an inflow of 53 – 57 t/yr and an outflow of 50 – 53 t/yr.

The net sum of cadmium loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 3.3, 3.0, and 4.4 t/yr, respectively. Under all of these estimates, there is a net cadmium load to Puget Sound.

Cadmium loading from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th -75th percentiles) and median for each pathway in Figure 8. Each pathway represented as a contribution to the total load is displayed in Figure 9.

Total cadmium loading from the major pathways assessed is estimated to be 0.05 – 0.53 t/yr. Groundwater potentially accounts for the largest loading pathway, at 24 – 82% of the total, but the groundwater numbers should be viewed with caution since they are driven largely by analytical reporting limits rather than measurable sample concentrations. The comparatively small contribution from surface runoff (4% – 15% of total) is also derived by non-detected values. Since the groundwater loading estimates are highly variable and load estimates at the low end of the range are small (0.012 t/yr), atmospheric deposition potentially represents the largest loading pathway (up to 62% of total load) if all estimates are assumed to be at the low end of the range.

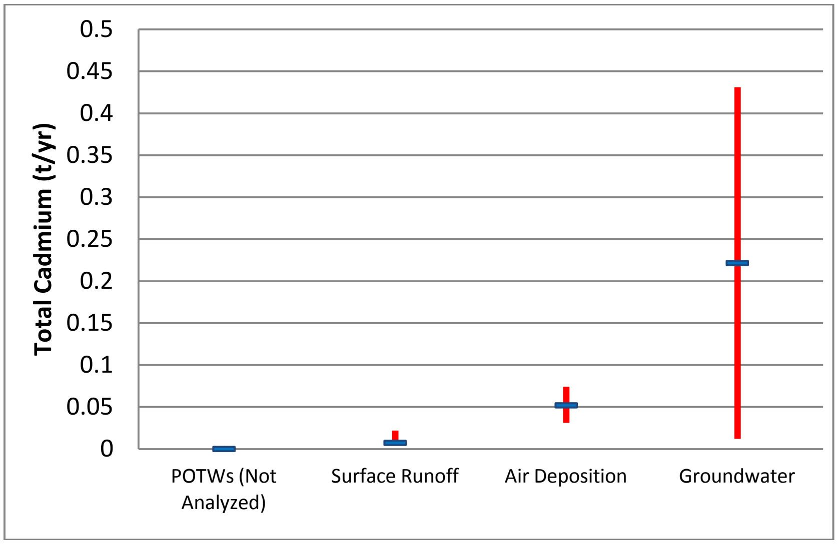


Figure 8. Range (25th - 75th percentiles) and Median Total Cadmium Loads to Puget Sound from Each Major Delivery Pathway.

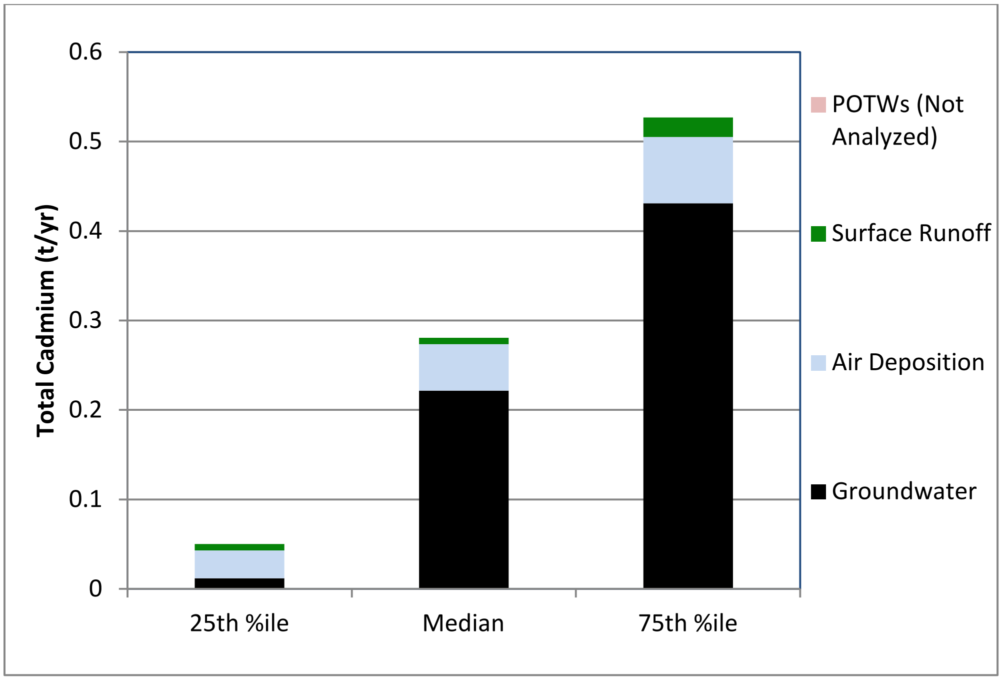


Figure 9. Total Cadmium Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of cadmium transport and fate following release is limited by a lack of data on cadmium in major loading pathways. The available information suggests that most of the anthropogenic cadmium released from primary sources – leaching from roofing material and fertilizers – would be initially mobilized in surface runoff. This may be reflected in the presence of cadmium in storm samples and a lack of cadmium in baseflow samples, but the data are too limited to establish any patterns with even moderate confidence.

The combined loading of cadmium from major controllable pathways (0.050 – 0.53 t/yr) is approximately 20 times lower than releases from all primary sources combined. Air releases of cadmium to the watershed (0.06 t/yr) are not substantially different than atmospheric deposition in marine waters (0.03 – 0.07 t/yr), although marine areas represent only about one-sixth of the watershed. It is not known what portion of the air releases in the basin is transported out of the airshed and what portion of deposited cadmium is imported from outside airsheds.

Hazard Evaluation

The hazard evaluation indicates that cadmium is a Priority 2 or unknown level of concern for the categories assessed except for freshwater sediment (Table 4). Hazards due to tissue residue effects, effects to wildlife, and effects to human health were not evaluated.

The 90th percentile values for dissolved cadmium in freshwater (approx. 0.3 ug/l) are one-half of the concentrations in freshwater where 10% of effects have been documented, and are below the chronic and acute water quality criteria. However, more than 5% of the observed cadmium concentrations in freshwater are above the chronic water quality criterion, and at least 10% of the observed values are above concentrations where 5% or more of the effects have been documented.

Despite enrichment from oceanic waters, the gap between observed cadmium concentrations and effects levels or criteria is much larger for marine waters than for freshwater. The 90th percentiles of dissolved cadmium concentrations in both nearshore and offshore marine waters (approx. 0.09 ug/l and 0.06 ug/l, respectively) are two orders of magnitude below the lowest 5-10% of effects as well as the acute and chronic water quality criteria. However, the limited dataset (n<50) for dissolved cadmium nearshore and offshore marine waters does not meet the criteria established for an adequate comparison, and this evaluation was assigned an unknown level of concern.

Median cadmium concentrations in both freshwater and marine sediments are below the lowest guidelines or standards. However, in freshwater sediments the 75th percentile (approx. 0.9 mg/kg dw) of observed cadmium concentrations exceed the floating percentile SQS concentration, and more than 10% of the observed values exceed the floating percentile CSL.

Cadmium concentrations in marine nearshore and offshore sediment have 90th percentile levels (approx. 1.0 mg/kg dw) one-fifth the SQS. However, the observed concentrations for both nearshore and offshore sediments exceed the Canadian TEL at the 75th percentile levels, and 5% of the nearshore concentrations are at the Lowest Apparent Effects Threshold (LAET).

Table 4. Summary of Hazard Evaluation for Cadmium.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	4,166	7%	No	Priority 2
	Nearshore Marine	32	100%	INS	U
	Offshore Marine	42	100%	INS	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	764	67%	Yes	Priority 1
	Nearshore Marine	462	62%	No	Priority 2
	Offshore Marine	471	70%	No	Priority 2
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

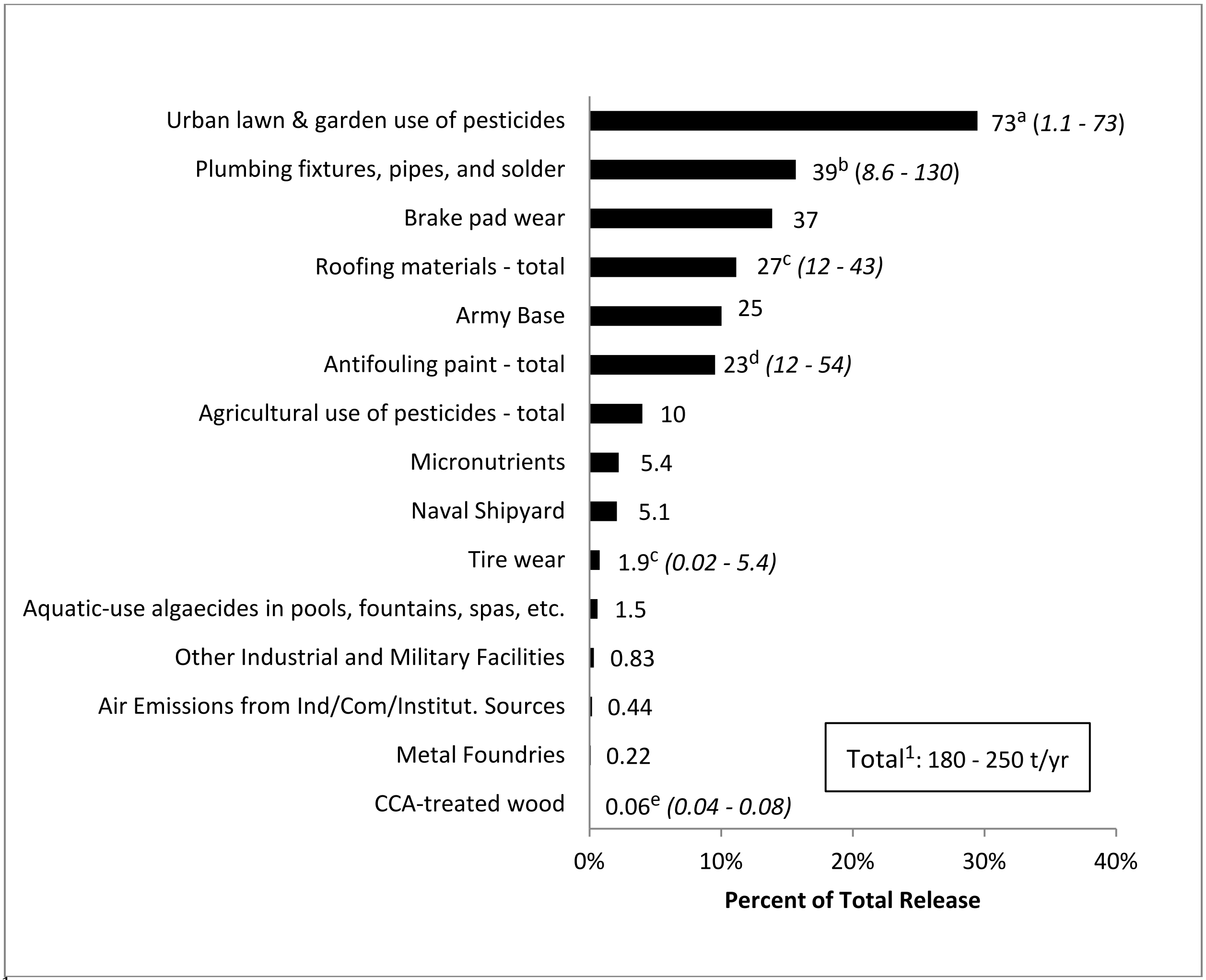
Yellow highlight indicates Priority 1 Level of Concern
FOD=Frequency of detection
INS=Insufficient observed data available for comparison to effects data
U=Unknown level of concern due to lack of sufficient data for adequate comparison

Copper

Copper is a heavy metal naturally occurring in the earth's crust and is nearly always detectable at concentrations >0.5 ug/l in water and >3,000 ug/kg (dw) in sediments from freshwater and marine environments (PTI, 1991; Serdar, 2008; Hallock, 2010; Appendix D). Copper is an essential element for all living organisms and is generally not toxic to humans and terrestrial wildlife at typical environmental concentrations. However, copper can be highly toxic to aquatic organisms at low concentrations.

Major Releases from Primary Sources

An inventory of primary copper sources suggests that approximately 180 – 250 metric tons (t) is released from anthropogenic sources annually in the Puget Sound basin. The largest current source of anthropogenic copper to the environment could potentially be due to urban lawn and garden use (Figure 10). Copper use in urban landscaping as an herbicide/fungicide or possibly as a micronutrient accounts for approximately 73 t/yr by some estimates, but may be as little as 1 t/yr based on other estimates. The authors of the *Sources Report* note the difficulty in obtaining accurate information on pesticide use and note that these data should be viewed with caution since they were not derived from market data, and use rates are difficult to estimate without this information (Ecology, 2011). Estimates of copper used as an agricultural pesticide and micronutrient in the Puget Sound basin are probably more accurate than estimates for urban use, but agricultural use of copper only represents 4% – 6% of the total annual release.



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

[a] High end of range

[b] Median

[c] Average

[d] Sum of means for recreational and commercial and mid-point for naval vessels

[e] Mid-point of range

Figure 10. Total Copper Release in the Puget Sound Basin (values shown are t/yr).

Other major releases of copper are leaching from plumbing components (39 t/yr), vehicle brake pad and tire wear (37 t/yr and 2 t/yr, respectively), and leaching from vessel anti-fouling paint (26 t/yr). Industrial, commercial, and institutional facilities are estimated to release a total of 31 t/yr of copper, with approximately four-fifths reported from activities at the Fort Lewis Army Base, possibly as solid copper from munitions use.

Smaller releases of copper also occur following the use of copper compounds in fountains and spas as an algaecide (1.3 t/yr), and from leaching of copper from CCA-treated wood (0.05 t/yr). There are no currently permitted uses of copper as an aquatic herbicide/algaecide in surface waters of the Puget Sound basin.

Major Delivery Pathways and Loading

Data on major delivery pathways for copper loading were obtained from PSTLA loading studies and are included in Table 5. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Table 5. Total Copper Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	0.099	2.19	4.27
Air Deposition	1.9	2.7	4.1
Surface Runoff	28.4	35.7	66.1
POTWs	2.5	4.33	5.5
Ocean Exchange (b)	-110	-100	-30

(a) Lowest, highest, and mid-point of estimated loads
(b) Negative values indicate a net outflow at the ocean boundary

Estimated groundwater loads of copper range by an order of magnitude (0.1 – 4.3 t/yr). The range in estimates is due primarily to differences in flows used to establish the possible range of loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude.

Copper discharged from POTWs in the Puget Sound basin accounts for loads estimated to be 2.5 – 5.5 t/yr. Phase 1 estimates suggest that copper loads from industrial wastewater are potentially substantial (6 t/yr; Hart Crowser et al., 2007), but this is based on a limited dataset and is far in excess of industrial discharge of copper to surface waters or transferred to POTWs as reported in the TRI (<0.7 t/yr total) (Ecology, 2011).

The deposition of atmospheric copper directly to the marine waters of Puget Sound is approximately 1.9 – 4.1 t/yr, based on fluxes ranging from 0.5 - 19 ug/m^2/d. Copper fluxes were generally <2 ug/m^2/d, except for one location within a high-density urban area (Tacoma) including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. Copper fluxes at this location were consistently an order of magnitude higher than other locations around the Puget Sound region, and were elevated five-fold above a nearby station that did not have the same air pollution influences in such close proximity.

Surface runoff loads for copper are estimated to be approximately 28.4 – 66.1 t/yr for the entire Puget Sound basin based on the surface runoff study. Overall, dissolved copper accounts for 63 – 76% of total copper concentrations in surface water, with the higher proportion of dissolved copper occurring during baseflows.

Total copper concentrations were highest in agricultural areas, whereas dissolved copper concentrations were similar in agricultural and commercial/industrial area. In agricultural, commercial/industrial, as well as forested areas, elevated copper concentrations appeared to correspond with elevations in TSS. The apparent links with TSS in forested sub-basins may be related to a substantial seasonal first-flush episode in forests. However, there appeared to be little overall increase in forest copper concentrations during storm events, whereas the median total copper concentrations increased by two- to three-fold during storms for all other land covers.

Based on sampling marine waters, there appears to be a large net export of copper at the ocean boundary, although this estimate is based on very limited data. Total copper concentrations (25th -75th percentile) in the incoming marine waters are 0.24 – 0.41 ug/l, and total copper concentrations in the outgoing marine waters are 0.38 – 0.46 ug/l. Total net export was 30 – 110 t/yr based on an inflow of 140 – 240 t/yr and an outflow of 250 – 270 t/yr.

The net sum of copper loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is -77, -55, and 50 t/yr, respectively. Under the 25th percentile and median estimates, there is a net export of copper out of Puget Sound due to the large mass exchanged at the ocean boundary. However, when the 75th percentile values are summed, the large surface water load outweighs the smaller export at the ocean boundary, leading to a net load of copper load to Puget Sound.

Copper loading from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th -75th percentiles) and median for each pathway in Figure 11. Each pathway represented as a contribution to the total load is displayed in Figure 12.

Total copper loading from the major pathways assessed is 33 – 80 t/yr. Surface water runoff accounts for the largest pathway (83 – 86%), followed by POTWs (7 – 8%) and air deposition (5 – 6%). Groundwater potentially accounts for up to 5% at the upper end of the estimated range, but this value should be viewed with caution since it is based on literature values of copper in wells and rough estimates of groundwater flow. At the lower end of the load range, copper in groundwater is estimated to account for <1% of the load to Puget Sound.

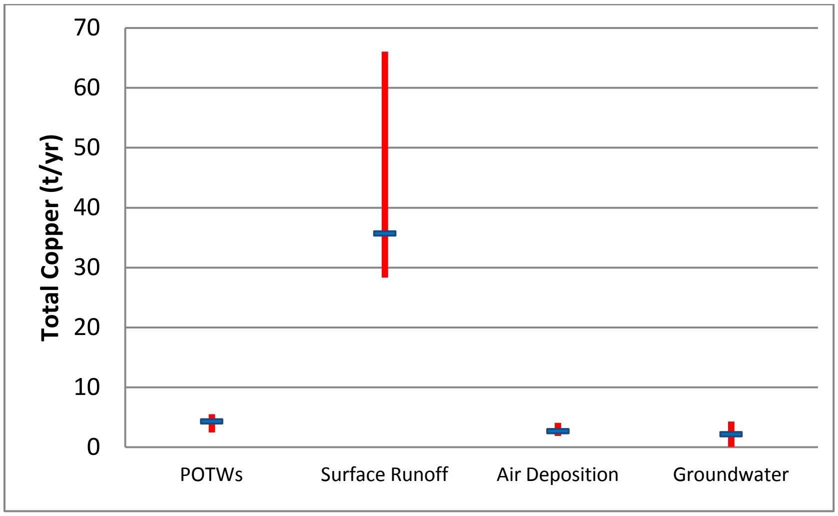


Figure 11. Range (25th - 75th percentiles) and Median Total Copper Loads to Puget Sound from Each Major Delivery Pathway.

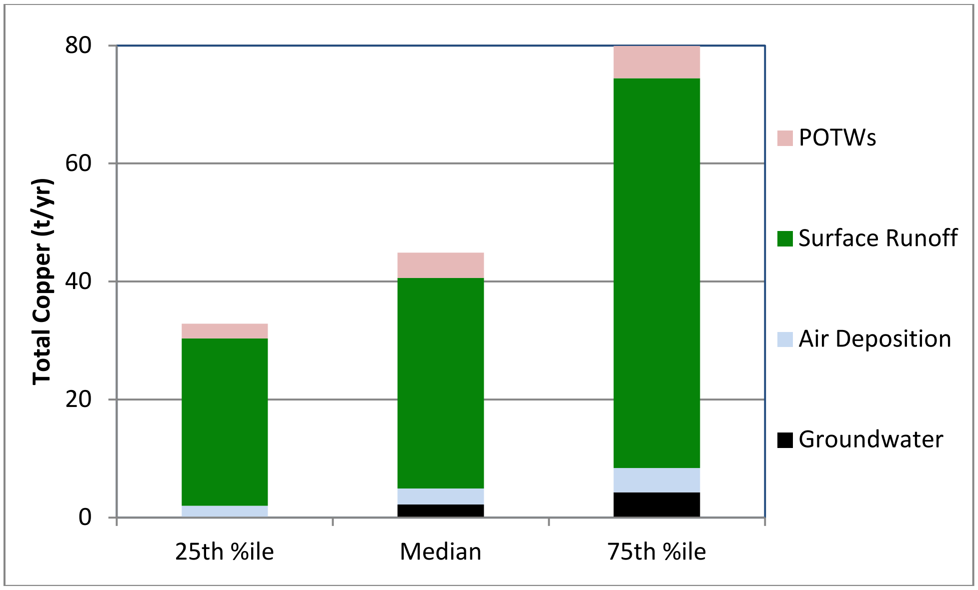


Figure 12. Total Copper Loads to Puget Sound as the Sum of Major Delivery Pathways

Relationship Between Sources and Pathways/Loading

The conceptual model of copper transport and fate following release suggests that much of the copper transported to Puget Sound will occur through surface runoff during storm events. Direct deposition to marine waters from atmospheric deposition and loading through direct groundwater discharges appear to be only a small portion (<15%) of overall loading. The high proportion of copper loading contributed by surface runoff is consistent with the types of sources accounting for the major copper releases.

Major unconstrained releases of copper are potentially from its use in urban landscaping and pesticides, leaching from rooftops, and from vehicle component wear. Together, these mostly urban sources account for as much as 140 t/yr of copper released to the environment in the Puget Sound basin.

It is difficult to draw conclusions regarding the fate of copper released from urban landscaping use and pesticide use. For instance, copper may be highly soluble depending on the formulation applied, and it may be released in dissolved form during storms or irrigation. However, since copper is likely to be used on recently disturbed soil in many instances, release through mobilization of particle-bound copper may also occur. This latter form of release is less likely to be infiltrated into groundwater, a seemingly distinct possible fate for copper solubilized in permeable soil. At the lower estimate of copper pesticide use in urban areas (1 t/yr), the comparatively low rate of use may be much more important locally than on a basin-wide scale.

Copper released from rooftops is likely to be in dissolved form since leaching is the likely release mechanism, but anticipating its pathway following initial release is difficult since it may run along roads and other impervious areas to surface waters, while some may be infiltrated into the soil or delivered to storm sewers and thereafter POTWs.

Brake pad and tire wear may result in a relatively high proportion of copper finding its way to surface runoff since approximately 50% is transported off-roadway as fugitive dust (Sinclair-Rosselot, 2006), although the fate of brake pad dust may vary greatly due to local conditions (Paulson et al., 2011-Draft). This and the possible attenuating factors discussed previously for copper initially released in water, mobilized by water, or released to an impervious surface such as a roadway likely account for much of the difference between amounts released from the unconstrained urban sources mentioned above (140 t/yr) and the amounts loaded to Puget Sound via surface runoff (28 – 66 t/yr).

The differences in copper releases from the unconstrained urban sources and the surface runoff on the regional scale are much smaller than the differences between releases and loads calculated during the mass-balance analysis of two small urban King County watersheds conducted by Paulson et al. (2011-Draft). They calculated that the annual copper mass discharged from these watersheds were less than 10% of the copper estimated to be released just from vehicle component (brake pad and tire) wear and roof runoff. At the much larger scale (entire Puget Sound basin), the high end (75th percentile) estimate of copper discharged to Puget Sound through surface water is equal to the mass of copper released just from vehicle wear and rooftops (66 t/yr). This suggests that while the conceptual relationships between copper sources and loading/pathways may be valid, these relationships may be much more complex and uncertain at finer scales.

Copper deposited atmospherically is difficult to link with its primary source(s). Copper released from stack air emissions is small compared to overall loads (<1%), and copper reported as fugitive air releases in the TRI accounts for only about 2% of the total annual release, for a total maximum release to air of approximately 6 t/yr to the Puget Sound basin. This is higher than the range of copper deposited directly to marine water from the atmosphere (1.9 – 4.1 t/yr), but the latter only accounts for one-sixth of the basin area. However, copper released as fugitive dust from brake pad wear is potentially substantial (>17 t/yr). This may account for the high levels of copper in atmospheric deposition samples at the high-density urban location, which is located near Interstates 5 and 705, associated interchanges, and other major roadways. Copper fluxes at this location were an order of magnitude higher than at most other locations, and the inventory of primary releases indicates that industrial sources may not be large contributors to airborne emissions. Copper fluxes at a location nearby but removed from close-proximity industrial and roadway influences were one-fifth those in the high-density urban area. This indicates that urban locations have strongly localized high copper flux signals, which are not reflected to the same degree in regional elevations of copper.

Disposal of copper at the Ft. Lewis Army Base (25 t/yr) presumably consists of solid copper material placed in waste piles or scattered throughout firing ranges. Solid copper disposal in the terrestrial environment will be retained in a soil reservoir and will only be transported to surface waters through gradual erosion or storm events with high energy flows.

Copper leached from vessel anti-fouling paint (26 t/yr) is presumed to be released entirely to marine waters with the possible exception of the Lake Washington/Lake Union system and freshwater marina areas near the mouths of the Snohomish and Duwamish Rivers.

Of the primary sources inventoried, copper released from residential plumbing components represents the only constrained source assessed. The annual load of copper discharged to POTWs from this source is estimated to be 28 t; discharges to septic systems were estimated to be an additional 11 t/yr (Ecology, 2011). The difference between the amount released and loading from POTWs (2.5 – 5.5 t/yr) is presumably due to the removal of solid material during the treatment process, an assumption that might be easily checked by conducting sampling of representative sludge material. Of course, copper from other constrained sources, naturally occurring copper in water, and copper in stormwater represent additional releases of copper to POTWs, but the exact extent of these contributions are not known.

Although patterns in copper loading pathways appear to be consistent with the types of primary sources, one confounding result is the high concentrations of copper in agricultural areas compared to other land covers. Overall copper releases as agricultural pesticides and micro-nutrients appear to be small (15.3 t/yr combined) compared to the other unconstrained releases previously mentioned, most of which are expected to occur in commercial/industrial and residential areas.

The high concentrations cannot simply be explained by excessive soil erosion in agricultural areas during storms, a scenario that would be expected to cause waters to become enriched with particle-bound copper. While copper in agricultural streams experienced a three-fold increase in concentration during storms, increases in TSS loads were lowest among all land covers (Herrera, 2011). One possible explanation for relatively high copper levels in agricultural streams may simply be that the form(s) of copper used and methods of application in agricultural settings are particularly prone to result in copper migration to surface waters.

Hazard Evaluation

The hazard evaluation indicates that copper is a Priority 1 level of concern for freshwaters, nearshore marine surface waters, and freshwater sediments (Table 6). Copper is a Priority 2 level of concern for offshore marine surface waters and marine sediments. Hazards due to tissue residue effects, effects to wildlife, and effects to human health were not evaluated.

Table 6. Summary of Hazard Evaluation for Copper.

Surface Water		**Total N**	**FOD**	**90^{th}%ile Observed Conc. >** *10^{th} %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	5,378	92%	Yes	Priority 1
	Nearshore Marine	107	100%	Yes	Priority 1
	Offshore Marine	71	100%	No	Priority 2
Sediment		**Total N**	**FOD**	**90^{th}%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	826	>99%	Yes	Priority 1
	Nearshore Marine	519	>99%	No	Priority 2
	Offshore Marine	560	98%	No	Priority 2
Tissue Residue Effects		**Total N**	**FOD**	**90^{th}%ile Observed Conc. >** *10^{th} %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90^{th}%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

Yellow highlight indicates Priority 1 Level of Concern

FOD=Frequency of detection

Dissolved copper concentrations in freshwater have a 90th percentile value of approximately 3.5 ug/l, higher than the level where more than 10% of effects documented for aquatic organisms occur and above the chronic water quality criterion (calculated at 25 mg/l calcium carbonate). At least 5% of the concentrations are above the acute water quality criterion (also calculated at 25 mg/l calcium carbonate).

In marine waters, nearshore concentrations of dissolved copper are distinctly higher than those observed offshore. At the 90th percentile level, the nearshore concentration (approx. 5 ug/l) is more than double the offshore concentration (approx. 2 ug/l) and exceeds both the chronic and acute water quality criteria. The upper levels (90th – 95th percentile values) of both the observed nearshore and offshore dissolved copper levels approach or exceed the 10th percentile values) of the ECOTOX dataset used for these comparisons, but only the observed nearshore data have 90th percentile values that exceed this threshold for assigning a Priority 1 level of concern.

Median copper concentrations in both freshwater and marine sediments are below all guidelines and standards except the marine Canadian TEL. However, in freshwater sediments the 90th percentile (approx. 90 mg/kg dw) of observed copper concentrations exceed the floating percentile SQS as well as the Canadian TEL and the consensus-based TEC. More than 5% of the observed freshwater sediment values exceed the Canadian PEL and the consensus-based PEC for copper.

In marine sediments, the 90th percentiles of the observed copper concentrations (approx. 90 mg/kg dw for nearshore and 70 mg/kg dw for offshore) are similar to those for freshwater sediments, but the marine SQS is much higher than the freshwater floating percentile SQS. As a result, all but possible outlier concentrations exceed the SQS in marine sediments.

Regionally Important Biological-Effects data

Copper is one of the most far-reaching potential priority toxicants in the Puget Sound region due largely to its ability to alter the sensory capacity and behavior of a wide variety of aquatic organisms. A number of local researchers have documented these effects in different organisms and in different ways.

Tierney et al. (2010) reviewed over 150 papers and found that avoidance behaviors were common in a variety of fresh and salt water fishes at less than 1 ug/l to concentrations ranging up to 20-30 ug/l. Tested species included coho and Chinook salmon as well as rainbow trout and golden shiner. Hecht et al. (2007) compiled a similar body of evidence for the disruptive effects of copper on juvenile salmonids. They used EPA methodologies to calculate benchmark concentrations predicted to represent 10% and 50% reductions in chemosensory response at 0.18 ug/l and 2.1 ug/l respectively. These values bracket a variety of other regional primary literature sources which confirm that the environmentally relevant range of <1.0 to 5.0 ug/l copper adversely impacts a variety of Puget Sound basin fish, particularly salmonids. Similar neurologic impacts were found by Linbo et al. (2006) on the mechanosensory lateral line of fish.

Sandahl et al. (2004) found copper concentrations of 4.4 ug/l produced sublethal neurotoxicity in coho salmon. In this laboratory study, copper reduced the ability of coho salmon to detect the natural odorants taurocholic acid and L-serine. Further study by Sandahl et al. (2007) confirmed that concentrations as low as 2 ug/l copper not only affect the neurologic systems of fish but also alter their behavioral responses to alarm pheromones. Other studies such as Baldwin et al. (2003) have also found olfactory inhibition at a comparable environmentally relevant concentration of 2.3 ug/l.

Hansen et al. (1999) produced a seminal work which was used by several of the subsequent reviews discussed above. In it they documented Chinook salmon avoidance behaviors at concentrations as low as 0.7 ug/l dissolved copper. However, Chinook also failed to avoid concentrations >44 ug/l due to the extensive neural saturation. This window of effect potentially contributes to mortality from prolonged copper exposure or impairment of olfactory dependent behaviors such as homing. Additional studies by McIntyre et al. (2008) found that water hardness had very little effect on copper's ability to alter olfactory function in coho salmon despite water hardness being a variable influencing the Washington State water quality criteria. All of these reviews and studies on regionally relevant species provide an additional line of evidence suggesting that copper is a very important toxicant at concentrations well within the range found it the Puget Sound regional environment.

Lead

Lead is a naturally occurring heavy metal that is a major constituent of more than 200 minerals and is nearly always detectable at concentrations > 0.01 ug/l in water and >100 ug/kg (dw) in sediments from freshwater and marine environments (PTI, 1991; Serdar, 2008; Meredith and Furl, 2009). Lead also accumulates in fish, particularly in bony material, but does not biomagnify to any meaningful extent (Eisler, 1988b).

Although lead occurs naturally in the earth's crust, human activity has increased environmental levels by one-thousand-fold during the past three centuries (ATSDR, 2007). Most recently, the use of tetra-ethyl lead in gasoline ("leaded gasoline") accounted for hundreds of millions of pounds of lead per year in the U.S. alone before being phased out from 1973 – 1996; by 1995, lead emissions from gasoline were estimated to be less than 1% of the level prior to initiation of the phase out (EPA, 1996).

Historically, concerns surrounding the effects of lead have been focused on toxicity to humans, particularly children. Ecology and WDOH (2009) have reviewed the history, exposure pathways, and effects of lead on humans in Washington. Environmental effects, particularly in the aquatic environment, are less apparent.

Major Releases from Primary Sources

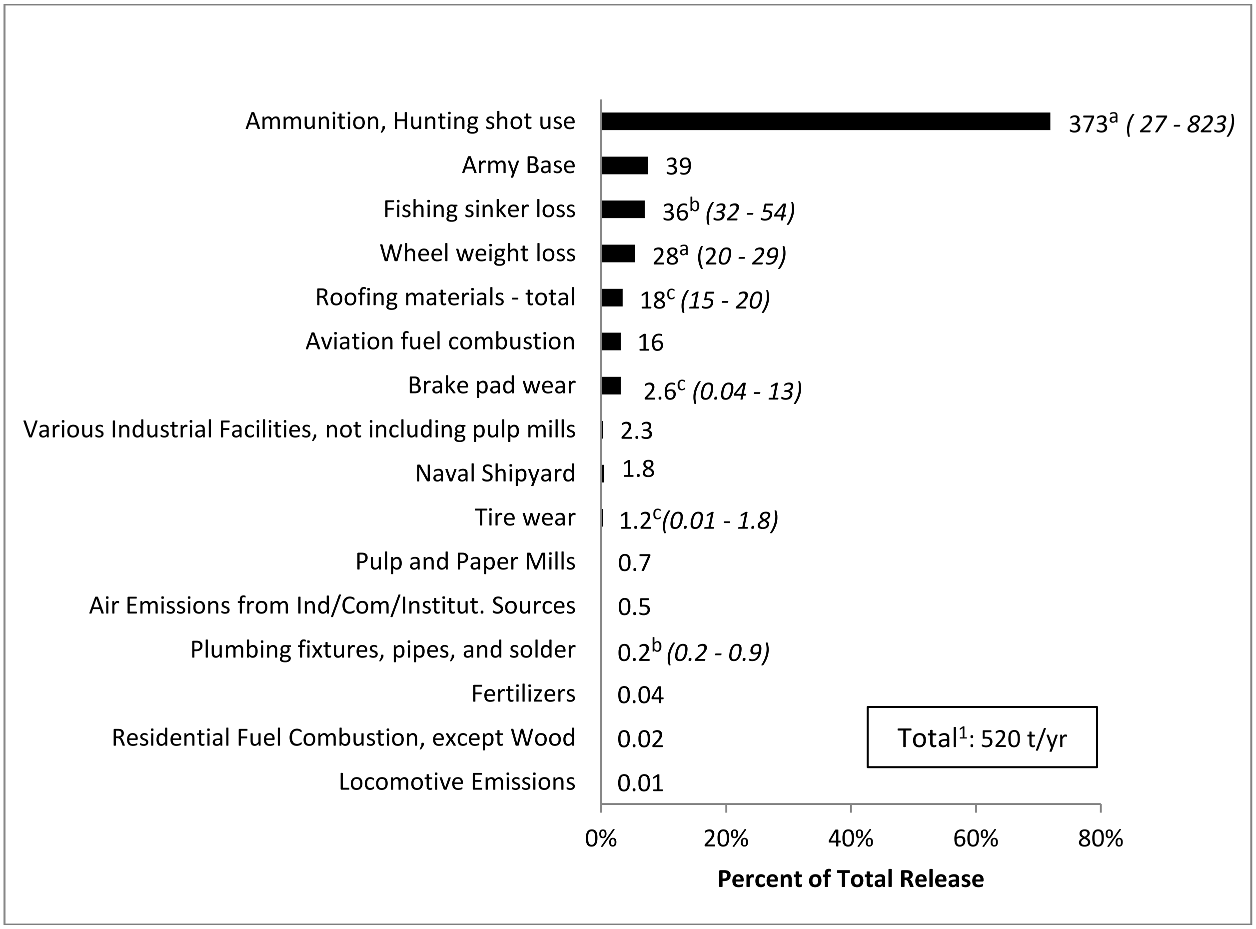
An inventory of primary lead sources suggests that approximately 520 metric tons (t) is released annually from anthropogenic sources in the Puget Sound basin. The largest current source of lead to the environment is the use of ammunition and lead shot (Figure 13). Together with lost wheel weights, fishing sinkers, and a self-reported release at Fort Lewis presumed to be from ammunition use, approximately 90% (480 t) of the anthropogenic releases of lead in the basin may be as solid metallic lead in bulk form.

Other sources of lead include leaching from materials such as roof runoff (18 t/yr) and abrasion of vehicle brake pads and tires (4 t/yr combined). Although these releases are small compared to ammunition use, they represent the most likely sources of lead to be mobilized in stormwater following release. To be more precise, lead in roof runoff requires rain storms for its release, and approximately 50% of brake pad particles are released to the road surface (Garg et al., 2000;

Sinclair- Rosselot, 2006) and may be subsequently entrained in stormwater (depending on season and conditions). Tire particles are presumably released mainly to road surfaces, although some portion becomes transported away from the release point as fugitive dust.

Additional releases of lead include emissions from combustion of aviation fuel (16 t/yr) and approximately 0.5 t/yr released to the air from point sources; pulp mill emissions appear to make up the bulk of this latter category.

Other smaller releases include approximately 1 t/yr released from residential plumbing components, and 0.040 t/yr (40 kg/yr) released through fertilizer application.



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

[a] Most reasonable estimate

[b] Median

[c] Mean

Figure 13. Total Lead Release in the Puget Sound Basin (values shown are t/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for lead loading were obtained from PSTLA loading studies and are included in Table 7. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Table 7. Total Lead Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	0.044	1.07	2.10
Air Deposition	0.63	1.1	1.5
Surface Runoff	2.80	4.67	7.64
POTWs	0.14	0.18	0.25
Ocean Exchange	21	21	18

(a) Lowest, highest, and mid-point of estimated loads

Estimated groundwater loads of lead range by two orders of magnitude (0.044 – 2.1 t/yr). The range in estimates is due to differences in flows used to establish the possible range of loads as well as differences in methods used to estimate representative lead concentrations; most of the data were non-detected values.

Lead discharged from POTWs in the Puget Sound basin accounts for loads estimated to be 0.14 – 0.25 t/yr. Phase 1 estimates suggest that lead loads from industrial wastewater are potentially substantial (0.3 – 9 t/yr; Hart Crowser et al., 2007). This is based on a limited dataset yet brackets the estimate of the industrial discharge of lead to surface waters or transferred to POTWs as reported in the TRI (1.4 t/yr total) (Ecology, 2011).

The deposition of atmospheric lead directly to the marine waters of Puget Sound is approximately 0.63 – 1.5 t/yr, based on fluxes ranging from 0.15 - 8.6 ug/m^2/d. Lead fluxes were generally <1 ug/m^2/d, except for one location within a high-density urban area (Tacoma) including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. Lead fluxes at this location were consistently an order of magnitude higher than other locations around the Puget Sound region, and were elevated five-fold above a nearby station that did not have the same air pollution influences in such close proximity

Surface runoff loads for lead are estimated to be approximately 2.8 - 7.6 t/yr for the entire Puget Sound basin based on the surface runoff study. Dissolved lead accounted for only a small portion of the total lead concentrations, and elevated concentrations of total lead appeared to correspond with elevated TSS (Herrera, 2011). Lead has a high affinity for particulate matter and is generally found at low proportions in the dissolved phase (Meredith and Furl, 2009; Hallock, 2010). Lead is therefore much more likely to be transported as particle-bound lead rather than in the dissolved phase.

The ratio of lead concentrations in storm flows-to-baseflows was consistently higher for lead than for other COCs analyzed. Lead in storm flows was higher compared to baseflows by factors of 3 to 6 depending on land cover (commercial/industrial was highest). This is consistent with particle-bound constituents which require storm flows to become mobilized.

Total lead was present at the highest concentrations in commercial/industrial land covers, generally by factors of 2 to 5. Overall median total lead concentrations in commercial/industrial areas increased by six-fold during storm events, while only increasing by factors of 2 to 3 in other land cover types. Although elevations in lead during storm flows were most pronounced in commercial/industrial areas, seasonal first-flush signals were only evident in residential (dissolved lead) and forest sub-basins (total lead).

Like cadmium, there appears to be a large import of lead through exchange at the ocean boundary compared to other load pathways, although this estimate is based on very limited data. Total lead concentrations (25th-75th percentile) in the incoming marine waters are 0.087 – 0.125 ug/l, and total lead concentrations in the outgoing marine waters are 0.047 – 0.087 ug/l. Total net import was 18 – 21 t/yr based on an inflow of 51 – 73 t/yr and an outflow of 30 – 55 t/yr.

The net sum of lead loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 25, 28, and 30 t/yr, respectively. Under all of these estimates, there is a net lead load to Puget Sound.

Lead loadings from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th - 75th percentiles) and median for each pathway in Figure 14. Each pathway represented as a contribution to the total load is displayed in Figure 15.

Total lead loading from the major pathways assessed is 3.6 – 12 t/yr. Surface water runoff accounts for the largest pathway (66 – 77%), followed by air deposition (13 – 17%). Groundwater potentially accounts for up to 18% at the upper end of the estimated range, but this value should be viewed with caution since it is based on literature values of lead in wells and rough estimates of groundwater flow. At the lower end of the load range, lead in groundwater is estimated to account for 1% of the load to Puget Sound. Loading through POTWs represents only a small portion of total lead loads to Puget Sound (2 – 4%).

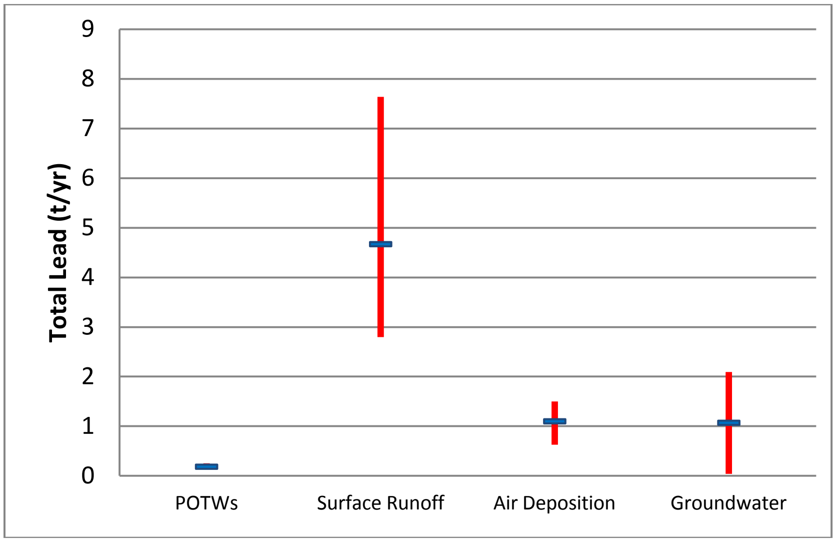


Figure 14. Range (25th - 75th percentiles) and Median Total Lead Loads to Puget Sound from Each Major Delivery Pathway.

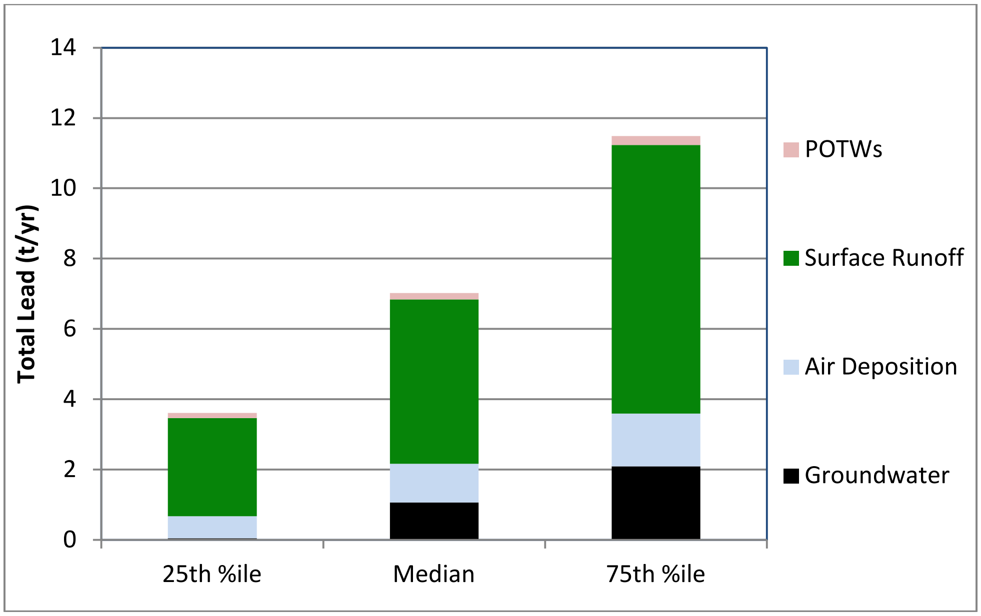


Figure 15. Total Lead Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of lead transport and fate following release suggests that much of the lead transported to Puget Sound will do so through surface runoff during storm events. Lead released to road surfaces through roof runoff, lost wheel weights, and tire and brake pad wear appears to represent the largest release to road surfaces. Combined, these account for an estimated 51 t/yr of lead released, or about 7-18 times the estimated lead load in surface runoff. These differences can be explained largely by the source for lead released to road surfaces. For instance, not all rooftop runoff will be delivered to roadways; some may be infiltrated or delivered to storm sewers and thereafter to POTWs. Lost wheel weights will largely remain in bulk metallic form and only gradually become pulverized and leached. Brake pad and tire wear may represent the lead source with the highest proportion of lead to find its way to surface runoff, even though a substantial fraction may be transported off-roadway as fugitive dust.

Lost fishing sinkers and lead shot and other ammunition landing in surface waters will gradual leach lead to the aquatic environment, although this likely results in only small increases in water column concentrations. Lead ammunition landing in the terrestrial environment will likely be retained in a soil reservoir and will only be transported to surface waters through gradual erosion or storm events with high energy flows. In general, lead from ammunition will be retained in the soil and not pose a problem to surface waters, with the exception of shooting ranges which may accumulate large enough masses of lead to impact nearby waterbodies. Two instances of high lead concentrations in streams and soils resulting from spent lead at shooting ranges have been documented recently in western Washington (Era-Miller, 2009; Ecology and WDOH, 2009).

The ultimate fate of lead emitted to air is less certain; only a small fraction of the estimated releases to air are deposited directly to the waters of Puget Sound, and it is not known what portion of the air releases in the basin are transported out of the airshed and the portion of deposited lead that is imported from outside airsheds. Approximately 19 t/yr are released to the air within the Puget Sound basin (not counting fugitive brake pad and tire dust) compared to 0.6 – 1.5 t/yr directly deposited to marine waters. Considering the area of the entire Puget Sound basin (six times the marine area) and assuming the same rate of deposition across the basin (an assumption that has not been verified), the ranges of air deposition fall within a factor of 2 compared with lead emissions to air. Atmospherically deposited lead would presumably be washed off surfaces in runoff – most likely in particulate form – and ultimately be transported to the Puget Sound through surface runoff, although infiltration to groundwater and paths to POTWs are other possible scenarios for secondary and tertiary pathways.

Although comparatively small amounts of lead are released in constrained sources, release of lead from residential plumbing fixtures (0.2 t/yr) almost certainly is received at POTWs. Annual loads of lead released to POTWs from this source appear to be nearly identical to the amount discharged from POTWs. Presumably, removal of lead would occur during the removal of solid material during the treatment process. Lead from other constrained sources, naturally occurring lead in water, and lead in stormwater represent additional releases of lead to POTWs, but the extent of these contributions are not known.

Hazard Evaluation

The hazard evaluation indicates that lead is a Priority 2 or unknown level of concern for all categories assessed (Table 8). Hazards due to tissue residue effects, effects to wildlife, and effects to human health were not evaluated.

The 90th percentile values for dissolved lead in freshwater (approx. 0.5 ug/l) are an order of magnitude below the 10th percentile of effects data and the acute water quality criterion, although the values are only slightly less than the chronic water quality criterion. In marine waters, the gap between observed concentrations and those where criteria are set and where effects occur is similar to that for freshwater. However, the dataset for observed nearshore marine water was too small (n<50) to assign a level of concern.

Table 8. Summary of Hazard Evaluation for Lead.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	4,427	33%	No	Priority 2
	Nearshore Marine	44	68%	INS	U
	Offshore Marine	77	88%	No	Priority 2
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	838	96%	No	Priority 2
	Nearshore Marine	472	95%	No	Priority 2
	Offshore Marine	478	99%	No	Priority 2
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

FOD=Frequency of detection
INS=Insufficient observed data available for comparison to effects data
U=Unknown level of concern due to lack of sufficient data for adequate comparison

Unlike most other metals, lead appears to have a fairly distinct pattern of higher concentrations in offshore marine waters compared with concentrations observed nearshore. This may reflect lead enrichment of marine waters through ocean exchange. For cadmium, the only other metal assessed which is comparatively high in oceanic waters, the higher concentrations in offshore water may also be a reflection of this ocean enrichment process.

At least 10% of the observed lead concentrations in freshwater sediments exceed the Canadian TEL and PEL as well as the consensus-based TEC and PEC. However, the 90th percentile value (approx. 200 mg/kg dw) did not exceed the floating percentile SQS, making lead one of the few COCs that did not exceed this threshold.

Lead concentrations in marine nearshore and offshore sediment have 90th percentile values of approximately 100 mg/kg dw and 70 mg/kg dw, respectively. These concentrations are not above the SQS and exceed only the consensus-based TEC among the guidelines and standards used for comparison.

As mentioned previously, lead hazards to fish, wildlife, and human health were not assessed due to the lack of effects data. However, although lead shot has been prohibited in Washington for all waterfowl, coot, and snipe hunting since a nationwide phase-in of non-toxic shot was implemented during 1986-1991, lead poisoning of birds due to ingestion of lead shot remains a concern (Ecology and WDOH, 2009).

Mercury

Mercury is a naturally occurring heavy metal in the earth's crust and is nearly always detectable at concentrations >0.005 ug/l in water and >5 ug/kg (dw) in sediments from freshwater and marine environments (PTI, 1991; Serdar, 2008; Hallock, 2010; Appendix D). Unlike other metals, mercury is liquid at typical ambient temperatures, is volatile, and bioaccumulates to a high degree in edible tissues of fish (i.e. fillet), particularly those occupying high trophic positions.

Mercury naturally degasses from soils, the rate of which may be increased dramatically by disturbances such as logging and land development, and inundation caused by dam construction. Historically, a large source of mercury to Puget Sound was a now-defunct chloralkali plant in Bellingham (PTI, 1991), although mercury is released through numerous industrial and combustion sources as well.

Major Releases from Primary Sources

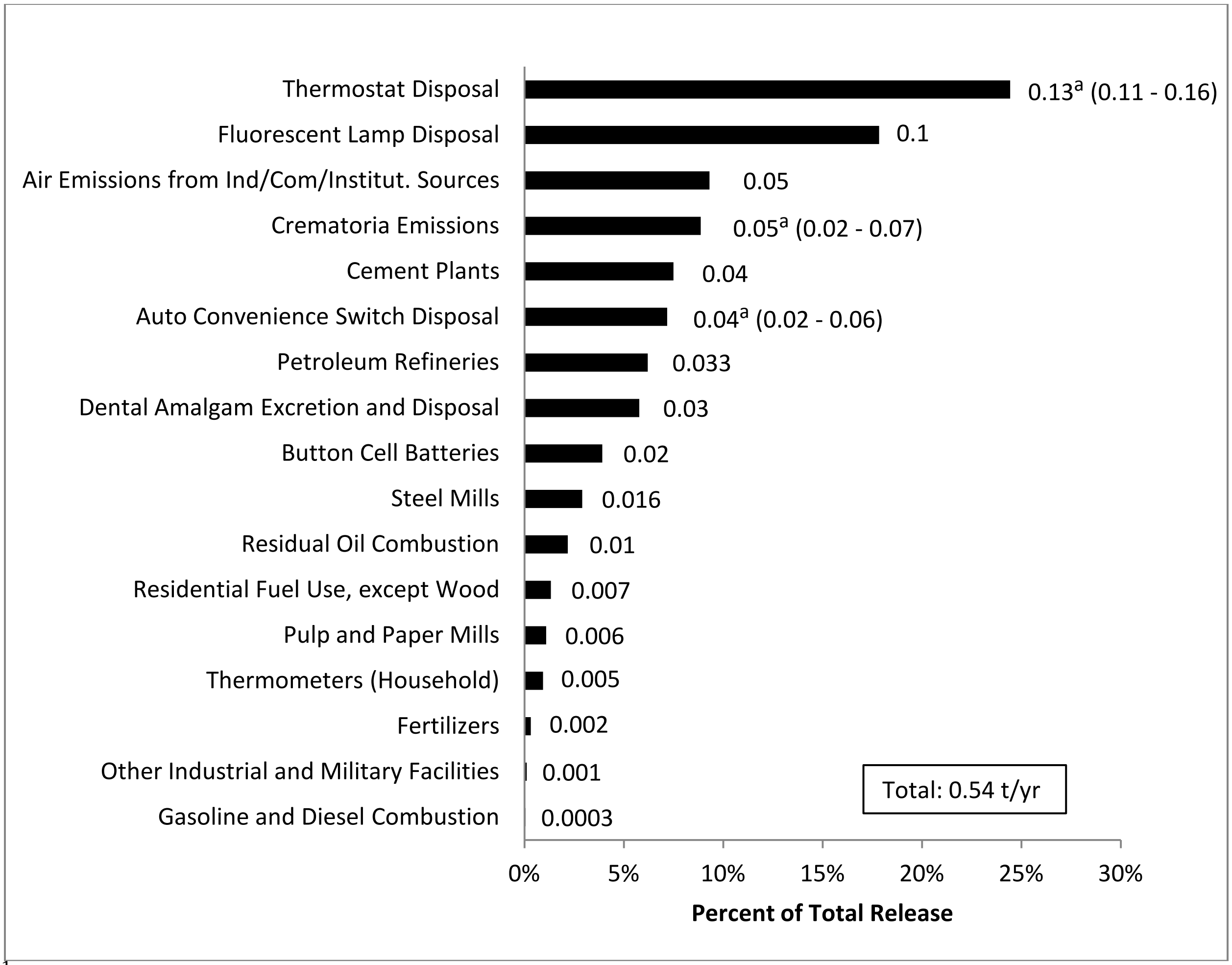
An inventory of primary mercury sources suggests that approximately 0.54 metric tons (t) is released annually from anthropogenic sources in the Puget Sound basin. The largest current source of anthropogenic mercury to the environment may be due to thermostat and fluorescent lamp disposals (24% and 18%, respectively) (Figure 16).

Mercury releases from improper disposal of other materials may account for an additional 11% of the total release in the Puget Sound basin. These products contain mercury as liquid, or as in the case of fluorescent lamps, in vapor form. Since mercury has the potential to volatilize, there is likely some portion of liquid mercury that is released from landfills due to disposal of these products, even though collection and recycling efforts are underway to prevent these circumstances. Nearly all of the anthropogenic mercury sources assessed in the *Sources Report* have been addressed in the Mercury Chemical Action Plan (Ecology and WDOH, 2003), and efforts are underway to reduce or eliminate mercury releases from these sources.

Air emissions from major industrial facilities reporting under TRI represent approximately 18% of the total mercury release, and four-fifths of these are stack air emissions. As much as of one-quarter of the mercury release to air in the Puget Sound basin may be through combustions emissions. Much of this may be due to fossil fuel combustion, although mercury emissions from crematoria and cement plants may originate from the source material rather than the fuel.

Mercury is also released from the TransAlta Centralia Generating Plant at an annual rate of approximately 0.15 t (Ecology, 2011). Although the TransAlta plant was not included in the source inventory since its location falls outside of the Puget Sound basin, it is upwind of the basin and at least two nearby lakes in the Puget Sound basin have mercury levels in sediment that appear to reflect deposition from the plant (Furl and Meredith, 2010).

Other mercury releases which do not fall under air emission or landfill disposal categories include disposal and excretion of dental amalgam (0.03 t/yr, 6% of total) and mercury contained in fertilizer, particularly nitrogen and potassium material (0.002 t/yr, <1% of total).



[1] Sum of best estimates. Best estimates are either the mean, mid-point, median, or most reasonable estimate for each source.

[a] Mid-point of range

Figure 16. Total Mercury Release in the Puget Sound Basin (values shown are t/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for mercury loading were obtained from PSTLA loading studies and are included in Table 9. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads. Mercury was not measured in marine waters to assess exchange at the ocean boundary.

Table 9. Total Mercury Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	0.0047	0.049	0.094
Air Deposition	0.0094	0.02	0.033
Surface Runoff	0.091	0.136	0.238
POTWs (b)	NR	0.0024	NR
Ocean Exchange	NA	NA	NA

(a) Lowest, highest, and mid-point of estimated loads
(b) Estimate from Phase 2 (Envirovision et al., 2008b)
NR=not reported
NA=not analyzed

The estimated groundwater mercury load ranges by an order of magnitude (0.005 – 0.09 t/yr). The range in estimates is due primarily to the range in flows used to calculate loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude.

Mercury was not measured in POTWs for the Phase 3 loading study. Phase 2 estimates for mercury loading through wastewater calculated an estimated release of 0.002 t/yr from municipal wastewater treatment plants and an additional 0.007 t/yr from industrial discharges, the latter of which is considered an underestimate due to incomplete sampling (Envirovision et al., 2008b).

The deposition of atmospheric mercury directly to the marine waters of Puget Sound is approximately 0.009 – 003 t/yr, based on fluxes ranging from 0.003 – 0.020 ug/m^2/d. Median mercury fluxes were generally ≤0.010 ug/m^2/d, except for one location within a high-density urban (Tacoma) area including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. Fluxes at this location were two- to three-fold higher than at other locations.

Surface water runoff loads for mercury are estimated to be approximately 0.09 – 0.24 t/yr for the Puget Sound basin based on the surface runoff study. Elevations in total mercury concentrations appeared to correspond with elevated TSS in all areas except agriculture land covers, although dissolved mercury accounted for one-half to two-thirds of the total mercury concentration.

During storm events, mercury concentrations in surface water increased by factors of 2 to 3 over baseflow concentrations. Agricultural areas have the highest mercury concentrations in surface water during both baseflow and storm flow conditions, followed by residential areas, commercial/industrial sub-basins, and forests. A substantial seasonal first-flush episode was evident for total mercury concentrations in forests but was not seen in other land covers.

The net sum of mercury loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 0.1, 0.2, and 0.3 t/yr, respectively. Under all of these estimates, there is a net mercury load to Puget Sound, although the possibility of a net export out of Puget Sound could not be explored since ocean boundary water was not sampled during the loading studies.

Mercury loading from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th - 75th percentiles) and median for each pathway in Figure 17. Each pathway represented as a contribution to the total load is displayed in Figure 18.

Total mercury loading from the major pathways assessed is 0.11 – 0.36 t/yr. Surface runoff accounts for the largest pathway (65 – 87%), followed by air deposition (9%). Groundwater potentially accounts for up to 26% at the upper end of the estimated range, but this value should be viewed with caution since it is based on literature values of mercury in wells and rough estimates of groundwater flow. At the lower end of the load range, mercury in groundwater is estimated to account for 4% of the load to Puget Sound. The Phase 2 estimate of loading through POTWs – data obtained from the literature – is roughly 2% of the total mercury load to Puget Sound.

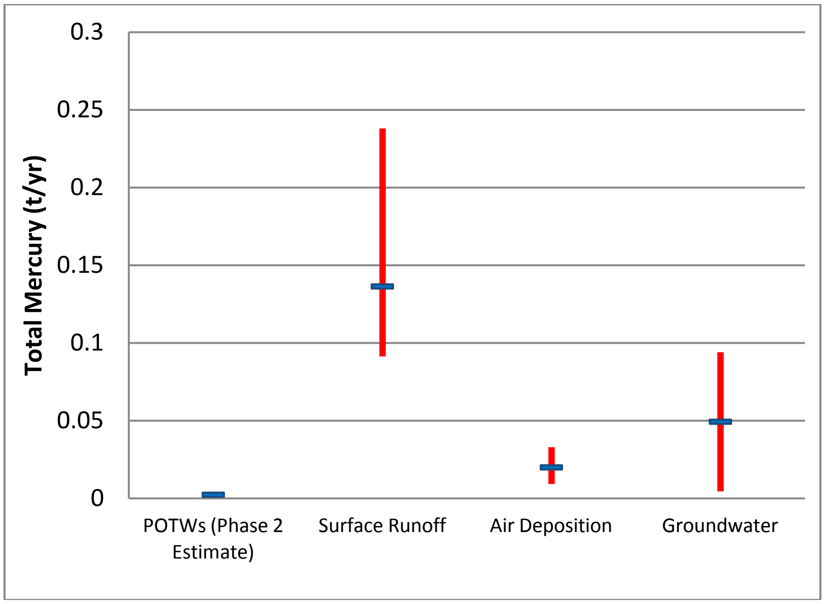


Figure 17. Range (25th - 75th percentiles) and Median Total Mercury Loads to Puget Sound from Each Major Delivery Pathway.

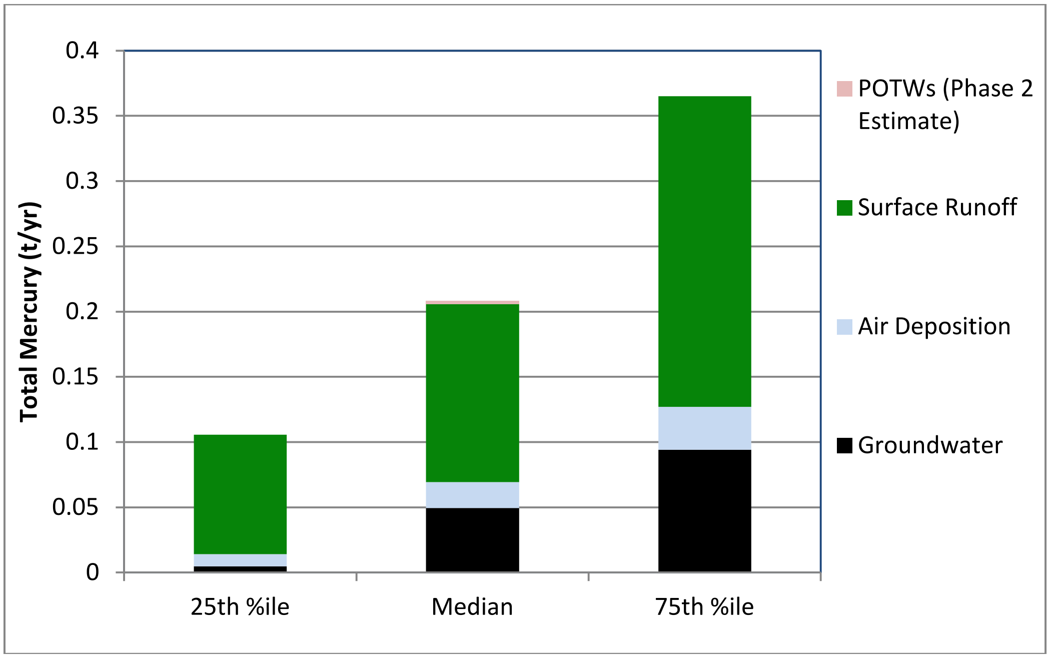


Figure 18. Total Mercury Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of mercury transport and fate following release suggests that much of the mercury transported to Puget Sound will occur through surface runoff, mostly during storm events, even as a high proportion of initial releases are emissions to air. Since most of the anthropogenic mercury releases occur as air emissions, the surface water pathway may be assumed to represent a secondary or tertiary pathway. Other possible explanations for the differences between the high proportion of air emission as a mercury source and the high proportion of surface runoff as a delivery pathway are natural sources of mercury or continuous mobilization of historic releases of mercury remaining in aquatic systems.

Total inventoried anthropogenic mercury releases to air in the Puget Sound basin are approximately 0.5 t/yr; closer to 0.7 t/yr if mercury released from the TransAlta plant is included. Since releases to air are at least double the loads from all major pathways combined, it seems reasonable that some of the mercury atmospherically deposited on land is entrained in surface runoff and transported to Puget Sound. Applying the known median atmospheric mercury deposition rates to marine waters to the entire Puget Sound watershed would result in an additional 0.1 t/yr of deposition. If all of the mercury assumed to be deposited to land surfaces under this scenario were mobilized in surface runoff, it would closely match the median load delivered to Puget Sound through the surface runoff pathway.

The air deposition study found that, unlike other trace elements measured, mercury did not vary significantly among stations, and much of the loading occurred as a result of washout during rain events. These findings appear to support widespread "dosing" of the watershed with aerially-transported mercury. However, the authors of the study (Brandenberger et al., 2010) note that while mercury deposition in the Puget Sound appears to be a result of regional transport, the bulk deposition methods used to estimate fluxes may underestimate the dry deposition of mercury. As a result, strong localized signals from industrial areas may be diluted out.

A consistent level of aerial mercury “dosing” across a watershed would likely result in similar mercury concentrations among land uses, particularly since much of the load is due to washout. The surface runoff results do not reflect a widespread dosing and washout scenario since forested areas have lower mercury concentrations than commercial/industrial and residential areas where combustion sources are likely to be located. However, higher mercury loads from commercial/ industrial and residential areas may simply be a result of enhanced mobilization from surfaces (due to the comparatively high proportion of impervious surfaces) rather than localized mercury sources.

The comparatively high concentration of mercury in agricultural area runoff samples remains a puzzle. Loss of mercury-enriched soil during storms may be one possible explanation, although baseflow mercury concentrations in agricultural areas are also higher than in other land covers, and TSS increases during storm flows are smaller in agricultural areas compared to other land types. It appears unlikely that major mercury sources would typically be located in close proximity to agricultural lands, and the one inventoried mercury release that is specific to agricultural practices is comparatively small (releases from fertilizer application, 0.002 t/yr).

The single inventoried source of mercury released in a constrained pathway is loss of dental amalgam through disposal (approximately 95% of the mercury used in dental offices is currently recovered) and excretion. Approximately 0.03 t/yr of mercury release in the Puget Sound basin is attributed to this source. This is approximately tenfold the estimated load from POTWs during the Phase 2 Study (0.002 t/yr) (Envirovision et al., 2008b). The differences are presumably due to the removal of solid material during the treatment process. Mercury from other constrained sources, naturally occurring mercury in water, and mercury in stormwater represent additional releases of mercury to POTWs, but the extent of these contributions are not known.

Hazard Evaluation

The hazard evaluation indicates that mercury is a Priority 1 level of concern for a range of media and receptors in both the freshwater and marine aquatic environments (Table 10).

Most (>95%) of the observed mercury concentrations in surface waters are one to two orders of magnitude below concentrations where most (95%) of the effects have been documented. The 90th percentile of observed total mercury concentrations are slightly above the chronic water quality criterion (0.012 ug/l), but observed dissolved concentrations are well below the acute criterion (2.1 ug/l). Interestingly, the chronic water quality criterion is based on a value designed to avoid exceedance of the Food and Drug Administration Action Level for mercury in seafood (1.0 mg/kg; EPA, 1985).

Table 10. Summary of Hazard Evaluation for Mercury.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	4,313	63%	Yes	Priority 1
	Nearshore Marine	7	100%	INS[a]	U
	Offshore Marine	14	93%	INS[a]	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	803	66%	Yes	Priority 1
	Nearshore Marine	459	70%	Yes	Priority 1
	Offshore Marine	367	79%	Yes	Priority 1
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Freshwater	b	100%	INS[a]	U
	Nearshore Marine	c	≥95%	INS[d]	U
	Offshore Marine	e	100%	INS[d]	U
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Great Blue Heron (FW)	--	--	Yes	Priority 1
	Osprey (SW)	--	--	Yes	Priority 1
	River Otter (FW)	--	--	Yes	Priority 1
	Harbor Seal (SW)	--	--	Yes	Priority 1
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Freshwater	f	>99%	No	Priority 2
	Nearshore Marine	g	>92%	No	Priority 2
	Offshore Marine	h	100%	No	Priority 2

Yellow highlight indicates Priority 1 Level of Concern

FOD=Frequency of detection

INS[a] =Insufficient observed data available for comparison to effects data

U=Unknown level of concern due to lack of sufficient data for adequate comparison

[b] N range is 11 – 16 and varies for organism type and tissue type

[c] N range is 42 – 169 and varies for organism type and tissue type

INS[d] =Insufficient effects data available for comparison to observed data

[e] N range is 5 – 190 and varies for organism type and tissue type

FW=Freshwater

SW=Saltwater

[f] N range is 34 – 776 and varies for organism type and tissue type

[g] N range is 107 – 197 and varies for organism type and tissue type

[h] N range is 37 – 346 and varies for organism type and tissue type

There are few observed data to compare mercury concentrations to effects data or criteria in marine waters. For instance, only seven usable values were found for nearshore marine waters and only 14 values for offshore waters. Ninety percent of the effects data were at least two orders of magnitude above the 90th percentile values for both the nearshore and offshore datasets. Although more than 25% of the offshore values exceed the chronic water quality criterion, the paucity of observed values precluded an adequate evaluation for any of these comparisons.

Mercury concentrations in freshwater sediments exceed the floating percentile at the 90th percentile concentration (approx. 0.6 mg/kg dw) of the observed dataset. Marine sediments also have observed mercury concentrations that exceed the SQS at 90th percentile levels for both the nearshore and offshore datasets (both approx. 0.5 mg/kg dw); these concentrations are also at or near the LAET.

Observed mercury concentrations in fish tissues are nearly identical to effects levels, but there were insufficient observed data for an adequate evaluation. Fewer effects values are available for marine waters. No marine effects concentrations were available for non-decapod invertebrates and fish, and only one marine decapod effect concentration was available. There are observed concentrations for all tissue types although only five for offshore decapods.

Evaluation of daily mercury doses based on fish and incidental sediment ingestion for the four species evaluated – great blue heron, osprey, river otter, and harbor seal – indicate that all species would be exposed to doses equal to or greater than the lowest effects dose. For the bird species, the lowest effects doses are based on reproductive effects, although heron also exceed a dose for growth effects. For the mammal species evaluated, both seal and otter exceed the lowest dose calculated for growth effects, while the otter also exceeds the lowest dose for mortality.

Edible tissues evaluated for comparison to the NTR criterion (based on the default consumption rate of 6.5 g/d) reveal that fish tissue generally has higher observed mercury concentrations than bivalves or other invertebrates, but for all organisms more than 95% of the observed values fell below the criterion (approx. 800 ug/kg wet weight).

Comparisons were also made using exposure assumptions outlined in the NTR but with varying daily consumption rates. More than one-half of the freshwater and marine fish tissue samples exceed the acceptable risk level using the EPA recommended subsistence rate of 142.4 g/d.
In the nearshore marine areas, more than one-half of the mercury concentrations found in invertebrates other than bivalves exceed the acceptable risk at the 142.4 g/d rate, and more than one-half of the bivalves exceed the acceptable risk based on the Suquamish tribal rate (769 g/d).
In the offshore marine areas, more than one-half of the mercury concentrations found in invertebrates other than bivalves exceed the acceptable risk at the 142.4 g/d rate, and more than one-half of the bivalves exceed the acceptable risk based on the Tulalip tribal/King Co. American Petroleum Institute (API) rate (242.5 g/d).

Regionally Important Biological-Effects Data

Grove and Henny (2008) analyzed mercury in river otter carcass livers obtained from trappers working in western Oregon and western Washington, including Puget Sound. Mercury liver concentrations were higher in Puget Sound adult river otters (mean of 7.89 mg/kg dw) than those from the northwest Washington area (mean of 5.85 mg/kg dw). Concentrations in Willamette River and coastal Oregon otter livers were slightly higher (mean of 9.2-9.3 mg/kg dw) but similar to Puget Sound levels. This study demonstrates that river otters living in the Puget Sound area bioaccumulate mercury.

In addition to the bioaccumulation of mercury by otters, accumulation in fish tissue has led to advisories for human consumption of fish in Puget Sound. The advisories, issued by Washington State Department of Health (WDOH), are based on data and consumption of particular species, and vary by region (Hardy and Palcisko, 2006). For instance, WDOH advises no consumption of yelloweye rockfish (*Sebastes ruberrimus*) caught anywhere in Puget Sound, and advises limited consumption of English sole (*Parophrys vetulus*) and other flatfish based on the marine area in which they are caught. In addition, there is a statewide mercury advisory for smallmouth bass (*Micropterus dolomieui*), largemouth bass (*M. salmoides*), and northern pikeminnow (*Ptychocheilus oregonensis*) with specific advice based on risks to population segments (e.g. children, nursing mothers) (McBride, 2003; WDOH, 2011).

Zinc

Zinc is a naturally occurring heavy metal abundant in the earth's crust and is nearly always detectable at concentrations >0.5 ug/l in water and >10,000 ug/kg (dw) in sediments from freshwater and marine environments (PTI, 1991; Serdar, 2008; Hallock, 2010; Appendix D). It occurs at comparatively high concentrations in natural waters, but zinc's wide use as a protective coating and alloy with other metals to reduce corrosion in outdoor environments may increase levels in the aquatic environment.

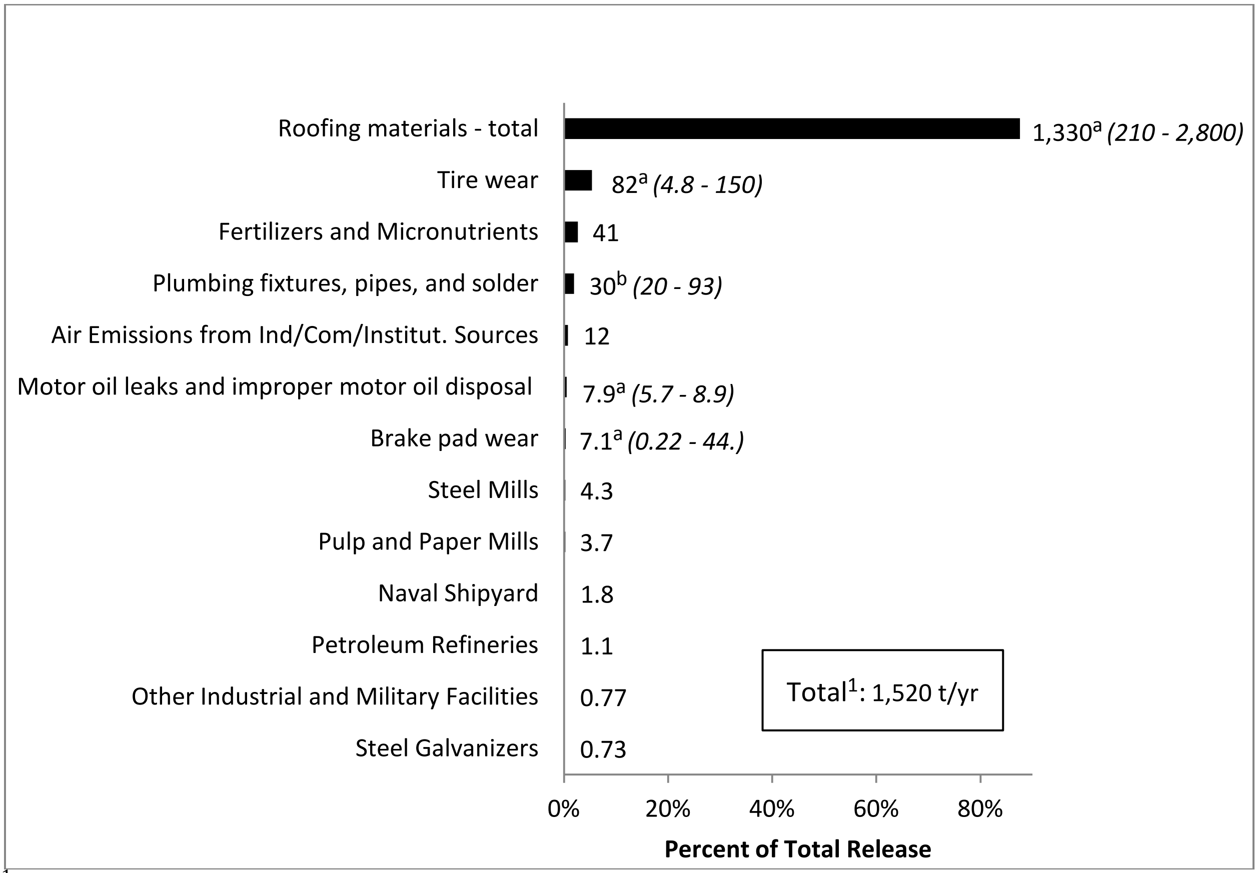
Major Releases from Primary Sources

An inventory of zinc released from primary sources suggests that approximately 1,500 metric tons (t) is released annually from anthropogenic sources in the Puget Sound basin. The largest current source of zinc to the environment is the leaching of zinc from rooftops, particularly those with galvanized components, accounting for approximately 1,300 t/yr of zinc released (Figure 19). The authors of the *Sources Report* note that total inventoried zinc releases to the Puget Sound basin probably underestimate the true extent of release since leaching from other galvanized items (e.g. culverts, light standards, guardrails) was not assessed (Ecology, 2011).

Although small in comparison to rooftop releases, zinc released from tire wear is substantial (82 t/yr), accounting for approximately 6% of the total. Brake pad wear accounts for approximately 5 t/yr of zinc released in the Puget Sound basin.

Zinc contained in fertilizers and micronutrients used in agricultural applications accounted for large zinc releases (41 t/yr). Similar to most other COC metals, concentrations were highest in phosphate fertilizers. However, zinc use in fertilizer applications (4 t/yr) is small compared to its use as an agricultural micronutrient (37 t/yr).

Other inventoried sources of anthropogenic release of zinc in the Puget Sound basin included leaching from residential plumbing components (21 t/yr) and industrial, commercial, and institutional emissions (approximately 24 t/yr). Of this latter category, approximately one-third of the zinc releases were from steel mills and pulp and paper mills.



[1] Sum of best estimates. Best estimates are either the mean, mid-point, median, or most reasonable estimate for each source.

[a] Mean

[b] Median

Figure 19. Total Zinc Release in the Puget Sound Basin (values shown are t/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for zinc loading were obtained from PSTLA loading studies and are included in Table 11. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Table 11. Total Zinc Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	1.97	10.8	19.7
Air Deposition	11	18	26
Surface Runoff	113	122	134
POTWs	16	19	24
Ocean Exchange (b)	-150	-80	10

(a) Lowest, highest, and mid-point of estimated loads
(b) Negative values indicate a net outflow at the ocean boundary

The estimated range of groundwater zinc loads is large (2.0 – 20 t/yr). The range in estimates is due almost entirely to differences in flows used to establish the possible range of loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude.

Zinc discharged from POTWs in the Puget Sound basin has a much narrower range of loading, accounting for loads of 16 – 24 t/yr. Phase 1 estimates suggest that zinc loads from industrial wastewater are potentially substantial (16 t/yr; Hart Crowser et al., 2007), but this is based on a limited dataset and is far in excess of industrial discharge of zinc to surface waters or transferred to POTWs as reported in the TRI (<4 t/yr total) (Ecology, 2011).

The deposition of atmospheric zinc directly to the marine waters of Puget Sound is approximately 11 – 26 t/yr, based on fluxes ranging from 2.2 - 52 ug/m^2/d. Median zinc fluxes were generally <10 ug/m^2/d, except for one location within a high-density urban (Tacoma) area including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. Zinc fluxes at this location were consistently an order of magnitude higher than other locations around the Puget Sound region, and were elevated five-fold above a nearby station that did not have the same air pollution influences in such close proximity. This pattern closely mirrored the deposition patterns of copper and lead among the air sampling locations.

Surface runoff loads for zinc are estimated to be approximately 113 – 134 t/yr for the entire Puget Sound basin based on the surface runoff study. Overall, dissolved zinc accounted for approximately one-half to three-quarters of the total zinc concentrations in surface water.

Absolute zinc loads were highest in forests, with little change in loading during storms compared to baseflows, although a seasonal first-flush episode was in forest, as well as agricultural areas. Zinc loads in other land covers increased dramatically during storms, particularly commercial/industrial areas, where zinc loads increased by an order of magnitude. This leads to a disproportionately high loading of zinc in commercial/industrial areas relative to other land areas.

Based on sampling marine waters, there appears to be a large net export of zinc at the ocean boundary using estimates derived from the 25th and 50th percentiles of the data, although the dataset is very limited. However at the high end of the reported data range (75th percentiles), there is virtually no net flux across the ocean boundary. Total zinc concentrations (25th -75th percentile) in the incoming marine waters are 0.53 – 0.88 ug/l, and total zinc concentrations in the outgoing marine waters are 0.70 – 0.80 ug/l. Zinc inflow is estimated to be 310 – 520 t/yr, and zinc outflow is estimated to be 460 – 510 t/yr.

The net sum of zinc loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is -8, 90, and 210 t/yr, respectively. Under the 25th percentile estimate, there is a comparatively small net export of zinc out of Puget Sound due to the large mass exchanged at the ocean boundary. However, when the median values are summed, the large surface water load outweighs the smaller export at the ocean boundary, leading to a net load of zinc load to Puget Sound, and all loads estimated at the 75th percentile indicate net loads to Puget Sound.

Zinc loading from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th - 75th percentiles) and median for each pathway in Figure 20. Each pathway represented as a contribution to the total load is displayed in Figure 21.

Total zinc loading from the major pathways assessed is 140 – 200 t/yr. Surface water runoff accounts for the largest pathway (66 – 83%), followed by POTWs (11 – 12%) and air deposition (8 – 13%). Groundwater potentially accounts for up to 10% at the upper end of the estimated range, but this value should be viewed with caution since it is based on literature values of zinc in wells and rough estimates of groundwater flow. At the lower end of the load range, zinc in groundwater is estimated to account for 1% of the load to Puget Sound.

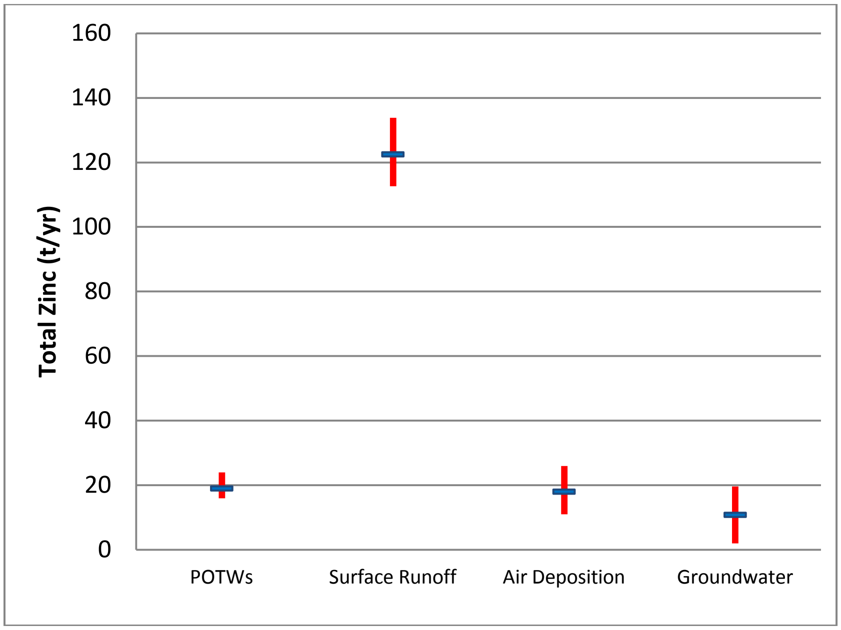


Figure 20. Range (25th - 75th percentiles) and Median Total Zinc Loads to Puget Sound from Each Major Delivery Pathway.

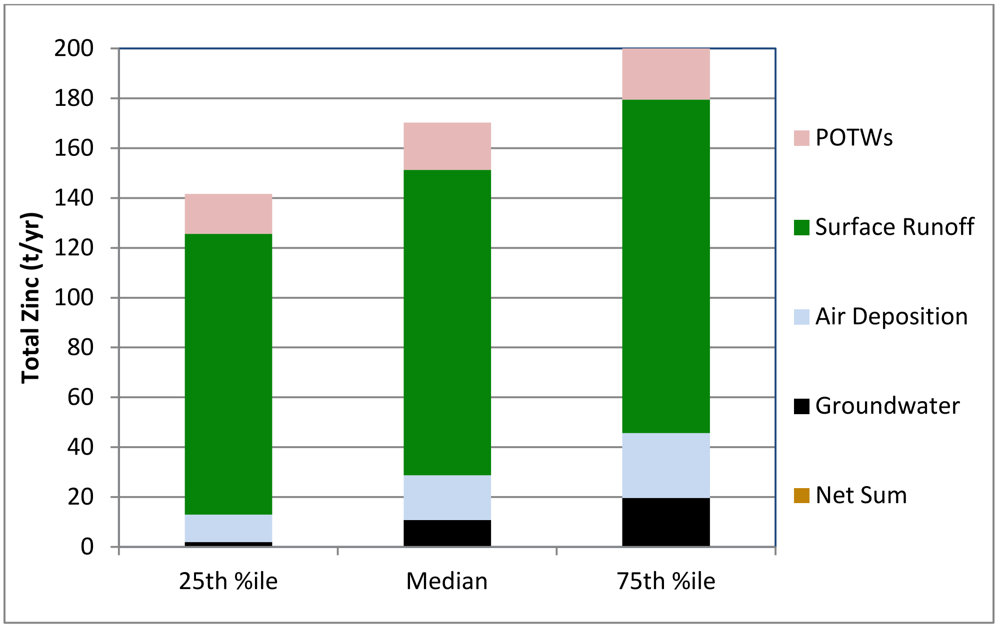


Figure 21. Total Zinc Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of zinc transport and fate following release suggests that much of the zinc transported to Puget Sound will occur through surface runoff during both baseflow conditions and storm events. The high proportion of zinc loading contributed by surface runoff is consistent with the types of sources accounting for the major zinc releases.

Major unconstrained releases of zinc are leaching from rooftops and from vehicle component wear. Together, these sources account for approximately 1,400 t/yr of zinc released to the environment in the Puget Sound basin.

Once zinc is released from rooftops it may be transported in runoff to any number of pathways. Zinc may continue to remain in runoff on impervious surfaces until it reaches surface waters or is diverted to wastewater treatment plants, or zinc may be initially or secondarily allowed to infiltrate into soils where it can migrate to groundwater or become retained in a soil reservoir. Once zinc is in soil, it can be slowly leached out in dissolved form, migrate to groundwater, or become released as soil particles during high-energy storms where it settles as aquatic sediments, including those found in catch basins.

The surface runoff results appear to be consistent with major zinc releases from rooftops. During storms, zinc is released through leaching, and in commercial/industrial areas, the high proportion of rooftop area and relative dearth of attenuating components would allow for the enriched runoff to reach surface waters. Most of the zinc released from rooftop and galvanized materials would presumably be in the dissolved form, consistent with elevations of dissolved zinc during storms.

Although this conceptual model appears to fit with commercial/industrial areas during storms, it does not explain the comparatively low concentrations of dissolved zinc from residential areas, nor does it explain the high zinc concentrations in commercial/industrial areas during baseflows. While there are few clues to explain the finding of low zinc in residential areas, the high levels in commercial/industrial area baseflows may be due to a high density of galvanized culverts or a reservoir of zinc-enriched sediments residing in aquatic systems.

Aside from zinc released from rooftops, zinc released from vehicle component wear would most likely occur in residential and commercial/industrial areas. Abraded particles released to roadways and mobilized in storm runoff would presumably result in increases in total zinc in excess of comparable increases in dissolved zinc. The increase in concentrations of total zinc in commercial/industrial and residential areas appears to be consistent with this supposition, rising two- to three-fold, with concentrations significantly correlated with TSS. There are virtually no elevations in total zinc in agricultural and forested land covers during storm events.

Overall zinc releases to air across the entire basin (not including fugitive dust from tire and brake pad wear) are estimated to be approximately 18 t/yr. Zinc released as fugitive dust from tire and brake pad wear is potentially substantial (48 t/yr), assuming 50% is emitted as airborne particles or becomes suspended in air following release to the road surface. This may account for the high levels of zinc in atmospheric deposition samples at the high-density urban location, which is located near Interstates 5 and 705, associated interchanges, and other major roadways. Zinc fluxes at this location were an order of magnitude higher than at other locations, and the inventory of primary releases indicates that industrial sources are not large contributors to airborne emissions. The total zinc air emissions across the basin (up to 66 t/yr) appears to match the deposition on marine waters (11 – 26 t/yr) when one considers that marine waters only constitute one-sixth of the basin area.

Of the primary sources inventoried, zinc released from residential plumbing components represents the only constrained source assessed. The annual load of zinc discharged to POTWs is estimated to be 21 t; an additional 8 t/yr is discharged to septic systems from this source. The estimate of zinc released from plumbing components is nearly identical to loads released from POTWs (16 – 24 t/yr), but it is unlikely that a mass balance has been achieved simply from these loading terms. It is much more likely that zinc from other constrained sources is delivered to POTWs, and naturally occurring zinc in water, as well as zinc in stormwater, represents additional releases of zinc to POTWs, but the exact extent is not known. At the treatment end, some quantity of zinc is presumably lost via solids removal prior to discharge.

Hazard Evaluation

The hazard evaluation indicates that zinc is a Priority 1 level of concern for offshore marine surface waters and for freshwater sediments (Table 12). A Priority 2 level of concern was assigned to fresh surface waters and marine sediments. The number of observed data in nearshore marine waters was insufficient for an adequate comparison with effects data or criteria. Hazards due to tissue residue effects, effects to wildlife, and effects to human health were not evaluated.

The 90th percentile values for dissolved zinc in freshwater (approx. 15 ug/l) are one-half the 10th percentile of effects levels and the chronic and acute water quality criteria. For marine waters, the differences between the observed and effects/criteria is even larger, with the difference between the 90th percentile of observed data (approx 2.1 ug/l for nearshore and 1.2 ug/l for offshore) are one to two orders of magnitude below the 10th percentile of the effects data and the chronic and acute water quality criteria.

Median zinc concentrations in both freshwater and marine sediments are about one-half of the lowest guidelines or standards. However, in freshwater sediments the 90th percentile (approx. 300 mg/kg dw) of observed zinc concentrations exceeds the floating percentile SQS concentration and floating percentile CSL.

Zinc concentrations in marine nearshore and offshore sediment have 90th percentile levels (approx. 180 mg/kg dw and 120 mg/kg dw, respectively) less than one-half the SQS concentration, although they exceed Canadian TEL.

Table 12. Summary of Hazard Evaluation for Zinc.

Surface Water		**Total N**	**FOD**	**90th %ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	4,844	88%	No	Priority 2
	Nearshore Marine	33	100%	INS	U
	Offshore Marine	57	95%	Yes	Priority 1
Sediment		**Total N**	**FOD**	**90th %ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	822	>99%	Yes	Priority 1
	Nearshore Marine	513	100%	No	Priority 2
	Offshore Marine	513	100%	No	Priority 2
Tissue Residue Effects		**Total N**	**FOD**	**90th %ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th %ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

Yellow highlight indicates Priority 1 Level of Concern
FOD=Frequency of detection
INS=Insufficient observed data available for comparison to effects data
U=Unknown level of concern due to lack of sufficient data for adequate comparison

PCBs

Polychlorinated biphenyls (PCBs) were manufactured commercially in the U.S. from 1929 until their ban in 1979 after the negative health and environmental impacts associated with PCBs became apparent (Sittig, 1980; EPA, 1999). EPA (1997) estimated that as of 1977, U.S. manufacturers had produced a total of 635,000 metric tons (t) of PCBs. Prior to federally imposed use restrictions, the PCB market spanned a wide range of end products. While electrical equipment represents the majority of PCB use – 77% from 1929-1975 according to EPA (1997) – their chemical stability and plasticizing properties made them useful in a variety of applications. PCBs in open system applications such as plasticizers, hydraulics fluids and lubricants, and carbonless copy paper accounted for >20% of their historic use.

Although banned more than three decades ago, PCBs continue to be found in environmental media. Many of the same properties that made PCBs commercially desirable – their stability and resistance to degradation – make them extremely persistent in the environment, and they have become one of the most ubiquitous of all environmental contaminants.

There are 209 individual forms of PCBs, known as congeners, based on the degree of chlorine substitution and arrangement on the biphenyl molecule. The persistence of PCBs increases with the degree of chlorination. Mono-, di-, and tri-chlorinated biphenyls biodegrade relatively rapidly, tetrachlorinated biphenyls biodegrade slowly, and higher chlorinated biphenyls are resistant to biodegradation. PCBs accumulate in the lipids (fats) of fish and other animals, with lipid solubility typically increasing with the degree of chlorination (Mabey et al., 1982).

PCBs are typically present at very low concentrations in ambient waters, with water column concentrations typically in the 10 – 1,00 pg/l range for total PCBs (Dangerfield et al., 2007; Appendix D), although few data are available for marine waters (Serdar, 2008). In sediments, total dry weight PCB concentrations are typically found in the 1 – 100 ug/kg (dw) range (Appendix D).

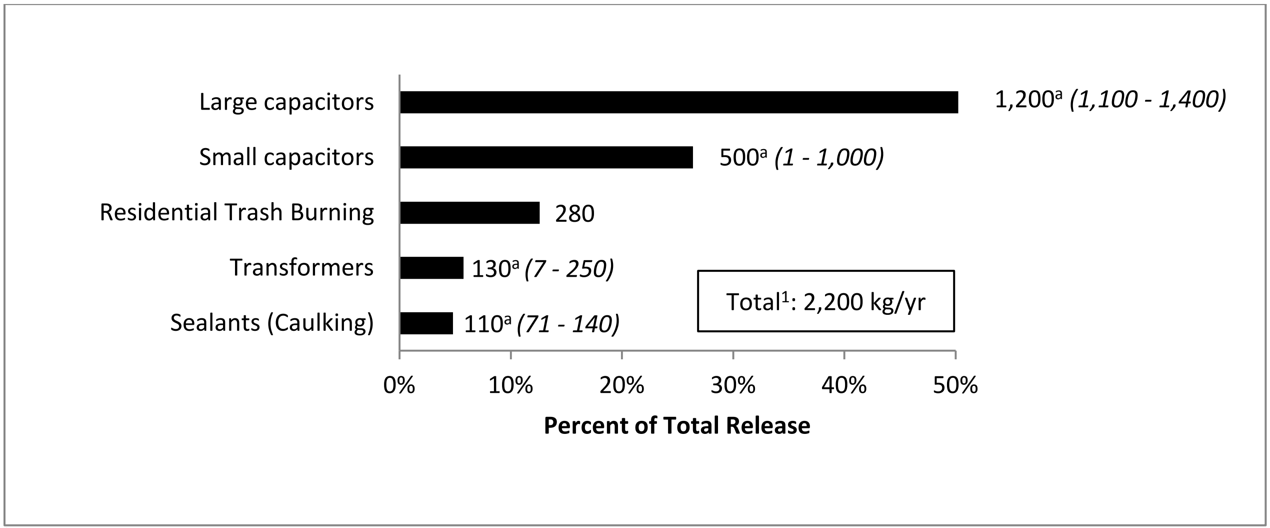
Major Releases from Primary Sources

An inventory of PCBs released from primary sources suggests that approximately 2,200 kg is released annually in the Puget Sound basin (Figure 22). PCB use can be placed in two categories: closed systems and opens systems. Closed systems include PCBs used in electrical transformers and capacitors, including those used in light ballasts. The release of PCBs due to leakage of closed systems was estimated at 1,800 kg/yr in the Puget Sound basin.

PCBs historically were used in a number of open-system products such as adhesives, carbonless copy paper, flame retardant coatings, pesticide extenders, lubricants, and caulking sealants. Of the products that incorporated PCBs, caulking sealants are among the most durable. Caulking used in commercial, industrial, and institutional buildings constructed during the 1940s through the 1970s may contain PCBs which may continue to be released through volatilization, leaching, or abrasion of the material. Based on the volume of commercial, industrial, and institutional buildings constructed in the Puget Sound basin during the era of PCB caulk use, an estimated 110 kg of PCBs are released from this source annually.

An additional source of PCB release is from residential trash burning. Based on modeling information generated by Ecology's Air Quality Program, PCBs are emitted from this source at a rate of 281 kg/yr in the Puget Sound basin.

The annual rate of PCB release, estimated to be 2,200 kg/yr, should be viewed with caution and likely overestimates actual releases. No regional sampling efforts to inventory PCB releases from primary sources have been conducted, and therefore PCB release estimates are based on literature values. There are also no regional field studies to estimate leakage rates, relative amounts released indoors and outdoors, and the proportion cleaned up and contained following spillage. The estimates displayed in Figure 22 assumed all leakage was unconfined.



[1] Sum of best estimates. Best estimates are either the mean, mid-point, median, or most reasonable estimate for each source.

[a] Mid-point of range

Figure 22. Total PCB Release in the Puget Sound Basin (values shown are kg/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for PCB loading were obtained from PSTLA loading studies and are included in Table 13. No PCB loading data are available for groundwater.

The estimated discharge of PCB from POTWs is 0.13 – 1.75 kg/yr. The POTW load estimates were based on limited sampling conducted only during the wet season.

The deposition of atmospheric PCBs directly to the marine waters of Puget Sound is approximately 0.7 – 3.7 kg/yr, based on fluxes ranging from 0.16 – 2.8 ng/m^2/d. Median PCB fluxes were generally <0.7 ng/m^2/d, except for one location within a high-density urban (Tacoma) area including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. PCB fluxes at this location were elevated five-fold above most other locations around the Puget Sound region, including a nearby station that did not have the same air pollution influences in such close proximity.

Table 13. PCB Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater	NA	NA	NA
Air Deposition	0.68	1.32	3.76
Surface Runoff	2.55	5.29	15.77
POTWs	0.126	0.342	1.75
Ocean Exchange (a)	-1.4	0.8	0.6
Returning Salmon (b)	NC	0.265	NC

NA=not analyzed
NC=not calculated
(a) Negative values indicate a net outflow at the ocean boundary
(b) Best estimate using available data

Surface runoff loads for PCBs are estimated to be approximately 2.6 – 15.8 kg/yr for the entire Puget Sound basin based on the surface runoff study. PCBs were detected in all land use types, and median concentrations among land covers were within a factor of 3 during baseflows. However, during storm flows, concentrations in commercial/industrial areas increased by an order of magnitude while concentrations in other areas remained virtually unchanged. PCB concentrations were particularly elevated during seasonal first-flush episodes in all land types except agricultural areas.

Overall PCB loads were generally proportional to land area when evaluated by land cover type, except commercial/industrial loads during storm events (percentage of the total PCB load was 15-fold higher than the percentage of commercial/industrial land cover in the Puget Sound basin). However, due to the large area and flows of forested areas, overall loads from forests accounted for 83% of the total PCB load.

Based on the sampling of marine waters, there appears to be an annual net export of 1.4 kg total PCBs at the ocean boundary using estimates derived from the 25th percentile of the data, although the dataset is very limited. At the median and higher range (75th percentile) of the estimates, there is less than 1 kg annual flux into Puget Sound at the ocean boundary. Total PCB concentrations (25th-75th percentile) in the incoming marine waters are 15 – 35 pg/l, and total PCB concentrations in the outgoing marine waters are 14 – 47 pg/l. PCB inflow is estimated to be 8.6 – 21 kg/yr, and PCB outflow is estimated to be 10 – 20 kg/yr.

In addition to major loading pathways, estimates of PCB influx to Puget Sound through returning adult salmon were based on typical whole-body PCB concentrations measured during 2004-2005 and escapement estimates from 2001. Rough estimates for five species of pacific salmon (*Oncorhynchus spp.*) suggest that the total influx of PCBs from this pathway is approximately 0.265 kg/yr based on whole-body PCB concentrations ranging from 4 ug/kg to 51 ug/kg (Sandie O’Neill, National Oceanic and Atmospheric Administration, written communication).

The net sum of PCB loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 2.2, 8.0, and 22 kg/yr, respectively. Under all of these estimates, there is a net PCB load to Puget Sound.

PCB loading from pathways that may represent *partially controllable* sources of COCs is shown as ranges (25th - 75th percentiles) and median for each pathway in Figure 23. Each pathway represented as a contribution to the total load is displayed in Figure 24.

Total PCB loading from the major pathways assessed is 3.3 – 21 kg/yr. Surface runoff accounts for the largest pathway (74 – 76%), followed by atmospheric deposition (18 – 20%) and POTWs (4 – 8%).

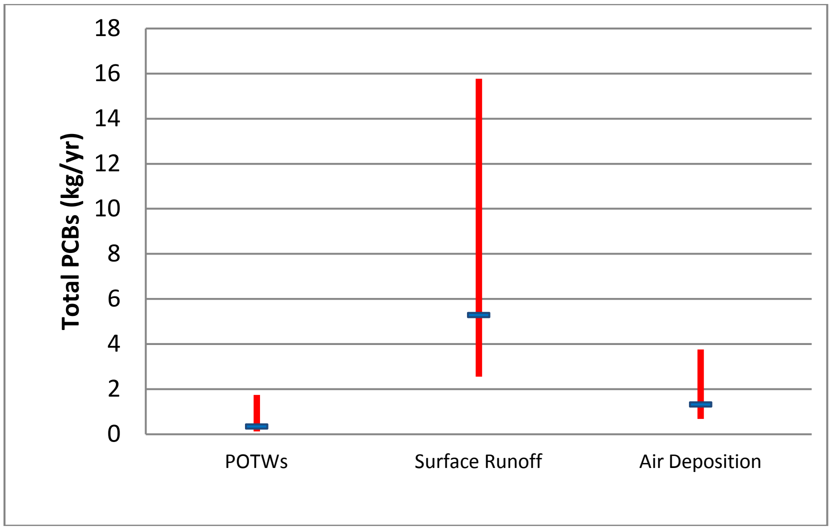


Figure 23. Range (25th - 75th percentiles) and Median Total PCB Loads to Puget Sound from Each Major Delivery Pathway.

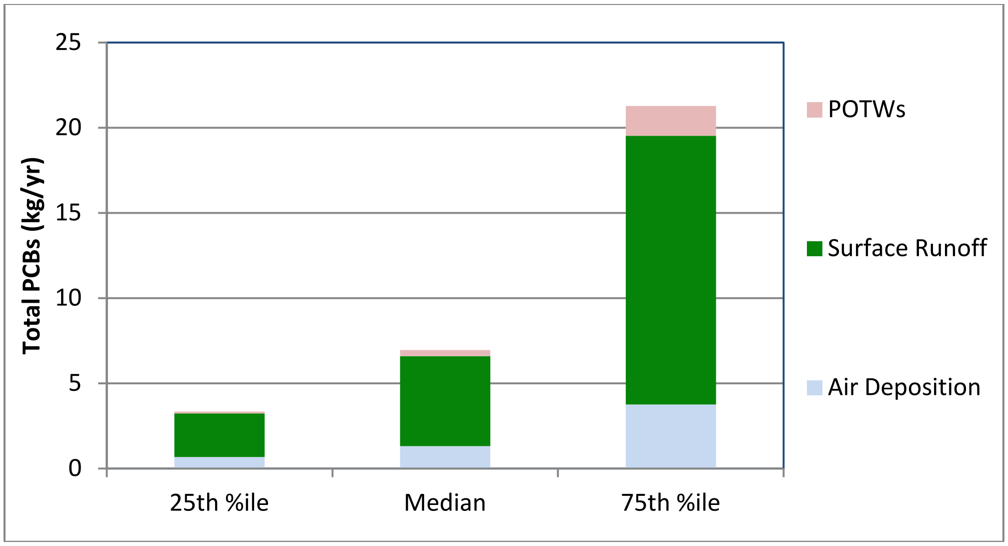


Figure 24. Total PCB Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of PCB transport and fate following release suggests that much of the PCBs transported to Puget Sound will do so through surface runoff during both baseflow and storm flow conditions. Surface runoff data suggest that in residential, agricultural, and forested areas, a continuous and low level of PCB dosing from instream or upland sources occurs during baseflow. PCB concentrations remain the same or decrease slightly during storms, indicating that stormwater contains similar or lower PCB concentrations than the stream baseflows, and any mobilization of instream PCB reservoirs do not effectively increase concentrations.

In commercial/industrial areas, the dynamics of PCBs in surface runoff appear to be much different. PCB concentrations during baseflow conditions are 40% - 180% higher than in other land covers. During storm events, PCB concentrations in commercial/industrial areas increase six-fold. Based on the available information, it is impossible to ascertain whether the increase is due to mobilization of land surface PCBs, re-suspension of instream PCB reservoirs, or a combination of the two circumstances.

The major PCB sources identified in the *Sources Report* (Ecology, 2011) do not appear to have a direct link with the surface runoff pathway. Most of the PCBs releases are likely to occur in and around buildings and become bound to soil following release, volatilize and become transported off-site, or occur indoors. Residential trash burning presumably occurs in residential areas. However, commercial/industrial areas are the most likely to deliver PCBs to surface waters based on the primary sources since PCBs released from buildings and from transformers/ capacitors are more likely to occur in commercial/industrial areas than in the other land covers assessed. In addition, PCBs atmospherically deposited on land surfaces are more likely to become mobilized during storms if they are deposited on impervious surfaces which are more prevalent in commercial/industrial areas.

One other possible source of PCB enrichment of streams is marine-derived PCBs delivered upstream by salmon returning to spawn. PCB residues per whole-body fish range from approximately 7 ug for pink salmon (*O. gorbuscha*) to 336 ug for Chinook (*O. tshawytscha*) (Sandie O'Neill, National Oceanic and Atmospheric Administration, written communication). While the total annual PCB load entering Puget Sound from salmon is estimated to be approximately 0.3 kg/yr, the impact to streams is likely to be somewhat less. The load estimate does not include losses from commercial and recreational takes, live fish and carcasses removed from streams by wildlife, and maternal transfer to eggs (and subsequent flux from out-migrating smolts). In addition, approximately one-third of the PCB burden is carried by two species – pink salmon and chum salmon (*O. keta)* – which spawn much lower in the watershed than other species, thus diminishing upstream PCB transport.

PCB releases to air from inventoried sources are several orders of magnitude greater than air deposition to marine water (approx. 300 – 400 kg/yr versus 0.7 – 3.7 t/yr), and this discrepancy is large even when the deposition rates to marine water are scaled to the entire watershed area. The primary releases to air are combustion emissions originating from residential trash burning (280 kg/yr) and volatilization from PCB-containing building sealants (maximum of 140 kg/yr). There is a large degree of uncertainty surrounding release estimates from both of these sources;

neither has been sufficiently analyzed to determine if reported release rates are representative of the Puget Sound region.

PCB deposition patterns indicate similar fluxes occur throughout Puget Sound, suggesting a widespread atmospheric deposition pattern compounded with additional deposition from near-field sources in high-density urban areas. PCB emissions from building sealants are expected to be concentrated in cities, particularly older industrial cities, although it is not clear if they are likely to be deposited near their point of release.

Based on the inventory of sources, none of the PCB releases were exclusive to constrained systems such as sanitary sewers. Therefore it is difficult to quantitatively assess the relationship between releases and POTW loads (0.1 – 1.8 kg/yr). Some of the PCBs released from building sealants are likely to occur indoors and find their way to sanitary sewers after attaching to dust particles, although the quantity has not been determined. It is likely that some portion of the PCBs delivered to POTWs occurs through stormwater, but the extent of this contribution is not known. Since PCBs were historically used in a variety of commercial, industrial, and consumer applications (see *Sources Report* [Ecology, 2011] for a discussion of PCB uses), releases to constrained and unconstrained sources are likely to continue from a variety of sources.

Hazard Evaluation

Comparisons to effects levels, criteria, and guidelines are done separately for both PCB Aroclor and congener data. PCBs were historically marketed in the U.S. as Aroclors, mixtures of individual PCB compounds (a.k.a. congeners) based on average chlorine content. Environmental analysis of PCBs historically has focused on these Aroclor mixtures, although once in the environment Aroclors quickly alter their original composition due to unequal degradation, fugacity, and bioaccumulation rates of their individual components.

Beginning in the mid-1990s, the analysis of PCB congeners gained wider acceptance as the laboratory capacity for this method became more widely available and the utility of congener analysis became more evident. Although much more expensive than Aroclor analysis, congener analysis provides detection limits several orders of magnitude lower than Aroclors (e.g. mid parts per quadrillion levels versus mid parts per trillion levels in water). As a result, environmental sample datasets are generally a mix of Aroclor and congener data. Due to the lower congener detection limits, results of measurable PCBs are typically lower for congeners (as mentioned previously, the hazard evaluation results are shown for detectable concentrations only).

The hazard evaluation indicates that PCBs are a Priority 1 level of concern for a range of media and receptors in both the freshwater and marine aquatic environments (Table 14).

Table 14. Summary of Hazard Evaluation for PCBs.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	1,248[a]	4%[a]	Yes	Priority 1
	Nearshore Marine	11[a]	0%[a]	INS[b]	U
	Offshore Marine	84[c]	100%[c]	No	Priority 2
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	506[a]	43%[a]	Yes	Priority 1
	Nearshore Marine	612[a]	63%[a]	No	Priority 2
	Offshore Marine	387[a]	47%[a]	Yes	Priority 1
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Freshwater	d,e	88%	Yes/INS[b]	Priority 1/U
	Nearshore Marine	d,f	100%	No/INS[g]	Priority2/U
	Offshore Marine	d,h	≥99%	No/INS[i]	Priority 2/U
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Great Blue Heron (FW)	--	--	Yes	Priority 1
	Osprey (SW)	--	--	Yes	Priority 1
	River Otter (FW)	--	--	Yes	Priority 1
	Harbor Seal (SW)	--	--	Yes	Priority 1
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Freshwater	d,j	≥77%	Yes	Priority 1
	Nearshore Marine	d,k	>33%	Yes	Priority 1
	Offshore Marine	d,l	>66%	Yes	Priority 1

Yellow highlight indicates Priority 1 Level of Concern

FOD=Frequency of detection

[a] Based on Aroclor data

INS[b]=Insufficient observed data available for comparison to effects data

U=Unknown level of concern due to lack of sufficient data for adequate comparison

[c] Based on congener data

[d] Based on Aroclor and congener data

[e] N = 123 – 142 for non-decapod invertebrates. Observed data insufficient to evaluate fish tissue.

[f] N = 27 – 28 for decapods, N = 57 – 99 for non-decapod invertebrates, and N = 70 – 96 for fish tissue. Effects data insufficient to evaluate fish tissue.

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INS[g]=Insufficient effects data available for comparison to observed data

[h] N = 11 – 32 for non-decapod invertebrates and N = 26 – 324 for fish tissue. Observed data insufficient to evaluate decapods. Effects data insufficient to evaluate fish tissue.

INS[i]=Insufficient observed or effects data available for comparison

FW=Freshwater

SW=Saltwater

[j] N range is 51 – 918 and varies for organism type, tissue type, and PCB type.

[k] N range is 68 – 344 and varies for organism type, tissue type, and PCB type.

[l] N range is 10 – 477 and varies for organism type, tissue type, and PCB type.

PCB concentrations in surface waters vary depending on whether Aroclor or congener data are considered. The 90th percentile of observed freshwater Aroclor concentrations (approx. 0.05 ug/l) is several times higher than the chronic water quality criterion, but the 90th percentile of observed freshwater congener concentrations (approx. 0.002 ug/l) is several times lower than the criterion. Although there are more Aroclor data available, the detection frequency is much higher for congener data. For both sets of observed data, most (>95%) of the observed concentrations are one to two orders of magnitude below concentrations where most (95%) of the effects have been documented. It is notable that the numerical value for the chronic water quality criterion (0.014 ug/l) is driven by adverse reproductive effects to mink through consumption of fish, demonstrating the importance of PCBs' high bioconcentration potential and manifestation of effects on higher trophic organisms.

There are no detectable PCB concentrations observed in nearshore marine waters to compare to effects data or criteria. For offshore marine waters, the 90th percentile of congener concentrations (approx. 0.00005 ug/l) is five orders of magnitude less than the 10th percentile of effects data and three orders of magnitude below the chronic water quality criterion.

In freshwater sediments, at least 25% of the observed PCB concentrations analyzed as congeners or Aroclors exceed the floating percentile SQS, although the number of congener samples is comparatively small. At least 5% of the Aroclor data exceed all of the guidelines and standards used for comparison.

PCB concentrations in marine sediments are difficult to characterize due to the vast differences between observed congener and Aroclor concentrations (Aroclors are two to four orders of magnitude higher), as well as large differences between concentrations in nearshore and offshore sediments (offshore Aroclors concentrations are two orders of magnitude higher than nearshore Aroclor concentrations). The congener concentration, assessed on either dry weight or organic-carbon normalized bases, are well below any guideline, whereas median nearshore Aroclor concentrations fall in the midst of guidelines, with the 75th percentile of the concentrations (approx. 20,000 ug/kg organic carbon) above the SQS.

Interestingly, although the nearshore Aroclor concentrations are two orders of magnitude higher than congeners, the concentrations are nearly identical on an organic-carbon normalized basis, suggesting that the differences can be partly attributed to high levels of organic carbon in the samples analyzed for Aroclor. The magnitude of difference between nearshore and offshore Aroclor concentrations remain after accounting for organic carbon. All level-of-concern assignments for sediments were based on Aroclor data since the congener datasets were not deemed sufficient for adequate comparisons (n ≥100; Appendix D-1).

Comparisons of observed PCB concentrations in tissues of fish, decapods, and other invertebrates to effects due to PCB burdens were difficult to evaluate due to a paucity of either observed or effects data. In freshwater where sufficient observed and effects data were available for non-decapod invertebrate, most of the observed concentrations measured as both Aroclor and congeners exceeded all of the effects concentrations.

For nearshore marine waters, both decapods and non-decapod invertebrates had sufficient (observed and effects) data to conduct an evaluation. For both organism types, the 90th percentile of observed data was at least five-fold lower than the 10th percentile of effects data. In offshore marine water, non-decapods invertebrate data were available to conduct comparisons; the 90th percentile value of observed concentrations was an order of magnitude below the 10th percentile of effects concentrations. There were not sufficient effects data for fish tissue to conduct an adequate evaluation in marine surface waters.

Evaluation of daily PCB doses based on fish and incidental sediment ingestion for the four species evaluated – great blue heron, osprey, river otter, and harbor seal – indicate that all species would be exposed to doses equal or greater than the lowest effects dose (assuming a 4% sediment ingestion rate for heron). For the bird species, the lowest effects doses are based on reproductive effects; osprey are exposed to doses three times the lowest of the effects level. For the mammal species evaluated, both seal and otter exceed the lowest dose calculated for reproductive effects by an order of magnitude.

Edible tissues evaluated for comparison to the NTR criterion (based on the default consumption rate of 6.5 g/d) indicate that PCB concentrations in nearly all of the fish and non-bivalves are higher than the NTR criterion. For freshwater, nearly all of the bivalve tissue had concentrations above the criterion as well. Bivalve PCB concentrations in nearshore areas are higher than those from offshore areas.

Regionally Important Biological-Effects data

PCBs have been detected in outmigrant juvenile salmon (Johnson et al., 2007) from multiple northwest estuaries and hatcheries, including three in the Puget Sound. Whole-body juvenile Chinook salmon from the Duwamish River contained the highest PCB concentration [103 ng/g wet weight (ww) or 3,100 ng/g lipid] of any of the locations tested. Johnson et al. (2007) note that this concentration is higher than the 2,400 ng/g lipid developed by Meador et al. (2002) as a tissue threshold for adverse health effects including reduced growth, altered enzyme and hormone activity, and increased mortality.

Separately, juvenile salmonid PCB exposures were documented as occurring via food source by an analysis of stomach content of outmigrants at three locations in Puget Sound (Stein et al., 1995). Meador et al. (2010) found that PCB tissue concentrations in outmigrant juvenile Chinook salmon from the Duwamish estuary varied by time and location within the estuary, suggesting that localized heterogeneity of sediment concentrations may substantially impact accumulation in fishes.

PCB concentrations in adult Puget Sound Chinook salmon tissues were found to be three to five times higher than those measured in six other populations of Chinook salmon on the West Coast of North America (O'Neill and West, 2009). Approximately 22% of maturing and sub-adult Puget Sound Chinook salmon had concentrations above the 2,400 ng/g lipid threshold mentioned previously. O'Neill and West (2009) note that these elevated tissue concentrations have resulted in consumption advisories, and have implications for the viability of these fish and southern resident killer whales. Cullon et al. (2009) found elevated PCBs in adult Chinook returning to the Duwamish River, as well as in Puget Sound Chinook smolts.

PCB concentrations in Puget Sound herring and Puget Sound flatfish have also been evaluated. Puget Sound herring were found to contain three to nine times higher concentrations of PCBs than herring from the Strait of Georgia, with Puget Sound whole-body concentrations ranging from about 120 to 160 ng/g wet weight (ww) (West et al., 2008).

The Puget Sound Partnership has adopted a target for PCB concentrations in fish as one of the first "dashboard indicators" for toxic chemicals in fish (PSP, 2011a). The dashboard indicators were developed to provide a broad range of measurements to assess the health of Puget Sound. The PCB target is based on the documented accumulation of PCBs in a variety of Puget Sound fish species and the availability of a PCB tissue threshold concentration (i.e., 2,400 ng/g lipid; Meador et al., 2002). Specifically, the target is to reduce PCB levels in Puget Sound so that 95% of the sampled species have tissue concentrations below the threshold. Currently, at least 15% and up too 100% of the Chinook salmon, Pacific herring, and English sole analyzed have PCB concentrations exceeding the threshold.

In addition to measurements of PCB accumulation in tissues, analyses of various biomarkers of pollution exposures in benthic flatfish were shown to successfully differentiate between sites with differing degrees of sediment contamination (Stein et al., 1992). Cullon et al. (2005) also found about seven times higher levels of PCBs in a mixture of fishes designed to represent the diet of Puget Sound harbor seals than in a similar mixture of fish designed to represent the diet of harbor seals from the Strait of Georgia. Sol et al. (2008) found a statistically significant correlation between PCB concentrations in English sole livers and two biological effects parameters.

A number of studies have been conducted in the Puget Sound region investigating exposure and/or effects of PCBs and other persistent and bioaccumulative contaminants on wildlife, particularly marine mammals. Johnson et al. (2009) measured PCB concentrations in osprey eggs from the Lower Duwamish River and compared them to those sampled from the upper Willamette River. Total PCB residues were significantly higher in Lower Duwamish River osprey eggs (geometric mean = 897 ug/kg ww) compared to those from the Willamette River (geometric mean = 182 ug/kg ww). These results demonstrate that adult osprey bioaccumulation and maternal transfer of PCBs is occurring in osprey nesting in PCB contaminated areas of Puget Sound. This study also compared egg residues over time and determined that PCB concentrations in osprey eggs from the Lower Duwamish River had decreased 53% between 2003 and 2007.

Grove and Henny (2008) also demonstrated the bioaccumulation of PCBs in river otter livers from Puget Sound. The Puget Sound area river otters accumulated more PCBs (as total PCBs) than otters from other areas in western Washington. PCBs and other organochlorines have been shown to cause immunosuppression, thyroid disruption, and possibly cancer in harbor seals (Tabuchi et al., 2006; Ylitalo et al., 2005; Simms et al., 2000; Ross et al., 1996; Ross et al., 1995; de Swart et al., 1996; de Swart et al., 1995; Van Loveren et al., 1994). Vitamin A disruption has also been observed in harbor seal pups found on the Washington State coast whose mothers contained high PCB residues in their blubber (Simms et al., 2000). This effect on seal pups is suspected to result from exposure to contaminated milk.

There is substantial evidence that Puget Sound harbor seals and killer whales are bioaccumulating PCBs at very high concentrations in their blubber. The prey items of Puget Sound harbor seals were measured to have seven times higher concentrations of PCBs than prey from Strait of Georgia on a lipid basis (Cullon et al., 2005), which corresponds to PCB concentrations measured in harbor seal blubber.

Tissue concentrations of PCBs have often been reported as dioxin toxicity equivalents (i.e. TEQs) which are toxicities of dioxin-like PCBs, dioxins, and furans relative to the most toxic dioxin (2,3,7,8-TCDD). Puget Sound harbor seals have significantly higher TEQs in blubber (158 ng/kg lipid weight) compared to seals from the Strait of Georgia (33 ng/kg lipid weight) (Ross et al., 2004), and the TEQ contribution was greater from PCBs than dioxins and furans. Levin et al. (2005) also found that the majority of TEQs in harbor seal pups (from southern B.C.) were from PCBs, not dioxins and furans.

Ross et al. (2000) reported measured mean total PCBs in transient and Southern resident male killer whales were 251 and 146 mg/kg lipid, respectively; the authors concluded these marine mammals are among the most contaminated in the world.

Further research on the northern, southern, and transient killer whale communities have discovered that males bioaccumulate more PCBs than females due to maternal transfer (Krahn et al., 2007; Krahn et al., 2009). PCB concentrations in the blubber of mothers decrease temporarily during nursing and can reach concentrations below those in their calves. Mothers initiate bioaccumulation again after calves are weaned. Total PCB concentrations in southern resident killer whales were measured to range from about 5,000 to 180,000 ug/kg lipid. For all but three recent mothers, the measured concentrations exceed a marine mammal threshold for blubber concentrations (17,000 ug/kg lipid). Although environmental concentrations of PCBs are gradually declining, one modeled estimate of southern resident killer whale recovery projects that blubber concentrations will not reach the marine mammal threshold until 2063 (Hickie et al., 2007).

Accumulation of PCBs in fish tissue has led to advisories for human consumption of fish from Puget Sound marine waters, as well as limited freshwaters in the basin. The advisories, issued by WDOH, are based on data and consumption of particular species, and vary by region (Hardy and Palcisko, 2006). For instance, WDOH advises limited consumption of rockfish and flatfish based on the marine area in which they are caught. Consumption limits are also recommended for Chinook salmon due to elevated PCB levels, and vary depending on whether fish are migratory or the resident (blackmouth) species. WDOH also provides consumption advice for several Puget Sound region freshwater lakes and rivers due to PCBs in fish, including Lake Washington, Green Lake, and the Lower Duwamish River (WDOH, 2011).

PBDEs

Polybrominated diphenyl ethers (PBDEs) have been incorporated as flame retardants in numerous consumer products for decades and as a result, have gradually been released to the environment where they persist and accumulate in biota. Unlike most other persistent organic pollutants addressed in this report, environmental concentrations of PBDEs appear to be escalating in some cases, although available data on which to assess trends are also much more limited than for other chemicals.

Manufacturers of many different materials and products have used PBDEs as flame retardant additives in their products since the 1960s. These products include fabrics, television sets, computers, ABS resins, high impact polystyrene, textile coatings, carpet, polyurethane foams, cushions, mattresses, and insulation for wire and cables.

PBDEs are not chemically bonded to the matrices of those materials and products, and therefore they potentially escape from their matrix through volatilization to the air. Products and materials partially composed of or treated with PBDEs off-gas PBDEs to the environment during the useful lifetime of the product or material (i.e., while the product or material is still in use). Volatilization is one of the primary mechanisms of the release of PBDEs to the environment (Lorber and Cleverly, 2010).

Since PBDEs are a complex mixture of 209 congeners (varying by the number of bromine atoms and location on the molecule), their use and behavior in manufactured materials, as well as their behavior once released from materials, varies substantially. Major homolog groups (groups classified by the number of bromine atoms per molecule) include penta-, octa-, and deca-brominated diphenylethers (commonly referred to as Penta, Octa, and Deca, respectively). Penta was used widely in polyurethane foam and textiles, while the heavier homologs (Octa and Deca) were used primarily in polymers and electronics. The heavier homologs tend to be less volatile than the lighter BDEs, although once in the environment they may degrade to the lighter homologs. Heavier congeners such as Deca may also bind to dust more strongly than the more volatile congeners.

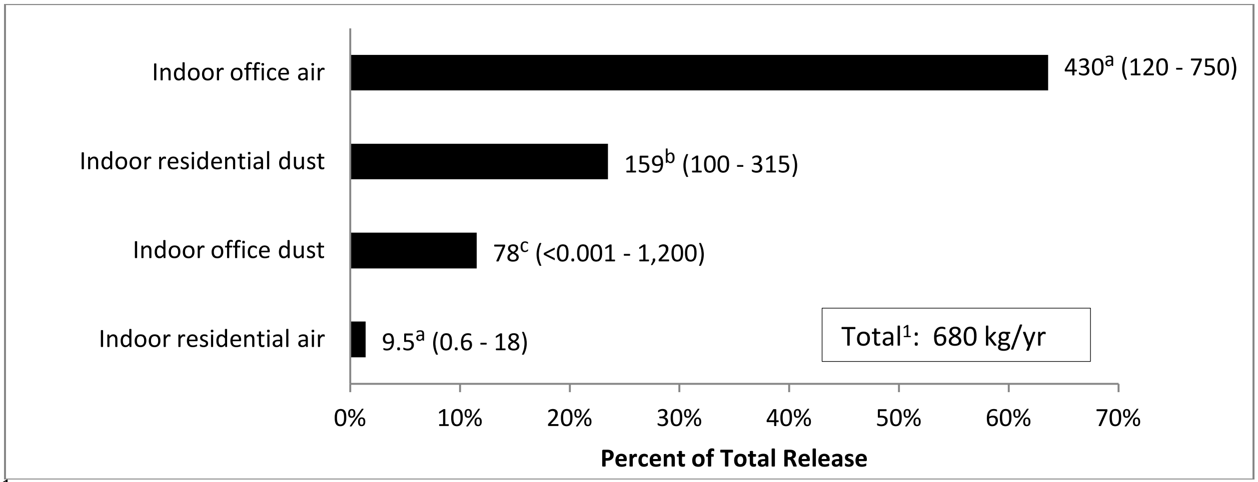
Beginning in the late-1990s, concerns began to emerge over the accumulation of PBDEs in animal tissues and the potential toxicity of PBDEs. Pressure to limit or ban PBDEs continued to mount until manufacturers of Penta and Octa voluntarily ceased production beginning in 2004. Deca manufacturers have agreed to discontinue the manufacture, import, and sales of Deca at the end of 2012, but in Washington State, Deca has been banned from mattresses since 2008 and was banned from televisions, computers, and residential upholstered furniture beginning January 1, 2011.

Major Releases from Primary Sources

Unlike most of the other COCs addressed in the present report, PBDEs are nearly all released by consumer products in constrained systems (i.e. indoors). For the inventory of primary sources (Ecology, 2011), no attempt was made to quantify environmental releases based on emissions from categories of PBDE-containing products such as computer monitors and mattress pads since most releases occur indoors and the attenuation between initial emissions and release to an environmental medium or pathway is uncertain. Therefore, release estimates were based on air exchange and dust generation in residential and commercial office spaces. This approach was taken to integrate individual component emissions and quantify PBDE releases in a simplified manner.

Total PBDE release from the four sources assessed totaled approximately 680 kg/yr (Figure 25). Indoor office space air accounted for 64% of the total release, while indoor residential air accounted for only 1%; indoor residential dust was the other major contributor at 23% while the indoor office dust contributed 12% to the overall releases. These release estimates should be viewed with caution since there is a high degree of uncertainty around all of the variables used to derive the values.

The PBDE Chemical Action Plan (Ecology and WDOH, 2006) largely addresses these sources and is consistent with the bans and restriction on PBDEs mentioned previously. However, many PBDE-containing consumer and office products are still in use and may represent diffuse sources of PBDEs to the environment during the remainder of their life cycle.



[1] Sum of best estimates. Best estimates are either the mean, mid-point, median, or most reasonable estimate for each source.

[a] Mid-point of range

[b] Median

[c] Geometric mean

Figure 25. Total PBDE Release in the Puget Sound Basin (values shown are kg/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for PBDE loading were obtained from PSTLA loading studies and are included in Table 15. No loading data are available for groundwater.

Table 15. PBDE Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater	NA	NA	NA
Air Deposition	15.7	20.3	23.8
Surface Runoff	5.14	5.67	9.95
POTWs	7.01	10.6	20.7
Ocean Exchange (a)	41	-11	240

NA=not analyzed
(a) Negative values indicate a net outflow at the ocean boundary

Loads from atmospheric deposition are estimated to be 16 – 24 kg/yr based on fluxes ranging from 4.5 to 27.3 ng/m^2/d (25th – 75th percentiles). Samples collected from the high-density urban station had higher PBDE fluxes than at other sites by factors of 3 to 4. PBDE flux patterns reflect some increased localized input, but regional sources may also play an important role in overall loading. The authors of the air deposition loading study point out that the estimates are likely to be conservative (high) due to the use of conservative assumptions to handle non-detected results.

PBDEs were frequently detected in the POTW loading study, with annual loads estimated at 7.0 – 21 kg. Although the authors of the POTW study caution against drawing conclusions about seasonal differences, they point out that PBDE concentrations are generally higher during the dry season.

Surface runoff loads for PBDEs are estimated to be approximately 5.1 – 10 kg/yr for the entire Puget Sound basin based on the surface runoff study. PBDEs were detected more frequently in storm runoff samples compared to baseflow. All samples from commercial/industrial areas contained detectable PBDE concentrations, but detection frequencies were close to 50% in other land covers (38% in forests).

Concentrations of PBDEs in commercial/industrial areas were higher than in other areas during both baseflows and storm flows. Like PCBs, concentrations in residential, agricultural, and forested areas were nearly identical among land types and were similar between baseflows and storm flows. PBDE concentrations in commercial/industrial areas increased by an order of magnitude during storms, although a seasonal first-flush episode was not evident in commercial/ industrial areas whereas it was seen in other land covers. Normalized to land cover area, commercial/industrial area loads were 10- to 20-fold above other areas. However, absolute loads from forests were larger overall due to the large area of forested land cover.

Based on marine water sampling and subsequent calculation of loads at the ocean boundary, there appears to be an annual net export of 11 kg total PBDEs at the ocean boundary using estimates derived from the median concentrations, while loads calculated from the 25th percentile and the 75th percentile concentrations appear to show net PBDE imports of 41 and 240 kg/yr, respectively. Total PBDE concentrations (25th-75th percentile) in the incoming marine waters are 760 – 1,600 pg/l, and total PBDE concentrations in the outgoing marine waters are 603 – 1,071 pg/l. PBDE inflow is estimated to be 440 – 940 kg/yr, and PBDE outflow is estimated to be 400 – 700 kg/yr.

The net sum of PBDE loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 69, 26, and 290 kg/yr, respectively. Under all of these estimates, there is a net PBDE load to Puget Sound.

PBDE loading from pathways that may represent *partially controllable* sources of COCs is shown as ranges (25th - 75th percentiles) and median for each pathway in Figure 26. Each pathway represented as a contribution to the total load is displayed in Figure 27.

Total PBDE loading from the major pathways assessed is 28 – 54 kg/yr. Atmospheric deposition accounts for the largest pathway (44 – 56%), followed by POTWs (25 – 38%) and surface runoff (18%). This pattern of source contribution is notably different than other COCs which typically have the largest, and often the majority, load input from surface runoff.

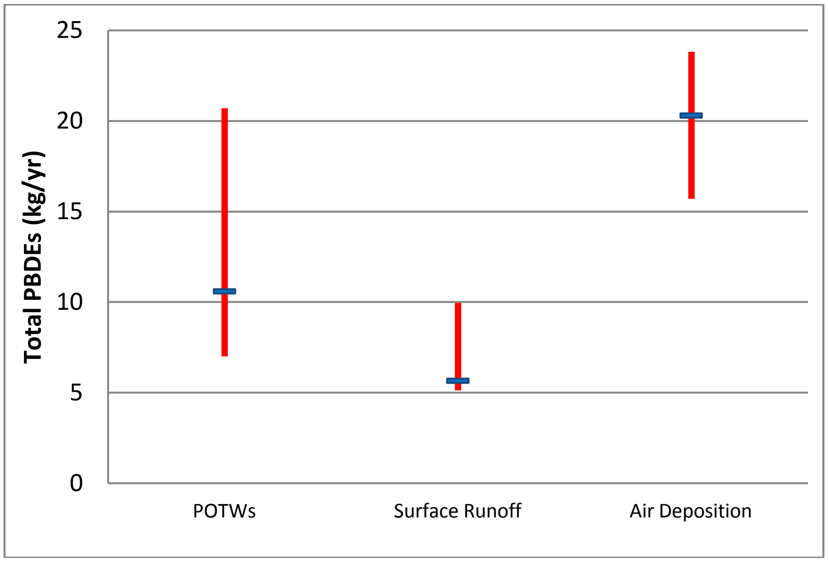


Figure 26. Range (25th - 75th percentiles) and Median Total PBDE Loads to Puget Sound from Each Major Delivery Pathway.

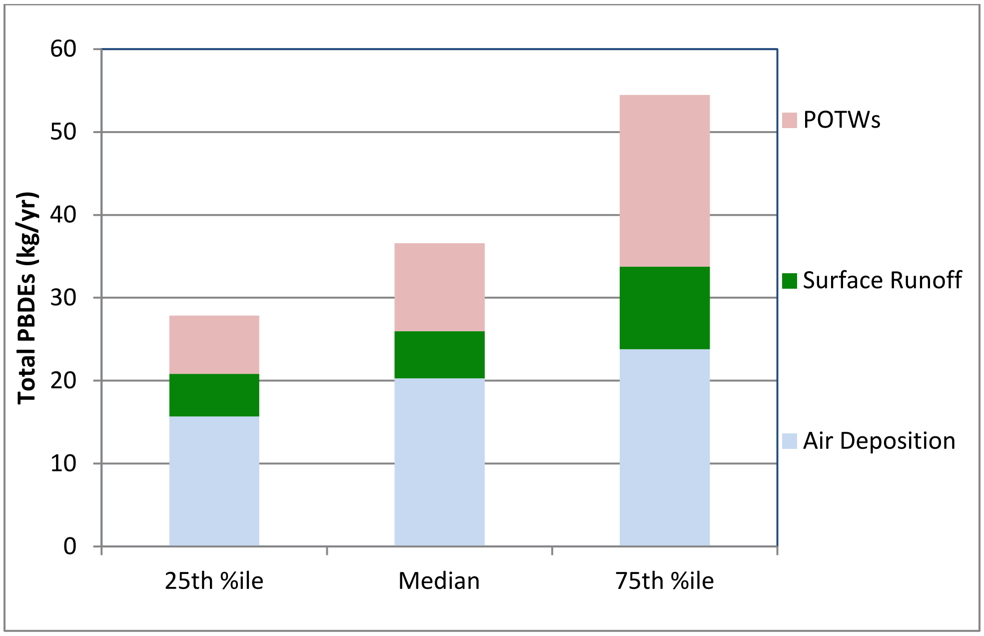


Figure 27. Total PBDE Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of PBDE transport and fate following release suggests that much of the PBDEs will be initially released to air and atmospheric transport will deliver comparatively high loads directly to Puget Sound. PBDEs deposited on land will also be mobilized during storm events and delivered to surface waters, but in quantities lower than for direct atmospheric deposition. Some of the PBDEs deposited to land are also likely to be transported in storm sewers and delivered directly to Puget Sound or indirectly by way of POTWs.

The inventory of primary sources (Ecology, 2011) suggests that PBDEs are released in the highest quantities in commercial areas compared to other land covers; this notion is supported by results of the loading studies. The air deposition study found higher PBDE fluxes in the high-density urban (Tacoma) location relative to other sites. The surface runoff study found much higher PBDE concentrations in commercial/industrial areas compared to other land covers.
The potential for large releases from indoor air is also supported by seasonal PBDE fluxes in atmospheric deposition; the authors found higher flux rates during the warm season and surmised that they may have been due to increased indoor air release (i.e. windows left open and increased ventilation).

PBDEs are released from indoor consumer and office products, become attached to dust particles, and are subsequently delivered to the sanitary sewer through washing machine rinse water during the washing of fabrics with the attached PBDE-enriched dust, and rinsing other materials with attached dust particles. This appears to be a reasonable pathway for PBDE release and transport, although the estimated quantity delivered to POTWs via this route is highly uncertain. However, the high frequency of detection and relative large loads from POTWs lends support to this concept. Furthermore, due to the nature of these PBDE sources, washing machine rinse water concentrations would be expected to remain steady throughout the year. This appears to be consistent with PBDE loads from POTWs which did not vary appreciably between wet and dry seasons.

Hazard Evaluation

PBDE data are available for surface waters and sediment, yet the paucity of documented effects, standards, or guidelines for PBDEs consistent with those used for other COCs preclude the assignment of a Priority 1 or Priority 2 level of concern (Table 16).

Table 16. Summary of Hazard Evaluation for PBDEs.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	255	59%	INS	U
	Nearshore Marine	0	--	INS	U
	Offshore Marine	126	20%	INS	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	77	97%	INS	U
	Nearshore Marine	1	100%	INS	U
	Offshore Marine	45	98%	INS	U
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

FOD=Frequency of detection
INS= Insufficient effects data available for comparison to observed data
U=Unknown level of concern due to lack of sufficient data for adequate comparison

Regionally Important Biological-Effects Data

PBDEs were detected in outmigrant Chinook salmon tissue and their stomach contents from four sites in Puget Sound (Sloan et al., 2010). Levels in wild outmigrant juveniles were higher than in hatchery fish, ranging from 67 to 13,000 ug/kg lipid, generally comparable to those measured in the Lower Columbia River and Estuary. Sloan et al. (2010) conclude that PBDEs may be contributing to reduced health and fitness in outmigrant juvenile Chinook salmon. PBDEs were detected in adult Chinook salmon returning to the Duwamish River and were not detected in adult Chinook returning to the Johnstone Strait, Lower Fraser River, or Deschutes River (Cullon et al., 2009).

Lema et al. (2008) demonstrated that dietary exposures to certain PBDEs by adult fathead minnows can alter thyroid status and thyroid hormone-regulated gene transcription. Arkoosh et al. (2010) found that juvenile Chinook salmon exposed to moderate doses of PBDEs in their diet may be at increased risk of disease relative to those exposed to higher or lower doses of

PBDEs in their diet. PBDE levels were found to be about four to five times higher in a mixture of fishes designed to represent the diet of Puget Sound harbor seals than in a similar mixture of fish designed to represent the diet of harbor seals from the Strait of Georgia (Cullon et al., 2005).

Very few studies have been conducted examining effects of PBDEs on birds. The studies reviewed indicate that PBDEs impact the reproduction and endocrine system similarly to PCBs. Exposure to BDE-71 for 75 days adversely impacted courtship and mating behavior of American kestrels (*Falco sparverius*)(Fernie et al., 2008). These birds also displayed significant delays in clutch initiation and smaller eggs (Fernie et al., 2009). Eggshell thinning and reduced hatching success also resulted. A study of species sensitivity to PBDEs (PBDE-71) observed that pentabrominated diphenyl ether (Penta BDE) exposure to eggs at 0.01 to 20 mg/kg caused decreased pipping and hatching success in American kestrels but not chickens (*Gallus gallus*) or Mallard ducks (*Anas platyrhynchus*)(McKernan et al., 2009). Species sensitivity was concluded to be Mallard ducks <chickens <American kestrels.

Total PBDE concentrations in osprey eggs and nestling plasma are significantly lower in the Lower Duwamish River (eggs: 321 ug/kg ww; plasma: 6 ug/kg ww) compared to those from the upper Willamette River (eggs: 897 pb ww; plasma: 22 ppb ww) (Johnson et al., 2009). Total PBDE concentrations in the osprey eggs did not change significantly between 2003 and 2007. Reproductive failure was observed in four of nine nests in the Lower Duwamish area. A small dataset from this study suggests that some nestlings may have experienced immunosuppression. However, the results were inconclusive due to the small sample size.

Compared to birds, a larger but still limited number of publications exist on the effects of PBDEs in mammals. Rodent exposure studies have demonstrated thyroid hormone disruption (Hallgren et al., 2001; Zhou et al., 2002) and developmental neurotoxic and behavioral effects (Ericksson et al., 2001; Viberg et al., 2003a; Viberg et al., 2003b). A study of grey seal pups and juveniles observed a relationship between circulating thyroid hormones, transport proteins, and PBDE uptake (Hall et al., 2003).

Similar to PCBs, there is evidence of bioaccumulation of PBDEs in marine mammals at high concentrations in blubber. However, absolute concentrations of total PBDEs appear to be lower than total PCBs. Cullon et al. (2005) measured PBDE concentrations five times higher in harbor seal prey from Puget Sound than the Strait of Georgia, but the mean PBDE concentration was five times lower than that measured for PCBs. Krahn et al. (2009) and Rayne et al. (2004) found the same pattern of killer whale blubber concentrations as found for PCBs in males, mothers, and calves. Krahn et al. (2009) measured total PBDE concentrations ranged from 680 to 15,000 ug/kg lipid. Mean PBDE concentrations in northern male killer whale blubber have been found to be significantly lower (203 ug/kg lipid) than those of southern resident (942 ug/kg lipid) and transient males (1,015 ug/kg lipid).

Although a quantitative effects assessment was not conducted for PBDE exposure to marine mammals, published research demonstrates that PBDEs are bioaccumulating to high concentrations in Puget Sound killer whales. This coupled with the growing evidence that PBDE exposure can cause thyroid and developmental effects in mammals strongly suggest that PBDEs are an important contaminant to monitor.

PCDD/Fs

Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs; a.k.a. dioxins) are a class of persistent bioaccumulative compounds ubiquitous in the environment at low concentrations. There are 210 individual PCDD/F congeners (75 PCDDs and 135 PCDFs), but only the 17 congeners (seven PCDD and ten PCDF) with chlorines occupying the 2,3,7, and 8 positions on the molecules are considered toxic.

PCDD/Fs are generally found in mixtures, with the toxicity of the mixture translated to that of TCDD (and more recently, PeCDD) which is the most toxic congener. Each of the 17 PCDD/Fs are assigned a toxicity factor relative to that of TCDD and PeCDD, and the toxicity factor multiplied by the congener concentration is termed the toxic equivalent (TEQ) when the congeners are summed. The TEQ of an environmental sample is generally useful shorthand for assessing comparisons to regulatory thresholds and for assessing risks. Sampling and source data are commonly expressed as TEQs, and this convention has been adopted in the present document.

Unlike many other environmental contaminants, PCDD/Fs are not produced intentionally, but instead are formed and released as by-products of industrial production and combustion of certain chlorinated materials. As a result, industrial and combustion sources are responsible for the majority of PCDD/F releases. In the Puget Sound region, the major historical sources of PCDD/Fs – use of elemental chlorine in pulp bleaching, pentachlorophenol wood treatment operations, and combustion of saltwater-infused hog fuel – are all but gone (Yake et al., 1998). However, PCDD/Fs are extremely persistent in the environment, particularly at sites where these activities historically occurred.

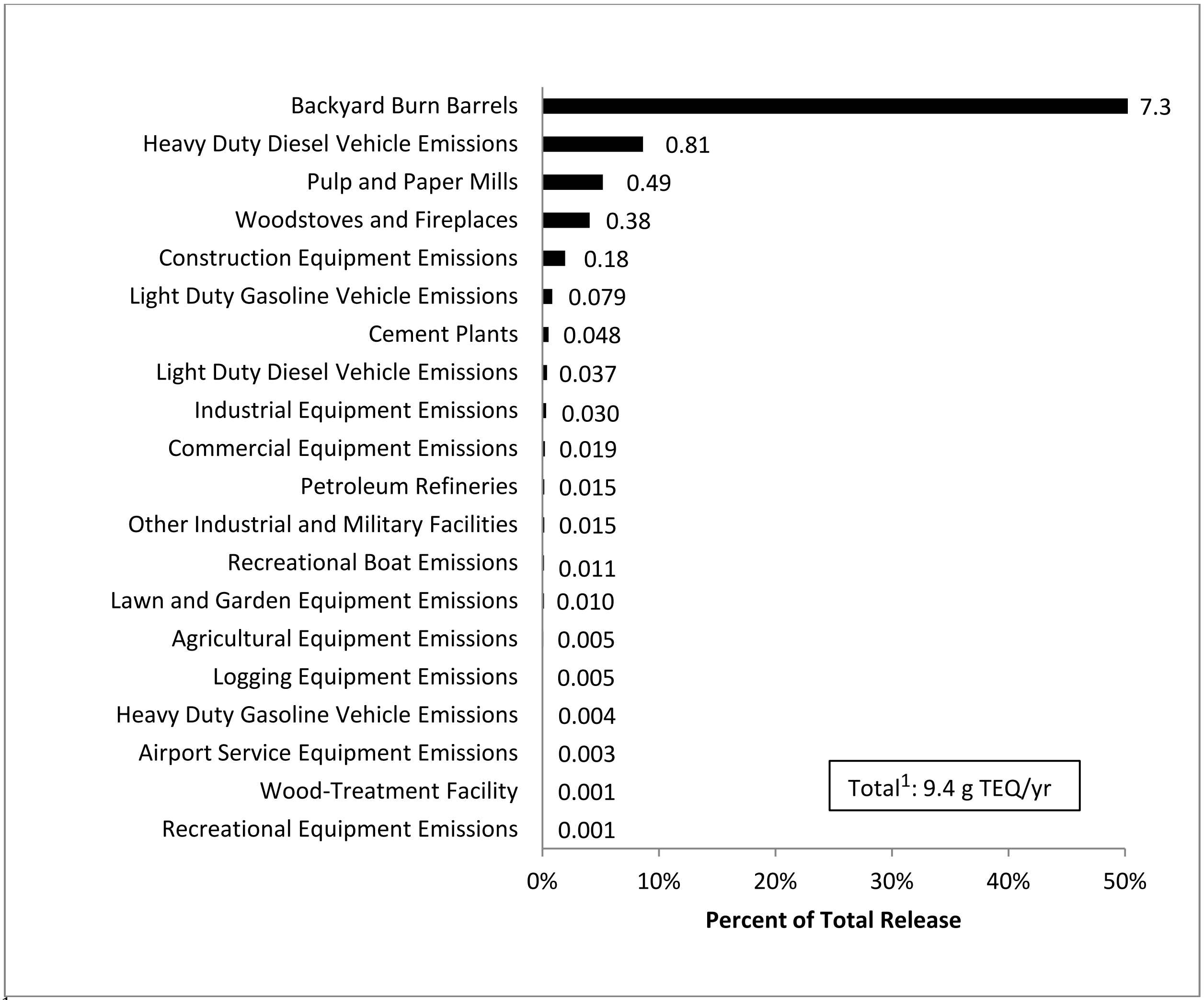
One other characteristic also distinguishes PCDD/Fs from most other environmental toxicants: their analysis requires expensive analytical techniques and is performed by only a limited number of commercial laboratories. As a result, they are commonly excluded from screening level investigations and are generally analyzed only if they are the focus of an environmental investigation. Since environmental PCDD/F data are not as prevalent as for other chemicals, there are fewer data on sources of their release to the environment.

PCDD/Fs are not typically detectable in ambient waters using conventional sampling and analytical techniques, even at detection limits in the low parts per quadrillion (pg/l) range. PCDD/Fs in sediments and biota are more typically found at low parts per trillion (ng/kg) levels, depending on the specific compound, organic carbon content of sediment, and lipid content in tissue.

Major Releases from Primary Sources

Annual PCDD/F release from the 20 sources assessed totaled approximately 9 g TEQ/yr (Figure 28). The largest single source is backyard burn barrels, accounting for nearly three-quarters of the PCDD/F release to the Puget Sound basin.

Combustion emissions to air account for 97% of the PCDD/F release. The remaining 3% of the release is to water, primarily from pulp and paper mills. This represents a substantial change from two to three decades previous when PCDD/F discharges to water from pulp mills represented the bulk of all releases to Washington State (EPA, 1991).



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

Figure 28. Total PCDD/F Release in the Puget Sound Basin (values shown are g TEQ/yr).

Major Delivery Pathways and Loading

None of the Phase 3 sampling studies included analysis of PCDD/Fs. The groundwater loading analysis included an estimate of PCDD/Fs from values reported in the literature. However, the groundwater data only included PCDD/Fs reported as total TCDD or total TCDF, with no indication of whether these are 2,3,7,8-substituted congeners.

Surface runoff load estimates were estimated during PSTLA Phase 2 based on a variety of U.S. and European runoff data, most of which were from urban areas (Envirovision et al., 2008a). The best estimates of the medians from these concentrations were 10 pg/l for commercial/ industrial areas, 5 pg/l for residential and agricultural areas, and 0.1 pg/l for forested area. When applied to the hydrologic model used in Phase 2, loads were estimated to be 6.1 – 103 g TEQ/yr (25th – 75th percentiles), with a median estimate of 25 g TEQ/yr. Most of the PCDD/F load (59%) was from residential areas, with the smallest percentage (6%) from commercial/industrial areas.

Estimates of PCDD/F loads to marine waters from atmospheric deposition were derived in Phase 1 from fluxes reported in Europe and adjusted to the Puget Sound region based on relative differences in air concentration (Hart Crowser at al., 2007). Fluxes of 0.1 – 10 pg/m^2/day (low to high end of range, 1 pg/m^2/day as medium value) were used to estimate the aerially deposited loads (0.31 – 31 g TEQ/yr, medium estimate of 3.1 g TEQ/yr).

Both the atmospheric deposition (Phase 1) and surface runoff (Phase 2) load estimates for PCDD/Fs have a large degree of associated uncertainty. The paucity of PCDD/F stream and air deposition data from the Puget Sound region makes gauging the representativeness of other data difficult. Therefore, these estimates should not be treated with the same level of confidence as those derived from Phase 3 sampling efforts.

Relationship Between Sources and Pathways/Loading

The conceptual model of PCDD/F transport and fate following release is complicated by the lack of sampling data. Based on the inventoried sources (Ecology, 2011), release to air is likely to be the primary initial pathway for PCDD/Fs. The dominance of combustion as a formation mechanism suggests that much of the PCDD/F release may be associated with airborne particles.

There are no reliable data to assess the degree of deposition for particle-bound PCDD/Fs in the Puget Sound basin, but near-field deposition may be expected for much of the emitted PCDD/Fs since the bulk of emission is from numerous non-point sources as opposed to high stacks designed to disperse emissions. Based on the primary sources in the basin, the release of PCDD/Fs is likely to occur in a mix of urban and rural locations, and may occur at a distance from the Puget Sound marine waters. Delivery to Puget Sound is therefore likely to occur through secondary pathways (e.g. surface runoff, POTWs) as well as direct deposition and would not be expected to be dominated by a single delivery mechanism.

Hazard Evaluation

The hazard evaluation indicates that PCDD/Fs are a Priority 1 level of concern for a wildlife mammalian species (river otter) and human health due to concentrations found in both the freshwater and marine aquatic environments (Table 17). However, there are insufficient observed or effects data to adequately evaluate PCDD/Fs in surface waters, sediments, or for tissue residue effects.

In fresh surface waters only five observed results are available to compare dioxin concentrations with effects data. Observed concentrations of 1,2,3,7,8-PeCDD and 1,2,3,4,7,8-HxCDD are one to two orders of magnitude below the lowest effects concentrations, and 2,3,7,8-TCDD is three orders of magnitude below levels where effects are documented. There are no observed environmental data available for PCDD/Fs in the marine water column.

In freshwater sediments, the median PCDD/F concentration (expressed as TEQ) is approximately equal to the lowest available guideline, the Canadian TEL. However, the interquartile range of concentrations spans four orders of magnitude, and at least 25% of the observed TEQs are well above the Canadian PEL where adverse effects are expected to frequently occur.

Median PCDD/F TEQ concentrations in marine sediments are similar to freshwater sediments, but the distribution of concentrations occupies a much narrower range. For both nearshore and offshore sediments, the median values exceed the Canadian TEL, but only 5 – 10% of the observed concentrations exceed the Canadian PEL.

There are few effects data to assess the potential concern of PCDD/Fs associated with tissue residue. For freshwater, there were sufficient effects data available for decapods, but no observed data. No tissue residue effects data were available for marine waters.

For the two bird species evaluated – great blue heron and osprey – only two daily effects doses of PCDD/Fs (as TEQ) were calculated: one for reproductive effects and one for mortality. Neither of the species are exposed to these doses, but heron are exposed to doses that are one-fifth to one-half of the lowest (reproductive) dose. Osprey are exposed to doses three orders of magnitude below the lowest effects dose. However, the low number of dose effects was not deemed sufficient for an adequate comparison with calculated doses (Appendix D-1).

Based on environmental concentrations of PCDD/Fs, river otter receive approximately five to ten times the daily doses (as TEQs) where reproductive effects have been documented, and within 10% of the lowest dose associated with mortality. Harbor seals are exposed to much lower daily PCDD/F doses; less than 10% of the lowest effect dose.

Concentrations of 2,3,7,8-TCDD in freshwater fish, bivalves, and other invertebrates were compared to the NTR criterion. Median concentrations for fish and tissues from other invertebrates were above the NTR criterion in both fresh and marine waters, although no detectable concentrations are available for 2,3,7,8-TCDD in marine nearshore fish. At least 90% of the 2,3,7,8-TCDD concentrations in freshwater bivalves are above the criterion, but in marine nearshore areas, less than 25% of the concentrations are above the criterion.

Table 17. Summary of Hazard Evaluation for PCDD/Fs.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc. or Acute WQC or Chronic WQC*	**Level of Concern**
	Freshwater	7	>14%	INS[a]	U
	Nearshore Marine	0	--	INS[a]	U
	Offshore Marine	0	--	INS[a]	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	36	89%	INS[b]	U
	Nearshore Marine	219	>99%	INS[b]	U
	Offshore Marine	106	>99%	INS[b]	U
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Freshwater	c	57%	INS[b]	U
	Nearshore Marine	d	≥97%[e]	INS[b]	U
	Offshore Marine	f	≥86%	INS[b]	U
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Great Blue Heron (FW)	--	--	INS[b]	U
	Osprey (SW)	--	--	INS[b]	U
	River Otter (FW)	--	--	Yes	Priority 1
	Harbor Seal (SW)	--	--	No	Priority 2
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Freshwater	g	≥25%	Yes	Priority 1
	Nearshore Marine	h	>18%[e]	Yes	Priority 1
	Offshore Marine	i	≥5%	Yes	Priority 1

Yellow highlight indicates Priority 1 Level of Concern

FOD=Frequency of detection

INS[a]=Insufficient observed data available for comparison to effects data

U=Unknown level of concern due to lack of sufficient data for adequate comparison

INS[b]=Insufficient effects data available for comparison to observed data

[c] N = 175 for non-decapod invertebrates. No observed data available for other organism types

[d] N = 76 for non-decapod invertebrates, N = 13 for decapods, and N = 1 for fish tissue.

[e] FOD=0% for fish tissue

[f] N = 28 for non-decapod invertebrates, N = 9 for decapods, and N = 10 for fish tissue.

[g] N range is 35 – 72 and varies for organism type and tissue type

[h] N range is 8 – 129 and varies for organism type and tissue type

[i] N range is 32 – 53 and varies for organism type and tissue type

Regionally Important Biological-Effects Data

Studies in Puget Sound of harbor seal and southern resident killer whale prey items have higher PCDD/Fs compared to the same prey items from the Strait of Georgia and British Columbia coast (Cullon et al., 2005, Cullon et al., 2009). Harbor seal prey were three to four times higher on a lipid basis than prey from the Strait of Georgia (Cullon et al., 2005). However, Ross et al. (2000) found that PCDD/F concentrations in killer whale blubber were much lower than PCBs, and there were no differences between whales from the northern and southern resident and transient communities. This was suspected to be due to metabolic removal of dioxins and furans.

DDT

The chlorinated insecticide dichlorodiphenyltrichloroethane (DDT) was banned in 1972 from general agricultural uses in the U.S. following concerns over its effects on wildlife and human health. However, potentially harmful levels are still found in the environment, together with its major breakdown and metabolic products dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD) due to their persistence and tendency to accumulate in fish and wildlife. In western Washington, DDT is only rarely detected in water, even at a typical analytical detection limit of about 1 ng/l (parts per quadrillion), but is nearly always detected in fish due to its extremely high bioaccumulation potential.

Major Releases from Primary Sources

DDT sources were not inventoried in the analysis of primary sources since it was banned nearly four decades ago and DDT had no uses other than as an agricultural insecticide and limited use as an urban pesticide. Due to its persistence, however, it continues to be found in environmental media, particularly soils and sediments, and is delivered to Puget Sound when these soil and sediment particles become entrained in surface water runoff.

Major Delivery Pathways and Loading

Data on major delivery pathways for DDT loading were obtained from PSTLA loading studies and are included in Table 18. No effort was made to assess DDT loads from direct deposition of atmospheric DDT to Puget Sound during Phase 3 sampling. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

The estimated range of groundwater DDT loads is large (0.2 – 7.3 kg/yr) due primarily to differences in flows used to establish the possible range of loads. DDT load estimates in groundwater should be used with caution since they are based primarily on non-detect data and numerous assumptions, including unconfirmed assumptions about DDT mobility in groundwater.

DDT compounds were analyzed in all ten POTWs during winter and summer sampling events, yet no concentrations were detectable. Reporting limits for DDT compounds in POTW samples were generally 2 – 3 ng/l.

Table 18. Total DDT Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	0.2	3.8	7.3
Air Deposition	NA	NA	NA
Surface Runoff (b)	2.2	23.9	25.1
POTWs	ND	ND	ND
Ocean Exchange	NC	NC	NC

(a) Lowest and highest estimated loads
(b) Detected in commercial/industrial areas only during baseflows and in commercial, agricultural, and forest areas only during storm flows
NA=not analyzed
ND=not detected
NC=not calculated due to insufficient data

Surface runoff loads for DDT are estimated to be approximately 2.2 – 25 kg/yr for the entire Puget Sound basin based on the surface runoff study. DDT compounds were detected in all land use types during storm events except residential covers, and >99% of the loads occurred during storm flows. Loads calculated during storms generally mirrored the amount of land area for each land use cover, a somewhat confounding result since agricultural areas would be expected to have larger loads relative to land area.

A single commercial/industrial area had the only detection of DDT compounds during baseflows, and only in very low concentrations. However, this particular location had DDT concentrations an order of magnitude above all other locations – regardless of land cover – during storm flows. For each land cover, the detection frequency for DDT compounds was low and never exceeded 50%, and therefore the calculated median loads were driven by non-detected values.

DDT loads were not calculated for the ocean exchange of marine waters due to the low frequency of detection. DDT compounds were detected in only three samples at locations in the northern boundary waters, all at low concentrations (<0.4 ng/l).

The net sum of DDT loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 2.5, 28, and 32 kg/yr, respectively. Under all of these estimates, there is a net DDT load to Puget Sound.

DDT loading from pathways that may represent *partially controllable* sources of COCs is shown as ranges (25th - 75th percentiles) and medians for each pathway in Figure 29. Each pathway represented as a contribution to the total load is displayed in Figure 30.

Total DDT loading measured from the major pathways is 2.5 – 32 kg/yr, all contributed through surface runoff and groundwater. Surface runoff accounts for the largest portion of DDT loading (77 – 88%), with the remaining amount (12 – 23%) contributed by the groundwater pathway.

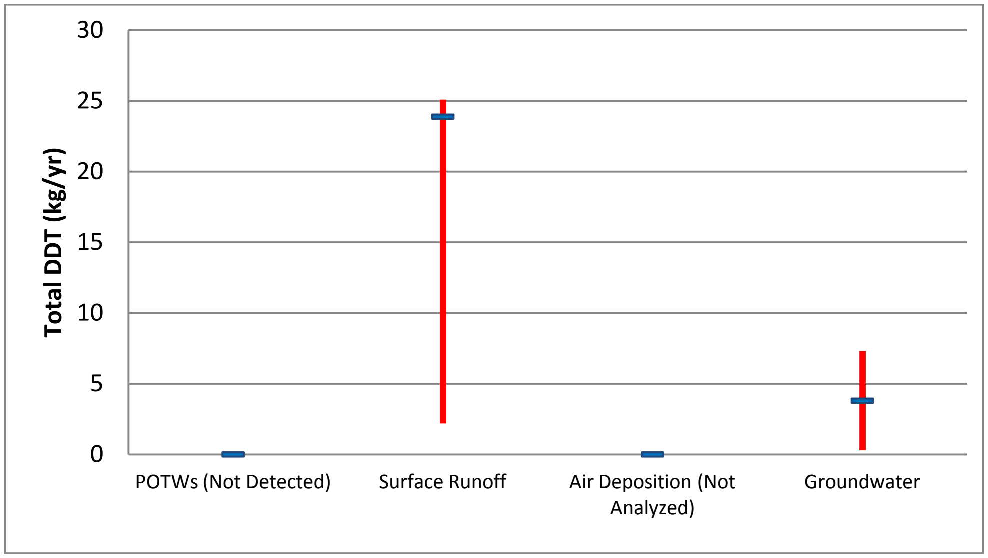


Figure 29. Range (25th - 75th percentiles) and Median Total DDT Loads to Puget Sound from Each Major Delivery Pathway.

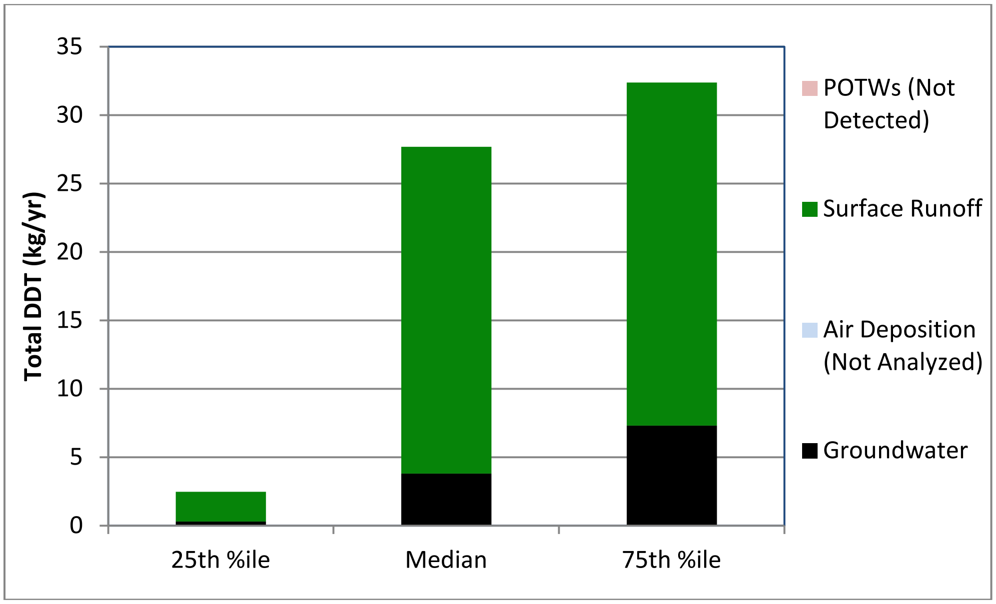


Figure 30. Total DDT Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of DDT transport and fate following release appears to be rather simple compared with other COCs. Releases from primary sources likely occurred during previous decades, and soils and sediments likely serve as the major reservoirs for DDT remaining in the environment. Soil and sediment-bound PCBs are mobilized during storm flows and delivered toward Puget Sound in surface runoff. Comparatively low DDT occurrence and concentrations in agricultural soils suggest that that the bulk of DDT mobilization from agricultural soils, where the majority of DDT was likely to have been originally released, has already occurred and the large DDT reservoirs may have advanced downstream and may largely reside in Puget Sound sediments. Conversion of agricultural lands to commercial or other land uses may explain high DDT concentrations in other land uses, particularly if soils are disturbed.

It is possible that DDT is also delivered to Puget Sound through direct atmospheric deposition to marine waters, or that some of the DDT in surface waters is due to aerially deposited DDT entrained in storm runoff. Loads of direct atmospheric deposition of DDT were calculated during the Phase 1 effort, and were estimated to be 1.2 – 31 kg/yr (low to high end of range, 6.2 kg/yr as medium value) based on fluxes reported in the eastern and midwestern U.S. (0.4 – 10 ng/m^2/day; 2 pg/m^2/day as medium value).

Hazard Evaluation

The hazard evaluation indicates that DDT compounds are a Priority 1 level of concern for a range of media and receptors in both the freshwater and marine aquatic environments (Table 19).

In fresh surface waters, the 90th percentile of total DDT (sum of DDT, DDE, and DDD) concentrations (approx. 1 ug/l) is slightly higher than the acute water quality criterion, and at least 95% of the observed concentrations are above the chronic water quality criterion. More than 90% of the values from the fairly extensive dataset on DDT effects are above the 90th percentile value for observed concentrations. There are not sufficient data to evaluate DDT in marine surface waters.

The chronic freshwater water quality criterion is three orders of magnitude lower than the acute water quality criterion. This difference stems from the high bioaccumulative potential of DDT, on which the chronic criterion is indirectly based (reproductive effects in the piscivorous brown pelican), whereas the acute criterion is based on LC_{50} concentrations for numerous fish and invertebrate species (EPA, 1980).

There are no SQS for freshwater or marine sediments to compare to DDT concentrations. However, median DDT concentrations exceed the Canadian TEL, and at least >75% of the concentrations exceed the consensus-based TEC, although concentrations are well below the Canadian PEL and consensus-based PEC.

In the marine environment, median DDT concentrations in both nearshore and offshore sediments are similar to the Canadian TEL. However, a number of the nearshore sediments have much higher concentrations than those from offshore locations, and at least 10% of the DDT concentrations exceed the Canadian PEL as well as the LAET and the 2LAET (2x the LAET).

Table 19. Summary of Hazard Evaluation for DDT.

		Total N	FOD	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
Surface Water	Freshwater	2,179	4%	Yes	Priority 1
	Nearshore Marine	11	0	INS[a]	U
	Offshore Marine	0	--	INS[a]	U
		Total N	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
Sediment	Freshwater	365	30%	INS[b]	U
	Nearshore Marine	350	41%	INS[b]	U
	Offshore Marine	457	25%	INS[b]	U
		Total N	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
Tissue Residue Effects	Freshwater	c	≥92%	No	Priority 2
	Nearshore Marine	d	≥31%	INS[b]	U
	Offshore Marine	f	≥18%	INS[b]	U
		Total N	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
Wildlife	Great Blue Heron (FW)	--	--	Yes	Priority 1
	Osprey (SW)	--	--	Yes	Priority 1
	River Otter (FW)	--	--	No	Priority 2
	Harbor Seal (SW)	--	--	No	Priority 2
		Total N	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
Human Health	Freshwater	g	>68%	Yes	Priority 1
	Nearshore Marine	h	≥20%	Yes	Priority 1
	Offshore Marine	i	≥6%[j]	No	Priority 2

Yellow highlight indicates Priority 1 Level of Concern
FOD=Frequency of detection
INS[a]=Insufficient observed data available for comparison to effects data
U=Unknown level of concern due to lack of sufficient data for adequate comparison
INS[b]=Insufficient effects data available for comparison to observed data
[c] N = 83 for non-decapod invertebrates and 139 for fish tissue
[e] N = 84 for non-decapod invertebrates, N = 20 for decapods, and N = 131 for fish tissue.
[f] N = 33 for non-decapod invertebrates, N = 5 for decapods, and N = 543 for fish tissue.
[g] N range is 56 – 634 and varies for organism type, tissue type, and DDT compound
[h] N range is 48 – 491 and varies for organism type, tissue type, and DDT compound
[1] N range is 33 – 1,036 and varies for organism type, tissue type, and DDT compound
[j] FOD=0% for 4,4’-DDD in bivalve tissue

Observed DDT concentrations in freshwater invertebrates and fish are well below concentrations where effects are documented. Insufficient effects data were available to adequately compare with observed concentrations from invertebrates or fish from the marine nearshore and offshore environments.

Calculation of DDT doses for the two bird and two mammalian species evaluated indicate that only great blue heron are exposed to daily DDT doses above a concentration where at least one effect (reproductive) has been documented. However, for osprey, the calculated daily DDT dose is only slightly (<50%) below this lowest effects dose. For both of the mammalian species evaluated – river otter for freshwaters and harbor seal for marine waters – calculated daily DDT doses are more than an order of magnitude below doses where effects have been documented.

NTR criteria for DDT compounds are based on individual DDT compounds (4,4’-DDD, 4,4’-DDE, and 4,4’-DDT) rather than total DDT. For freshwater tissues, DDD and DDE 90th percentile concentrations exceed the NTR criterion for invertebrates other than bivalves. In nearshore marine waters, the observed 90th percentile DDT concentration exceeds the criterion for fish and invertebrates other than bivalves. None of the tissues have observed 90th percentile values exceeding the NTR criterion in offshore marine waters.

In general, the interquartile range of concentrations for all three compounds falls between the NTR criteria at the 17.5 g/d EPA recreational consumption rate and the 769 g/d Suquamish Tribal rate. This pattern is consistent across the observed concentrations in freshwater and in nearshore and offshore marine waters.

Regionally Important Biological-Effects Data

Total DDT (sum of DDT, DDE, and DDD) concentrations in stomach contents of outmigrant juvenile Chinook salmon were found to be elevated in fish from the Duwamish Estuary and Commencement Bay relative to the stomach content concentrations of fish from the Nisqually Estuary (Stein et al., 1995). Whole-body total DDT concentrations of juvenile Chinook salmon were found to be relatively high (over 1,000 ng/g lipid or 25 ng/g ww) in fish from the Nisqually, Duwamish, and Columbia River estuaries (Johnson et al., 2007).

Johnson et al. (2007) also found detectable levels of DDTs in stomach contents, with stomach content concentrations substantially higher in Columbia River and Grays Harbor juvenile Chinook than in Duwamish and Nisqually Estuary. They suggested that at the levels measured, DDTs are unlikely to cause adverse effect by themselves, but that they may contribute via additive or synergistic effects with other contaminants. Substantially higher levels of DDTs were found in adult Chinook salmon returning to the Duwamish River than in adult Chinook returning to Johnstone Strait, the Lower Fraser River, or the Deschutes River (Cullon et al., 2009).

An analysis of DDT concentrations in Pacific herring tissues found that concentrations from Puget Sound herring were 1.5 to 2.5 times higher than those from the Strait of Georgia (West et al., 2008), with Puget Sound concentrations ranging from 19 to 27 ng/g ww (240 to 330 ng/g lipid). Cullon et al. (2005) found similar levels of DDTs in a mixture of fishes designed to represent the diets of Puget Sound and Strait of Georgia harbor seals.

Grove and Henny (2008) did not find detections of DDT and only low detections of DDE (mean of 0.004-0.28 mg/kg ww) in river otter livers from Puget Sound. These DDE levels are much lower than those found in river otters living along the Columbia River (mean of 0.12-1.65 mg/kg ww). The prey items of harbor seals in Puget Sound are 1.6 times higher in total DDT (lipid weight) than those from the Strait of Georgia (Cullon et al., 2005).

Puget Sound Chinook, the major prey of southern resident killer whales, have higher body residues of DDTs and lower lipids compared to Chinook from the British Columbia coast (Cullon et al., 2009). Krahn et al. (2009) found the same pattern of killer-whale blubber concentrations as found for PCBs in males, mothers and calves; total DDT concentrations ranged from 1,000 to 160,000 ug/kg lipid.

PAHs

Polycyclic aromatic hydrocarbons (PAHs) are a class of compounds characterized by two or more fused aromatic rings composed of carbon and hydrogen. There are hundreds of such compounds, but most studies have focused on 16 compounds that were designated as “priority pollutants” in the federal Clean Water Act. These 16 compounds are:

<u>Low Molecular Weight PAHs (LPAHs)</u>
- Acenaphthene
- Acenaphthylene
- Anthracene
- Fluorene
- Naphthalene
- Phenanthrene

<u>High Molecular Weight PAHs (HPAHs)</u>
- Benzo(a)anthracene*
- Benzo(a)pyrene*
- Benzo(b)fluoranthene*
- Benzo(k)fluoranthene*
- Benzo(g,h,i)perylene
- Chrysene*
- Dibenzo(a,h)anthracene*
- Fluoranthene
- Indeno(1,2,3-c,d)pyrene*
- Pyrene

*Designated as probable human carcinogens by EPA (cPAHs)

LPAHs tend to be found at elevated concentrations in uncombusted fossil fuels, while HPAHs are formed during incomplete combustion of fossil fuels and other organic materials such as wood (PTI, 1991). However, source identification of PAHs found in the environment cannot simply be distilled down to comparisons of LPAHs to HPAHs for a variety of reasons. LPAHs and HPAHs are not typically exclusive to particular sources; releases occur from diffuse sources, and degradation processes may alter PAH compositions following their release.

Most PAHs are found in mixtures, but biochemical processes and accumulation potentials, as well as toxicity of individual PAHs, may vary considerably. Creosote, a tarry substance formed as coke distillate, is used to preserve wood and has historically been a major source of PAHs in Puget Sound, particularly in areas with pole treating operations adjacent to marine waters.

In Puget Sound, PAHs are associated with liver disease and reproductive impairment of English sole, particularly in urban bays (PSAT, 2007). Concentrations in the water are difficult to measure, but limited data suggest that typical freshwater concentrations for total PAHs are in the 0.1 – 1.0 ug/l range (Appendix D-3), with marine water column concentrations slightly lower (Serdar, 2008). Total PAHs in freshwater and marine sediments are typically 100 – 1,000 ug/kg (dw) (Appendix D-4) although mean concentrations in urban bays may be up to ten-fold higher (Partridge et al., 2005).

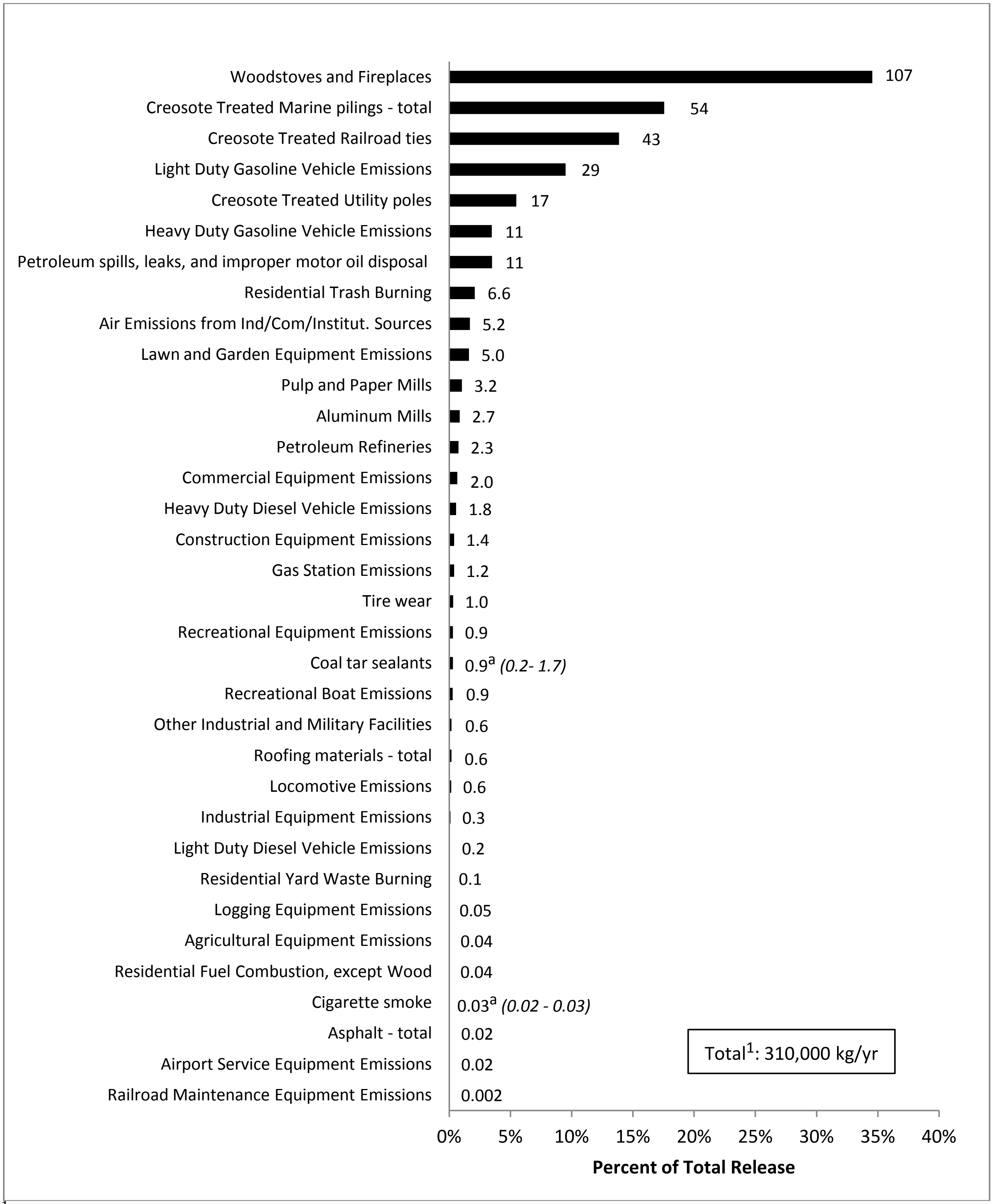
Major Releases from Primary Sources

Total annual PAH releases from sources inventoried total approximately 310,000 kg/yr in the Puget Sound basin (Figure 31). Generally speaking, the releases can be placed into two categories: combustion emissions and releases from creosote-treated wood.

Combustion releases account for most (55%) of the PAH release in the Puget Sound basin, with more than half of that amount due to woodstove and fireplace use, and smaller amounts due to residential trash burning and industrial emissions. The remainder of the combustion emissions is from petroleum fuel combustion, primarily due to gasoline use in vehicles.

Creosote-treated wood accounts for approximately one-third of the PAH release, with marine pilings (54 t/yr), railroad ties (43 t/yr), and utility poles (17 t/yr) representing the major sources.

Releases from large petroleum spills (≥ one gallon) and minor petroleum drips leaks, spillage, and improper disposal of motor oil account for PAH release of approximately 11 t/yr.



[1] Sum of best estimates. Best estimates are either the mean, mid-point, median, or most reasonable estimate for each source.

[a] Mid-point of range

Figure 31. Total PAH Release in the Puget Sound Basin (values shown are thousands kg/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for PAH loadings were obtained from PSTLA loading studies and are included in Table 20. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Table 20. PAH Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
		LPAH	
Groundwater (a)	7	159	311
Air Deposition	NA	NA	NA
Surface Runoff (b)	102	104	190
POTWs	3.27	8.05	34.9
Ocean Exchange	ND	ND	ND
		HPAH	
Groundwater (a)	6	124	244
Air Deposition	48.8	95.8	153
Surface Runoff (c)	25.2	36.2	50.7
POTWs	3.71	4.93	7.46
Ocean Exchange	ND	ND	ND
		cPAH	
Groundwater (a)	5	83	161
Air Deposition	20.8	43.2	69.8
Surface Runoff (d)	18.0	24.0	34.0
POTWs	NC	NC	NC
Ocean Exchange	ND	ND	ND
		Total PAH	
Groundwater (a)	13	284	555
Air Deposition (e)	48.8	95.8	153
Surface Runoff (b)	119	224	244
POTWs	7.55	18.5	45.8
Ocean Exchange	ND	ND	ND

(a) Lowest, highest, and mid-point of estimated loads
(b) Detected in commercial/industrial areas only during baseflows
(c) Detected in commercial areas only during baseflows and in commercial, residential, and agricultural areas only during storm flows
(d) Surface runoff loads based on storm flows only; not detected in any land covers during baseflows and in commercial, residential, and agricultural areas only during storm flows
(e) Total PAH based on HPAH only
NA=not analyzed
ND=not detected
NC=not calculated due to insufficient data

The estimated range of groundwater total PAH loads is large (13 – 555 kg/yr). The range in estimates is due to differences in flows used to establish the possible range of loads as well as differences in methods used to estimate representative PAH concentrations; most of the data were non-detected values. The groundwater loading calculations suggest that slightly over one-half of the groundwater loads of PAHs may be due to LPAH loads.

PAH load estimates in groundwater should be used with caution since they are based primarily on non-detect data and numerous assumptions, including unconfirmed assumptions about PAH mobility in groundwater. It is also notable that the "rule" used to sum individual PAHs to establish total PAHs (e.g. LPAH) resulted in higher values than results derived when applying summing rules used for other loading studies.

The deposition of atmospheric PAHs directly to the marine waters of Puget Sound is approximately 50 – 153 kg/yr, based on fluxes ranging from 0.012 – 0.69 ug/m^2/d. This estimate is based completely on HPAH; LPAHs were not analyzed. Median PAH fluxes were generally <0.05 ug/m^2/d, except for one location within a high-density urban (Tacoma) area including a nearby pulp mill, metal refiners, other industrial activities, and close to major roadways including interstate highways. PAH fluxes at this location were consistently an order of magnitude higher than other locations around the Puget Sound region, and were elevated six-fold above a nearby station that did not have the same air pollution influences in such close proximity. This pattern closely mirrored the deposition patterns of copper, lead, and zinc among the air sampling locations.

The total PAH load discharged from POTWs is estimated to be 6.6 – 46 kg/yr. Approximately one-half to three-quarters of the PAHs loaded from POTWs are LPAHs. Phase 1 estimates suggest that PAH loads from industrial wastewater are potentially substantial (2 – 87 kg/yr; Hart Crowser et al., 2007), although this is based on a limited dataset. The amount reported to be discharged to surface waters or transferred to POTWs from industries – as reported in the TRI – is also highly uncertain, with a high-end estimate of 90 kg PAH/yr (Ecology, 2011).

Surface water runoff loads for total PAH are estimated to be approximately 119 – 244 t/yr for the entire Puget Sound basin based on the surface runoff study, with LPAHs comprising approximately four-fifths of the load. The higher reported LPAH loads may be attributable in part to overall higher detection frequencies for LPAHs, although individual HPAH components were detected at generally higher frequencies than individual LPAH components.

In terms of land cover, PAHs are detected much more frequently in commercial/industrial areas (83%), about four times more frequently than in any other land cover. HPAH concentrations were highest in commercial areas, leading to loads calculated to be 16 – 32 kg/yr. Most of the remaining surface water PAH surface water loads were driven by a single LPAH constituent (phenanthrene) detected in 16% of the samples from forested lands, leading to a high calculated LPAH load for forests (102 – 190 kg/yr).

Most of the PAH detections occurred during storm events; PAHs were rarely detected during baseflows. Commercial/industrial areas were the only land covers where PAHs were detected during baseflow, and detection frequencies were so low (7% each for LPAH and HPAH) that baseflow loads for total PAH were ≤1 kg/yr under all scenarios used for load calculations.

PAHs were not detected in any of the marine water samples, and therefore no exchange could be calculated at the ocean boundary.

The net sum of total PAH loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 190, 620, and 1,000 kg/yr, respectively. Under all of these estimates, there is a net PAH load to Puget Sound. However, it was not possible to assess the possibility of a net export out of Puget Sound since no PAHs were detectable in marine waters.

PAH loading from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th - 75th percentiles) and medians for each pathway in Figures 32-35. Each pathway represented as a contribution to the total load is displayed in Figures 36-39.

The surface runoff and groundwater are the largest loading pathways, accounting for a combined total of 70 – 82% of total PAH loads. Estimates at the median and 75th percentile levels suggest that approximately one-half of the total PAH loading occurs through groundwater. Air deposition accounts for 15 – 26% of the total PAH loads, while POTW loads account for 3 – 5%.

As noted previously, estimates of PAH loads from surface runoff and groundwater are driven by concentrations derived from non-detected results. Since these are the two largest reported loading pathways for PAHs, there is a large degree of uncertainty surrounding these load estimates. The authors of the present report did not attempt to modify or otherwise recalculate loads reported in the individual loading studies. However, readers are encouraged to review the loading studies to gain an understanding of the methodologies used to estimate loads where many of the sample results were below reporting limits.

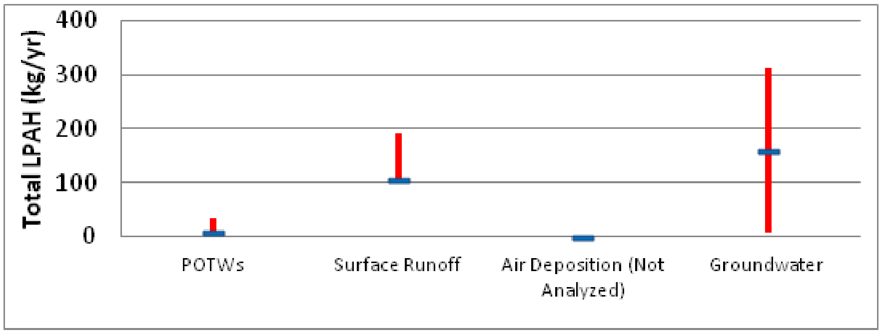


Figure 32. Range (25th - 75th percentiles) and Median LPAH Loads to Puget Sound from Each Major Delivery Pathway.

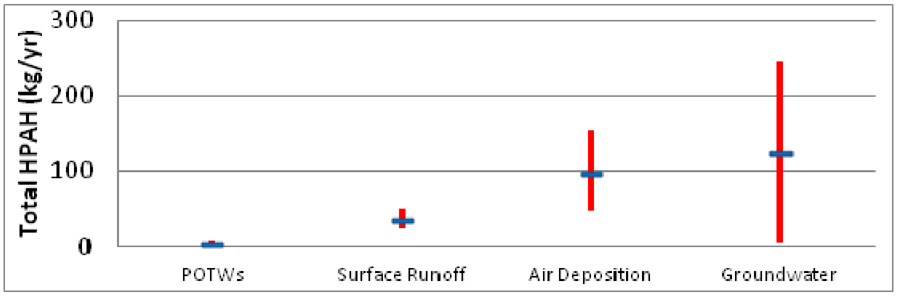


Figure 33. Range (25th - 75th percentiles) and Median HPAH Loads to Puget Sound from Each Major Delivery Pathway.

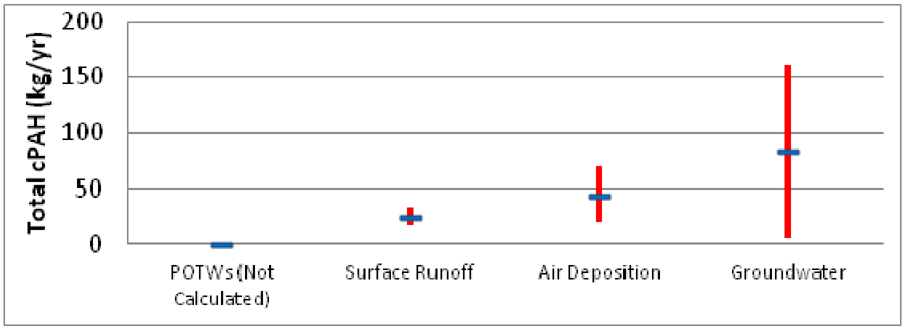


Figure 34. Range (25th - 75th percentiles) and Median cPAH Loads to Puget Sound from Each Major Delivery Pathway.

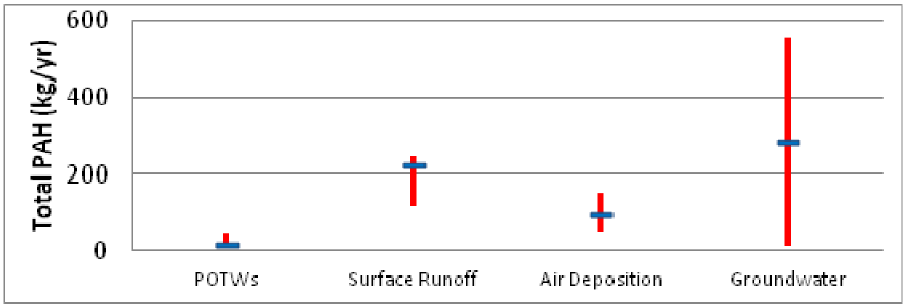


Figure 35. Range (25th - 75th percentiles) and Median Total PAH Loads to Puget Sound from Each Major Delivery Pathway.

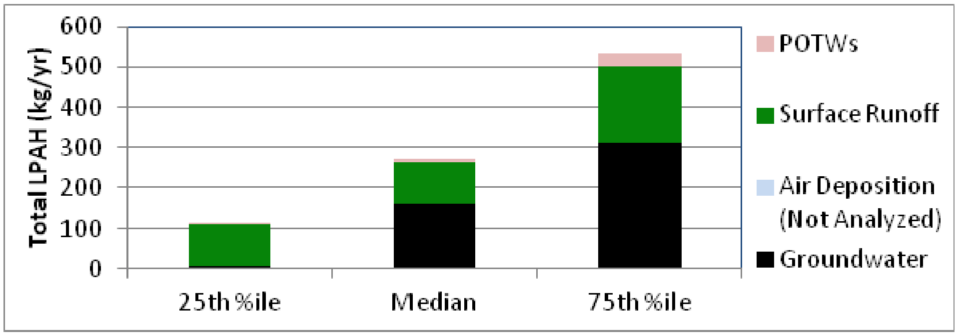


Figure 36. LPAH Loads to Puget Sound as the Sum of Major Delivery Pathways.

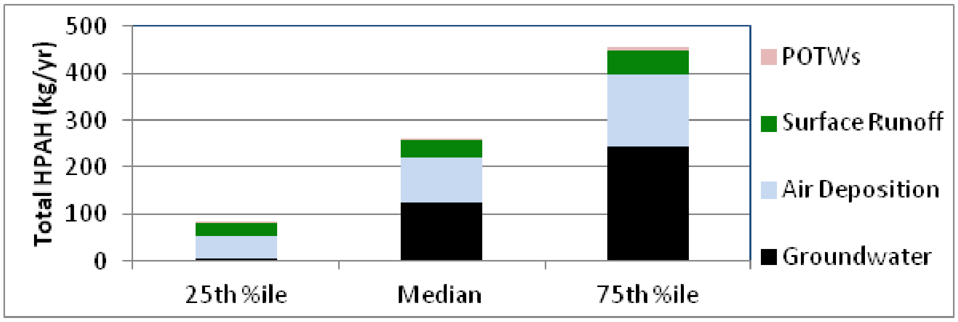


Figure 37. HPAH Loads to Puget Sound as the Sum of Major Delivery Pathways.

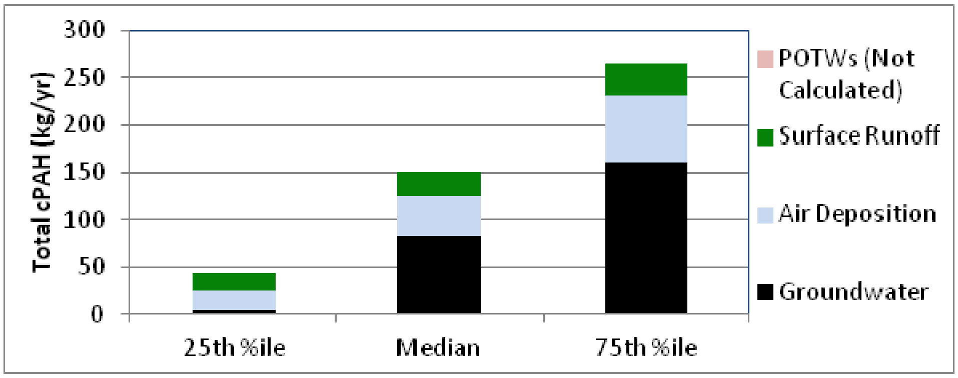


Figure 38. cPAH Loads to Puget Sound as the Sum of Major Delivery Pathways.

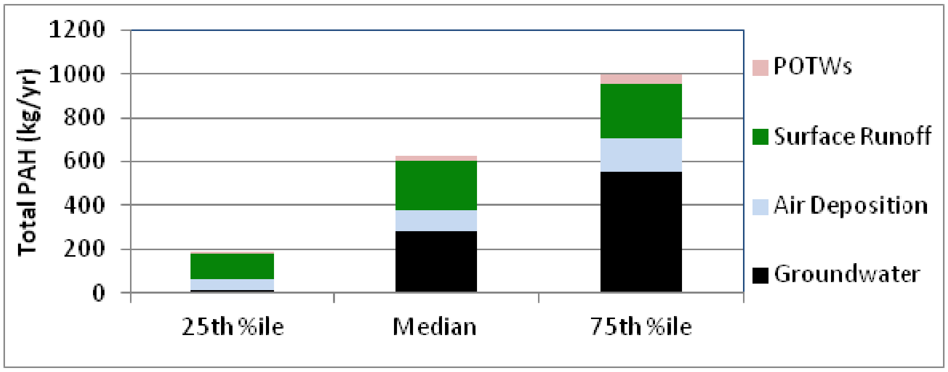


Figure 39. Total PAH Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of PAH transport and fate following release is complex, and the ability to draw conclusions is hampered by the limitations of PAH loading estimates derived for Puget Sound.

The inventory of sources (Ecology, 2011) suggests that releases to air – either in particle, aerosol, or vapor form – account for two-thirds of the PAH released in the Puget Sound basin (approximately 200,000 kg/yr). Releases of chemicals to air are by nature difficult to track through a watershed, but several generalizations may be made regarding PAH releases. For instance, nearly all of the PAHs released to air originate from combustion sources and would therefore be expected to be HPAHs, the major type of PAHs formed pyrogenically.

The Air Emissions Inventory (Ecology, 2007) indicates that woodstove use is the largest single combustion source (and overall PAH source) to the Puget Sound basin (Ecology, 2011). Through analysis of anhydrosugars (markers of wood combustion), the air deposition study appears to confirm a strong signal of woodstove use during the late winter months. Nearly all of the remaining PAH combustion sources are from petroleum, such as light-and heavy-duty vehicle emissions, and from the use of other machinery using internal combustion engines.

The air deposition study measured several LPAHs and related compounds to assess PAH source signatures. The authors concluded that all of the PAHs were derived from combustion sources, originating from a mixture of petroleum and biomass (Brandenberger et al., 2010). Geographically, the widespread and relatively homogeneous distribution of PAHs among many of the sampling stations – except those in urban areas – supports a notion of a widespread regional distribution of combustion products. Air deposition sites located in urban areas showed higher PAH concentrations apparently derived from fossil fuel combustion sources, a finding supported by correlation with metals (copper and lead) associated in part with vehicle traffic.

The air deposition study appears to be consistent with the types of PAH sources inventoried in the Puget Sound basin and with other contemporary studies of PAH sources conducted on a regional level (e.g. Stein et al., 2006). However, the amounts released are three orders of magnitude higher than the amounts delivered to Puget Sound from all major loading pathways combined. If the air deposition results were extended to the entire Puget Sound watershed (approximately 750 kg/yr at the 75th percentile), and all of the deposited PAHs were entrained and delivered through surface runoff, this load would still represent <0.5% of the combustion releases. One explanation for the difference is that PAHs loads reported for surface runoff may underestimate actual loads to Puget Sound, while at the same time releases from combustion sources may be largely overestimated. However, there are no clear lines of evidence to support either supposition.

Of the remaining non-combustion sources of PAHs (130,000 kg/yr), approximately 90% is released from creosote marine pilings, railroad ties, and utility poles (Ecology, 2011). Valle et al. (2007) estimated that in the New York/New Jersey Harbor area, approximately 13% of the PAHs released over the lifetime of these products is to air, resulting in a total loss to air of 14,000 kg/yr from all three product types combined. Remaining releases occur through leaching and washout, presumably directly to marine waters for pilings. PAH leaching from rail ties and utility poles is most likely to result in enrichment of adjacent soils (except in the case where these products are surrounded by impervious surfaces, or over-water in the case of railroad bridges). Once bound to soils, PAHs will generally remain immobile unless soils are removed or scoured through mechanical force. It is possible that some of the PAHs detected in commercial/ industrial area surface runoff during storm events were derived from utility poles or rail crossings, but the lack of major PAH components from creosote (naphthalene, acenaphthene) suggests that creosote leaching is not a major source in these instances.

Aside from PAHs released from creosote structures mounted on impervious surfaces, PAHs released from spillage of petroleum products is a potentially large source of LPAH to surface waters. An inventory of petroleum spills ≥ one gallon in the Puget Sound basin suggests that approximately 1,000 kg/yr of PAHs are released due to spillage of over 150,000 kg/yr of petroleum (Ecology, 2011). However, much larger quantities of PAHs released from small oil drips and leaks (8,500 kg/yr) and from improper disposal of used oil (1,300 kg/yr) account for the bulk of PAHs released as spills. Minor drips and leaks are likely to occur on impervious surfaces, which vastly increase the odds that PAH from this source will become entrained in runoff, some of which will find its way to surface waters. However, the results of the surface runoff study do not indicate motor oil as a major source of PAHs. Although the overall load of LPAH was higher than for HPAH, this did not appear to reflect widespread petroleum releases on impervious surfaces since the bulk of the LPAH load was from forested watersheds.

Of the POTW sources inventoried, only improper disposal of used oil is likely to be released in a constrained pathway. Most of the PAH loads discharged by POTWs is due to LPAHs, and the individual compounds frequently detected are those which are typically found at the highest concentrations in motor oil (fluoranthene, naphthalene, pyrene). This supports “down-the-drain” disposal of motor oil as a potential source of PAHs. Overall detection frequencies and concentrations of motor oil related PAHs in POTW effluent were similar between winter and summer season sampling, indicating a non-stormwater source of these PAHs and supporting the notion that improper disposal of motor oil may be a continuing PAH source to POTWs. However, there remain large differences in the quantity of PAHs released from this source (1,300 kg/yr) and the amount discharged from POTWs (8 – 46 kg/yr). At the treatment end, some quantity of PAH is presumably lost via solids removal prior to discharge, but the degree and extent of this removal is not known.

Hazard Evaluation

The hazard evaluation indicates that PAHs are a Priority 1 level of concern for freshwater sediments and for human health (Table 21). No effects data were available to adequately compare observed concentrations to tissue residue effects or effects to wildlife. The hazard evaluation indicates that levels of concern for PAHs may vary considerably depending on the media evaluated and whether PAHs are assessed individually or as groups (i.e. LPAH or HPAH).

In general, it appears that observed PAH concentrations in surface waters are much lower than effects data, although effects data are limited for freshwaters and observed data are limited for marine waters. Where both observed data and effects data were sufficient to conduct adequate comparisons, 90th percentile values of the observed concentrations were generally well below the 10th percentile values for effects concentrations.

Table 21. Summary of Hazard Evaluation for PAHs.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	a	≥5%	No[b]/INS[c]	Priority 2/U
	Nearshore Marine	11-12	>8%	INS[d]	U
	Offshore Marine	e	<4%	No[b]/INS[f]	Priority 2/U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	g	>25%	Yes/No[h]	Priority 1/2
	Nearshore Marine	i	≥44%	No	Priority 2
	Offshore Marine	j	>34%	No	Priority 2
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Freshwater	k	>21%[l]	Yes/No[m]	Priority 1/2
	Nearshore Marine	n	>20%	Yes/No[o]	Priority 1/2
	Offshore Marine	p	>2%	No[b]/INS[f]	Priority 2/U

Yellow highlight indicates Priority 1 Level of Concern

FOD=Frequency of detection

[a] N range is 1,447 – 1,577 and varies for Individual PAH or PAH group

[b] No for several individual PAHs

INS[c]=Insufficient effects data available for comparison to observed data for several individual PAHs

U=Unknown level of concern due to lack of sufficient data for adequate comparison

INS[d]=Insufficient observed data available for comparison to effects data

[e] N range is 12 – 84 and varies for individual PAH or PAH group

INS[f]=Insufficient observed data available for comparison to effects data for several individual PAHs

[g] N range is 284 – 1,182 and varies for individual PAHs or PAH group

[h] No for benzo(a)anthracene; Yes for all other individual PAHs or PAH groups

[i] N range is 196 – 1,051 and varies for individual PAHs or PAH group

[j] N range is 217 – 906 and varies for individual PAHs or PAH group

[k] N range is 17 – 102 and varies for organism type, tissue type, and for individual PAHs

[l] FOD=0% for fish tissue

[m] Yes for 5 of 9 individual PAHs

[n] N range is 50 – 117 and varies for organism type, tissue type, and for individual PAHs

[o] Yes for 4 of 9 individual PAHs

[p] N range is 14 – 74 and varies for organism type, tissue type, and for individual PAHs

In freshwater sediments, for all individual PAHs (except benzo(a)anthracene), LPAH, and HPAH, the 90th percentile values of observed concentrations are above the floating percentile SQS. In many cases, more than 25% of the values exceed this threshold.

In marine sediments, none of the 90th percentiles of observed concentrations exceed the SQS. Median concentrations of LPAH in marine sediments are much closer to the lowest guideline, and the 75th percentile concentrations exceed this level (Canadian TEL). Sediments located in the nearshore environment had slightly higher LPAH concentrations than those located offshore. The 95th percentiles of nearshore LPAH concentrations exceed all of the guidelines. However, on an organic carbon-normalized basis, at least 95% of the nearshore and offshore concentrations are below the lowest guideline. HPAH concentrations in marine sediments mirror the patterns (relative to guidelines) of LPAHs, except median HPAH concentrations in both nearshore and offshore sediments exceed the lowest guideline.

Human health concerns were evaluated for nine of the 16 individual PAHs, but not for LPAH or HPAH since there are no NTR criteria for PAHs as groups. Several individual PAHs pose a Priority 1 level of concern for human health based on comparisons to the NTR criteria. For the nine PAHs evaluated for human health, benzo(a)pyrene, benzofluoranthenes (b and k), dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceed the NTR for at least one organism type in either freshwater or marine waters.

Regionally Important Biological-Effects Data

Multiple investigations have identified biomarkers of exposures to PAHs in various Puget Sound fishes. Bile and stomach content of outmigrant juvenile Chinook salmon were found to contain various PAHs (Johnson et al., 2007), demonstrating that diet pathways are important for PAH exposures. The authors suggest that the levels of exposure may result in immunosuppression and other health effects. These results expanded and confirmed previously documented PAH exposures (Stein et al., 1992; Stein et al., 1995). A dietary feeding study on juvenile Chinook documented growth and physiological responses from dietary exposures to PAHs at concentrations that were environmentally realistic in the Puget Sound (Meador et al., 2006).

Biomarkers of PAH exposures were confirmed in Puget Sound English sole, rock sole, and starry flounder collected from up to five sites in Puget Sound (Stein et al., 1992). Stein et al. (1992) found the biomarkers of exposure were related to the degree of sediment contamination. Further field study by Johnson (2000) resulted in recommended various threshold sediment concentrations of PAHs to protect English sole against liver lesions, DNA adducts in liver, and other effects. The causal relationship between elevated sediment PAH concentrations and English sole liver effects was confirmed by Myers et al. (2003). In a study of English sole from the Hylebos Waterway and Colvos Passage, Sol et al. (2008) found no correlation between PAH exposure and age and little correlation between reproductive end points and PAH exposure. However, Pacific herring embryos were found to be affected by tricyclic PAHs in weathered crude oil (Incardona et al., 2009; Carls et al., 1999).

Several laboratory studies have documented that developmental defects in fish are associated with exposures to PAHs released by weathered crude oil, notably the tricyclic-PAHs (Incardona et al., 2005; Incardona et al., 2006; Carls et al., 2008). Carls and Meador (2009) developed a description of the oil weathering, PAH toxicity, and embryo exposures to explain the observed toxicity from PAHs in weathered oil at relatively low levels. Driscoll et al. (2010) developed a framework for describing PAH exposure as a dose to fishes in order to understand the mechanisms of exposure and toxicity.

Bis(2-ethylhexyl) phthalate

Phthalates are 87% of the 10.4 billion pounds per year world market for plasticizers, with bis(2-ethylhexyl) phthalate (a.k.a. di(2-ethylhexyl) phthalate [DEHP]) as the most common plasticizer for polyvinylchloride (PVC), constituting more than 50% of the phthalates produced (SPWG, 2007; ECB, 2008). Approximately 90-95% and possibly as much as 97% of DEHP is used to plasticize PVC products, which may contain up to 60% DEHP, although 30% may be more typical (ECB, 2008). Roughly 200-300 million pounds of DEHP are produced in the U.S. each year, with unknown amounts contained in imported products. According to ATSDR (2002), relatively little is imported (4 million pounds in 1998) or exported (14-27 million pounds per year in 1994-1998).

Phthalates are not covalently bound to PVC polymer chains and migrate out over time (Rudel and Perovich, 2009). The amount of phthalates that leach out of the PVC into air is quite variable. Factors that affect the rates of volatilization include the temperature and surface area of the material; emission rates among phthalates may also be quite variable. At a certain point the PVC undergoes glassification when it becomes stiff and brittle, and very little phthalate continues to off-gas. Once emitted, phthalates tend to adhere to dust particles rather than remain in vapor phase (ATSDR, 2002; SPWG, 2007).

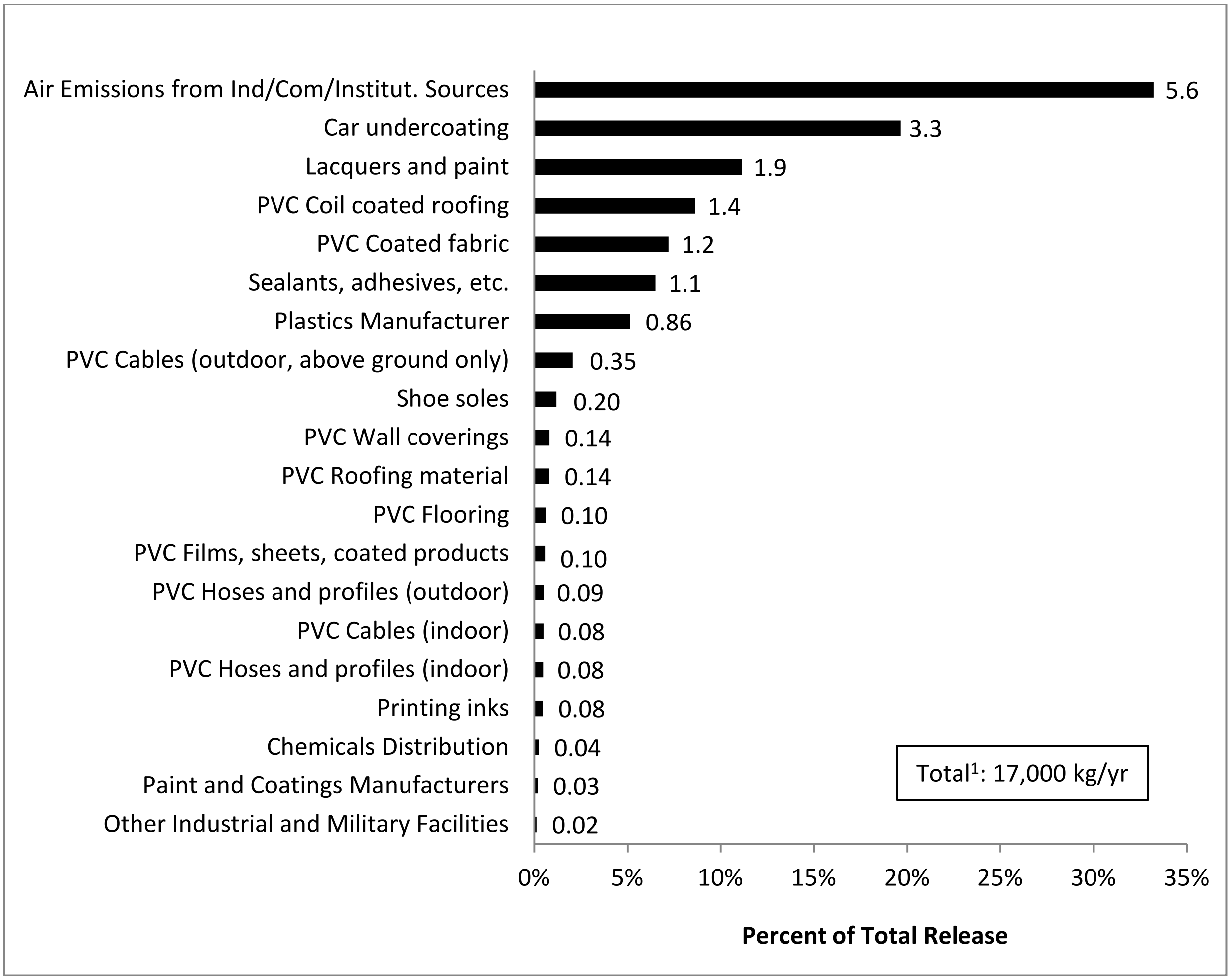
Plasticized PVC products are widely used and include exterior siding and roofing materials, automobiles, wires/cabling, advertizing banners, flooring, weather stripping, upholstery, garden hoses, swimming pool liners, footwear, clothing, food containers, tablecloths, shower curtains, rainwear, and toys. Rigid PVC products, such as pipes and windows, do not contain phthalates or other plasticizers. In Western Europe, DEHP emissions were estimated at 300 tons per year from indoor uses and 2,600 tons per year from exterior uses after measuring emissions to the air from PVC products (ATSDR, 2002). The population of Western Europe is about 400 million people, compared to about six million people in Washington State.

Non-plasticizer (non-polymer) uses of DEHP are a small percentage (<10%) of overall use. These uses include PCB replacement (dielectric fluids for electric capacitors), de-foaming agents in paper manufacturing and detergents, as well as chemical intermediates for insect repellent, cosmetics, lacquers, munitions, ceramics, printing inks, adhesives, sealants, and industrial lubricants.

Once in the environment, DEHP biodegrades in water but may accumulate in aquatic organisms to some degree (PTI, 1991). It has relatively low solubility and may resist degradation once bound to soil particles. In the aquatic environment, DEHP is nearly always detectable at concentrations >0.01 ug/l in freshwater and marine waters, and >0.01 mg/kg (dw) in sediment (PTI, 1991; Appendices D-3 and D-4).

Major Releases from Primary Sources

The inventory of phthalate sources in the Puget Sound basin suggests that total phthalate release is approximately 34,000 kg/yr for the six phthalates assessed (Ecology, 2011). Emissions from plasticized PVC products are the primary source of phthalates (SPWG, 2007), with DEHP as the dominant phthalate used as a plasticizer. In addition to releases from polymer use, DEHP releases occur through non-polymer uses, for a total annual release estimated to be 17,000 kg/yr (Figure 40).



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

Figure 40. Total DEHP Release in the Puget Sound Basin (values shown are thousands kg/yr).

DEHP release from polymer use accounts for approximately 40% of the total annual release, with large contributions from car undercoating (3,300 kg/yr), coil coated roofing (1,400 kg/yr), and coated fabric (1,200 kg/yr). Indoor polymer use accounts for approximately 5% of the loss through polymers.

Releases of DEHP from non-polymer uses include loss from lacquers, paints, sealants, adhesives, and printing inks. Combined, these account for approximately 15 - 20% of DEHP release in the Puget Sound basin. The remaining 40% (6,600 kg/yr) of DEHP releases are through industrial, commercial, and institutional point-source air emissions.

Total phthalate releases from personal care products combined are approximately 11,000 kg/yr including releases from fragrances, deodorant, nail polish, hair spray, and body lotion. According to testing data from U.S. and Swedish non-governmental organizations, diethyl phthalate (DEP) is the primary phthalate used in cosmetics and personal care products, with some products also containing di-n-butyl phthalate (DBP). However, there appears to be little if any use of DEHP in these products (DiGangi and Norin, 2002; Houlihan et al., 2002; EPA, 2009).

Major Delivery Pathways and Loading

Data on major delivery pathways for DEHP loading were obtained from PSTLA loading studies and are included in Table 22. No effort was made to assess DEHP loads from direct atmospheric deposition of DEHP to Puget Sound during Phase 3 (Brandenberger et al., 2010). As mentioned previously, loadings through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Table 22. DEHP Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater (a)	14	227	440
Air Deposition	NA	NA	NA
Surface Runoff (b)	1,746	1,777	1,863
POTWs	216	439	904
Ocean Exchange	NC	NC	NC

(a) Lowest, highest, and mid-point of estimated loads
(b) Detected in residential areas only during baseflows
NA=not analyzed
NC=not calculated due to insufficient data

The estimated range of groundwater DEHP loads is large (14 – 440 kg/yr). The range in estimates is due primarily to differences in flows used to establish the possible range of loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude. DEHP load estimates in groundwater should be used with caution since they are based primarily on non-detect data and numerous assumptions, including unconfirmed assumptions about DEHP mobility in groundwater.

DEHP loads discharged from POTWs are approximately 220 – 900 kg/yr. Although field blank contamination and higher-than-desired laboratory quantitation limits for some samples resulted in uncertainty regarding some of the results, it appears that detection frequencies and concentrations between seasons (wet and dry) were not substantially different. However, seasonal first-flush concentrations were evident in agricultural sub-basins.

Surface water runoff loads for DEHP are estimated to be approximately 1,750 – 1,860 kg/yr for the entire Puget Sound basin based on the surface runoff study. DEHP was rarely detected during baseflows (3% frequency of detection) but was detected at a moderate frequency (30%) during storm flows, mostly in commercial/industrial areas. Although overall concentrations were slightly higher in commercial/industrial areas, loads generally mirror the amount of land cover represented by each land cover category; forested areas account for approximately 84% of the total DEHP load in surface runoff load to Puget Sound.

Loads of DEHP in marine waters were not calculated due to the low frequency of detection. DEHP was detected in only three samples – two in Hood Canal and one in the northern boundary waters – at low levels (≤0.06 ug/l).

The net sum of DEHP loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sum for the 25th, median (50th), and 75th percentile values is 2,000, 2,400, and 3,200 kg/yr, respectively. Under all of these estimates, there is a net DEHP load to Puget Sound.

DEHP loadings from pathways that may represent *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange) are shown as ranges (25th -75th percentiles) and medians for each pathway in Figures 41. Each pathway represented as a contribution to the total load is displayed in Figures 42.

Total DEHP loading from the major pathways assessed is 2,000 – 2,800 kg/yr. Surface runoff accounts for the largest pathway (58 – 88%), followed by POTWs (11 – 28%) and groundwater (1 – 14%).

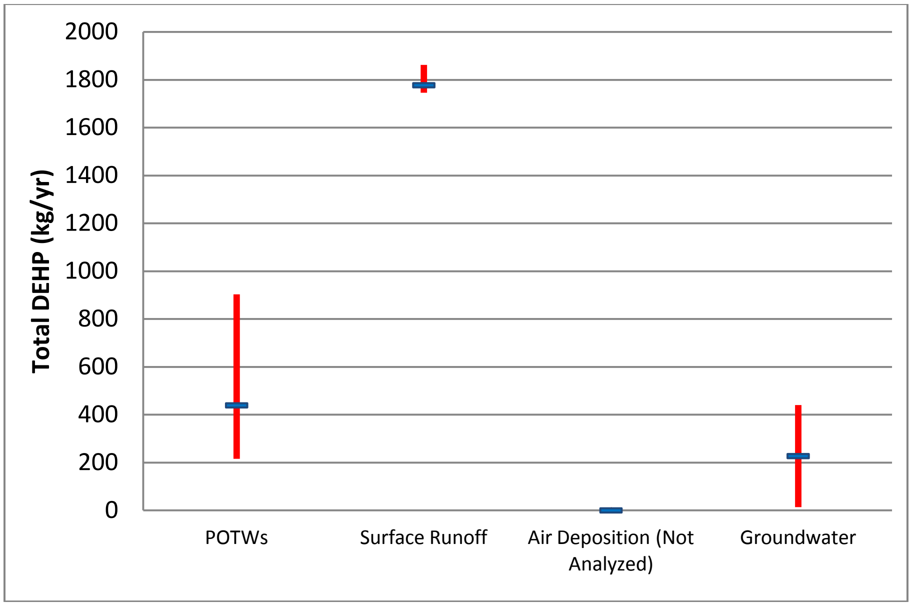


Figure 41. Range (25th - 75th percentiles) and Median DEHP Loads to Puget Sound from Each Major Delivery Pathway.

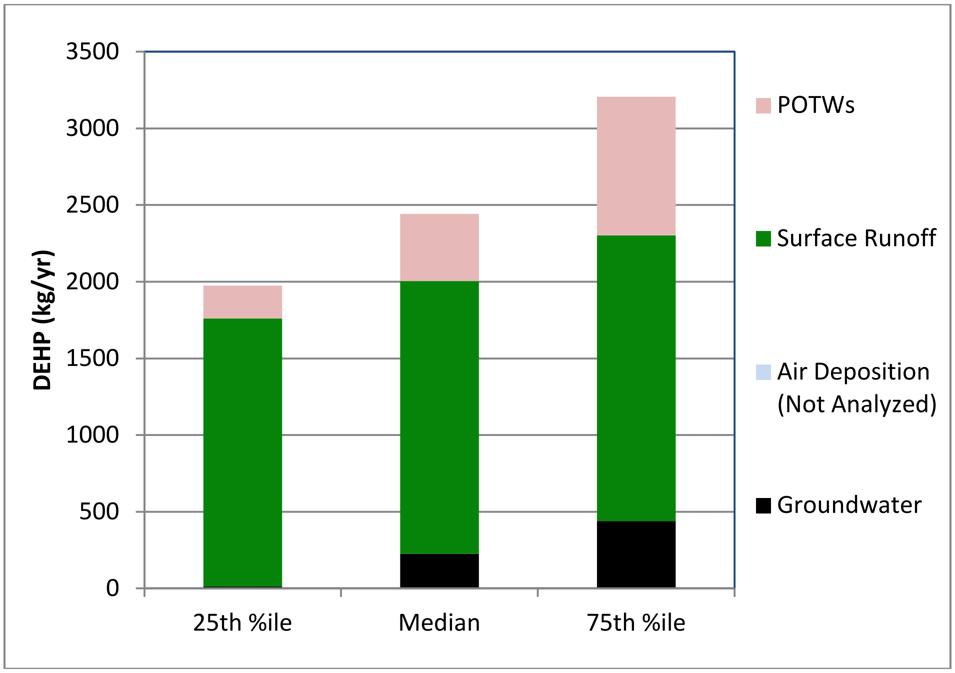


Figure 42. Total DEHP Loads to Puget Sound as the Sum of Major Delivery Pathways.

Relationship Between Sources and Pathways/Loading

The conceptual model of DEHP transport and fate following release is limited due to the low frequency of detection in surface runoff and the lack of data on DEHP in atmospheric deposition. DEHP depositions to Puget Sound of 310 to 16,000 kg/yr were estimated during the Phase 1 project, but these data were based largely on very limited sampling in an urban area (Hart Crowser et al., 2007) and may not have been representative for the Puget Sound basin. Data on atmospherically deposited DEHP loads would have proven particularly useful since the primary sources of DEHP suggest that volatilization is the principal release mechanism, followed by attachment to dust particles. In this respect, DEHP may be similar to PBDEs in their transport and fate in the environment. If DEHP follows a similar mode of fate and transport to that of PBDEs, the air deposition and POTW pathways would be expected to deliver loads of the same relative magnitude as those for surface runoff.

A portion of the DEHP emitted from both polymer and non-polymer sources is likely to occur indoors, and some fraction of these releases is presumably delivered to the sanitary sewer system. Estimates of DEHP delivered to POTWs through washing machine rinse water were conducted by the Washington Toxics Coalition and People for Puget Sound during 2009 (WTC/PPS, 2009). They estimated that roughly 960 kg/yr DEHP are delivered to Puget Sound POTWs each year due to dust-bound DEHP which becomes attached to clothing and is subsequently rinsed down the drain during the washing process.

As pointed out by the authors of the POTW loading report (Ecology and Herrera, 2010), it is difficult to draw conclusions regarding seasonal differences in COC loads from POTWs. However, it appears that POTWs discharge fairly constant DEHP loads between seasons, suggesting the presence of a steady source of DEHP. This appears to be consistent with the indoor emissions of this compound, followed by attachment to dust particles and delivery to POTWs through sanitary drains. The inventory of sources suggests that approximately 500 kg/yr DEHP is released indoors through loss from polymers, although some of the DEHP release from non-polymer use (3,000 kg/yr) may also occur indoors. While neither the WTC/PPS report nor the present loading studies provide enough information to calculate a mass-balance of DEHP delivered to, and discharged from, POTWs, the information suggests that the amount delivered to POTWs is likely on the order of thousands of kg per year.

Some of the DEHP delivered to POTWs is likely to be from stormwater, but the contribution from this pathway may be comparatively small. Surface runoff DEHP loads in areas where stormwater is potentially diverted to POTWs (i.e. commercial/industrial and residential areas) are calculated to be approximately 120 – 230 kg/yr during storm events (Herrera, 2011). Therefore, the DEHP load in stormwater diverted to POTWs is presumed to be only a fraction of that amount.

Hazard Evaluation

The hazard evaluation indicates that DEHP is a Priority 1 level of concern for sediments and for human health (Table 23). Hazard due to tissue residue effects and effects to wildlife were not evaluated.

In fresh, nearshore marine, and offshore marine surface waters, the 90th percentile of DEHP concentrations (approx. 4 ug/l, 2 ug/l, and 3 ug/l, respectively) is two orders of magnitude below the lowest 10% of effects for freshwater, and perhaps even a greater magnitude below 10% of the effects data for marine waters, although the latter is difficult to assess due to a paucity of effects data. No water quality criteria are available for comparison.

More than 25% of the DEHP concentrations in freshwater exceed the floating percentile SQS as well as the CSL, and the median concentration (approx. 120 ug/kg dw) approaches the SQS. In marine sediments, the 90th percentiles of the nearshore and marine sediments (approx. 10,000 ug/kg organic carbon and 5,000 ug/kg organic carbon, respectively) exceed the SQS, and the 90th percentile of nearshore DEHP concentrations exceed the CSL as well.

DEHP is rarely detected in freshwater or marine fish tissue, but it is detected more frequently in bivalves and (in the case of freshwater) other invertebrates as well. The 90th percentile of DEHP concentrations in freshwater bivalves (approx. 240 ug/kg) is slightly above the NTR criterion. The nearshore marine fish tissue concentration exceeds the NTR criterion as well (at the 90th percentile level), but this is based on few data (n=8 detected concentrations). The 95th percentile concentrations in other freshwater invertebrate tissues approach the NTR criterion, and the median values for freshwater bivalves, other freshwater invertebrates, and marine nearshore bivalves all exceed the criterion adjusted to the EPA-recommended subsistence rate (142.4 g/d).

Table 23. Summary of Hazard Evaluation for DEHP.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	1,484	84%	No	Priority 2
	Nearshore Marine	12	92%	INS	U
	Offshore Marine	84	54%	INS	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	548	87%	Yes	Priority 1
	Nearshore Marine	513	74%	Yes	Priority 1
	Offshore Marine	474	67%	Yes	Priority 1
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Freshwater	a	>57%[b]	yes	Priority 1
	Nearshore Marine	c	>9%	yes	Priority 1
	Offshore Marine	d	>24%[b]	INS	U

Yellow highlight indicates Priority 1 Level of Concern
FOD=Frequency of detection
INS=Insufficient observed data available for comparison to effects data
[a] N range is 9 – 99 and varies for organism type and tissue type
[b] FOD=0% for fish tissue
[c] N range is 42 – 79 and varies for organism type and tissue type
[d] N range is 16 – 33 and varies for organism type and tissue type

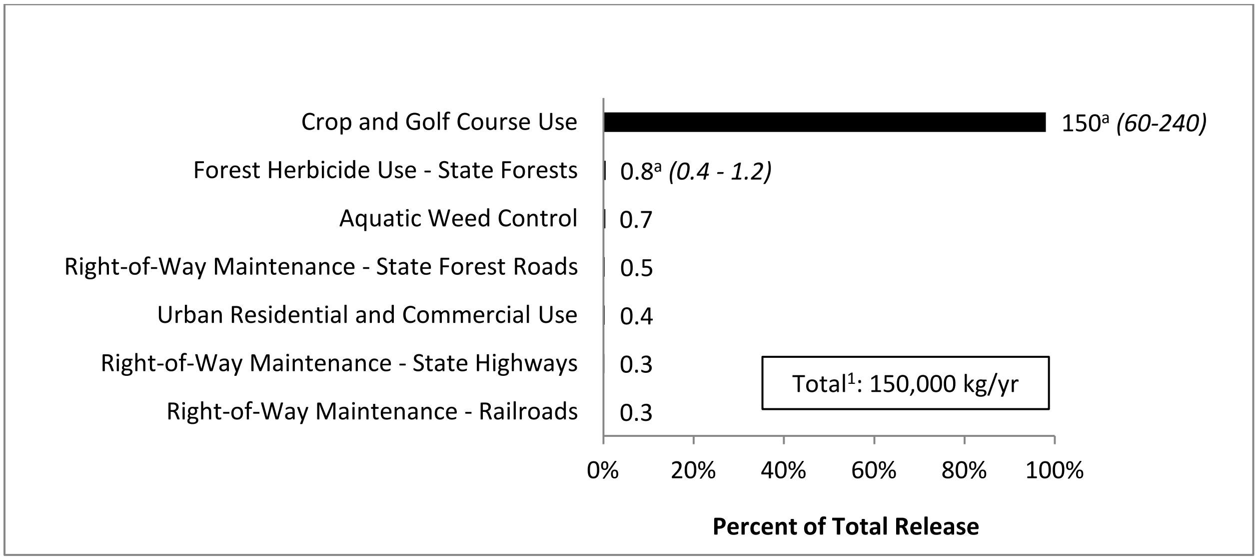
Triclopyr

Triclopyr [((3,5,6-trichloro-2-pyridinyl)oxy)acetic acid)] is a broad-leaf herbicide used primarily for rice, pasture and rangeland, rights-of-way, and turf, including home lawns and gardens (EPA, 1998). It also has limited use to control nuisance vegetation in freshwater lakes and is permitted under Ecology's Aquatic Pesticide General Permit. Triclopyr is applied as the triethylamine (TEA) salt and butoxyethyl ester (BEE) formulations and is sold under the product names Garlon® and Crossbow® for terrestrial use and Renovate® for aquatic use.

Following release in the environment, triclopyr formulations are dissociated to the triclopyr anion which is readily soluble in water. Half-lives of triclopyr formulations following terrestrial applications are generally 10 days or less. In terrestrial soils, triclopyr undergoes microbial degradation with a half-life generally less than 20 days. Once in the aquatic environment, photolysis is the major degradation mechanism and occurs rapidly, generally with a half-life of several days or less (EPA, 1998). Although triclopyr half-lives tested under laboratory conditions suggest little persistence, environmental studies conducted following applications indicate that actual half-lives may be substantially greater, perhaps on the order of 100 days or more. Due its solubility, absorption to soil particles is not a major fate process, and triclopyr does not bioaccumulate in aquatic organisms.

Major Releases from Primary Sources

Total triclopyr release from the seven application categories assessed totaled approximately 150,000 kg/yr (Figure 43). Agricultural uses of triclopyr accounted for 76 – 94% of the total release, with golf course use accounting for 5 – 22%. The remaining triclopyr use was primarily for right-of-way maintenance (0.7%), aquatic weed control (0.5%), and domestic use (0.3%). The small amounts calculated for domestic and forestry use likely underestimate actual usage rates.



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

[a] Mid-point of range

Figure 43. Total Triclopyr Release in the Puget Sound Basin (values shown are thousands kg/yr).

Major Delivery Pathways and Loading

Data on major delivery pathways for triclopyr loading were obtained from PSTLA loading studies and are included in Table 24. No effort was made to assess triclopyr loads from direct atmospheric deposition or exchange of ocean waters. Due to the low frequency of detection in POTW effluent, loads were not calculated (Ecology and Herrera, 2010). No triclopyr data were found for groundwater, and therefore no attempt was made to calculate loading from direct groundwater discharge to Puget Sound (Pitz, 2011).

Table 24. Triclopyr Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater	NA	NA	NA
Air Deposition	NA	NA	NA
Surface Runoff (a)	641	652	686
POTWs	NC	NC	NC
Ocean Exchange	NA	NA	NA

(a) Detected in commercial/industrial and agricultural areas only during baseflows
NA=not analyzed
NC=not calculated due to insufficient data

Surface runoff loads for triclopyr are estimated to be approximately 641 – 686 kg/yr for the entire Puget Sound basin based on the surface runoff study. Triclopyr was detected more frequently during storm flows than during baseflows, with the highest rate of detection during the fall first flush (63%). Overall detection rates were highest in commercial/industrial areas (47%), followed by residential areas (41%), agricultural areas (31%), and forests (16%). Detected concentrations varied little across different land covers, with typical levels in surface water of 0.03 ug/l. Although triclopyr was detected only in commercial/industrial and agricultural areas during baseflows, overall loads generally mirrored the amount of land cover represented by each land cover category. As a result, forested areas account for approximately 90% of the total surface runoff load to Puget Sound.

Hazard Evaluation

Triclopyr hazards were difficult to evaluate due to the lack of observed environmental data for all media except fresh surface waters (Table 25). Over 1,600 measurements of triclopyr are available for fresh surface waters, with a detection frequency of 33%. The 90th percentile of these detected triclopyr values is approximately 0.1 ug/l, three orders of magnitude lower than the 10th percentile of the effects data.

Table 25. Summary of Hazard Evaluation for Triclopyr.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	1,632	33%	No	Priority 2
	Nearshore Marine	0	--	INS	U
	Offshore Marine	0	--	INS	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	0	--	INS	U
	Nearshore Marine	0	--	INS	U
	Offshore Marine	0	--	INS	U
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

FOD=Frequency of detection
INS=Insufficient effects or observed data available for evaluation

Nonylphenol

Nonylphenol is a commonly detected organic chemical of particular interest due to its potential to disrupt endocrine function in aquatic organisms. While there are limited uses for the direct use of nonylphenol, it has a broad range of applications as a precursor for nonionic surfactants, particularly alkylphenol ethoxylates which are used in domestic and industrial cleaning products and emulsifiers. These include uses as domestic and commercial laundry detergents, pulp and paper processing, and as deicers and in firefighting foams and gels. Annual production in the U.S. is on the order of 200 to 300 millions of pounds per year (EPA, 2005).

The breakdown of alkylphenol ethoxylates to nonylphenol occurs largely during the sewage treatment process, although the breakdown process does not require active sewage sludges for this to occur (EPA, 2005). Nonylphenol is more resistant to further degradation than its parent compounds. It has low solubility in water and partitions to sediments where its resistance to degradation is generally increased. Based on log K_{ow} values, nonylphenol's capacity for bioaccumulation is considered moderate, but it is generally found at low concentrations in fish tissue, possibly suggesting fish have some ability to metabolize nonylphenol (EPA, 2005).

Major Releases from Primary Sources

Total nonylphenol release in the Puget Sound basin totals approximately 180 kg/yr. All of the inventoried nonylphenol releases were from point-source air emissions. No effort was made to calculate nonylphenol releases from diffuse sources. Nonylphenol is not a required reporting requirement under the TRI, and therefore no industrial or institutional nonylphenol releases were catalogued (Ecology, 2011).

Major Delivery Pathways and Loading

Major delivery pathways for nonylphenol loading are included in Table 26. No effort was made to assess nonylphenol loads from direct atmospheric deposition. Due to the low frequencies of detection, nonylphenol was not detected in POTW effluent or in exchange of ocean waters (Ecology and Herrera, 2010; Gries and Osterberg, 2011). No nonylphenol data were found for groundwater, and therefore no attempt was made to calculate loading from direct groundwater discharge to Puget Sound (Pitz, 2011).

Table 26. Nonylphenol Loads (kg/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
Groundwater	NA	NA	NA
Air Deposition	NA	NA	NA
Surface Runoff (a)	23	23	24
POTWs	NC	NC	NC
Ocean Exchange	NC	NC	NC

(a) Surface runoff loads based on storm flows only; not detected in any land covers during baseflows and in commercial/industrial areas only during storm flows
NA=not analyzed
NC=not calculated due to insufficient data

Surface water runoff loads for nonylphenol are estimated to be approximately 23 – 24 kg/yr for the entire Puget Sound basin based on the surface runoff study. There was a single detection of nonylphenol among the 126 samples analyzed in surface runoff, and therefore no patterns related to land cover types or hydrological conditions could be established.

Hazard Evaluation

Nonylphenol hazards were difficult to evaluate due to the lack of observed environmental data in some media and a lack of effects data for other media (Table 27). For fresh surface waters, however, there are ample observed data as well as effects data. The 90th percentile of observed concentrations of 4-nonylphenol (approx. 4 ug/l) is slightly below the chronic water quality criterion and several times lower than the 10th percentile of effects data; the 95th percentile of observed values exceeds the chronic criterion.

Table 27. Summary of Hazard Evaluation for 4-Nonylphenol.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	539	26%	No	Priority 2
	Nearshore Marine	11	27%	INS[a]	U
	Offshore Marine	84	17%	No	Priority 2
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	251	12%	INS[b]	U
	Nearshore Marine	67	15%	INS[b]	U
	Offshore Marine	91	29%	INS[b]	U
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

FOD=Frequency of detection
INS[a]=Insufficient observed data available for comparison to effects data
U=Unknown level of concern due to lack of sufficient data for adequate comparison
INS[b]=Insufficient effects data available for comparison to observed data

In marine surface waters, there are few observed data of 4-nonylphenol for the nearshore (n= 11) dataset. For the offshore marine waters, there are sufficient data (n=84) for comparisons to effects and criteria. Concentrations for all marine water data are well below the water quality criteria and at least 95% of the effects data.

Of the guidelines used to assess hazards in sediments, the Canadian TEL was the only guideline with numerical values for nonylphenol; no SQS was available for freshwater or marine sediments. In freshwater sediments at least 5% of the values exceeded the TEL and over 10% of the values exceeded the TEL in marine sediments. However, the TEL was above the 95th percentile values in offshore sediments.

There are no data to assess residue effects levels in aquatic organisms, or to evaluate nonylphenol hazards to wildlife or humans. This likely reflects nonylphenol's low to moderate accumulation potential in fish and macroinvertebrates.

Oil & Grease and Petroleum Hydrocarbons

Unlike other COCs, oil & grease does not refer to one or more specific chemicals, but instead refers to a group of chemicals with loosely related chemical and physical properties. These chemicals include non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases, and related materials. The working definition of oil & grease is based on the analytical method to determine the concentration in water or soil. More specifically, oil & grease is the fraction of a sample that is extractable by n-hexane, and is sometimes referred to as hexane extractable material (HEM).

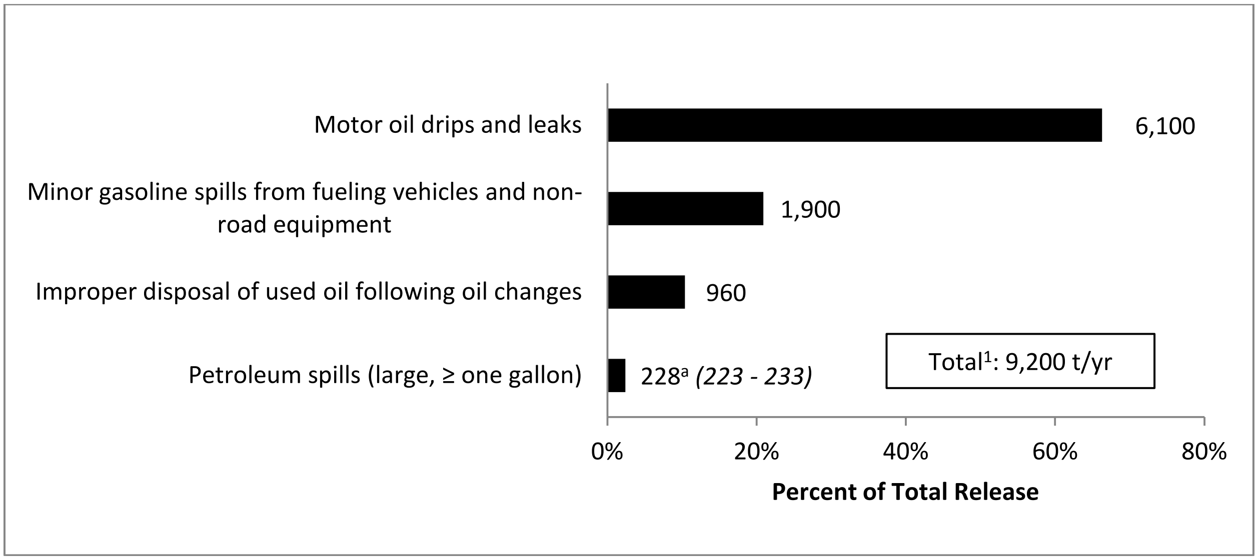
Like oil & grease, petroleum is not a specific compound, but may instead contain hundreds of chemicals, with crude oil as the ultimate source. Petroleum hydrocarbons – sometimes referred to as total petroleum hydrocarbons (TPH) – may further be divided into fractions based on the number of carbons of the major constituents. Gasoline range organics (GRO) refers to the methanol extractable fraction of organic chemicals with six to ten carbons, and generally includes a variety of gasoline alkanes, naphtha, mineral spirits, stoddard solvent, and other volatile petroleum products. Diesel range organics (DRO) are the fraction extracted with methylene chloride and have 11 – 28 carbons, and covers semi-volatile petroleum products (jet fuels through heavy fuel oils). Lube oils are typically characterized by molecules containing 29 – 35 carbons.

Major Releases from Primary Sources

The report on COC sources in the Puget Sound basin (Ecology, 2011) estimated releases of petroleum from various sources. Oil & grease releases were not estimated. Petroleum releases in the Puget Sound basin were inventoried by estimating releases from four major categories: petroleum spills ≥ one gallon, motor oil drips and leaks, minor gasoline spills, and improper disposal of used motor oil. The total quantity of petroleum released annually in the Puget Sound basin was estimated to be 9,200 metric tons (t)/yr (Figure 44). Other possible sources of petroleum including aviation fuel leaks and uncombusted oil and fuel discharged from marine engines were not estimated.

Petroleum spills ≥ one gallon were estimated to account for releases of 230 t/yr, with approximately one-half of the releases occurring in freshwaters, much of which occurs in the Lake Washington-Lake Union-Ship Canal system. Of the remaining spills, most of the volume was released to soils, followed by unknown receiving media and marine waters. Approximately one-quarter of the spill quantity was diesel fuel, followed by gasoline (approx. 10%) and jet fuel (approx. 3%), although these estimates vary depending on the source of information (see Ecology, 2011).

Although large spills may garner a host of attention, it appears that small motor oil and gasoline spills, drips, and minor leaks are responsible for approximately 87% of the total petroleum released annually in the Puget Sound basin. Improper disposal of used motor oil accounts for an additional 11% of petroleum releases inventoried.



[1] Sum of best estimates. Best estimates are either mid-point, median, mean, or most reasonable estimate for each source.

[a] Mid-point of range

Figure 44. Total Petroleum Release in the Puget Sound Basin (values shown are t/yr).

Approximately 6,100 t/yr of motor oil is estimated to drip and leak from vehicle crankcases during the 58 billion kilometers travelled each year on roads in the region. Another 960 t/yr of motor oil is disposed of improperly following oil changes.

Minor gasoline spills that occur during fueling of vehicles and other motorized equipment, as well as spills that occur during the transport of portable fuel containers, lead to an estimated annual gasoline release of approximately 1,900 t, including 570 t released annually during on-road vehicle fueling at the pump. This estimate only includes liquid spillage; gasoline released through volatilization of fuel and vapor displacement during fueling was not included in this estimate.

Major Delivery Pathways and Loading

Data on major delivery pathways for oil & grease and petroleum loading were obtained from PSTLA loading studies and are included in Table 28. No effort was made to assess oil & grease or petroleum loads from direct atmospheric deposition, exchange of ocean waters, or POTWs. As mentioned previously, loading through direct groundwater discharge was estimated from literature values, whereas loadings through other pathways were estimated from field studies specifically designed to estimate loads.

Surface runoff was the only major loading pathway where oil & grease was analyzed. Loads were estimated to be approximately 8,500 – 10,600 t/yr for the entire Puget Sound basin based on the surface runoff study. Due to the low frequency of detection (<50%) in all land uses under both base and storm flow conditions, comparisons among land covers and flow conditions are not meaningful. However, seasonal first-flush elevations in oil & grease concentrations were evident for all but the forest land covers. Absolute loads calculated from surface runoff were a reflection of land cover proportions and flows, with forest lands making up the bulk of the load.

Table 28. Oil & Grease and Petroleum Loads (t/yr) to Puget Sound from Major Pathways.

	25th %ile	Median	75th %ile
	Oil & Grease		
Groundwater	NA	NA	NA
Air Deposition	NA	NA	NA
Surface Runoff	8,469	8,469	10,598
POTWs	NA	NA	NA
Ocean Exchange	NA	NA	NA
	Lube Oil		
Groundwater (a)	6.03	34.2	62.4
Air Deposition	NA	NA	NA
Surface Runoff (b)	320	345	360
POTWs	NA	NA	NA
Ocean Exchange	NA	NA	NA
	Diesel Range		
Groundwater (a)	1.84	18.0	34.2
Air Deposition	NA	NA	NA
Surface Runoff	ND	ND	ND
POTWs	NA	NA	NA
Ocean Exchange	NA	NA	NA
	Gasoline Range		
Groundwater (a)	2.85	23.8	44.7
Air Deposition	NA	NA	NA
Surface Runoff	ND	ND	ND
POTWs	NA	NA	NA
Ocean Exchange	NA	NA	NA

(a) Lowest, highest, and mid-point of estimated loads
(b) Detected in agricultural areas only during baseflows
NA=not analyzed
ND=not detected

Lube oil loads were estimated for the groundwater pathway (6-62 t/yr) and for the surface runoff pathway (320 – 360 t/yr). The range of estimates for groundwater was due to differences in flows used to establish the possible range of loads; groundwater discharges used in the groundwater loading study ranged by an order of magnitude.

For surface water runoff, lube oil was detected at the highest concentrations and frequencies (75%) in commercial/industrial sub-basins during storm events. Lube oil was also detected in other land covers during storms – residential and agricultural areas displayed seasonal first-flushes – yet overall detection frequencies were low (<50%) in all but commercial/industrial land covers. Detections of lube oil were even more infrequent during baseflow sampling, where only agricultural streams had measurable lube oil.

Diesel and gasoline loads were estimated for groundwater (1.8 – 34 t/yr and 2.8 – 45 t/yr, respectively), but neither of these petroleum fractions were detected in surface water. The range of estimates for the groundwater loads was primarily due to differences in flows used to establish the possible range of loads.

The net sum of total oil & grease and petroleum loads to Puget Sound through the pathways assessed may be calculated by summing the loads for a specified percentile value for each of the pathways. The net sums for the following parameters at the respective 25th, median (50th), and 75th percentile values are: Oil and grease - 8,500, 8,500, and 10,600 t/yr; diesel – 1.8, 18, and 34 t/yr; and gasoline 2.8, 24, and 45 t/yr.

Loads for lube oil, the only form of petroleum with loading estimates available for more than one pathway, are shown in Figure 45. Total lube oil loads at the respective 25th, median (50th), and 75th percentile values are 330, 380, and 420 t/yr. Surface runoff accounts for 85 – 98% of the lube oil loads with the remaining 2 – 15% contributed by groundwater (Figure 46).

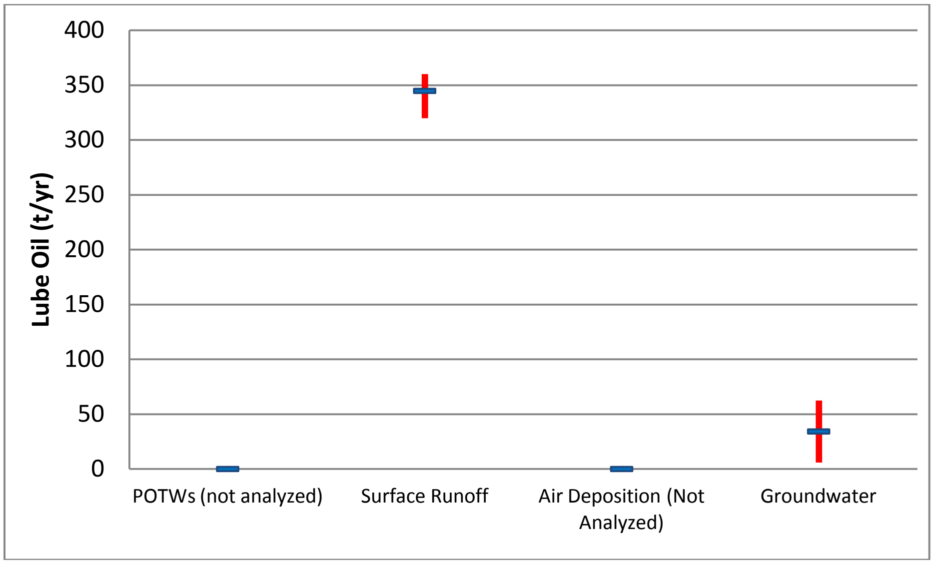


Figure 45. Range (25th - 75th percentiles) and Median Petroleum Lubricating Oil Loads to Puget Sound from Each Major Delivery Pathway.

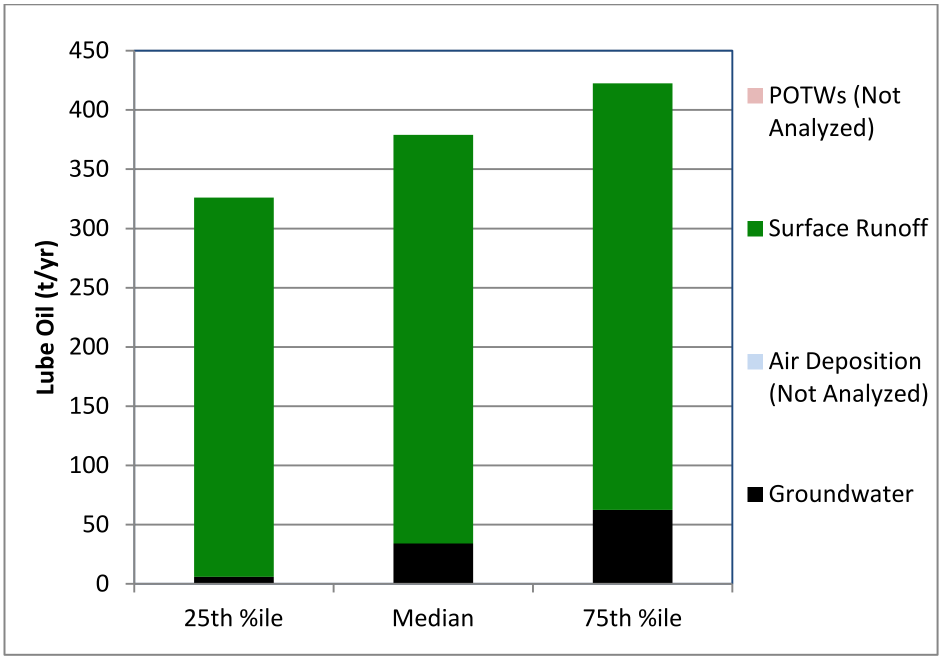


Figure 46. Petroleum Lubricating Oil Loads to Puget Sound from Each Major Delivery Pathway.

Relationship Between Sources and Pathways/Loading

The transport of oil & grease and petroleum hydrocarbons is not likely to be complex compared to many of the COCs addressed in this report. However, the lack of data in a variety of pathways, particularly the presumed major pathway (surface runoff), leaves little information on which to develop a conceptual model based on the data specific to this project.

Based on the source inventory, it appears that thousands of metric tons (t) of petroleum are released in the watershed each year. Most of the petroleum release is in the form of motor oil from engine drips and leaks (6,100 t/yr) and therefore likely to be directly to pavement. Since motor oil is only slowly degraded and is non-volatile, most would be expected to remain on the pavement until entrained by stormwater. Once entrained in stormwater, the oil may be transported directly or indirectly to surface waters, to POTWs, or become sequestered in reservoirs such as soil, detection ponds, and roadside ditches. Once bound to soil, lube oil may not be further transported unless the soil is dislodged.

Overall, it appears that approximately 6% of the motor oil released annually in the Puget Sound basin is transported to Puget Sound in surface water runoff. Diesel released on land from large spills (approximately 20 t/yr) or gasoline released during small fueling and transport spills (1,900 t/yr) was not reflected in measurable surface runoff loads. While it is possible that surface runoff estimates grossly underestimate petroleum loads due to analytical or sampling design errors, petroleum indicator PAHs (e.g. fluoranthene, naphthalene, pyrene) were also rare in surface runoff samples (Herrera, 2011), suggesting limited contribution from petroleum as a source.

Of the POTWs sources inventoried, only improper disposal of used oil (960 t/yr) is likely to be released in a constrained pathway. Petroleum was not assessed in POTWs, so there are no estimates available for this pathway. As mentioned previously in the PAH section, some of the PAHs associated with petroleum were frequently detected in POTW discharge samples, suggesting a possible petroleum source.

Hazard Evaluation

Toxicological evaluation of petroleum mixtures have historically been conducted in the aftermath of oil spills and similar events, and as a result, the majority of available petroleum toxicity data for are for crude oils. However, crude oil toxicity data are generally unsuitable for the Puget Sound basin hazard evaluation since none of the available observed environmental data are for crude oils.

A large amount of observed oil and grease data were available although these data are non-specific and do not describe a specific petroleum product; they encompass waxes, greases and other fatty acid substances from both animal, vegetable and petroleum origins. Because these environmental data are non-specific, and potentially toxic components may vary within the same concentration measured by this method; these data were considered unusable for this assessment.

Both toxicity data and environmental data were only available for four petroleum products in freshwater; heavy fuel/bunker oil, diesel fuel, gasoline, and lube oil. Toxicity data for these fours products were almost entirely based on lethal concentrations to 50% of the exposed population (LC_{50}s). Environmental data for these four products were plotted against the available toxicity data (Appendix D-3).

Only two petroleum product data results were available for marine waters and these were insufficient to estimate priority levels. No observed or effects data were available for sediment evaluation. Hazards due to tissue residue effects, effects to wildlife, and effects to human health were not evaluated.

For fresh surface waters, the median concentration for gasoline (approx. 2.5 mg/l) is above the 10th percentile of effects data, and the 75th percentile of gasoline concentrations exceeds the median effects concentration. For lube oil, the 90th percentile of concentrations (approx. 4 mg/l) exceeds at least 95% of the effects data. For heavy fuel oil and diesel, all of the observed concentrations were two- to five-fold below effects data. In all cases, however, there were not sufficient effects data for an adequate evaluation.

Only toxicity results assessing the water soluble fraction (without free product) were used to assess these data. A more complete evaluation of petroleum would require analysis of parent and alkyl PAHs as well as issues such as phototoxicity which were beyond the scope of this assessment. In addition to the specific assessment for petroleum described here, a suite of individual and high/low molecular weight PAHs were evaluated in both the water and sediment assessments previously described above.

There are no sediment guidelines to assess the level of concern posed by petroleum in sediments, and neither effects data nor observed data are available to evaluate hazards due to residues in aquatic organisms or to evaluate petroleum hazards to wildlife or humans. Due to the uncertainties discussed above and the lack of effects data, there is a high level of uncertainty for the petroleum evaluation.

Table 29. Summary of Hazard Evaluation for Petroleum.

Surface Water		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.* *or* *Acute WQC* *or* *Chronic WQC*	**Level of Concern**
	Freshwater	a	>8%	INS[b]	U
	Nearshore Marine	0	--	INS[c]	U
	Offshore Marine	0	--	INS[c]	U
Sediment		**Total N**	**FOD**	**90th%ile Observed Conc. >** *SQS*	**Level of Concern**
	Freshwater	0	--	INS[c]	U
	Nearshore Marine	0	--	INS[c]	U
	Offshore Marine	0	--	INS[c]	U
Tissue Residue Effects		**Total N**	**FOD**	**90th%ile Observed Conc. >** *10th %ile Effects Conc.*	**Level of Concern**
	Not Analyzed				
Wildlife		**Total N**	**FOD**	**Daily Dose >** *10% of Lowest Effects Dose*	**Level of Concern**
	Not Analyzed				
Human Health		**Total N**	**FOD**	**90th%ile Observed Conc. >** *NTR Criterion*	**Level of Concern**
	Not Analyzed				

FOD=Frequency of detection[a] N = 17 for heavy fuel oil, N = 295 for diesel, N = 359 for gasoline, and N = 894 for lube oil

INS[b]=Insufficient effects data available for comparison to observed data

INS[c]=Insufficient observed or effects data available for comparison

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Summary of Findings

General Considerations

Projects conducted under Phase 3 of the PSTLA which evaluated sources, loading, pathways, and relative hazards of selected COCs in the Puget Sound basin were the key sources of data used for this assessment.

The PSTLA focused on the narrow list of COCs shown below. This list was developed during Phase I of the project based on the COCs' presence in Puget Sound and their potential to cause harm, and to ensure that a broad variety of delivery pathways would be represented. There is a wide variety of chemicals in the Puget Sound basin which have the potential to cause biological and ecological harm, yet environmental data are lacking for many of them. Therefore, this assessment should be viewed as the starting point for development of a much larger toxic chemical assessment.

- Arsenic
- Cadmium
- Copper
- Lead
- Mercury
- Zinc
- Polychlorinated biphenyls (PCBs)
- Polybrominated diphenyl ethers (PBDEs)
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs)
- Dichlorodiphenyltrichloroethane (DDT) and metabolites DDD and DDE
- Low molecular weight polycyclic aromatic hydrocarbons (LPAHs)
- High molecular weight polycyclic aromatic hydrocarbons (HPAHs)
- Carcinogenic polycyclic aromatic hydrocarbons (cPAHs)
- Diethylhexyl phthalate (DEHP, a.k.a. bis(2-ethylhexyl) phthalate)
- Triclopyr
- Nonylphenol
- Oil and petroleum hydrocarbons

The geographical area addressed in this *Assessment Report* includes the Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits (Figure 1). This is consistent with all of the land-based PSTLA loading projects (e.g. Hart Crowser et al., 2007; Envirovision et al., 2008a), except the groundwater loading analysis which excludes loads from the western Strait of Juan de Fuca.

Summary of COC Releases

A summary of the total estimated release and largest potential source for each COC is shown in Table 30. A complete list of individual sources is shown in Appendix C.

Table 30. Summary of Estimated Anthropogenic Releases of COCs in the Puget Sound Basin.

Chemical of Concern (Release Rate)	**Major Sources**	**Modes of Release**
Arsenic (0.8 t/yr)	Industrial sources	Releases to air.
	CCA-treated wood, roofing materials	Leaching from precipitation.
Cadmium (1 t/yr)	Roofing materials	Leaching from precipitation.
Copper (180 – 250 t/yr)	Urban lawn & garden use as pesticides[a]	Direct application to soil.
	Plumbing components, roof material	Leaching from precipitation or directly to POTWs.
	Brake pads	Abrasion leading to fugitive dust emission or loss directly to roadway.
	Vessel anti-fouling paint	Leaching directly to marine water.
Lead (520 t/yr)	Ammunition and hunting shot use, loss of fishing sinkers, loss of wheel weights	Release of solid metallic lead.
	Roofing materials	Leaching from precipitation.
	Aviation fuel	Combustion emissions.
Mercury (0.5 t/yr)	Thermostats, fluorescent lamps, button cells batteries, other mercury-containing material	Volatilization and leaching following disposal.
	Crematoria, industrial plants	Combustion and other air emissions.
Zinc (1,500 t/yr)	Roofing materials	Leaching from precipitation.
	Vehicle tires	Abrasion leading to fugitive dust emission or loss directly to roadway.
Total PCBs (2 t/yr)	Electrical equipment[a]	Spills and leaks.
	Residential trash burning	Combustion emissions.
	Building sealant (caulk)	Volatilization, abrasion to dust and larger particles.
Total PBDEs (0.7 t/yr)	Furniture, computer monitors, and other components of residential and commercial indoor environments	Indoor air and dust.
PCDD/Fs (9 grams TEQ/yr)	Backyard burn barrels	Combustion emissions.
Total PAHs (310 t/yr)	Woodstoves and fireplaces, light and heavy-duty vehicles	Combustion emissions.
	Creosote-treated piling, railroad ties, and utility poles	Leaching and washout, volatilization.
DEHP (17 t/yr)	Industrial, commercial, and institutional point sources	Air emissions.
	Car undercoating, roofing	Leaching, volatilization.
Triclopyr (150 t/yr)	Crop and golf course use as herbicides	Direct application to plants or soil.
Nonylphenol (0.2 t/yr)[b]	Industrial, commercial, and institutional facilities	Air emissions.
Petroleum (9,200 t/yr)	Vehicle crankcase oil	Motor oil drips, leaks, and improper disposal of used oil.
	Vehicle and off-road equipment fueling	Gasoline (minor) spillage.
DDT	NA	NA

t=metric ton (appr. 2.2 tons)

TEQ= Toxic Equivalents

NA=Not analyzed

[a] Estimate is highly uncertain

[b] Sources were not fully assessed

Information on COC releases from primary sources in the Puget Sound basin can be summarized as follows:

- Petroleum is estimated to be released in the largest quantity, followed by zinc which is the only other COC estimated to be released at a rate greater than 1,000 metric tons (t) per year. Lead, PAHs, and copper are estimated to be released at rates greater than 200 t/yr, triclopyr is released at an estimated rate over 100 t/yr, and approximately 15 t of DEHP is released annually. PCBs, cadmium, mercury, PBDEs, arsenic, nonylphenol, and PCDD/Fs are generally released at rates near one t/yr or less.

- In general, industrial, commercial, and institutional point sources do not account for large releases of COCs. Instead, a variety of diffuse sources account for a majority of the COC releases.

- Runoff and leaching of chemicals from roofing materials is potentially an important source of metals. For two metals – cadmium and zinc – release from roofing materials were estimated to account for the majority of total release, and nearly one-third of arsenic is released through roof runoff. Zinc releases from roof runoff are particularly large (>1,000 t/yr). There were also estimated to be substantial releases of copper and lead from roof materials. Leaching of metals from rooftop runoff is likely to be largely in the form of unconstrained releases. Leaching of metals from plumbing components also accounts for substantial releases of copper and zinc, but these are likely to be constrained to sanitary sewer systems and POTWs.

- Vehicle and road-related COC releases occur primarily through wear of vehicle components, combustion of fuel, and leaks of motor oil and fuel. Abrasion of brake pads account for up to one-third of the total release of copper. The second largest source of zinc was estimated to come from tire wear. Vehicle-related fuel combustion releases large quantities of COCs, accounting for about 10% of the total PAH release due to gasoline and diesel combustion, and about 5% of the total PCDD/F release, primarily due to heavy-duty diesel vehicles.

- Petroleum represents the largest COC quantity released to roadways and other impervious surfaces. Motor oil lost via drips and leaks appears to account for over 60% of the total petroleum release and likely occurs along roadways or impervious surfaces – parking lots and driveways – connected to roadways. In addition, gasoline is released at a rate of approximately 1,900 t/yr, including 570 t/yr released during on-road vehicle fueling at the pump. PAHs contained in uncombusted petroleum are also released along with the leaked petroleum at a rate of approximately 10 t/yr.

- Emissions from backyard burn barrels account for about three-quarters of the total PCDD/Fs released, and nearly all of the PCDD/F release is from combustion sources.

- Woodstoves were estimated to be the largest source of PAHs (about one-third of the total PAH release), and aside from zinc roof runoff and petroleum leakage, represent the only COC source exceeding 100 t/yr.

- About 10% of the total PCBs released in the basin was estimated to come from residential trash burning.

- Since few of the COCs assessed are typically associated with agriculture, releases from agricultural uses are generally small. Triclopyr, the only COC used exclusively as a pesticide (herbicide), is an exception with over 100 t/yr applied to crops in the Puget Sound basin. There are also some releases of metals in fertilizers applied to agricultural crops, with zinc releases being the largest (>40 t/yr).

- Copper is used in agriculture as both a pesticide and a micronutrient. Approximately 10 t/yr of copper is used as an agricultural pesticide alone, with an additional 5 t/yr used as a micronutrient. Use of copper as an urban pesticide is potentially substantial, as much as 70 t/yr by some estimates, but other estimates put it at a much lower rate (1 t/yr). The high level of uncertainty in these estimates underscores the limited information available regarding pesticide use.

- PAH releases from creosote-treated wood (railroad ties, marine pilings, and utility poles) appear to account for over one-third of the PAHs released annually in the Puget Sound basin.

- PCB leakage from electrical equipment appears to be substantial, possibly as much as 2,000 kg/yr. However, this amount may also include indoor leakage or that which is immediately cleaned up and contained, and so may overestimate actual PCB release in the Puget Sound basin by a large degree.

- PBDE and phthalate releases are difficult to assess due to the passive nature of their emissions from the materials and products in which they are used. For PBDEs, their loss via air emissions and dust particles into air and dust from commercial offices and homes, followed by subsequent release to the outdoor environment, appears to be the major release pathway. Phthalates may be released in the same manner, although releases from domestic products – including personal care products – may be more important sources. For both of these COCs, attachment to indoor dust and subsequent release to sanitary sewers may also be an important release pathway.

COC Loading and Pathways

One component of the PSTLA was to assess chemical loading from various pathways. The chemical-specific information focused on surface water runoff, atmospheric deposition, and groundwater discharge directly to marine waters, and POTWs as the major pathways for COC delivery. The flux of COCs across the Puget Sound – ocean boundary was also assessed where data were available.

For each of the pathways mentioned above, separate projects were conducted to assess loading. Descriptions of these projects are described in the introductory sections of this report. Tables 31-33 show summaries of the COC amounts loaded from each of the pathways that have *partially controllable* sources of COCs (i.e. all of the major pathways except ocean exchange).

Summaries of the relative COC contributions delivered from each of the loading pathways are shown in Figures 47 and 48.

Caution should be used interpreting Figures 47 and 48 since load estimates are incomplete for some COCs. In particular, air deposition and groundwater loading data are not available for most of the organic COCs.

Table 31. Summary of Metals Loading to Puget Sound through Major Pathways.

Metals		**POTWs**	**Surface Runoff**	**Air Deposition**	**Ground-water***	**SUM**
Total Arsenic (t/yr)	25th %ile	NA	13.5	0.2	0.1	14
	Median	NA	16.9	0.4	0.4	18
	75th %ile	NA	23.4	0.5	0.8	25
Total Cadmium (t/yr)	25th %ile	NA	0.01 [a]	0.03	0.01	0.05
	Median	NA	0.01 [a]	0.05	0.22	0.28
	75th %ile	NA	0.02 [a]	0.07	0.43	0.53
Total Copper (t/yr)	25th %ile	2.5	28.4	1.9	0.1	33
	Median	4.3	35.7	2.7	2.2	45
	75th %ile	5.5	66.1	4.1	4.3	80
Total Lead (t/yr)	25th %ile	0.1	2.8	0.6	0.1	3.6
	Median	0.2	4.7	1.1	1.1	7.0
	75th %ile	0.3	7.6	1.5	2.1	12
Total Mercury (t/yr)	25th %ile	NR	0.09	0.01	0.005	0.11
	Median	0.002 [b]	0.14	0.02	0.05	0.21
	75th %ile	NR	0.24	0.03	0.09	0.37
Total Zinc (t/yr)	25th %ile	16	113	11	2	140
	Median	19	122	18	11	170
	75th %ile	24	134	26	20	200

* Lowest, highest, and mid-point of estimated loads
t=Metric ton (appr. 2.2 tons)
NA=Not analyzed
NR=Not reported
[a] Surface runoff loads based on storm flows only; not detected in any land covers during baseflows and in commercial/industrial areas only during storm flows
[b] Estimate from Phase 2 (Envirovision et al., 2008b)

Table 32. Summary of Organic Chemical Loading to Puget Sound through Major Pathways.

Organics		POTWs	Surface Runoff	Air Deposition	Ground-water*	SUM
Total PCBs (kg/yr)	25th %ile	0.1	2.5	0.7	NA	3.4
	Median	0.3	5.3	1.3	NA	6.9
	75th %ile	1.8	15.8	3.7	NA	21
Total PBDEs (kg/yr)	25th %ile	7.0	5.1	15.7	NA	28
	Median	10.6	5.7	20.3	NA	37
	75th %ile	20.7	10.0	23.8	NA	54
PCDD/Fs (g TEQ/yr)	25th %ile	NA	NA	NA	NA	NA
	Median	NA	NA	NA	NA	NA
	75th %ile	NA	NA	NA	NA	NA
Total DDT (kg/yr)	25th %ile	ND	2.2 [a]	NA	0.3	2.5
	Median	ND	23.9 [a]	NA	3.8	28
	75th %ile	ND	25.1 [a]	NA	7.3	32
LPAH (kg/yr)	25th %ile	3	102 [b]	NA	7	110
	Median	8	104 [b]	NA	159	270
	75th %ile	35	190 [b]	NA	311	540
HPAH (kg/yr)	25th %ile	4	25 [c]	49	6	84
	Median	5	36 [c]	96	124	260
	75th %ile	7	51 [c]	153	243	450
cPAH (kg/yr)	25th %ile	NC	18 [d]	21	5	44
	Median	NC	24 [d]	43	83	150
	75th %ile	NC	34 [d]	70	161	260
Total PAH (kg/yr)	25th %ile	8	119 [b]	49	13	190
	Median	18	224 [b]	96	284	620
	75th %ile	46	244 [b]	153	554	1,000
DEHP (kg/yr)	25th %ile	216	1,750 [e]	NA	14	2,000
	Median	439	1,780 [e]	NA	227	2,400
	75th %ile	904	1,860 [e]	NA	440	3,200
Triclopyr (kg/yr)	25th %ile	NC	641 [f]	NA	NA	640
	Median	NC	652 [f]	NA	NA	650
	75th %ile	NC	686 [f]	NA	NA	690
Nonylphenol (kg/yr)	25th %ile	NC	23 [g]	NA	NA	23
	Median	NC	23 [g]	NA	NA	23
	75th %ile	NC	24 [g]	NA	NA	24

* Lowest, highest, and mid-point of estimated loads.

NA=Not analyzed; ND=Not detected; NC=Not calculated due to insufficient data.

[a] Detected in commercial/industrial areas only during baseflows and in commercial/industrial, agricultural, and forest areas only during storm flows.

[b] Detected in commercial/industrial areas only during baseflows.

[c] Detected in commercial/industrial areas only during baseflows and in commercial, residential, and agricultural areas only during storm flows.

[d] Surface runoff loads based on storm flows only; not detected in any land covers during baseflows and in commercial, residential, and agricultural areas only during storm flows.

[e] Detected in residential areas only during baseflows.

[f] Detected in commercial/industrial and agricultural areas only during baseflows.

[g] Surface runoff loads based on storm flows only; not detected in any land covers during baseflows and in commercial/industrial areas only during storm flows.

Table 33. Summary of Petroleum and Oil & Grease Loading to Puget Sound through Major Pathways.

Petroleum and Oil & Grease		POTWs	Surface Runoff	Air Deposition	Ground-water*	SUM
Oil & Grease (t/yr)	25th %ile	NA	8,470	NA	NA	8,500
	Median	NA	8,470	NA	NA	8,500
	75th %ile	NA	10,600	NA	NA	11,000
Lube Oil (t/yr)	25th %ile	NA	320 [a]	NA	6	330
	Median	NA	345 [a]	NA	34	380
	75th %ile	NA	360 [a]	NA	62	420
Diesel (t/yr)	25th %ile	NA	ND	NA	2	2
	Median	NA	ND	NA	18	18
	75th %ile	NA	ND	NA	34	34
Gasoline (t/yr)	25th %ile	NA	ND	NA	3	3
	Median	NA	ND	NA	24	24
	75th %ile	NA	ND	NA	45	45

* Lowest, highest, and mid-point of estimated loads
t=Metric ton (appr. 2.2 tons)
NA=Not analyzed
ND=Not detected
[a] Detected in agricultural areas only during baseflows

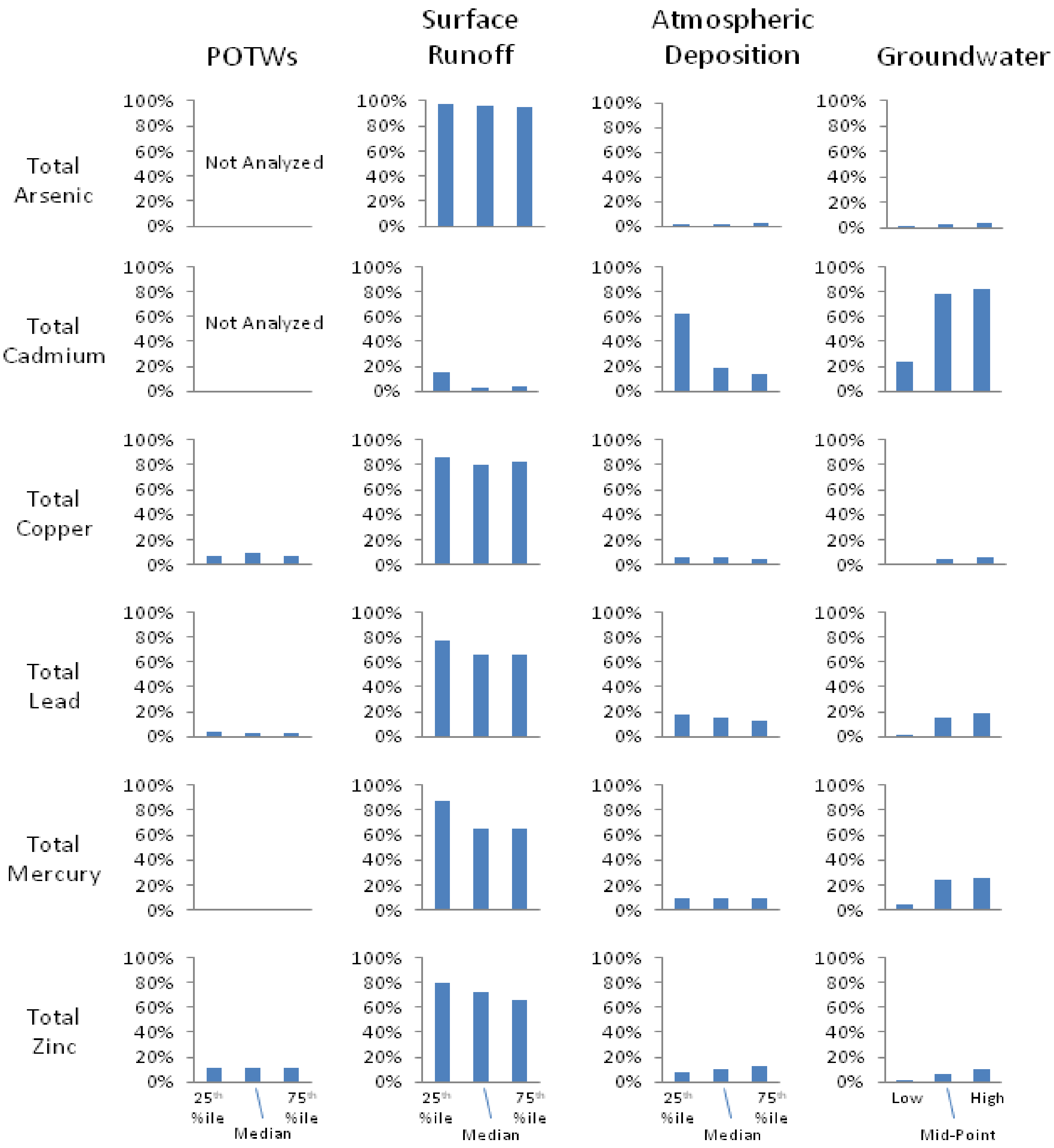

Figure 47. Percent Contribution of Major Pathways to Metals Loading in Puget Sound.

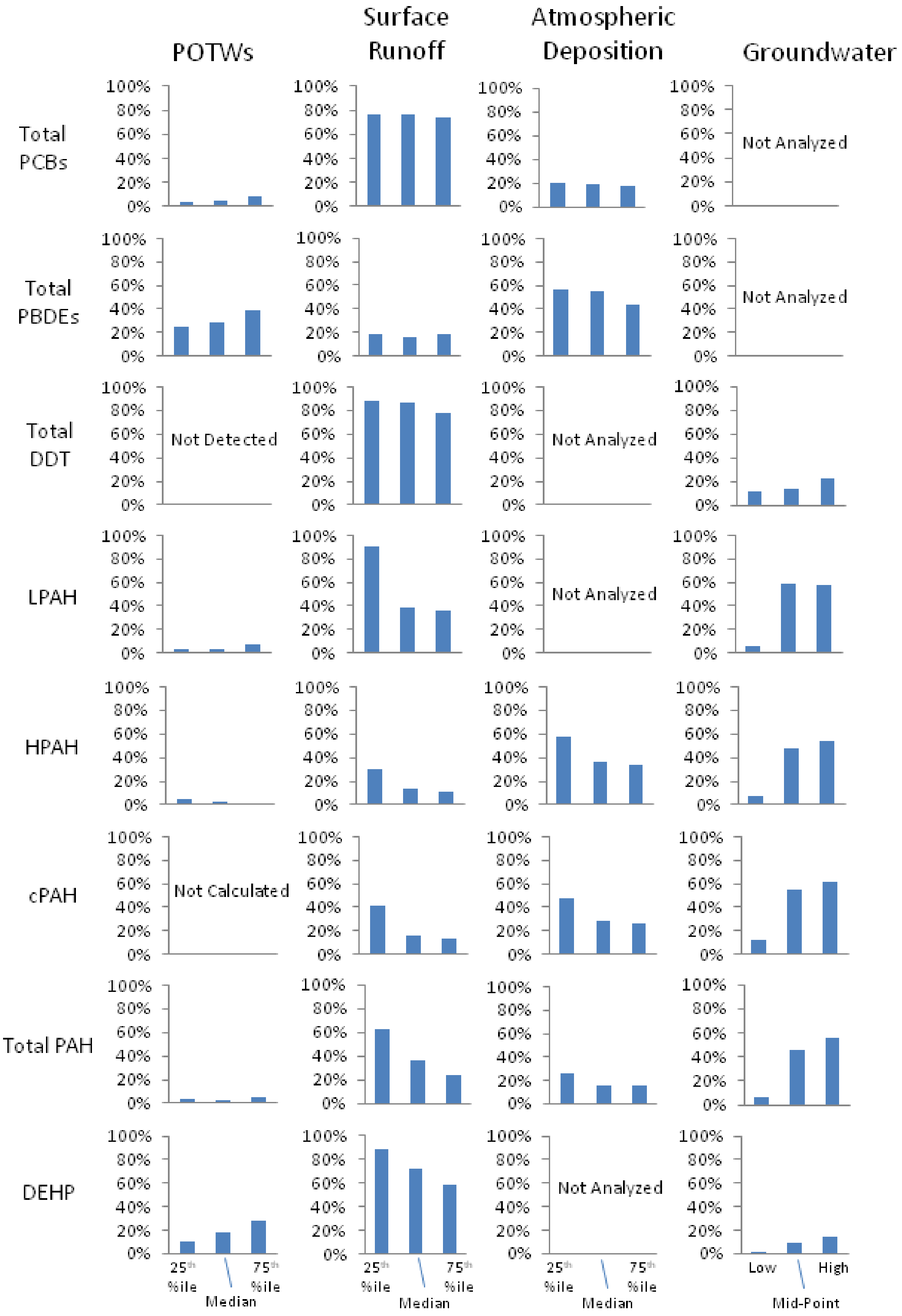

Figure 48. Percent Contribution of Major Pathways to Organic Chemical Loading in Puget Sound.

Information on the COC loading and pathways can be summarized as follows:

- Surface water runoff is the dominant pathway for all metals except cadmium. Metals are generally found at the highest concentrations in commercial/industrial and agricultural land covers, followed in decreasing order by residential and forested areas. However, forest areas account for the bulk of metals loading simply due to the comparatively high proportion of forest land cover (83% of land area) which generates the majority of the flow entering Puget Sound.

- PCBs, PBDEs, and DEHP are present in surface runoff from all land covers at very low concentrations, but tend to be highest in commercial/industrial areas, particularly during storm flows. Like most other COCs in surface runoff, the largest absolute loads are from forested areas as a result of the high proportion of forest cover and associated volume of water.

- POTW-delivered loads were comparatively small for all metals assessed. Cadmium and arsenic were not measured in POTW effluent. To some degree, loads of copper, lead, and zinc mirrored the discharge volume of POTWs relative to other annual land-based water discharge (groundwater and surface runoff) to Puget Sound (~4% of total).

- Groundwater loads directly to marine waters were estimated to constitute approximately 5-10% of the total loading for most metals. The greatest mass of metals loaded annually to Puget Sound through groundwater are from non-urban ambient areas, followed by urban ambient areas and impacted areas. The volume of groundwater discharge alone does not account for the relative contribution of groundwater loads, since groundwater accounts for only 0.2 – 2% of the total annual land-based water discharged to Puget Sound.

- Atmospheric deposition directly to the marine waters of Puget Sound is estimated to account for approximately 5 –15% of the total annual loads of copper, lead, mercury, and zinc. Lower relative loads were estimated for arsenic ($\leq$3%), and higher loads were estimated for cadmium (14 – 62%). For all metals, the atmospheric deposition flux measured was much greater at a particular sampling location within a high-density urban area that was proximal to a nearby pulp mill, metal refiners, other industrial activities, and also close to major roadways including interstate highways. In most cases, the flux at this location was at least five-fold higher than at other locations without these urban influences.

- PBDE loads deposited directly to marine waters from the atmosphere are roughly equal to loads from surface runoff and POTWs combined. With the possible exception of HPAH, PBDEs are the only COC with the predominant load contributed by direct atmospheric deposition. In addition, PBDEs are the only COC with higher loads delivered through POTWs compared with surface runoff.

- Fluxes at the ocean boundary generally show a net export of metals out of Puget Sound. However, for cadmium and lead, there is a net import to Puget Sound from oceanic waters. Marine fluxes of cadmium and lead into Puget Sound are greater than loads from all other pathways combined.

- For most organic compounds, patterns of pathway loading are more difficult to assess than for metals due to inconsistencies in analysis among loading studies and comparatively low frequencies of detection. For instance, HPAHs were the only organic constituents analyzed in the four major pathways assessed.

- For PAHs, accurate delivery patterns and loads are difficult to assess due to infrequent detection in surface runoff. A cursory examination of loads delivered by surface runoff, atmospheric deposition, and groundwater does not reveal a clear loading pattern or principal transport pathway. However, the atmospheric deposition data appear to be the most reliable; surface runoff and groundwater loading data are derived largely from sample data with non-detect results.

- Among all of the COCs assessed, oil & grease was estimated to be delivered to Puget Sound in the largest quantity (>8,000 t/yr) with surface runoff accounting for the entire load. Although oil & grease is relatively meaningless in terms of chemical specificity – it simply refers to the fraction of a sample extractable by n-hexane – some portion of the oil & grease measured in surface runoff may be petroleum product, particularly in urban areas.

Limitations and Uncertainty of Data on COC Sources and Loads

All of the individual projects in the PSTLA contain a degree of uncertainty in the reported results, and all have limitations due to study design or due to the nature of the data collected. Limitations and uncertainty affect the usefulness of the individual projects as well as the ability to compare results among projects. Some of the most common and intractable issues are mentioned here. However, the reader is encouraged to review the individual reports in order to fully gauge uncertainty and understand how results were derived.

The projects were not designed to analyze for an identical suite of COCs. This resulted in a limited ability to fully gauge each pathway's contribution to overall loading and to compare COC quantities released among studies. For instance, air deposition and groundwater loading data are not available for most of the organic COCs, and the source inventory (Ecology, 2011) did not fully account for all major sources of zinc, nonylphenol, and petroleum releases. Appendix B shows a summary of the COCs analyzed for each project.

Much of the uncertainty surrounding the reported results for loading projects is due to sample results below reporting or detection limits (i.e. non-detects). In many cases, results were derived using datasets where more than one-half of the concentration values were reported as non-detects. There was a particularly heavy reliance on non-detects in the surface runoff and groundwater loading projects. For the assessment, this source of uncertainty is compounded by the lack of consistency in the assumptions and rules for handling data (including non-detects) among projects. It should be noted, however, that estimates of releases and loads used for this assessment are those reported in the original projects, and no attempt was made to recalculate or "normalize" results according to a common set of rules. A summary of project-by-project rules used to handle non-detects is shown in Appendix B.

It is also notable that the study conducted to assess loads from surface runoff, the major delivery pathway for most COCs, did not actually measure COC concentrations at the point of delivery to Puget Sound. The authors of the surface runoff study (Herrera, 2011) offer a detailed explanation of this and other potential sources of bias in the surface runoff project.

Relationship between Sources and Pathways/Loading

The relationships between COC sources and loading/pathways discussed in this report essentially provide a framework for the first step in developing mass-balances for COCs, from their initial release to their delivery to Puget Sound. Information provided for these conceptual models include the identification of the primary sources of COCs, mechanisms of release (e.g. combustion emission), estimates of the quantities released, COC prevalence and levels in delivery pathways, and characteristics of loading pathways (e.g. land cover) related to COC prevalence and levels.

Although the conceptual models of the relationships between sources and loading/pathways were developed on a very broad scale, some patterns appear to emerge. For instance, it appears that for most of the COCs assessed there is a one to two order of magnitude difference between the quantity released and the quantity estimated to be loaded to Puget Sound through various pathways. Notable exceptions are PCBs, triclopyr, and PAHs which have estimated releases three orders of magnitude higher than loads. However, the loading estimates for PAHs do not include the estimated release directly to marine waters from creosote-treated marine pilings.

Arsenic is the only COC with estimated loads to Puget Sound larger than releases from primary sources. This appears to be due to the natural enrichment of soils and surface runoff with arsenic, coupled with comparatively low arsenic releases from ongoing anthropogenic sources.

Estimated quantities of COCs released do not necessarily translate to equivalent loads in transport/delivery pathways due to a variety of factors affecting their behavior and fate once released in the environment. For instance, the case studies of copper mass-balance in small watersheds (Paulson et al., 2011-Draft) showed a much greater relative difference between releases and loading at the small (watershed) scale compared to the relative difference between releases and loading at the large (Puget Sound basin) scale.

In many cases, the specific COC source and the mechanism of release may have more environmental relevance then the absolute quantity released. The relationships between COC releases and their presence in specific pathways were therefore examined at finer scales than simply comparing the total annual mass released to the total annual mass loading to Puget Sound.

The following patterns reveal consistencies between releases and pathways at finer scales:

- Overall it appears that there is approximately an order of magnitude decrease between the quantity of a COC discharged to a POTW and the reported load discharged from POTWs to Puget Sound. This appears to be the case for copper, lead, and DEHP. Sources of PBDEs suggest a substantial proportion is released to POTWs as well.

- Metals (copper, lead, and zinc) and PAHs associated with vehicle sources are highly elevated in air deposition samples located near high-density urban areas and interstate highways.

- COCs which are released to air through combustion or volatilization have large load contributions from atmospheric deposition directly to marine waters compared to other pathways. PBDEs and PAHs are two primary examples. DEHP and PCDD/Fs might be expected to follow this pattern as well, but they were not measured in air deposition samples. Mercury, which is largely emitted to the air through combustion or volatilization, does not exhibit the comparatively large load from direct deposition as might be expected.

Hazard Evaluation

As noted in the introductory sections of this report, the hazards posed by different COCs are not simply associated with the quantities released to the environment or loaded to Puget Sound, but are rather more appropriately evaluated by comparing their concentrations in various environmental media to reported effects levels. To assess the relative toxic hazard posed by COCs in various media and for various receptors, the hazard evaluation assessed COCs in various media by comparing observed concentrations to data on effects or guidelines, standards, and criteria for the following categories:

- Direct hazard to aquatic life through surface water exposure
- Direct hazard to benthic organisms through sediment exposure
- Direct hazard to aquatic life based on tissue residue levels
- Hazard to wildlife based on ingestion of prey, water, and sediment
- Hazard to human health through fish/seafood consumption

The results of these comparisons were grouped into three broad “level of concern” categories: a Priority 1 level of concern, a Priority 2 level of concern, or unknown (U) level of concern due to lack of sufficient data for an assessment. Results were classified as a Priority 1 when high observed concentrations (e.g. 90th percentile values) exceeded low effects concentrations (e.g. 10th percentile values), selected criteria, or other threshold values. A Priority 2 level of concern was assigned in cases where high observed concentrations were below threshold values. In cases where there were not sufficient data to make a meaningful comparison, results were assigned a U. Appendix D-1 details the thresholds used for comparisons and the minimum data required for the comparisons. Table 34 provides a summary of the hazard evaluation for all of the categories and sub-categories assessed.

The hazard evaluation has several limitations that should be considered prior to acting on the results. In particular, the hazard evaluation is not a risk assessment but is instead designed to assess the *relative* level of concern of COCs *across the entire Puget Sound basin*. Although a COC may be assigned Priority 2 or U for a particular sub-category, this should not be interpreted to mean there are no hazards associated with that COC. Locally, concentration hot spots exist near major sources and may cause localized toxicity to aquatic organisms or lead to violations of standards.

In addition to the systematic methodology used to evaluate relative hazards for each COC, a review of relevant regional studies was conducted. This review was conducted to capture information on regionally important biological effects that may not have been included among the data used for the hazard evaluation. Information from these reviews was not used to assign the Priority levels summarized in Table 34, but instead was used as an additional line of evidence for assessing priorities for toxic chemical reduction and control strategies.

Table 34. Summary of the Hazard Evaluation Based on the Priority Levels of Concern for Each Sub-Category (see text for definitions of Priority levels).

COC	Surface Water			Sediment			Tissue Residue			Wildlife		Human Health			Regional Effects Data?
	Frsh.	Marine		Frsh.	Marine		Frsh.	Marine		Frsh.	Marine	Frsh.	Marine		
		nr.	off.		nr.	off.		nr.	off.				nr.	off.	
Arsenic	U	U	U	1	2	2	NA	NA	NA	NA	NA	U	U	U	No
Cadmium	2	U	U	1	2	2	NA	NA	NA	NA	NA	NA	NA	NA	No
Copper	1	1	2	1	2	2	NA	NA	NA	NA	NA	NA	NA	NA	Yes
Lead	2	U	2	2	2	2	NA	NA	NA	NA	NA	NA	NA	NA	No
Mercury	1	U	U	1	1	1	U	U	U	1	1	2	2	2	Yes
Zinc	2	U	1	1	2	2	NA	NA	NA	NA	NA	NA	NA	NA	No
PCBs	1	U	2	1	2	1	1/U	2/U	2/U	1	1	1	1	1	Yes
PBDEs	U	U	U	U	U	U	NA	NA	NA	NA	NA	NA	NA	NA	Yes
PCDD/Fs	U	U	U	U	U	U	U	U	U	1/U	2/U	1	1	1	Yes
DDT	1	U	U	U	U	U	2	U	U	1/2	1/2	1	1	2	Yes
PAHs	2/U	U	2/U	1/2	2	2	NA	NA	NA	NA	NA	1/2	1/2	2/U	Yes
DEHP	2	U	U	1	1	1	NA	NA	NA	NA	NA	1	1	U	No
Triclopyr	2	U	U	U	U	U	NA	NA	NA	NA	NA	NA	NA	NA	No
Nonylphenol	2	U	2	U	U	U	NA	NA	NA	NA	NA	NA	NA	NA	No
Petroleum	U	U	U	U	U	U	NA	NA	NA	NA	NA	NA	NA	NA	No

1=Priority 1 (highlighted in yellow)
Frsh.=freshwater
nr.=nearshore
off.=offshore
2=Priority 2
U=Unknown
NA=not analyzed

Information on the hazard evaluation and regionally important biological-effects data can be summarized as follows:

- All of the COCs except lead, PBDEs, triclopyr, nonylphenol, and petroleum were assigned a Priority 1 level of concern for at least one category. Of the COCs not assigned a Priority 1, only lead had sufficient effects data to conduct a meaningful evaluation.

- PCBs are the only COC assigned a Priority 1 in all five categories evaluated. Mercury and DDT were the only other COCs evaluated for all five categories, and they were assigned Priority 1 for four categories and three categories, respectively.

- COC concentrations in surface waters and sediments – particularly freshwater – resulted in the most COCs assigned Priority 1. Tissue residue, wildlife, and human health evaluations resulted in the fewest COCs receiving Priority 1. However, only bioaccumulative chemicals were evaluated for these latter categories, and so fewer Priority 1 assignments were expected.

- Reviews of regionally important biological-effects data showed that levels of copper, mercury, PCBs, PBDEs, PCDD/Fs, DDT, and PAHs found in the Puget Sound basin result in documented or potentially adverse effects to a variety of aquatic organisms.

Chemical-by-Chemical Summary

Arsenic

Arsenic was found to be a Priority 1 level of concern for freshwater sediments, one of the three categories for which data were sufficient for an adequate hazard evaluation. Observed data were lacking to conduct adequate evaluations for surface waters and human health.

Releases of anthropogenic arsenic are small compared to loads. The largest ongoing anthropogenic source appears to be point-source air emissions, although these are relatively small on a basin-wide scale. Loading to Puget Sound is substantial, presumably due to natural sources and possibly from historical releases, and is dominated by surface runoff. The finding that, unlike most metals, arsenic concentrations in surface runoff decrease during storm events may support the notion that a substantial portion of the arsenic in surface waters is due to natural or historic sources.

Cadmium

Cadmium was found to be a Priority 1 level of concern for freshwater sediments, one of the two categories for which data were sufficient for an adequate hazard evaluation. Observed data were lacking to conduct adequate evaluations for surface waters.

Both anthropogenic releases and loading of cadmium appear to be small. The largest ongoing source of cadmium to the environment appears to be leaching of cadmium from roofing material, constituting more than one-half of the total estimated release. Releases of cadmium from roofing material do not appear to translate to appreciable levels in surface runoff, which represents the smallest delivery pathway.

Copper

Sufficient data were available for full hazard evaluations of copper in surface waters and sediments. Copper was found to be a Priority 1 level of concern for freshwater sediments, nearshore marine sediments, and fresh surface waters. Regionally relevant biological-effects data provide additional lines of evidence to indicate a comparatively high hazard potential for copper. These regional studies have demonstrated that dissolved copper concentrations commonly found in urban and agricultural area streams reduce olfactory function in salmonids (e.g., Hecht et al., 2007).

The source inventory (Ecology, 2011) suggests that large ongoing copper releases occur from a variety of sources including abrasion of vehicle brake pads, leaching from roofing materials, leaching of vessel anti-fouling paint, pesticide applications and micronutrient use in agricultural applications, and possibly pesticide use in urban areas. These releases result in elevated levels in surface water at locations where they are most likely to occur such as agricultural, commercial/industrial, and high-density urban areas, as well as nearshore marine waters.

Lead

Sufficient data were available for full hazard evaluations of lead in surface waters and sediments except nearshore marine waters. Lead was not a Priority 1 level of concern for any of the categories assessed. There is no indication that lead concentrations in fish and shellfish from the Puget Sound basin pose a risk to human health, although lead was not evaluated in tissue due to lack of National Toxics Rule criteria for lead. Lead remains a human health hazard through exposures from material such as lead house paint (Ecology and WDOH, 2009), but no hazard emerges from exposures that include an aquatic environment pathway.

Ongoing anthropogenic releases of lead are substantial, largely due to ammunition use, fishing sinkers, and wheel weight loss. These solid metallic lead sources and mechanisms of release appear to result in limited enrichment of the aquatic environment except in some localized instances. Surface water runoff represents the largest delivery pathway, but loads are small compared to the estimated releases from ongoing anthropogenic sources.

Mercury

Mercury was found to be a Priority 1 level of concern for fresh surface waters, freshwater and marine sediments, and all freshwater and marine wildlife species evaluated. There were not sufficient observed data to conduct adequate hazard evaluations for marine sediments or effects data to evaluate tissue residue effects. Mercury concentrations in freshwater and marine seafood were generally well below the threshold used to assign a Priority 1 level of concern for the human health evaluation. However, consumption advisories for various fish species and locations in the Puget Sound basin have been established by the Washington State Department of Health due to mercury residues in tissues.

There appears to be a variety of ongoing anthropogenic mercury releases, although a number of the regional sources have been addressed in the Mercury Chemical Action Plan (Ecology and WDOH, 2003) and it is unclear if release estimates accurately portray current releases to the environment. Mercury releases due to improper disposal of materials appear to be the largest category of ongoing anthropogenic release, followed by industrial emissions. Surface runoff is the largest delivery pathway for mercury and to some degree may reflect entrainment of mercury deposited atmospherically.

Zinc

Zinc was found to be a Priority 1 level of concern for offshore marine surface waters and for freshwater sediments. Sufficient data were available for surface water and sediment, except nearshore marine surface waters.

Zinc appears to be released at high rates from a variety of roofing materials and to a lesser degree in vehicle tire wear. The study of primary sources (Ecology, 2011) indicated that zinc releases may have been underestimated because many sources (e.g. leaching from galvanized materials) were not assessed. Surface runoff was the dominant pathway for zinc loading to Puget Sound. Zinc levels in streams from commercial/industrial areas were found to be highly elevated, possibly as a reflection of galvanized material leachate and vehicle tires where these sources are likely to be most prevalent.

Polychlorinated biphenyls (PCBs)

PCBs are a Priority 1 level of concern for all five categories assessed and for nine of the 13 sub-categories where sufficient data were available. In addition, regional data show PCB levels that may result in adverse effects to locally important fish and marine mammals. Fish consumption advisories to protect human health have also been issued for both marine and freshwaters of the Puget Sound basin.

Release estimates are highly uncertain and may overestimate the degree to which PCBs continue to be released from ongoing anthropogenic sources (Ecology, 2011). Electrical equipment (capacitors and transformers) leakage is the largest PCB source category, with loss from sealants and release from residential trash burning also making up a substantial portion. However, loading is small compared with releases and may support the notion that releases were overestimated.

Due to their persistence, PCBs that were released from historical sources and continue to be released from highly contaminated areas, such as the lower Duwamish River, continue to cycle in the aquatic environment of Puget Sound. The substantial accumulation in biological tissues may be primarily a result of legacy contamination as opposed to ongoing releases.

While PCBs remain a concern, levels appear to be declining in Puget Sound harbor seals (Noel et al., 2011) and mussels (Mearns et al., 2009). While temporal PCB trends in fish do not show a clear trend (West and O'Neill, 2007), modeling results suggest that substantial declines in English sole should be expected by 2020 at current loading rates (Pelletier and Mohamedali, 2009).

Polybrominated diphenyl ethers (PBDEs)

PBDEs are an unknown level of concern due to a lack of environmental effects data, criteria, and guidelines for PBDEs. However, the lack of effects data used in the hazard evaluation methodology should not be interpreted as a low level of concern since a growing body of evidence suggests environmental concentrations may cause adverse effects to humans (Ecology and WDOH, 2006), marine animals (Ross, 2006), and birds (Fernie et al., 2009). The historical record is generally not adequate to assess PBDE trends in the Puget Sound environment since PBDEs have not typically been included in sampling investigations prior to the beginning of the 21st century.

Cessation of production through voluntary actions and bans since the mid-2000s has removed major PBDE formulations from new consumer products such as mattresses, televisions, computers, and residential upholstered furniture. However, much of the PBDEs produced historically may remain in consumer products and commercial office products and these potentially represent substantial diffuse ongoing sources.

PBDE loading patterns are different than for other COCs assessed. Direct atmospheric deposition represents the largest delivery pathway, followed by POTWs and surface runoff. The high proportion of PBDE loading through atmospheric deposition and POTWs appears to be consistent with the major sources and release mechanisms.

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs)

PCDD/Fs are a Priority 1 level of concern for a species representing a freshwater mammal (river otter) and for human health due to residue levels in freshwater and marine seafood. In addition, regional data show that Puget Sound harbor seal and southern resident killer whale prey items have higher PCDD/Fs compared to the same prey from the Strait of Georgia and the British Columbia coast. There were not sufficient data to conduct hazard evaluations for surface waters or sediments, or to evaluate tissue residue effects.

In the Puget Sound region, the major historical sources of PCDD/Fs – use of elemental chlorine in pulp bleaching, pentachlorophenol wood treatment operations, and combustion of saltwater-infused hog fuel – have been eliminated to a large extent (EPA, 1991; Yake et al., 1998; EPA, 2006), and ongoing releases are from combustion sources such as backyard burn barrels. Accumulation in biota is likely to be mainly a result of historical releases which continue to cycle in the aquatic environment, although no loading analyses were conducted to corroborate the small releases estimated for the Puget Sound basin.

Dichlorodiphenyltrichloroethane (DDT) and metabolites DDD and DDE

DDT compounds were found to be a Priority 1 level of concern for fresh surface waters, the freshwater and saltwater bird species evaluated, and human health. There were not sufficient observed or effects data to conduct hazard evaluations for marine surface waters, sediments (fresh and marine), or direct effects based on marine tissue residues. Regional data show high levels in accumulation for a variety of Puget Sound fish and marine mammals, including evidence to show apparent links between high levels in top-level, marine-mammal predators and their prey items.

Although a ban on DDT use in the United States has been in effect for decades, DDT compounds continue to exceed numerous documented effects levels due to their persistence, particularly in freshwater. DDT also persists in tissues of aquatic biota due to its highly bioaccumulative nature, but concentrations in Puget Sound basin fish are generally low, particularly when compared to watersheds with intensive agricultural use outside of the basin, such as watersheds in eastern Washington (e.g. Schneider and Coots, 2006; Johnson et al., 2010b). There are no apparent ongoing anthropogenic releases of DDT in the Puget Sound basin, and overall loading to Puget Sound appears to be low. DDT compounds will likely persist in the aquatic environment due to mobilization of DDT-bound soil particles and continued cycling in the aquatic environment due to historical releases.

Polycyclic aromatic hydrocarbons (PAHs)

PAHs are a Priority 1 level of concern for freshwater sediments and human health. There were not sufficient observed data to conduct adequate hazard evaluations for all individual PAHs in surface waters or for human health due to residues in offshore marine seafood. Localized areas with high degrees of PAH-contaminated sediments have also been a historical problem in Puget Sound, and resulting liver lesions in English sole have been a well-documented pathology associated with exposure to these sediments (Malins et al., 1987; Landahl et al., 1990; Myers et al., 1990). Recent evidence suggests that risks of liver lesions dramatically decrease when PAH-contaminated sediments are capped or removed (PSAT, 2007), and liver disease in English sole is currently being proposed as a Puget Sound-wide indicator of ecosystem health (PSP, 2011b).

There appears to be large, ongoing anthropogenic releases of PAHs in the Puget Sound basin. Generally speaking, PAH sources may be broken down into two categories: combustion emissions and releases from creosote-treated materials. PAH loads to Puget Sound are three orders of magnitude lower than estimated releases, but these loading estimates do not take PAH releases from creosote-treated pilings directly to marine waters into account. Groundwater appears to be the largest delivery pathway for PAHs, but the groundwater loading estimates are based largely on estimates derived from non-detects and should be viewed with caution. Estimated PAH loads through surface runoff are comparatively small due to the infrequency at which PAHs were detected in surface water samples.

To some degree, the lack of detectable PAHs in surface runoff may reflect the major sources and release mechanism. Few of the major sources would be expected to release PAHs directly to impervious surfaces, with the possible exception of PAH releases through motor oil loss.

Bis (2-ethylhexyl) phthalate (DEHP)

DEHP is a Priority 1 level of concern for freshwater sediments and human health. There were not sufficient observed data to conduct adequate hazard evaluations for marine surface waters or human health due to residues in offshore marine seafood.

There appears to be large ongoing anthropogenic DEHP releases in the Puget Sound basin. In addition to air emissions from point sources, DEHP is released from a variety of materials, particularly those containing PVC, although DEHP may be released from some non-polymer products as well. Surface runoff is the largest delivery pathway, although DEHP was not measured in air deposition samples. The major DEHP sources and mechanisms of release suggest that atmospheric deposition may be a major pathway. DEHP loads from POTW discharge are also relatively high and may indicate loss through indoor consumer products, and subsequent rinsing down the drain is another important delivery pathway.

Triclopyr

Triclopyr was evaluated only for hazards in fresh surface waters and was assigned a Priority 2 level of concern. There were not sufficient observed or effects data to conduct adequate hazard evaluations for marine surface waters or sediments.

Unlike other COCs evaluated, triclopyr’s only intended use is as an herbicide, and therefore its usage equates to environmental release. Major uses in the Puget Sound basin appear to be from crop and golf course use, with minor applications to road and railroad right-of-ways and for limited aquatic weed control. Surface runoff was the only delivery pathway where loads were calculated; loads were estimated to be two orders of magnitude below release estimates.

Nonylphenol

Nonylphenol was evaluated only for hazards in fresh surface waters and marine offshore waters; it was assigned a Priority 2 level of concern for both. There were not sufficient observed or effects data to conduct adequate hazard evaluations for nearshore marine surface waters or sediments. Nonylphenol is not highly toxic, but instead may exert effects at the sub-lethal level, and has documented endocrine-disrupting effects (King County, 2007). Compared with most other COCs, little is known about nonylphenol sources and effects in the Puget Sound basin.

There were limited release and loading estimates calculated for nonylphenol. Sources of nonylphenol were not fully assessed in the study of primary sources (Ecology, 2011), and loading was calculated only for surface runoff. Although a major source of nonylphenol is reported to be the breakdown of alkylphenol ethoxylates during the sewage treatment process (EPA, 2005), it was not detected frequently enough in POTW effluent to calculate loads from this pathway.

Oil and petroleum hydrocarbons

Petroleum was not fully evaluated for hazards in surface waters or sediments due to a lack of effects data (fresh surface waters) or observed data (sediments, marine surface waters). Evidence suggests that weathered crude oil has specific toxic effects to marine organisms, such as cardiac impairment and other effects in fish (Incardona et al., 2005; Incardona et al., 2006; Carls et al., 2008). However, these effects are due to specific components of weathered oil, most notably PAHs. The complexities of evaluating effects from petroleum exposure are discussed in the report section dealing specifically with petroleum.

The source inventory indicates that petroleum is released to the Puget Sound basin in much larger quantities than other COCs addressed, and the loading studies indicate it is loaded in the largest quantity. Most of the petroleum release is in the form of motor oil from engine drips and leaks and therefore likely to be directly to pavement. The large lube oil loads in surface water runoff may be a reflection of these releases. However, the large estimated releases of gasoline due to small fueling and transport spills did not translate to measurable loads in surface runoff.

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Prioritizing Chemicals of Concern and Recommendations to Fill Data Needs

Prioritizing COCs

A lines-of-evidence approach was used to move further toward a goal of deciding how best to prioritize actions and resources for controlling toxic chemicals in the Puget Sound basin. This lines-of-evidence approach considers information on the four major components of the assessment (sources, loading, pathways, and the relative hazards), but the approach mostly relies on COC sources and the relative hazards posed by COCs as determined by the hazard evaluation and review of other regional studies.

This approach adopts the rationale that chemicals with the greatest potential to elicit toxic effects at existing concentrations should be an important factor in determining the priority for source control efforts. Priority was also given to COCs associated with large opportunities for source control. This reflects the extent to which there are existing regulatory actions to control releases, such as bans, management of materials, or other permanent actions which reduce releases to the environment. Given the uncertainty associated with individual estimates of releases or loadings, this lines-of-evidence approach provides a supportable rationale for establishing relative priorities for control actions.

Opportunities for source control are considered large where the major sources of a COC have not been addressed by control actions; where some of the major sources have been addressed, opportunities may be considered medium. In cases where actions have been implemented to control and reduce all or most of the major sources and this appears to have resulted in low rates of loading to Puget Sound, the opportunities for controlling a COC are considered small. This assessment relies principally on the *Sources Report* (Ecology, 2011) with limited input by Ecology staff and management to gauge the opportunities for source control; this assessment was not intended to be a detailed review of management initiatives. Table 35 summarizes major sources for each COC and possible opportunities for reducing those sources.

Based on the lines-of-evidence approach, copper, PAHs, DEHP, and petroleum sources were rated as have the highest priority for early actions. The reasoning for this determination is as follows:

- A substantial portion of the fresh and marine water copper data observed basin-wide falls within concentrations where effects have been documented (including reduced olfactory function in salmonids). Copper is released in large quantities from a variety of sources which appear to translate to substantial loads to the Puget Sound ecosystem. The use of copper in pesticide applications and the release of copper from roofing materials are sources which warrant further investigation. In addition, the effectiveness of recent legislation to limit copper in brake pads and vessel anti-fouling paint should be evaluated.
- A number of individual PAHs surpass (do not meet) freshwater sediment guidelines and human health criteria. In addition, a variety of studies have demonstrated links between PAH

exposure and adverse effects to regionally relevant aquatic species. There appear to be numerous opportunities for control actions, primarily for combustion sources and for creosote-treated wood.

- Observed DEHP concentrations in both freshwater and marine environments exceed (do not meet) criteria for protection of benthic species and human health. Substantial amounts of DEHP are released in the Puget Sound basin, much of which occurs initially through releases to air from off-gassing of plasticized polymers and point-source air emissions. Several non-polymer uses of DEHP may also provide opportunities for source reduction.
- The relative hazard posed by petroleum in the Puget Sound basin was not able to be evaluated due primarily to the lack of biological-effects data and the absence of criteria to protect aquatic organisms, wildlife, or human health. However, some of the COCs addressed in this assessment are components of petroleum and may be released in substantial quantities along with the release of petroleum. In particular, substantial releases of PAHs are estimated to be released from petroleum. The major sources of petroleum are diffuse, such as motor oil drips and leaks and minor gasoline spillage during vehicle fueling, and therefore offer ample opportunities for reduction efforts.

Several COCs were found to be a Priority 1 level of concern based on the hazard evaluation but were not determined to be among the highest priorities for reduction actions since the major sources have been addressed through regulatory programs or other efforts. For instance, mercury poses a relatively high hazard to freshwater and marine aquatic organisms and wildlife based on doses calculated from observed data. However, many of the historical regional sources of mercury to the Puget Sound basin have been eliminated or are being addressed by the Mercury Chemical Action Plan (Ecology and WDOH, 2003). Similarly, PCBs are a Priority 1 level of concern for all hazard evaluation categories, but PCBs have been banned for decades, the major sources (use in electrical equipment) are highly regulated, and current loads to Puget Sound appear to be small.

Although the systematic prioritization approach identified four COCs for early actions, other factors should be considered to determine the need and feasibility for developing control and reduction strategies for other COCs. For instance, PBDEs are ubiquitous environmental contaminants, and although voluntary actions and bans have removed major PBDE formulations from new consumer products, much of the PBDEs produced historically may remain in consumer products and commercial office products and these potentially represent substantial diffuse ongoing sources. The hazard evaluation was not able to adequately assess the relative hazards associated with PBDEs due to a lack of environmental standards, although there is evidence in the available literature to suggest this COC may pose a hazard at observed concentrations.

Additional research is needed to assess the relative hazards posed by PBDEs and other COCs for which there are only limited environmental data. By the same token, COCs with limited source information should be further evaluated to assess additional opportunities for source control. Of the COCs addressed in this report, PBDEs and nonylphenol were the COCs that should receive top attention for further research on potential hazard as well as possible opportunities for source control.

Table 35. Summary of Possible Actions to Reduce COCs in the Environment.

COC	Opportunities for Source Control	Major Ongoing Anthropogenic Sources	Possible Actions for Reductions
Arsenic	Medium	Industrial air emissions	Maintain existing permit controls.
		CCA-treated wood leaching	Continue ban for most non-structural uses.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
Cadmium	Medium	Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
Copper	Large	Pesticides use on urban lawns and gardens	More data needed on actual pesticide use.
		Residential plumbing component leaching	Continue to implement Lead and Copper Rule.
		Brake pad abrasion	Continue to implement legislation enacted to reduce source.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
		Vessel anti-fouling paint leaching	Continue to implement legislation enacted to reduce source.
Lead	Small	Ammunition and hunting shot use	Implement CAP and enforce existing regulations.
		Loss of fishing sinkers and wheel weights	Implement CAP and enforce existing regulations.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
		Aviation fuel combustion	Implement CAP and enforce existing regulations.
Mercury	Medium	Consumer product improper disposal	Continue to implement CAP and enforce existing regulations.
		Crematoria and industrial air emissions	Continue existing permit limits.
Zinc	Large	Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
		Vehicle tire abrasion	Investigate source where it poses local concern.
Total PCBs	Small	Electrical equipment spills and leakage	Continue programs for management and disposal.
		Residential trash burning	Continue enforcing existing ban.
		Building sealant (caulk) volatilization and abrasion	Investigate source where it poses local concern.
Total PBDEs	Medium	Furniture, computer monitors, and other components of residential and commercial indoor environments	Enforce ban on new products but consider control actions to reduce the release from existing products.
PCDD/Fs	Small	Backyard burn barrels	Continue enforcing existing ban.
Total DDT	Small	None apparent	Investigate source where it poses local concern.
Total PAHs	Large	Woodstoves and fireplace combustion emissions	Continue change out programs, investigate catalysts/capture devices, promote alternatives to wood heat.
		Vehicle combustion emissions	Anti-idling programs, continue/expand engine retrofits for private section engines, enforce existing vehicle controls.
		Creosote-treated piling, railroad ties, and utility poles	Control actions needed, gather information to identify highest priority areas.
DEHP	Large	Polymer (primarily PVC) off-gassing	Gather additional information on extent of releases.
		Industrial, commercial, and institutional air emissions	Maintain existing permit controls.
		Roofing material leaching	Possible opportunity for source control, but more data needed on extent of releases.
Triclopyr	Medium	Herbicide use on crops and golf courses	More data needed on pesticide use.
Nonylphenol	Unknown	Industrial, commercial, and institutional air emissions	More information needed on emissions from these sources and unidentified releases.
Petroleum	Large	Motor oil drips and leaks Used motor oil improper disposal	Expand existing education/workshop programs.
		Gasoline spillage (minor) during fueling	Possible opportunity for source control, but more data needed on extent of releases.

Bold=Recommended as priority for near-term actions based on lines-of-evidence approach.

Strategies to control toxic chemicals in the environment may be accomplished using two general approaches: control at the source and control along the pathway. Source control strategies aimed at limiting or eliminating the initial release of chemicals may be achieved through education, chemical alternatives, release prevention technologies, or banning the use of specific chemical products. Control of a chemical once it has been released in the environment is typically more difficult and expensive, involving the use of a management actions (e.g. timing of pesticide application) or physical and technological resources (e.g. grass-lined ditches along roadways, wastewater treatment plants).

Prevention is the preferred option for controlling toxic chemicals in the environment, but source control options are not always feasible or necessary. While finding, reducing and eliminating primary releases of COCs at their source is critical to a clean and sustainable Puget Sound, so too is ensuring compliance with hazardous waste regulations, inspecting permitting facilities to ensure air and water quality, responding to spills, and cleaning up toxic messes when COCs are mismanaged.

The following recommendations provide a mixture of possible source and pathway control priorities for the target list of COCs addressed in this report.

General Recommendations

- Use results from the Puget Sound Toxics Loading Analysis (PSTLA) to help develop a long-term strategy to reduce toxic threats to Puget Sound. This strategy should include a comprehensive list of actions to prevent and manage chemical releases in conjunction with cleanup actions to reduce overall contaminant levels.

- Develop a list of specific control actions or source/pathway investigations to support control actions that may be incorporated into Ecology’s long-term strategy for control of toxic chemicals under the National Estuary Program. These actions or investigations should be consistent with the findings and broader recommendations presented in this report. Examples of specific actions or investigations might be (1) adopting Low Impact Development Best Management Practices in commercial/industrial areas or (2) assessing the effectiveness of piling removal programs to reduce PAHs in the aquatic environment.

- Couple source control actions with effectiveness monitoring to assess if and how source control actions are actually reducing contaminant levels. This information is needed for an adaptive management framework to evaluate which actions should continue or be discontinued in favor of more effective actions.

Specific Recommendations

- Roofing materials appear to be an important source of metals and possibly DEHP in the Puget Sound basin. Monitoring should be conducted to further evaluate the release of these contaminants from roofing materials.

- Reduce copper loads to freshwater streams and marine waters, and assess the impacts of these efforts. The impact of recently passed legislation limiting copper and other metals in brake pads will not likely be known for at least a decade. In the meantime, the impact of copper released from pesticide/micronutrient use and vessel bottom paint should be investigated. One of the largest sources of copper is potentially from the urban use of copper in agricultural products by homeowners. Better information should be collected to evaluate the importance of these releases.

- Strategies to control the release of petroleum should be a high priority. Results of the *Sources* study (Ecology, 2011) indicate that over 9,000 metric tons of petroleum is released annually in the Puget Sound basin. Petroleum is generally released to impervious surfaces, enhancing its capacity to become mobilized in stormwater. There appears to be considerable opportunities for controlling sources of lube oil and gasoline since they are primarily released from crankcase drips and leaks and from minor spillage during fueling operations. The importance of these sources should be further evaluated.

- Strengthen existing programs to remove creosote pilings and bulkheads from the aquatic environment. Information analyzed on PAH sources and loading suggests creosote pilings may account for the largest overall PAH release to surface waters. The feasibility and need to remove creosote-treated rail ties that are over water or adjacent to sensitive aquatic areas should also be evaluated.

- Evaluate the effectiveness of actions implemented to reduce the amount of mercury released to the environment. Multiple programs and agencies have been involved with mercury disposal and recycling programs since the initiation of the Mercury Chemical Action Plan in 2003 (Ecology and WDOH, 2003). Organizing and streamlining information would make it easier to track ongoing releases to the environment and end-of-life data for mercury-containing materials.

- Evaluate the factors that appear to be effectively attenuating metals from roof and road runoff in low-density residential areas, and consider how to apply these factors in commercial/ industrial areas where there appears to be little attenuation between sources and streams. If warranted, consider applying these attenuation mechanisms to high-density residential areas.

- Conduct inspections once every three years at those businesses in Washington that routinely handle large amounts of COCs. Washington is failing to find and resolve environmental threats from millions of pounds of hazardous waste in the Puget Sound basin. Hazardous wastes are toxic, flammable, or reactive, and when mismanaged, they contaminate soil, air, and water. Ten years ago, hazardous waste inspectors found serious environmental threats at 27% of businesses; the current rate is 63% (Darin Rice, Ecology Hazardous Waste and Toxics Reduction Program, written communication). Additional resources are needed to reduce the environmental threat rate to 30% by 2015, resulting in less contamination to soil, air, and water.

Data Needs

PSTLA was a four-year effort primarily focused on assessing chemical loads to Puget Sound from all of the major delivery pathways (groundwater, air deposition, surface water runoff, publicly-owned treatment works, and ocean exchange). This assessment will be useful in putting other scientific studies and action priorities into perspective, and possibly helping to shape new ones. However, there appears to be little value in pursuing further refinements to basin-wide loading assessments for the chemicals already addressed. This does not preclude the need for additional loading refinements for particular pathways or basin-wide modeling exercises, but it appears that current data needs should be conducted at a finer resolution to focus specific actions. These smaller scales may be geographical (e.g. watersheds, specific land covers, urban bays), specific pathways (e.g. stormwater), related to specific sources (e.g. the contribution of emissions sources to chemicals in stream runoff), or assessments of hazards (e.g. local hazard evaluation).

The following recommendations are provided to fill these finer-scale data needs:

- Characterize the factors that lead to high COC concentrations in streams draining commercial/industrial and agricultural areas. Assess runoff in high-density urban areas and, if warranted, assess the factors leading to high COC concentrations as well.

- Collect information on agricultural and urban usage of copper-based products in the Puget Sound basin.

- Evaluate concentrations of cadmium, copper, lead, zinc, and DEHP released from various roofing materials.

- For any work conducted to assess PAHs and petroleum hydrocarbons in surface runoff or POTWs, include sampling and analytical methods better suited to detection of these chemicals.

- Stormwater discharges directly to Puget Sound or to major rivers near their mouths should be assessed for chemicals to evaluate the importance of this loading pathway. Although the surface runoff study (Herrera, 2011) theoretically encompassed these conveyances, they were likely underestimated since high-density urban areas were under-represented in the study. Much of the information required for such an assessment may soon be available through data collection and reporting requirements of the Phase 1 municipal stormwater permit. A detailed analysis of this dataset should be conducted.

- Incorporate the data collected under PSTLA into the Puget Sound Box Model for the purpose of evaluating reductions needed to meet the Puget Sound “dashboard indicators” and other appropriate environmental targets. In addition to PCBs, selected metals, PBDEs, and PAHs appear to be good candidates for modeling since there are ample opportunities for control actions and the model may be able to predict conditions needed to meet reduction targets.

- More information is needed to help distinguish natural and legacy sources of contaminants in environmental pathways such as surface water runoff. This will help gauge the feasibility and effectiveness of actions taken to reduce releases of chemicals from contemporary anthropogenic (human-caused) releases.

- Continue to identify and assess chemicals that may be more detrimental to the Puget Sound ecosystem than the COCs addressed in PSTLA studies. Current-use pesticides, pharmaceuticals, and personal care products are examples of chemicals that are delivered to fresh and marine surface waters of the Puget Sound basin, yet their potential for effects is poorly understood (Lubliner et al., 2010).

- In general, industrial, commercial, and institutional point sources do not account for large releases of COCs. Instead, a variety of diffuse (nonpoint) sources account for a majority of the COC releases. However, it will be important to ensure that both the results of this *Assessment Report* and data on existing prevention and management controls help guide future actions and investments on Puget Sound clean-up and restoration work.

  Lack of investment in existing programs designed to safely manage COCs produced by commerce can let otherwise controlled and contained COCs “out of their bottle,” where they become a threat to Puget Sound. For example, Washington ranks near the bottom of states in the U.S. for safe hazardous waste management (Darin Rice, Ecology Hazardous Waste and Toxics Reduction Program, written communication). Hazardous wastes are persistent, toxic, flammable, or reactive, and when mismanaged, they contaminate land, air, and water. Environmental threats are posed from millions of pounds of hazardous waste and hazardous products in the Puget Sound basin. Conducting fewer hazardous waste inspections results in more violations that directly contaminate land and water. So it is not surprising that as state inspection resources have diminished, the chance of finding spills of COCs and other significant environmental threats are at historic highs (Darin Rice, Ecology Hazardous Waste and Toxics Reduction Program, written communication).

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Appendices

Appendix A. Summary of the Puget Sound Toxics Loading Analysis (PSTLA) Projects

Project	Ref	Preparer	Status	Type of Study
Phase 1				
Initial Estimate of Toxic Chemical Loadings to Puget Sound	Hart Crowser et al., 2007	Hart Crowser, Ecology, EPA, Partnership	Completed - 2007	Loading estimates. Simple model using available data.
Phase 2				
Improved Estimates of Loadings from Surface Runoff and Roadways Addendum 1 (related to oil and petroleum) Addendum 2 (related to loading calculation method)	Envirovision et al., 2008a Ecology, 2009 Herrera, 2010	EnviroVision, Herrera, Ecology Ecology Herrera	Completed - 2008 Addendum 1 - 2009 Addendum 2 - 2010	Loading estimates. Simple model using available data. Clarification of oil and petroleum definitions. Revised and improved methodology for estimating runoff volumes.
Improved Estimates of Loadings from Dischargers of Municipal and Industrial Wastewater	Envirovision et al., 2008b	EnviroVision, Herrera, Ecology	Completed - 2008	Loading estimates. Simple model using available data.
Sediment Flux/Puget Sound Sediments Bioaccumulation Model – Derived Concentrations for Toxics	Ecology and Environment, 2009	Ecology and Environment	Completed - 2009	Criteria Evaluation. Bioaccumulation model using available data.
Identification and Evaluation of Water Column Data for Puget Sound and Its Ocean Boundary	Serdar, 2008	Ecology	Completed - 2008	Inventory and evaluation of existing data.
Studies to Support a Human Health Risk Assessment		EPA/Kissinger	Status unknown	Studies using available information to assess risks to human health from ingestion of toxicants in seafood.
Development of Simple Numerical Models – The Long-Term Fate and Bioaccumulation of Polychlorinated Biphenyls in Puget Sound	Pelletier, and Mohamedali, 2009	Ecology	Completed - 2009	Fate and bioaccumulation model for PCBs. Complex model using available data.
A Toxics-Focused Biological Observing System for Puget Sound	Johnson et al., 2010a	NOAA, UC Davis, WDFW	Completed - 2010	Proposal to monitor toxicants. Based on review of existing data.
Phase 3				
Characterize Toxic Chemical Loadings via Surface Runoff	Herrera, 2011	Herrera, Ecology	Completed - 2011	Sampling and loading estimates. Simple model using newly acquired field data.
Modeling Surface Runoff in Two Pilot Watersheds	Under Development	Under Development	Under development	Under Development
Study of Atmospheric Deposition of Air Toxics to the Waters of Puget Sound	Brandenberger et al., 2010	Battelle, Ecology	Completed - 2010 (PCBs complete 2011)	Sampling and loading estimates. Simple model using newly acquired field data.
Characterization of Toxic Chemicals in Marine Waters and Selected Tributaries to Puget Sound	Gries and Osterberg, 2011	Ecology	Completed - 2011	Sampling and loading estimates. Simple model using newly acquired field data.
Refine Numerical Model of Toxics in Puget Sound and Evaluate Pollution Reduction Scenarios	Under Development	Under Development	Under development	Under Development
Priority Pollutant Scans of Ten POTWs	Ecology and Herrera, 2010	Ecology, Herrera	Completed - 2011	Sampling and loading estimates. Simple model using newly acquired field data.
Primary Sources of Selected Toxic Chemicals and Quantities Released in the Puget Sound Basin	Ecology, 2011	Ecology	Completed - 2011	Inventory of chemical releases using available data.
Pharmaceuticals and Personal Care Products in Wastewater Treatment Systems	Lubliner et al., 2010	Ecology, EPA	Completed - 2010	Evaluation of POTW treatment efficacy and sampling. Evaluation based on newly acquired field data.
Persistent Organic Pollutants in Three Guilds of Pelagic Marine Species from the Puget Sound	West, et al., 2011a and b; Noel et al., 2011	WDFW	Completed - 2011	Assessment of bioaccumulative chemicals in plankton, fish, and harbor seals. Based on newly acquired field data
Toxic Chemical Loadings via Groundwater Discharge Directly to Puget Sound	Pitz, 2011	Ecology	Completed - 2011	Loading estimates. Simple model using available data.
Assessment Report	Present Report	Ecology, King County DNR	Completed - 2011	Synthesis of existing PSTLA loading and sources information, hazard evaluation

Appendix B. Chemicals Analyzed for Loading Studies and Methods Used to Handle Non-Detects

Table B-1. Chemicals Analyzed for Loading Studies.

Chemical Class		Loading Study				
	Chemical	Surface Runoff [a]	Atm. Dep.[b]	POTWs[c]	Ocean Exch.[d]	Ground-water[e]
Metals						
	Aluminum	X				
	Arsenic	**X**	**X**		**X**	**X**
	Barium	X				
	Beryllium	X				
	Cadmium	**X**	**X**		**X**	**X**
	Cobalt	X				
	Copper	**X**	**X**	**X**	**X**	**X**
	Lead	**X**	**X**	**X**	**X**	**X**
	Manganese	X				
	Mercury	**X**	**X**			**X**
	Monomethyl mercury		X			
	Nickel	X				
	Selenium	X				
	Thallium	X				
	Tin	X				
	Zinc	**X**	**X**	**X**	**X**	**X**
Polychlorinated Biphenyls (PCBs)						
	21 "NOAA Status & Trends" Congeners[f]		**X**			
	209 PCB Congeners	**X**		**X**	**X**	
Polybrominated Diphenyl Ethers (PBDEs)						
	14 PBDE Congeners[g]		**X**			
	38 PBDE Congeners[h]	**X**		**X**	**X**	
Polychlorinated Dibenzodioxins and Furans (PCDD/Fs)						
	Total TCDD					**X**
	Total TCDF					**X**

Table B-1 (Cont'd). Chemicals Analyzed for Loading Studies.

Chemical Class		Loading Study				
	Chemical	Surface Runoff [a]	Atm. Dep.[b]	POTWs[c]	Ocean Exch.[d]	Ground-water[e]
Chlorinated Pesticides						
	2,4'-DDD	**X**		**X**	**X**	**X**
	2,4'-DDE	**X**		**X**	**X**	**X**
	2,4'-DDT	**X**		**X**	**X**	**X**
	4,4'-DDD	**X**		**X**	**X**	**X**
	4,4'-DDE	**X**		**X**	**X**	**X**
	4,4'-DDT	**X**		**X**	**X**	**X**
	Aldrin	X		X	X	
	alpha-BHC	X		X	X	
	beta-BHC	X		X	X	
	delta-BHC	X		X	X	
	gamma-BHC (Lindane)	X		X	X	
	Chlorpyriphos	X		X	X	
	cis-Chlordane	X		X	X	
	trans-Chlordane	X		X	X	
	Chlordane	X		X	X	
	Dacthal (DCPA)	X		X	X	
	DDMU			X		
	Dieldrin	X		X	X	
	Endosulfan I	X		X	X	
	Endosulfan II	X		X	X	
	Endosulfan sulfate	X		X	X	
	Endrin	X		X	X	
	Endrin Aldehyde	X		X	X	
	Endrin Ketone	X		X	X	
	Heptachlor	X		X	X	
	Heptachlor epoxide	X		X	X	
	Hexachlorobenzene	X		X	X	
	Methoxychlor	X		X	X	
	Mirex	X		X	X	
	cis-Nonachlor	X		X	X	
	trans-Nonachlor	X		X	X	
	Oxychlordane	X		X	X	
	Toxaphene	X		X	X	

Table B-1 (Cont'd). Chemicals Analyzed for Loading Studies.

Chemical Class		Loading Study				
	Chemical	Surface Runoff [a]	Atm. Dep.[b]	POTWs[c]	Ocean Exch.[d]	Groundwater[e]
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)						
	Acenaphthene	**X**		**X**	**X**	**X**
	Acenaphthylene	**X**		**X**	**X**	**X**
	Anthracene	**X**	**X**	**X**	**X**	**X**
	Fluorene	**X**		**X**	**X**	**X**
	Naphthalene	**X**		**X**	**X**	**X**
	Phenanthrene	**X**	**X**	**X**	**X**	**X**
High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)						
	Benzo(a)anthracene*	**X**	**X**	**X**	**X**	**X**
	Benzo(a)pyrene*	**X**	**X**	**X**	**X**	**X**
	Benzo(b)fluoranthene*	**X**	**X**	**X**	**X**	**X**
	Benzo(g,h,i)perylene	**X**	**X**	**X**	**X**	**X**
	Benzo(k)fluoranthene*	**X**	**X**	**X**	**X**	**X**
	Chrysene*	**X**	**X**	**X**	**X**	**X**
	Dibenzo(a,h)anthracene*	**X**	**X**	**X**	**X**	**X**
	Fluoranthene	**X**	**X**	**X**	**X**	**X**
	Indeno(1,2,3-cd)pyrene*	**X**	**X**	**X**	**X**	**X**
	Pyrene	**X**	**X**	**X**	**X**	**X**
Phthalate Esters						
	Bis(2-ethylhexyl)phthalate	**X**		**X**	**X**	**X**
	Butylbenzylphthalate	X		X	X	
	Diethylphthalate	X		X	X	
	Dimethylphthalate	X		X	X	
	Di-N-butylphthalate	X		X	X	
	Di-N-octylphalate	X		X	X	
Herbicides						
	2,3,4,5-Tetrachlorophenol	X		X		
	2,3,4,6-Tetrachlorophenol	X		X		
	2,4,5-T	X		X		
	2,4,5-TP (Silvex)	X		X		
	2,4,5-Trichlorophenol	X		X	X	
	2,4,6-Trichlorophenol	X		X	X	
	2,4-D	X		X		
	2,4-DB	X		X		
	3,5-Dichlorobenzoic acid	X		X		
	Acifluorfen	X		X		

Table B-1 (Cont'd). Chemicals Analyzed for Loading Studies.

Chemical Class		Loading Study				
	Chemical	Surface Runoff [a]	Atm. Dep.[b]	POTWs[c]	Ocean Exch.[d]	Ground-water[e]
Herbicides						
	Bentazon	X		X		
	Bromoxynil	X		X		
	Clopyralid	X		X		
	Dicamba I	X		X		
	Dichlorprop	X		X		
	Diclofop-methyl	X		X		
	Dinoseb	X		X		
	Ioxynil	X		X		
	MCPA	X		X		
	MCPP (Mecoprop)	X		X		
	Pentachloroanisole	X		X	X	
	Pentachlorophenol	X		X	X	
	Picloram	X		X		
	Triclopyr	**X**		**X**		
Semivolatile Organics						
	1,2,4,-Trichlorobenzene	X		X	X	
	1,2-Dichlorobenzene	X		X	X	
	1,2-Diphenylhydrazine	X			X	
	1,3-Dichlorobenzene	X		X	X	
	1,4-Dichlorobenzene	X		X	X	
	1,7-Dimethylphenanthrene		X			
	1-Methylnaphthalene	X		X	X	
	2,2'-Oxybis[1-chloropropane]				X	
	2,4-Dichlorophenol	X		X	X	
	2,4-Dimethylphenol	X		X	X	
	2,4-Dinitrophenol	X		X	X	
	2,4-Dinitrotoluene	X		X	X	
	2,6-Dimethylphenanthrene		X			
	2,6-Dinitrotoluene			X	X	
	2-Chloronaphthalene	X		X	X	
	2-Chlorophenol	X		X	X	
	2-Methylnaphthalene	X		X	X	
	2-Methylphenol			X	X	
	2-Nitroaniline	X		X	X	
	2-Nitrophenol	X		X	X	

Table B-1 (Cont'd). Chemicals Analyzed for Loading Studies

Chemical Class		Loading Study				
	Chemical	Surface Runoff [a]	Atm. Dep.[b]	POTWs[c]	Ocean Exch.[d]	Ground-water[e]
Semivolatile Organics						
	3,6-Dimethylphenanthrene		X			
	3,3'-Dichlorobenzidine	X		X	X	
	3B-Coprostanol			X	X	
	3-Nitroaniline	X		X	X	
	4,6-Dinitro-2-methylphenol	X		X	X	
	4-Bromophenylphenylether	X		X	X	
	4-Chloro-3-methylphenol	X		X	X	
	4-Chloroaniline	X		X	X	
	4-Chlorophenyl-Phenylether	X		X	X	
	4-Methylphenol	X		X	X	
	4-Nitroaniline	X		X	X	
	4-Nitrophenol	X		X	X	
	4-Nonylphenol	**X**		**X**	**X**	
	Benzoic acid			X	X	
	Benzyl alcohol			X	X	
	bis(2-Chloroethoxy)methane	X		X	X	
	bis(2-Chloroethyl)ether	X		X	X	
	Bisphenol A	X		X	X	
	Caffeine	X		X	X	
	Carbazole	X		X	X	
	Cholesterol	X		X	X	
	Dibenzofuran	X		X	X	
	Ethanol, 2-chloro, phosphate (3:1)	X		X	X	
	Hexachlorobutadiene	X		X	X	
	Hexachlorocyclopentadiene	X		X	X	
	Hexachloroethane	X		X	X	
	Isophorone	X		X	X	
	Nitrobenzene	X		X	X	
	N-Nitrosodimethylamine	X		X		
	N-Nitrosodi-N-propylamine	X		X	X	
	N-Nitrosodiphenylamine	X		X	X	
	Perylene		X			
	Phenol	X		X	X	
	Retene	X	X	X	X	
	Triclosan	X		X	X	
	Triethylcitrate	X		X	X	

Table B-1 (Cont'd). Chemicals Analyzed for Loading Studies

Chemical Class		Loading Study				
	Chemical	Surface Runoff [a]	Atm. Dep.[b]	POTWs[c]	Ocean Exch.[d]	Ground-water[e]
Oil & Grease and Petroleum Hydrocarbons						
	Oil & Grease	**X**				
	TPH-Gas range	**X**				**X**
	TPH-Diesel range	**X**				**X**
	TPH-Lube oil range	**X**				**X**
Anhydrosugars						
	Galactosan		X			
	Levoglucosan		X			
	Mannosan		X			
Perfluorinated Compounds						
	Perfluorodecanoate			X		
	Perfluoroheptanoate			X		
	Perfluorohexanoate			X		
	Perfluorononanoate			X		
	Perfluorooctanoate			X		
	Perfluorooctane sulfonate			X		
	Perfluoropentanoate			X		
	Perfluorohexane sulfonate			X		
	Perfluorobutanoate			X		
	Perfluorobutane sulfonate			X		
	Perfluorooctane sulfonamide			X		
	Perfluoroundecanoate			X		
	Perfluorododecanoate			X		

Bolded and Shaded cells indicate Chemicals of Concern

[a] Herrera, 2011

[b] Brandenberger et al., 2010

[c] Ecology and Herrera, 2010

[d] Gries and Osterberg, 2011

[e] Pitz, 2011

[f] 21 "NOAA Status & Trends" Congeners = PCB-8, -18, -28, -44, -52, -66, -77, -101, -105, -118, 126, -128, -138, -153, -170, -180, -187, -195, -200, -206, and -209

[g] 14 PBDE Congeners = PBDE-17, -28, -47, -66, -71, -85, -99, -100, -138, -153, -154, -183, -190, -209

[h] 38 PBDE Congeners = PBDE-7, -10, -15, -17, -28, -30, -47, -49, -66, -71, -77, -85, -99, -100, -119, -126, -138, -139, -140, -153, -154, -156/159, -171, -180, -183, -184, -191, -196, -197/204, -201, -203, -205, -206, -207, -208, -209

* Carcinogenic PAHs (cPAHs)

Table B-2. Methods Used to Derive Representative Chemical of Concern (COC) Concentrations Where Sample Results Include Non-Detects.

Loading Study	**Scenario and Substitution Methods for Non-Detects (NDs)**		**Rules for Summing Constituents for Groups (e.g. PAHs, PCBs)**	**Possible Bias as a Result of Method**	**COCs Where Substitution Method Was Used**
	All of data set NDs	**Part of data set NDs**			
Surface Runoff (Herrera, 2011)	Maximum RL used and the final derived values were presented as "<" and flagged with a "U"	Where ≥ 50% of results were ND, ½ MRL assigned to NDs and final value flagged as "E" Where < 50% of results were ND, ½ MRL assigned to NDs with no flag for final value	Only detected results were summed (zero assigned to NDs) Where all results were ND, the highest MRL was used to represent the sum	Substitution of ND with ½ MRL appears to be reasonable estimate in cases where up to 70% results are ND[a]. At higher rates of ND, this substitution method may yield conservative results (biased high) For summed parameters, the procedure used yields minimum or near-minimum possible values	Arsenic and copper were 0% ND (detected in 100% of samples) ½ MRL assigned to NDs for Lead, mercury, zinc, total PCBs, and total PBDEs were <50% ND (detected in ≥ 50% and < 100% of samples) ½ MRL assigned to NDs for cadmium, total PAHs, cPAH, LPAH, HPAH, DEHP, triclopyr, nonylphenol, and lube oil were ≥ 50% ND (detected in < 50% of samples)
Atmospheric Deposition (Brandenberger et al., 2010)	Not applicable	For all parameters except PCBs, MDLs assigned to NDs For PCBs, zero assigned to NDs	For all parameters except PCBs, detected results and NDs (assigned MDLs) were summed For PCBs, only detected results were summed (zero assigned to NDs)	For all parameters except PCBs, the procedure used yields maximum possible values For PCBs, the procedure used yields minimum possible values	MDLs assigned to NDs for PBDEs Zero assigned to NDs for PCBs
POTWs (Ecology and Herrera, 2010)	No attempt was made to derive representative concentration where FOD < 50%	Where n ≥ 10 and FOD ≥ 50%, ROS used to calculate representative concentration Where n < 10 and FOD ≥ 65%, ½ MRL assigned to NDs	Only detected results were summed (zero assigned to NDs) Where all results were ND, the highest MRL was used to represent the sum	Substitution of ND with ½ MRL appears to be reasonable estimate in cases where up to 50% results are ND[a]. This substitution procedure was not used at higher FODs. ROS method was found to yield similar results when compared to substitution of ND with ½ MRL. For summed parameters, the procedure used yields minimum or near-minimum possible values	Copper, lead, and zinc were 0% ND (detected in 100% of samples) ROS used for some PBDE congeners, some individual PAHs, and DEHP ½ MRL assigned to NDs for some PCB congeners Representative concentrations not calculated for DDT compounds, some individual PAHs, triclopyr, nonylphenol

Table B-2 (Cont'd). Methods Used to Derive Representative Chemical of Concern (COC) Concentrations Where Sample Results Include Non-Detects.

Loading Study	Scenario and Substitution Methods for Non-Detects (NDs)		Rules for Summing Constituents for Groups (e.g. PAHs, PCBs)	Possible Bias as a Result of Method	COCs Where Substitution Method Was Used
	All of data set NDs	**Part of data set NDs**			
Ocean Exchange (Gries and Osterberg, 2011)	No attempt was made to derive representative concentrations where all of data set were NDs	When most of the samples had detected results, only detected values were used to calculate representative concentrations When few of the samples had detected results, ½ RL assigned to NDs	Only detected results were summed (zero assigned to NDs) Where all results were ND, the highest MRL was used to represent the sum	Using only detected concentrations yields maximum possible values Substitution of ND with ½ MRL appears to be reasonable estimate in cases where up to 70% results are ND [a]. At higher rates of ND, this substitution method may yield conservation results (biased high) For summed parameters, the procedure used yields minimum or near-minimum possible values	Arsenic, cadmium, copper, and zinc were 0% ND (detected in 100% of samples) Only detected values were used to calculate representative lead concentrations ½ MRL assigned to NDs for PCBs and PBDEs Representative concentrations not calculated for DDT compounds, PAHs, DEHP, nonylphenol
Groundwater (Pitz, 2011)	Two methods were used: (1) ½ RL assigned to NDs, and (2) the minimum RL of the data set was assigned to NDs	Two methods were used: (1) ½ RL assigned to NDs, and (2) the minimum RL of the data set was assigned to NDs	All values were summed after values for individual chemicals were generated using the ND substitution procedures (½ RL or minimum RL)	Results appear to be biased low when comparing to results generated from using only detected values. Assignment of the minimum RL to NDs generates the most downward bias.	All procedures applied to all COCs

ND=non-detected
RL=reporting limit
MRL=maximum reporting limit
MDL=method detection limit
FOD=frequency of detection
ROS=regression on order statistics

[a] Antweiler, R.C. and H.E Taylor, 2008. Evaluation of statistical treatments of left-censored environmental data using coincident uncensored data sets: I. Summary statistics. Environmental Science and Technology 42: 3732-3728.

Appendix C. Summary of Release Estimates for All COCs (from Ecology, 2011)

Table C-1. Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Arsenic	**TOTAL**					**0.79 (0 - 1.7)**	**t/yr**	**100%**
Arsenic	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Unknown release	Unknown form	Air	0.28	t/yr	36% (0% - 100%)
Arsenic	Pesticides and Wood Preservation	CCA-treated wood	Leaching	Solubilized in water	Soil, Surface water	0.27 (0.04 - 0.5)	t/yr	34% (0% - 100%)
Arsenic	Buildings and Grounds	Roofing materials - asphalt shingle	Leaching, Corrosion	Solubilized in water, Particulate matter in water	Surface water, POTWs, Groundwater	0.15 (0 - 0.84)	t/yr	19% (0% - 100%)
Arsenic	Miscellaneous Material Use	Fertilizers	Direct application to soil	Solid, Liquid	Soil	0.06	t/yr	8% (0% - 100%)
Arsenic	Industrial and Institutional Point Sources	Wood-Treatment Facility	Unknown release	Unknown form	Water	0.01	t/yr	2% (0% - 100%)
Arsenic	Buildings and Grounds	Residential Fuel Use, except Wood	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	t/yr	1% (0% - 100%)
Cadmium	**TOTAL**					**0.96 (0.84 - 1.2)**	**t/yr**	**100%**
Cadmium	Buildings and Grounds	Roofing materials - total	Leaching, Corrosion	Solubilized in water, Particulate matter in water	Surface water, POTWs, Groundwater	0.59 (0.5 - 0.7)	t/yr	61% (53% - 68%)
Cadmium	Miscellaneous Material Use	Fertilizers	Direct application to soil	Solid, Liquid	Soil	0.26	t/yr	27% (22% - 31%)
Cadmium	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Fugitive air release	Dust, Vapor	Air	0.06	t/yr	6% (5% - 7%)
Cadmium	Vehicles and Roads	Tire wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	0.03 (<0.01 - 0.06)	t/yr	3% (<1% - 6%)
Cadmium	Vehicles and Roads	Brake pad wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	0.03 (<0.01 - 0.06)	t/yr	1% (<1% - 7%)
Cadmium	Buildings and Grounds	Residential Fuel Use, except Wood	Dispersal of dust following wear	Particulate matter, Fugitive dust	air	0.01	t/yr	<1%
Cadmium	Buildings and Grounds	Woodstoves and Fireplaces	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	t/yr	<1%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Cadmium	Non-Point Combustion Sources	Locomotive Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	t/yr	<1%
Cadmium	Industrial and Institutional Point Sources	Specialty Glass Manufacturer	Fugitive air release, Combustion	Dust, Vapor, Aerosols, Particulate matter	Air	<0.01	t/yr	<1%
Copper	**TOTAL**					**180 - 250 (120 - 390)**	**t/yr**	**100.0%**
Copper	Buildings and Grounds	Urban lawn & garden use of pesticides	Direct application to soil or vegetation	Solid, Liquid	Soil, Vegetation	1.1 - 73	t/yr	0.6% - 29% (0.3% - 38%)
Copper	Buildings and Grounds	Plumbing fixtures, pipes, and solder	Leaching	Solubilized in water	POTWs	39 (8.6 - 130)	t/yr	16% - 22% (4% - 45%)
Copper	Vehicles and Roads	Brake pad wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	37	t/yr	15% - 21% (10% - 31%)
Copper	Buildings and Grounds	Roofing materials - total	Leaching, Corrosion	Solubilized in water, Particulate matter in water	Surface water, POTWs, Groundwater	27 (12 - 43)	t/yr	11% - 16% (3% - 29%)
Copper	Industrial and Institutional Point Sources	Army Base	Unknown release	Unknown form	Unknown	25	t/yr	10% - 14% (6% - 21%)
Copper	Pesticides and Wood Preservation	Antifouling paint - total	Leaching, Ablation	Solubilized in water, Particulate matter in water	Marine surface water, Marine sediment	23 (12 - 54)	t/yr	9% - 13% (3% - 34%)
Copper	Pesticides and Wood Preservation	Agricultural use of pesticides - total	Direct application to soil or vegetation	Solid, Liquid	Soil, Vegetation	10	t/yr	4% - 6% (2% - 8%)
Copper	Miscellaneous Material Use	Micronutrients	Direct application to soil	Solid, Liquid	Soil	5.4	t/yr	2% - 3% (1% - 5%)
Copper	Industrial and Institutional Point Sources	Naval Shipyard	Fugitive air release, Undefined release to surface water	Dust, Vapor, Undefined form released to surface water	Air, Surface water, Other	5.1	t/yr	2% - 3% (1% - 4%)
Copper	Vehicles and Roads	Tire wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	1.9 (0.02 - 5.4)	t/yr	<1% - 1% (<1% - 4%)
Copper	Pesticides and Wood Preservation	Aquatic-use algaecides in pools, fountains, spas, etc.	Direct application to water in contained pools (swimming pools, fountains, etc.)	Solid, Liquid	POTWs, Soils	1.5	t/yr	<1% - 1% (<1% - 1%)

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Copper	Industrial and Institutional Point Sources	Other Industrial and Military Facilities	Unknown release	Unknown form	Unknown	0.83	t/yr	<1%
Copper	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Fugitive air release, Combustion	Dust, Vapor, Aerosols, Particulate matter	Air	0.44	t/yr	<1%
Copper	Industrial and Institutional Point Sources	Metal Foundries	Fugitive air release	Dust, Vapor	Air	0.22	t/yr	<1%
Copper	Pesticides and Wood Preservation	CCA-treated wood	Leaching	Solubilized in water	Soil, Surface water	0.06 (0.04 - 0.08)	t/yr	<1%
Lead	**TOTAL**					**520 (150 - 1,000)**	**t/yr**	**100%**
Lead	Outdoor Product Use	Ammunition, Hunting shot use	Intentional loss	Soilid metal	Soil, Surface water	370 (27 - 820)	t/yr	72% (13% - 87%)
Lead	Industrial and Institutional Point Sources	Army Base	Unknown release	Unknown form	Unknown	39	t/yr	8% (4% - 25%)
Lead	Outdoor Product Use	Fishing sinker loss	Unintentional loss	Soilid metal	Surface water, Aquatic sediment	36 (32 - 54)	t/yr	7% (3% - 31%)
Lead	Vehicles and Roads	Wheel weight loss	Unintentional loss	Solid metal	Impervious surfaces, Roadside areas	28 (20 - 29)	t/yr	5% (2% - 18%)
Lead	Buildings and Grounds	Roofing materials - total	Leaching, Corrosion	Solubilized in water, Particulate matter in water	Surface water, POTWs, Groundwater	18 (15 - 20)	t/yr	3% (2% - 12%)
Lead	Non-Point Combustion Sources	Aviation fuel combustion	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	16	t/yr	3% (2% - 10%)
Lead	Industrial and Institutional Point Sources	Various Industrial Facilities, not including pulp mills	Unknown release	Unknown form	Unknown	2.3	t/yr	<1% (<1% - 2%)
Lead	Industrial and Institutional Point Sources	Naval Shipyard	Unknown release	Unknown form	Unknown	1.8	t/yr	<1% (<1% - 1%)
Lead	Vehicles and Roads	Brake pad wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	2.6 (0.04 - 13)	t/yr	<1% (<1% - 8%)
Lead	Vehicles and Roads	Tire wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	1.2 (0.01 - 1.8)	t/yr	<1% (<1% - 1%)
Lead	Industrial and Institutional Point Sources	Pulp and Paper Mills	Undefined release to surface water	Undefined form released to surface water	Water	0.66	t/yr	<1%
Lead	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Fugitive air release, Combustion	Dust, Vapor, Aerosols, Particulate matter	Air	0.53	t/yr	<1%
Lead	Buildings and Grounds	Plumbing fixtures, pipes, and solder	Leaching	Solubilized in water	POTWs	0.21 (0.2 - 0.9)	t/yr	<1%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Lead	Miscellaneous Material Use	Fertilizers	Direct application to soil	Solid, Liquid	Soil	0.04	t/yr	<1%
Lead	Buildings and Grounds	Residential Fuel Use, except Wood	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.02	t/yr	<1%
Lead	Non-Point Combustion Sources	Locomotive Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	t/yr	<1%
Mercury	**TOTAL**					**0.54 (0.47 - 0.61)**	**t/yr**	**100%**
Mercury	Miscellaneous Material Use	Thermostat Disposal	Volatilization, Leaching, Washout	Vapor, Liquid, Particle-bound	Air, Groundwater, Soil	0.13 (0.11 - 0.16)	t/yr	24% (20% - 31%)
Mercury	Miscellaneous Material Use	Fluorescent Lamp Disposal	Volatilization	Vapor	Air	0.10	t/yr	18% (16% - 20%)
Mercury	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Unknown release	Unknown form	Air	0.05	t/yr	9% (8% - 11%)
Mercury	Industrial and Institutional Point Sources	Crematoria Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.05 (0.02 - 0.07)	t/yr	9% (4% - 12%)
Mercury	Industrial and Institutional Point Sources	Cement Plants	Volatilization, Combustion	Vapor, Aerosols, Particulate matter	Air	0.04	t/yr	8% (7% - 9%)
Mercury	Miscellaneous Material Use	Auto Convenience Switch Disposal	Volatilization, Leaching, Washout	Vapor, Liquid, Particle-bound	Air, Groundwater, Soil	0.04 (0.02 - 0.06)	t/yr	7% (4% - 12%)
Mercury	Industrial and Institutional Point Sources	Petroleum Refineries	Volatilization, Combustion	Vapor, Aerosols, Particulate matter	Air	0.03	t/yr	6% (5% - 7%)
Mercury	Personal Care Products	Dental Amalgam Excretion	Human Excretion	Excrement	POTWs, Groundwater	0.02	t/yr	4% (3% - 4%)
Mercury	Miscellaneous Material Use	Button Cell Batteries	Volatilization, Leaching, Washout	Vapor, Liquid, Particle-bound	Air, Groundwater, Soil	0.02	t/yr	4% (3% - 4%)
Mercury	Industrial and Institutional Point Sources	Steel Mills	Unknown release	Unknown form	Unknown	0.02	t/yr	3%
Mercury	Industrial and Institutional Point Sources	Residual Fuel Oil Combustion	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	t/yr	2%
Mercury	Personal Care Products	Dental Office Amalgam Waste	Wastewater	Liquid	POTWs, Groundwater	0.01	t/yr	2%
Mercury	Buildings and Grounds	Residential Fuel Use, except Wood	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	t/yr	1%
Mercury	Industrial and Institutional Point Sources	Pulp and Paper Mills	Undefined release to surface water	Undefined form released to surface water	Surface water	0.01	t/yr	1%
Mercury	Miscellaneous Material Use	Thermometers (Household)	Volatilization, Leaching, Washout	Vapor, Liquid, Particle-bound	Air, Groundwater, Soil	<0.01	t/yr	<1%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Mercury	Miscellaneous Material Use	Fertilizers	Direct application to soil	Solid, Liquid	Soil	<0.01	t/yr	<1%
Mercury	Industrial and Institutional Point Sources	Other Industrial and Military Facilities	Unknown release	Unknown form	Unknown	<0.01	t/yr	<1%
Mercury	Vehicles and Roads	Gasoline and Diesel Combustion	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	t/yr	<1%
Zinc	**TOTAL**					**1,500 (300 - 3,200)**	**t/yr**	**100%**
Zinc	Buildings and Grounds	Roofing materials - total	Leaching, Corrosion	Solubilized in water, Particulate matter in water	Surface water, POTWs, Groundwater	1,330 (210 - 2,800)	t/yr	87% (37% - 97%)
Zinc	Vehicles and Roads	Tire wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	82 (4.8 - 150)	t/yr	5% (<1% - 33%)
Zinc	Miscellaneous Material Use	Fertilizers and Micronutrients	Direct application to soil	Solid, Liquid	Soil	41	t/yr	3% (1% - 13%)
Zinc	Buildings and Grounds	Plumbing fixtures, pipes, and solder	Leaching	Solubilized in water	POTWs	30 (20 - 93)	t/yr	2% (<1% - 25%)
Zinc	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Volatilization, Fugitive air release, Combustion	Vapor, Dust, Aerosols, Particulate matter	Air	12	t/yr	<1% (<1% - 4%)
Zinc	Vehicles and Roads	Motor oil leaks and improper disposal				7.9 (5.7 - 8.9)	t/yr	<1% (<1% - 3%)
Zinc	Vehicles and Roads	Brake pad wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	7.1 (0.22 - 44)	t/yr	<1% (<1% - 13%)
Zinc	Industrial and Institutional Point Sources	Steel Mills	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	4.3	t/yr	<1% (<1% - 1%)
Zinc	Industrial and Institutional Point Sources	Pulp and Paper Mills	Undefined release to surface water	Undefined form released to surface water	Surface water	3.7	t/yr	<1% (<1% - 1%)
Zinc	Industrial and Institutional Point Sources	Naval Shipyard	Fugitive air release	Dust, Vapor	Air	1.8	t/yr	<1%
Zinc	Industrial and Institutional Point Sources	Petroleum Refineries	Unknown release	Unknown form	Unknown	1.1	t/yr	<1%
Zinc	Industrial and Institutional Point Sources	Other Industrial and Military Facilities	Unknown release	Unknown form	Unknown	0.77	t/yr	<1%
Zinc	Industrial and Institutional Point Sources	Steel Galvanizers	Unknown release	Unknown form	Unknown	0.73	t/yr	<1%
PCBs	**TOTAL**					**2,100 (1,500 - 2,800)**	**kg/yr**	**100%**
PCBs	Miscellaneous Material Use	Large capacitors	Leakage	Liquid	Soil, Impervious surfaces	1,100	kg/yr	52% (40% - 75%)
PCBs	Miscellaneous Material Use	Small capacitors	Leakage	Liquid	Soil, Impervious surfaces	500 (1 - 1,000)	kg/yr	24% (<1% - 41%)

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
PCBs	Buildings and Grounds	Residential Trash Burning	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	280	kg/yr	13% (10% - 19%)
PCBs	Miscellaneous Material Use	Transformers	Leakage	Liquid	Soil, Impervious surfaces	130 (7 - 250)	kg/yr	6% (<1% - 15%)
PCBs	Buildings and Grounds	Sealants (Caulking)	Volatilization, Abrasion and fragmentation from weathering	Vapor, Sorption to dust particles	Air, Fugitive dust	110 (71 - 140)	kg/yr	5% (3% - 9%)
PBDEs	**TOTAL**					**680** **(220 - 2,300)**	**kg/yr**	**100%**
PBDEs	Buildings and Grounds	Indoor office space air	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	430 (120 - 750)	kg/yr	64% (7% - 88%)
PBDEs	Buildings and Grounds	Indoor residential dust	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	160 (100 - 320)	kg/yr	23% (5% - 72%)
PBDEs	Buildings and Grounds	Indoor office space dust	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	78 (<0.01 - 1,200)	kg/yr	12% (<1% - 84%)
PBDEs	Buildings and Grounds	Indoor residential air	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	9.5 (0.6 - 18)	kg/yr	1% (<1% - 8%)
PCDD/Fs	**TOTAL**					**9.4**	**g TEQ/yr**	**100%**
PCDD/Fs	Buildings and Grounds	Backyard Burn Barrels	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	7.3	g TEQ/yr	77%
PCDD/Fs	Vehicles and Roads	Heavy Duty Diesel Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.81	g TEQ/yr	9%
PCDD/Fs	Industrial and Institutional Point Sources	Pulp and Paper Mills	Combustion, Undefined release to surface water	Aerosols, Vapor, Undefined form released to surface water	Air, Surface water	0.49	g TEQ/yr	5%
PCDD/Fs	Buildings and Grounds	Woodstoves and Fireplaces	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.38	g TEQ/yr	4%
PCDD/Fs	Non-Point Combustion Sources	Construction Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.18	g TEQ/yr	2%
PCDD/Fs	Vehicles and Roads	Light Duty Gasoline Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.08	g TEQ/yr	<1%
PCDD/Fs	Industrial and Institutional Point Sources	Cement Plants	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.05	g TEQ/yr	<1%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
PCDD/Fs	Vehicles and Roads	Light Duty Diesel Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.04	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Industrial Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.03	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Commercial Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.02	g TEQ/yr	<1%
PCDD/Fs	Industrial and Institutional Point Sources	Petroleum Refineries	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.02	g TEQ/yr	<1%
PCDD/Fs	Industrial and Institutional Point Sources	Other Industrial and Military Facilities	Unknown release	Unknown form	Air, Surface water	0.02	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Recreational Boat Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	g TEQ/yr	<1%
PCDD/Fs	Buildings and Grounds	Lawn and Garden Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Agricultural Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.01	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Logging Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	g TEQ/yr	<1%
PCDD/Fs	Vehicles and Roads	Heavy Duty Gasoline Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Airport Service Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	g TEQ/yr	<1%
PCDD/Fs	Non-Point Combustion Sources	Recreational Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	g TEQ/yr	<1%
PCDD/Fs	Industrial and Institutional Point Sources	Wood-Treatment Facility	Unknown release	Unknown form	Unknown	<0.01	g TEQ/yr	<1%
PAH	**TOTAL**					**310**	**t/yr**	**100%**
PAH	Buildings and Grounds	Woodstoves and Fireplaces	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	110	t/yr	34%
PAH	Pesticides and Wood Preservation	Creosote Treated Marine pilings - total	Leaching, Washout, Volatilization	Solubilized in water, Vapor	Surface water, Air	54	t/yr	18%
PAH	Pesticides and Wood Preservation	Creosote Treated Railroad ties	Leaching, Washout, Volatilization	Solubilized in water, Vapor	Soil, Air, Surface water	43	t/yr	14%
PAH	Vehicles and Roads	Light Duty Gasoline Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	29	t/yr	10%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
PAH	Pesticides and Wood Preservation	Creosote Treated Utility poles	Leaching, Washout, Volatilization	Solubilized in water, Vapor	Soil, Air, Surface water	17	t/yr	6%
PAH	Vehicles and Roads	Heavy Duty Gasoline Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	11	t/yr	3%
PAH	Vehicles and Roads	Petroleum spills, leaks, and improper motor oil disposal	Leakage, Spillage, Direct release, Improper disposal	Liquid	Impervious surfaces, Soils, Stormwater, POTWs, Landfills	11	t/yr	3%
PAH	Buildings and Grounds	Residential Trash Burning	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	6.5	t/yr	2%
PAH	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Combustion, Volatilization	Aerosols, Vapor, Particulate matter	Air	5.2	t/yr	2%
PAH	Buildings and Grounds	Lawn and Garden Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	5.0	t/yr	2%
PAH	Industrial and Institutional Point Sources	Pulp and Paper Mills	Volatilization, Fugitive air release, Combustion	Vapor, Dust, Aerosols, Particulate matter	Air	3.2	t/yr	1%
PAH	Industrial and Institutional Point Sources	Aluminum Mills	Volatilization, Fugitive air release, Combustion	Vapor, Dust, Aerosols, Particulate matter	Air	2.7	t/yr	<1%
PAH	Industrial and Institutional Point Sources	Petroleum Refineries	Fugitive air release, Volatilization, Combustion	Dust, Vapor, Aerosols, Particulate matter	Air	2.3	t/yr	<1%
PAH	Non-Point Combustion Sources	Commercial Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	2.0	t/yr	<1%
PAH	Vehicles and Roads	Heavy Duty Diesel Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	1.8	t/yr	<1%
PAH	Non-Point Combustion Sources	Construction Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	1.3	t/yr	<1%
PAH	Vehicles and Roads	Gas Station Emissions	Volatilization	Vapor	Air	1.2	t/yr	<1%
PAH	Vehicles and Roads	Tire wear	Abrasion	Particulate matter	Impervious surfaces, Roadside areas, Air, POTWs	0.98	t/yr	<1%
PAH	Non-Point Combustion Sources	Recreational Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.94	t/yr	<1%

Table C-1 (Cont’d). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
PAH	Vehicles and Roads	Coal tar sealants	Leaching, Abrasion	Solubilized in water, Particulate matter in water	stormwater, fugitive air, dust	0.92 (0.17 - 1.7)	t/yr	<1%
PAH	Non-Point Combustion Sources	Recreational Boat Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.86	t/yr	<1%
PAH	Industrial and Institutional Point Sources	Other Industrial and Military Facilities	Unknown release	Unknown form	Air, Surface water, Other	0.58	t/yr	<1%
PAH	Buildings and Grounds	Roofing materials - total	Leaching	Particulate matter, Solubilized in water	Surface water, POTWs	0.57	t/yr	<1%
PAH	Non-Point Combustion Sources	Locomotive Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.49	t/yr	<1%
PAH	Non-Point Combustion Sources	Industrial Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.30	t/yr	<1%
PAH	Vehicles and Roads	Light Duty Diesel Vehicle Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.21	t/yr	<1%
PAH	Buildings and Grounds	Residential Yard Waste Burning	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.15	t/yr	<1%
PAH	Non-Point Combustion Sources	Logging Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.05	t/yr	<1%
PAH	Non-Point Combustion Sources	Agricultural Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.04	t/yr	<1%
PAH	Buildings and Grounds	Residential Fuel Use, except Wood	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.04	t/yr	<1%
PAH	Non-Point Combustion Sources	Cigarette smoke	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.03 (0.02 - 0.03)	t/yr	<1%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
PAH	Vehicles and Roads	Asphalt - total	Leaching, Abrasion	Solubilized in water, Particulate matter in water	stormwater, fugitive air, dust	0.02	t/yr	<1%
PAH	Non-Point Combustion Sources	Airport Service Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	0.02	t/yr	<1%
PAH	Non-Point Combustion Sources	Railroad Maintenance Equipment Emissions	Combustion emissions	Aerosols, Particulate matter, Vapor	Air	<0.01	t/yr	<1%
Phthalates	**TOTAL**					**34**	**t/yr**	**100%**
Phthalates	Personal Care Products	Fragrance	Washout, Volatilization	Liquid, Vapor	POTWs, Groundwater, Air	11	t/yr	32%
Phthalates	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Unknown release	Unknown form	Air	9.6	t/yr	28%
Phthalates	Vehicles and Roads	Car undercoating	Washout, Vapor	Liquid, Vapor	Surface water, Soil, Air	3.3	t/yr	10%
Phthalates	Miscellaneous Material Use	Lacquers and paint	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	1.9	t/yr	5%
Phthalates	Buildings and Grounds	PVC Coil coated roofing	Leaching, Volatilization	Liquid, Vapor	Surface water, POTWs, Air	1.5	t/yr	4%
Phthalates	Personal Care Products	Nail polish	Washout, Volatilization	Liquid, Vapor	POTWs, Groundwater, Air	1.4	t/yr	4%
Phthalates	Miscellaneous Material Use	PVC Coated fabric	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	1.2	t/yr	4%
Phthalates	Miscellaneous Material Use	Sealants, adhesives, etc.	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	1.1	t/yr	3%
Phthalates	Industrial and Institutional Point Sources	Plastics Manufacturer	Volatilization	Vapor	Air	0.86	t/yr	3%
Phthalates	Personal Care Products	Hair spray (aerosol and pump spray)	Washout, Volatilization	Liquid, Vapor	POTWs, Groundwater, Air	0.4	t/yr	1%
Phthalates	Miscellaneous Material Use	PVC Cables (outdoor, above ground)	Volatilization	Vapor, Sorption to soil	Air	0.35	t/yr	1%
Phthalates	Personal Care Products	Deodorant (solid)	Washout, Volatilization	Liquid, Vapor	POTWs, Groundwater, Air	0.29	t/yr	<1%
Phthalates	Miscellaneous Material Use	Shoe soles	Abrasion	Dust particles	Surface runoff, POTWs, Fugitive dust	0.2	t/yr	<1%
Phthalates	Buildings and Grounds	PVC Wall coverings	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	0.14	t/yr	<1%
Phthalates	Buildings and Grounds	PVC Roofing material	Leaching, Volatilization	Solubilized in water, Vapor	Surface water, POTWs, Air	0.14	t/yr	<1%
Phthalates	Buildings and Grounds	PVC Flooring	Volatilization, Abrasion	Vapor, Dust particles	Air, Fugitive dust	0.1	t/yr	<1%
Phthalates	Miscellaneous Material Use	PVC Films, sheets, coated products	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	0.1	t/yr	<1%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Phthalates	Buildings and Grounds	PVC Hoses and profiles (outdoor)	Volatilization	Vapor	Air	0.09	t/yr	<1%
Phthalates	Buildings and Grounds	PVC Cables (indoor)	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	0.08	t/yr	<1%
Phthalates	Buildings and Grounds	PVC Hoses and profiles (indoor)	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	0.08	t/yr	<1%
Phthalates	Miscellaneous Material Use	Printing inks	Washout, Volatilization	Liquid, Vapor	POTWs, Groundwater, Air	0.08	t/yr	<1%
Phthalates	Industrial and Institutional Point Sources	Boat Manufacturer	Volatilization	Vapor	Air	0.05	t/yr	<1%
Phthalates	Industrial and Institutional Point Sources	Chemicals Distribution	Volatilization	Vapor	Air	0.04	t/yr	<1%
Phthalates	Industrial and Institutional Point Sources	Paint and Coatings Manufacturers	Volatilization	Vapor, Sorption to dust particles	Air, Fugitive dust	0.03	t/yr	<1%
Phthalates	Industrial and Institutional Point Sources	Other Industrial and Military Facilities	Volatilization	Vapor	Air	0.02	t/yr	<1%
Triclopyr	**TOTAL**					**150 (63 - 240)**	**t/yr**	**100%**
Triclopyr	Pesticides and Wood Preservation	Crop and Golf Course Use	Direct application to vegetation	Liquid	Vegetation and soils	150 (60 - 240)	t/yr	98% (95% - 99%)
Triclopyr	Pesticides and Wood Preservation	Forest Herbicide Use - State Forests	Direct application to vegetation	Liquid	Vegetation and soils	0.8 (0.4 - 1.2)	t/yr	<1% (<1% - 1%)
Triclopyr	Pesticides and Wood Preservation	Aquatic Weed Control	Direct application to surface water	Liquid or granular	Surface water	0.68	t/yr	<1% (<1% - 2%)
Triclopyr	Pesticides and Wood Preservation	Right-of-Way Maintenance--State Forests	Direct application to vegetation	Liquid	Vegetation and soils	0.5	t/yr	<1%
Triclopyr	Buildings and Grounds	Urban lawn & garden use of pesticides	Direct application to soil or vegetation	Liquid	Soil, Vegetation	0.43	t/yr	<1%
Triclopyr	Vehicles and Roads	Right-of-Way Maintenance - State Highways	Direct application to vegetation	Liquid	Vegetation and soils	0.3	t/yr	<1%
Triclopyr	Vehicles and Roads	Right-of-Way Maintenance - Railroads	Direct application to vegetation	Liquid	Vegetation and soils	0.1	t/yr	<1%
Nonylphenol	**TOTAL**					**0.18**	**t/yr**	**100%**
Nonylphenol	Industrial and Institutional Point Sources	Ind, Comm, Inst Sources (primarily Title V)	Unknown release	Unknown form	Air	0.18	t/yr	100%

Table C-1 (Cont'd). Summary of Release Estimates for All COCs.

COC	Activity/Source Category	Specific Source	COC Release Mechanism	Form of Release	Initial Receiving Medium	Best Estimate of Release (Range)	Unit	Percent of Total (Range)
Petroleum	**TOTAL**					**9,300**	**t/yr**	**100%**
Petroleum	Vehicles and Roads	Motor oil drips and leaks	Leakage	Liquid	Impervious surfaces	6,100	t/yr	66%
Petroleum	Vehicles and Roads	Minor gasoline spills from fueling vehicles and non-road equipment	Spillage	Liquid	Impervious surfaces, Soils	1,900	t/yr	21%
Petroleum	Vehicles and Roads	Improper disposal of used oil following oil changes	Direct release, Improper disposal	Liquid	Stormwater, Soils, POTWs, Landfills	960	t/yr	10%
Petroleum	Miscellaneous Material Use	Petroleum spills (large)	Spillage	Liquid	Surface water, Soil, Impervious surfaces	228 (223 - 233)	t/yr	3% (2% - 3%)

Appendix D. Hazard Evaluation Summary

Appendix D-1. Description of Methodology and Data Assessed (see the following pages)

The following sections of Appendix D are available only online as links to this *Assessment Report:* www.ecy.wa.gov/biblio/1103055.html

Appendix D-2. Hazard Evaluation – Results of Prioritization

Appendix D-3. Hazard Evaluation – Plots of Observed and Effects Data for Surface Waters

Appendix D-4. Hazard Evaluation – Plots of Observed Data and Threshold Values for Sediments

Appendix D-5. Hazard Evaluation – Plots of Observed and Effects Data for Tissue Residues

Appendix D-6. Hazard Evaluation – Plots of Estimated and Effects Doses for Wildlife

Appendix D-7. Hazard Evaluation – Plots of Observed Data and Criteria for Human Health

Appendix D-8. Hazard Evaluation – Summary Statistics for Environmental (Observed) Data

Appendix D-9. Hazard Evaluation – Water Effects Summary Data

Appendix D-10. Hazard Evaluation – Sediment Guidelines

Appendix D-11. Hazard Evaluation – Tissue Residue Effects Data

Appendix D-12. Hazard Evaluation – Wildlife Effects Data

Appendix D-13. Hazard Evaluation – ECOTOX QA Summary

Description of Contents for Appendix D

Appendix D-1
Description of the methodology and data assessed for the hazard evaluation. Includes a narrative summary of the results.

Appendix D-2
Tables showing results for the hazard evaluation. Each table shows a summary of whether the observed concentrations exceed threshold values, and notes on the data used for the comparisons.

Appendix D-3
Plots comparing observed environmental concentrations to effects concentrations for surface water.

Appendix D-4
Plots comparing observed environmental concentrations to guidelines for sediment.

Appendix D-5
Plots comparing observed environmental concentrations to effects concentrations for tissue residue.

Appendix D-6
Plots comparing calculated environmental doses to effects doses for wildlife.

Appendix D-7
Plots comparing observed environmental tissue concentrations to criteria for human health.

Appendix D-8
Tables showing summary statistics for the observed environmental concentrations used in the hazard evaluation.

Appendix D-9
Folder containing tables with summaries of ECOTOX data used in the hazard evaluation (the petroleum effects data are not from ECOTOX). A file containing ECOTOX codes is also included in this folder.

Appendix D-10
Table showing guidelines and other threshold values for sediment.

Appendix D-11
Tables showing summaries of the tissue residue effects for Lower Willamette River and the Lower Duwamish River Remedial Investigations

Appendix D-12
Folder containing tables with summaries of wildlife effects data. A list of references reviewed for the wildlife evaluation is also included in this folder.

Appendix D-13
Folder containing tables with summaries of the quality assurance (QA) review of the ECOTOX data and units.

Appendix D-1

Hazard Evaluation for Chemicals of Concern in the Puget Sound Basin – Description of Methodology and Data Assessed

Introduction

This chapter outlines the methods and results of the assessment conducted to estimate the relative hazard posed by exposure to the chemicals of concern (COCs) assessed in the Puget Sound Toxics Loading Analysis (PSTLA) studies. The primary purpose of this assessment was to provide a general overview of the potential for these COCs to cause adverse effects (to aquatic life and select wildlife species), and to a lesser extent, human health effects through seafood consumption within the Puget Sound basin. The assessment described here was not intended to identify specific ecological effects or quantify risk. The primary purpose of the assessment was to provide an additional weight of evidence (WOE), along with the loadings and sources information (documented in the main body of this report), to prioritize COCs for further action.

The large scale regional focus was intended to evaluate COCs at a broad level. A key goal of this effort was to provide information to help prioritize COCs based on their potential to cause adverse effects. The assessment used some of the chemical concentration data generated by the PSTLA studies discussed in this report; however, readily available environmental data for water, sediment and tissue from other sources were the primary basis of this prioritization process. To estimate the potential for effects, environmental data were compared to readily available toxicity data obtained primarily from established databases, sources and regulations. The outcome of this process was used to establish a general "priority" for management of each of the COCs.

This assessment included the following evaluations:

- Direct hazard to aquatic life through surface water exposure
- Direct hazard to benthic organisms through sediment exposure
- Direct hazard to aquatic life based on tissue residue levels
- Hazard to wildlife based on ingestion of prey, water and sediment
- Hazard to human health through fish/seafood consumption

Although some elements of the "Risk Assessment" process were applied to the hazard prioritization presented here, this effort is not intended to serves as a risk assessment. Conducting such an assessment for the Puget Sound region was beyond the scope of this effort. The remainder of this section describes the process used to acquire both the observed environmental data and toxicity data, in addition to the assumptions used to access and use this information. The section also documents the methods used to conduct the effects prioritization, including a description of the process used to determine the priority for each COC. Finally, the results of the assessment (organized by COC) and a discussion of the uncertainty and limitations associated with this process are presented.

Methods

The following sections describe the process used to identify and acquire both the observed environmental data and the toxicity data used for this assessment. Also described is the approach used to assess effects to wildlife, including selection of representative species ("receptors") and appropriate COCs, derivation of daily doses (to estimate toxicity from ingestion pathways) and the model used to estimate exposure to COCs by wildlife. Lastly, the processes used to summarize the environmental and effects data, determine the potential for effects and priority are described.

Environmental Data Collection

Environmental data, collected from a variety of sources, were used to estimate the general range of possible exposure concentrations to COCs. With the exception of a few specific sources, data collection was limited to readily available public databases and only those data collected between January 1, 2000 and July 2010 were considered "recent" and included. When available, surface water, sediment and tissue data were collected from the sources outlined in Table 1. Due to the different purposes for which some of these data were collected, not all sources included data for all matrices in both fresh water and marine environments.

Table 1. Summary of data sources and data types used in this assessment. All data were accessed from their respective sources in July 2010.

Data Source	Matrix					
	Water		Sediment		Tissue	
	Fresh	Marine	Fresh	Marine	Fresh	Marine
Ecology's EIM System [1]	X	X	X	X	X	X
King County's LIMS[2]	X	X	X	X	X	X
US Geological Survey [3]	X	N/A	See Footnote[3]	N/A	X	N/A
Puget Sound Ambient Monitoring Program	N/A	N/A	N/A	N/A	N/A	X
Regional EMAP [4]	N/A	N/A	N/A	X	N/A	X
ENNVEST Study [5]	N/A	N/A	N/A	N/A	N/A	X
Toxics Loading Studies [6]	X	X	N/A	N/A	N/A	X
WDFW[7]	N/A	N/A	N/A	N/A	N/A	X

N/A – data not available

1 - EIM – Ecology's Environmental Information Management System

2- LIMS - Laboratory Information Management System, King County data not previously submitted to EIM

3 - USGS data obtained from online database. Sediment data were obtained but not used; USGS only analyzes the <63µ sediment fraction, which is not comparable to the remainder of the data used in this assessment.

4 - Includes NOAA's mussel watch data (Valerie Partridge, Environmental Assessment Program, written communication, 2010).

5- US Department of Defense (Johnston, R.K. 2007)

6 - Includes Ecology's Ocean Exchange/River Mouth Loading study, Fish Tissue Assessment and Surface Runoff studies discussed in this document.

7 – Washington Department of Fish and Wildlife (West et al. 2011).

The datasets described in Table 1 were combined into a composite database. This process required a number of "rules" and assumptions to ensure that data were consistently formatted (similar naming conventions, units etc.) and in a chemical form appropriate for later comparison to effect concentrations. Table 2 outlines the key rules and assumptions used to combine and process the environmental data.

Table 2. Summary of rules and assumptions used to acquire and summarize observed environmental data.

All Data

- The COC list was expanded to include all forms of these chemicals.
- Data from all sources were standardized to reflect parameter and qualifier names as defined by EIM. When no EIM parameter (for certain co-eluting PBDE congeners) was available the closest match was selected.
- Only data collected between January 1, 2000 and July, 2010 were acquired.
- All data were standardized to common units.
- **Qualified** ”B” qualified data and “estimated data” were included. Data with the <u>following qualifiers were not included</u> in the assessment:
    - “Rejected Data”
    - The following “U” qualified non-detect data - “U”, “U?”, “UJ”, “UJG”, “UJK”,” UJL”.
- **Summing** - Polychlorinated biphenyl’s (PCBs), polycyclic aromatic hydrocarbons (PAHs) and dioxins in all matrices were summed based on SMS rules:
    - For summed compounds, only compounds detected in a sample were summed.
- **PAHS**
    - LPAHs include naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene
    - HPAHs include fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes (B, J and K), Benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
    - cPAHs were not summed for any media because standards and toxicity information for the sum of cPAHs whereas not available for water, sediment, tissue, or in the NTR.
- **Petroleum Compounds** – data for the following petroleum related compounds were identified and collected: TPH as heavy fuel oil, Diesel range TPH, Gasoline range TPH, Lube oil range TPH.

Sediment Data

- Organic carbon (OC) normalization was conducted for marine sediment data when the corresponding sediment quality value was OC-normalized. Otherwise, all sediment data were dry-weight normalized.
- USGS freshwater sediment data were presented as the chemical concentration in the <63 µm fraction. These sediment data were not used due to incompatibility with the majority of the available sediment data.

Tissue Data

- Tissue data were grouped into common tissue type designations for the tissue residue, wildlife and human health assessments. For example, mussel tissue data labeled as “somatic” and “visceral” were categorized as “whole body no shell”. Whole body tissue data labeled as “no-gut”, “no exoskeleton” were classified as “whole body”. Fillet data classified as “skin on”, “no skin” were combined and classified as “fillet”. Lipid-normalized tissue data were not used in this assessment due to the inconsistencies and availability of lipid data for all tissue concentrations.

The majority of data used in the assessment were obtained from EIM, followed by the King County LIMs. The remaining datasets were relatively small in comparison, but were included because the parameters and matrices measured complemented the EIM and LIMS datasets. While it is recognized that there may be other sources of environmental data (e.g., various research publications, NOAA, USFW) that could have been included in this assessment, due to the scope and timeline associated with this task, it was necessary to focus on the largest and most readily available electronic sources of primarily ambient data that did not require significant data review or re-entry. Since the intent of this effort was to better understand general regional conditions and not identify "hot spots", these data are assumed to provide reasonable estimates of exposure.

A review of the NOAA database (http://response.restoration.noaa.gov/type_subtopic_entry.php?RECORD_KEY%28entry_subtopic_type%29=entry_id,subtopic_id,type_id&entry_id(entry_subtopic_type)=751&subtopic_id(entry_subtopic_type)=5&type_id(entry_subtopic_type)=1) indicated that a significant proportion the applicable data were already included in EIM and LIMs and much of the data had been collected before 2000. A large proportion of the remaining data were primarily collected from the Duwamish River CERCLA site. It was decided that inclusion of these data in the assessment would possibly skew the results.

The primary goal of this assessment was to provide a high level summary evaluation of relative hazard; therefore, the data were differentiated into three course spatial scales; (1) freshwater, (2) marine nearshore, and (3) marine offshore. The freshwater to nearshore boundary was defined by the original data. If data were classified as "freshwater" by the original data source, they were retained as such; if classified as marine/saltwater the data were further parsed between near and offshore. Nearshore was defined as all marine areas less than 10 meters deep (based on MLLW); offshore was defined as all other marine areas.

Data records not meeting the intent of the nearshore/offshore designation were adjusted accordingly (e.g., marine locators >10m in depth in estuaries like the Duwamish were classified as nearshore). Some sample depths varied due to tidal influences. However, relatively few samples were attributed close enough to the 10m depth (e.g. 9m or 11m) to potentially fall into a different marine area based on depth of tide at the time of sampling.

Comparison of sediment data to sediment guidelines (described below) required that the marine sediment data for nonionic/non-polar organic chemicals be organic carbon (OC) -normalized. Dry-weight concentrations were used for marine sediment samples when OC was outside the range of 0.5 to 3.0%. No associated OC data were available for approximately 35% of the sediment samples. To utilize these samples, these data were OC-normalized using the mean nearshore (2.22%) or mean offshore (1.74%) OC percentages from the remaining sediment results. The process of correcting sediment data for OC resulted in some differences in the total number of measurements (N) for OC and dry weight normalized data presented in the summary tables and figures. For example, for a given COC the N for dry weight-based measurements may be 5, while the N for the OC-normalized measurements is 1.

Tissue data were grouped differently depending on which assessment was being conducted. Tissue samples were segregated into fresh, nearshore and offshore samples based on the location they were collected. Table 3 attributes tissue to freshwater or marine species for informational purposes.

Table 3. Fish and invertebrate tissues and their groupings for the assessments using tissue data.

Common name	Latin Name	Fresh vs Marine	Tissue Assessment	Human Health Assessment	Wildlife Assessment
Asian clam	*Corbicula fluminea*	FW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Bay ghost shrimp	*Neotrypaea californiensis*	SW	Decapod	Other invertebrate	not included
Bay mussel	*Mytilus trossulus*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Bent-nose macoma	*Macoma nasuta*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Black bullhead	*Ameiurus melas*	FW	Fish	Fish	Fish
Black crappie	*Pomoxis nigromaculatus*	FW	Fish	Fish	Fish
Blackmouth (Resident) Chinook salmon	*Oncorhynchus tshawytscha*	SW	Fish	Fish	Fish
Blue mussel	*Mytilus edulis*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Bluegill	*Lepomis macrochirus*	FW	Fish	Fish	Fish
Brook trout	*Salvelinus fontinalis*	FW	Fish	Fish	Fish
Brown bullhead	*Ameiurus nebulosus*	FW	Fish	Fish	Fish
Brown Rockfish	*Sebastes auriculatus*	SW	Fish	Fish	Fish
Brown trout	*Salmo trutta*	FW	Fish	Fish	Fish
Bull trout	*Salvelinus confluentus*	FW	Fish	Fish	Fish
Butter clam	*Saxidomus giganteus*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate

Table 3. Fish and invertebrate tissues and their groupings for the assessments using tissue data.

Common name	Latin Name	Fresh vs Marine	Tissue Assessment	Human Health Assessment	Wildlife Assessment
California mussel	*Mytilus californianus*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Catworm genus	*Nephtys*	SW	Bivalve + other invertebrates	Other invertebrate	not included
Channel catfish	*Ictalurus punctatus*	FW	Fish	Fish	Fish
Chinook salmon	*Oncorhynchus tshawytscha*	SW	Fish	Fish	Fish
Chum salmon	*Oncorhynchus keta*	SW	Fish	Fish	Fish
Coho salmon	*Oncorhynchus kisutch*	SW	Fish	Fish	Fish
Common carp	*Cyprinus carpio*	FW	Fish	Fish	Fish
Copper rockfish	*Sebastes caurinis*	SW	Fish	Fish	Fish
Cutthroat trout	*Oncorhynchus clarkii*	FW	Fish	Fish	Fish
Dabs	*Pleuronectidae*	SW	Fish	Fish	Fish
Dock shrimp	*Pandalus danae*	SW	Decapod	Other invertebrate	not included
Dungeness crab	*Cancer magister*	SW	Decapod	Other invertebrate	Invertebrate
English sole	*Parophrys vetulus*	SW	Fish	Fish	Fish
Fat gaper	*Tresus capax*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Flathead sole	*Hippoglossoides elassodon*	SW	Fish	Fish	Fish
Gaper clam	*Tresus sp.*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Graceful rock crab	*Cancer gracilis*	SW	Decapod	Other invertebrate	Invertebrate
Hake	*Merluccius*	SW	Fish	Fish	Fish

Table 3. Fish and invertebrate tissues and their groupings for the assessments using tissue data.

Common name	Latin Name	Fresh vs Marine	Tissue Assessment	Human Health Assessment	Wildlife Assessment
	productus				
Japanese littleneck	*Tapes philippinarum*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Kokanee	*Oncorhynchus nerka*	FW	Fish	Fish	Fish
Largemouth bass	*Micropterus salmoides*	FW	Fish	Fish	Fish
Largescale sucker	*Catostomus macrocheilus*	FW	Fish	Fish	Fish
Lingcod	*Ophiodon elongatus*	SW	Fish	Fish	Fish
Longnose sucker	*Catostomus catostomus*	FW	Fish	Fish	Fish
Lumbriculus oligochaete	*Lumbriculus*	FW	Bivalve + other invertebrates	Other invertebrate	not included
Macoma clams	*Macoma sp.*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Mediterranean mussel	*Mytilus galloprovincialis*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Melita amphipods	*Melitidae*	SW	Decapod	Other invertebrate	not included
Milky venus	*Compsomyax subdiaphana*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Mountain whitefish	*Prosopium williamsoni*	FW	Fish	Fish	Fish
Northern pikeminnow	*Ptychocheilus oregonensis*	FW	Fish	Fish	Fish
Pacific Dover sole	*Microstomus*	SW	Fish	Fish	Fish

Table 3. Fish and invertebrate tissues and their groupings for the assessments using tissue data.

Common name	Latin Name	Fresh vs Marine	Tissue Assessment	Human Health Assessment	Wildlife Assessment
	pacificus				
Pacific geoduck	*Panopea abrupta*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Pacific herring	*Clupea pallasii*	SW	Fish	Fish	Fish
Pacific littleneck	*Protothaca staminea*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Pacific oyster	*Crassostrea gigas*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Pacific staghorn sculpin	*Leptocottus armatus*	SW	Fish	Fish	Fish
Pacific Tomcod	*Microgadus proximus*	SW	Fish	Fish	Fish
Peamouth	*Mylocheilus caurinus*	FW	Fish	Fish	Fish
Pile perch	*Rhacochilus vacca*	SW	Fish	Fish	Fish
Pink salmon	*Oncorhynchus gorbuscha*	SW	Fish	Fish	Fish
Pollock	*Theragra chalcogramma*	SW	Fish	Fish	Fish
Prickly sculpin	*Cottus asper*	SW	Fish	Fish	Fish
Pumpkinseed sunfish	*Lepomis gibbosus*	FW	Fish	Fish	Fish
Purple mahogany-clam	*Nuttallia obscurata*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Pygmy whitefish	*Prosopium coulterii*	FW	Fish	Fish	Fish
Quillback rockfish	*Sebastes maliger*	SW	Fish	Fish	Fish
Rainbow trout	*Oncorhynchus mykiss*	FW	Fish	Fish	Fish

Table 3. Fish and invertebrate tissues and their groupings for the assessments using tissue data.

Common name	Latin Name	Fresh vs Marine	Tissue Assessment	Human Health Assessment	Wildlife Assessment
Ratfish	*Hydrolagus colliei*	FW	Fish	Fish	Fish
Red rock crab	*Cancer productus*	SW	Decapod	Other invertebrate	Invertebrate
Redside shiner	*Richardsonius balteatus*	FW	Fish	Fish	Fish
Reticulate sculpin	*Cottus perplexus*	FW	Fish	Fish	Fish
Rock bass	*Ambloplites rupestris*	FW	Fish	Fish	Fish
Rock sole	*Lepidopsetta bilineata*	SW	Fish	Fish	Fish
Sand sole	*Psettichthys melanostictus*	SW	Fish	Fish	Fish
Scorpion fishes (Order)	Scorpaeniformes	SW	Fish	Fish	not included
Sea cucumber	*Molpadia intermedia*	SW	Bivalve + other invertebrates	Other invertebrate	Invertebrate
Shiner perch	*Cymatogaster aggregata*	SW	Fish	Fish	Fish
Signal crayfish	*Pacifastacus leniusculus*	FW	Decapod	Other invertebrate	Invertebrate
Sixgill shark	*Hexanchus griseus*	SW	Fish	Fish	not included
Slender sole	*Eopsetta exilis*	SW	Fish	Fish	Fish
Smallmouth bass	*Micropterus dolomieui*	FW	Fish	Fish	Fish
Softshell clam	*Mya arenaria*	SW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Spot prawn	*Pandalus platyceros*	SW	Decapod	Other invertebrate	not included

Table 3. Fish and invertebrate tissues and their groupings for the assessments using tissue data.

Common name	**Latin Name**	**Fresh vs Marine**	**Tissue Assessment**	**Human Health Assessment**	**Wildlife Assessment**
Staghorn Sculpin	*Leptocottus armatus*	SW	Fish	Fish	Fish
Starry flounder	*Platichthys stellatus*	SW	Fish	Fish	Fish
Striped seaperch	*Embiotoca lateralis*	SW	Fish	Fish	Fish
Western Pearlshell	*Margaritifera falcata*	FW	Bivalve + other invertebrates	Bivalve-clam	Invertebrate
Yellow perch	*Perca flavescens*	FW	Fish	Fish	Fish

Summary Statistics

All environmental data were combined by matrix (water, sediment, tissue) and spatial location (freshwater, marine near- and offshore). Tissues were also grouped into “bivalve”, “fish” and “other invertebrate” categories for the human health assessment. Both fillet and whole-body samples were used for the human health assessment. For the tissue residue assessment, tissues were divided into “fish”; “non-decapod invertebrates”, and “decapods” (crabs and shrimps); all tissue residue comparisons were based on whole-body tissue concentrations. Summary statistics (min, max, mean, median, total number of samples, and frequency of detection) for these data were calculated using MSAccess and Total Access Statistics. Summary statistics for each matrix are presented in Appendix E.

Identification of Effects Concentrations

Unless noted otherwise, all toxicity data used in this assessment were obtained from readily available databases. A literature search was conducted to identify studies of contaminant impacts to northwest regional species which may not have been included in available toxicity databases. In many cases the regional data were not dose-response effects data and inappropriate to directly compare with observed environmental concentrations (i.e. data were lipid normalized, study included multiple chemical exposures, field based studies, etc.). These data are primarily discussed as an additional WOE when evaluating the overall hazard for each COC. The following sections describe the process used to obtain the effects data and any assumptions used in their selection.

Surface Water – Direct Effects to Aquatic Life

To determine the potential for effects to aquatic life from direct exposure to COCs in surface water, relevant effects concentrations were identified to compare with the observed environmental data. EPA’s ECOTOXicology (ECOTOX) database (http://cfpub.epa.gov/ecotox) was the primary source of surface water effects data. The “Advanced Database Query” option in ECOTOX was used to obtain the majority of the data which allows for selection of specific taxonomic, chemical, result, condition, publication, and report formats to suit the project needs.

The following rules were used to identify the appropriate toxicological effects data.

- Both aquatic plant and animal data were included in the search process (animal data were accessed in July 2010; plant data were accessed and added in June 2011).
- Effect concentrations classified as EC0, LC0, NOEC, NOEL, and NR-ZERO were not included because they were considered “no effect” results.
- Concentration units based on area (e.g., AI kg/ha, ae kg/ha), or any unit other than volume were excluded. Molar-type units (i.e., M, uM, nM) were converted to ug/L.
- The following endpoint types were included from the ECOTOX database: Lethal Concentration (LC)/Lethal Dose (LD), Effect Concentration (EC)/Effect Dose (ED), Lowest Observable Effect Concentration (LOEC), Lowest Observable Effect Level (LOEL), and NR-LETH (Near Lethal) values, and all effect measurements for both fresh and saltwater organisms. Endpoint types such as bioaccumulation factor, inhibition concentration, and time to mortality were not used. Bioaccumulation was addressed to some degree in the tissue,

wildlife and human health assessments described below. A detailed evaluation of the potential for effects associated with bioaccumulation was beyond the scope of this assessment.

- Washington State water quality criteria were included for comparison when available. Concentration types were selected to match the water quality criteria where available. Thus, for most metals, effects associated with the dissolved concentration type were used for comparison to freshwater and marine observed data. Total and dissolved mercury were used due to the different forms used by the acute and chronic WQC. Formulation type (F) was excluded for COCs except triclopyr, DDTs, and PCBs.
- If "NR" (not reported) was the result for concentration or media type (freshwater or saltwater), then that effect value was excluded.

A summary of the data derived from the ECOTOX database used in this assessment can be found in Appendix D-9.

Although efforts are made by EPA to accurately represent toxicity data in the ECOTOX database, the data are not thoroughly vetted through a detailed quality control process. It was beyond this effort's capacity to review each of the thousands of original papers and documents from which ECOTOX was derived. However, to provide additional confidence in the quality of the ECOTOX data, 125 randomly selected documents were obtained and reviewed for accuracy and correspondence with ECOTOX. These papers represented approximately 5% of those identified by this assessment.

To evaluate the accuracy of molar unit conversions by ECOTOX, 25 papers were reviewed. Molar units were found to be converted correctly by 24 of the 25 randomly selected papers. One paper did not measure metallic zinc as reported by ECOTOX, it was instead evaluating zinc pyrithione, an organic zinc antifouling compound. If this paper is considered as reporting error the "unit error" rate is 3%.

To evaluate the ability of the ECOTOX database to accurately represent the data presented in the original source, 100 journal articles were reviewed representing 821 individual toxicity values. The review resulted in identification of 171 values that were incorrectly represented by ECOTOX (20% error rate) and would have an impact on the outcome of the assessment. A number of other errors were identified (e.g., misclassification of effects types and test species), but they did not impact the outcome of this assessment. The majority of errors were associated with use of the salt concentration of a COC to represent the effect concentration, rather than the active ingredient concentration.

Other common errors were associated with the classification of NOEC values as effect concentrations and the use of mixture concentrations to represent a single chemical exposure. Use of the salt concentration as the effect concentration rather than the active ingredient would likely underestimate the potential for effects, while use of NOEC values would likely overestimate the potential. A summary of the results of the ECOTOX QA/QC process can be found in Appendix D-13.

Sediment – Direct Effects to Benthic Organisms

To determine potential hazard to benthic organisms from direct exposure to sediment COCs, relevant sediment guidelines and thresholds were identified for comparison with the observed environmental data. The primary standards and guidelines used in this assessment were the Washington State Marine Sediment Management Standards (SMS) and the Floating Percentile (FP) based freshwater sediment guidelines developed by Ecology (Avocet Consulting 2003; Avocet Consulting and SAIC 2002; RESET 2009). A number of other sediment guidelines were also used to provide additional context to assess the sediment data. Because this effort was not exhaustive, not all available guidelines were included.

Three sets each of freshwater and marine sediment guidelines (total of 6 sets of guidelines) were selected for comparison to observed sediment concentrations. It is acknowledged that sediment pore water may be an additional important route of exposure for benthic organisms; however, readily accessible pore water toxicity data and observed pore water concentration data for the Puget Sound regional were not available. In addition, variability in the methods used to extract and analyze pore water makes comparison across studies challenging.

Marine sediment data were compared to the following guidelines/standards:

- The Washington State SMS (Chapter 173-204 WAC), which consist of two levels, a "Sediment Quality Standard" (SQS) and "Cleanup Screening Level" (CSL) and the "Apparent Effects Thresholds" (AETs) including the "Lowest AET" (LAET) and the "Second Lowest AET" (2-LAET)
- The Canadian Marine Sediment Guidelines (CCME 2001) which consist of a "threshold effect level" (TEL) and a "probable effects level" (PEL).

The SMS SQS was the primary standard used to evaluate the marine sediment data; the remainder of the guidelines presented and described here were intended to provide additional context and included as part of the WOE discussion.

The SMS SQS represents the concentration below which no adverse effects to biological resources are expected; the CSL is less stringent and corresponds to the concentration at which minor adverse effects to biological resources are expected. For comparison to the SMS, all nonionic/nonpolar organic compounds were normalized to percent total organic carbon (TOC) content. However, if TOC content was outside the range considered appropriate for normalization, (i.e., less than 0.5 or greater that 3.0 percent), these data were only compared with the Puget Sound AETs. An AET represents the chemical concentration above which adverse biological effects have been demonstrated to always occur. The LAET was used as the equivalent of the SQS, and the 2LAET was used to represent the CSL.

The Canadian Marine Sediment Guidelines consist of two thresholds. The TEL represents the concentration below which adverse biological effects are expected to rarely occur, while the PEL defines the level above which adverse effects are expected to frequently occur. The TELs and PELs represent three effect ranges:

- The minimal effect range within which adverse effects rarely occur (i.e., fewer than 25% of samples have adverse effects occur below the TEL)
- The possible effect range within which adverse effects occasionally occur (i.e., the range between the TEL and PEL)
- The probable effect range within which adverse biological effects frequently occur (i.e., more than 50% of samples have adverse effects above the PEL) (CCME 2001).

The freshwater sediment data were compared to three sets of sediment guidelines. Ecology's FP based freshwater sediment guidelines Avocet Consulting 2003; Avocet Consulting and SAIC 2002; RESET 2009, the Canadian Freshwater Sediment Guidelines (CCME 2001, Smith et al. 1996), and the Consensus-based Guidelines (MacDonald et al. 2000) were used; all guidelines consist of a set of two thresholds.

The 2003 Draft Washington FP guidelines obtained from Ecology's EIM database were used in this assessment and include the "Sediment Quality Standard" (FP-SQS) and a "Cleanup Screening Value" (FP-CSL). The FP-SQS was the primary threshold used to evaluate the freshwater sediment data; the remainder of the thresholds/guidelines described here were used to provide additional context and included as part of the WOE discussion. The FP thresholds were developed based on bioassay hit definitions from Washington's marine SQS and the CSL. The FP thresholds include a third guideline based on a statistically significant difference (STAT); the STAT guideline was not used in this prioritization process.

The FP SQS defines a biological effect when the difference between the mortality rate in the test and control is greater than 10%, when the growth test/control ratio is less than 0.8 and when the decrease in Microtox® luminescence test/control ratio is less than 0.85. The FP CSL defines a biological effect when the test results for the same bioassays are greater than 25%, less than 0.7, and less than 0.75, respectively. A more detailed description of the derivation of these thresholds can be found in Avocet Consulting (2003) and Avocet Consulting and SAIC (2002).

Similar to the marine guidelines described above, the Canadian Freshwater Sediment guidelines (CCME 2001) consist of a "Threshold Effect Level" or TEL that represents the concentration below which effects are infrequently observed and a "Probable Effects Level" or PEL, which represents the concentration above which effects are frequently observed.

The Consensus Based Freshwater Sediment Guidelines (MacDonald et al. 2000) consist of a "Threshold Effects Concentration" or TEC, the level below which effects are not expected and a "Probable Effects Concentration" or PEC, the level above which effects are expected. In this context the term "consensus" does not mean agreement among scientists on the best guideline, but rather that a variety of sediment quality guidelines from different sources were combined to generate the thresholds. A more detailed discussion of the derivation of all of these sediment thresholds (except the FP's) can be found in Wenning et al. 2005. A summary of the sediment guidelines used in this assessment are presented in Appendix D-10,

Tissue – Direct Effects to Aquatic Life

To determine the potential for effects to aquatic life via waterborne or dietary exposure to the COCs, relevant tissue residue effect concentrations were identified for comparison with the observed environmental tissue residue data described above. Initially, the Environmental Residue Effects Database (ERED) (http://el.erdc.usace.army.mil/ered/) was identified as the source of effects data for the tissue assessment.

Due to the complexities associated with tissue residue data and concern for using data appropriate for this assessment, 25% of the 100 original papers on which the ERED data were based were reviewed for accuracy. Review of the original literature resulted in an unacceptable error rate (~50%). Numerous errors were identified and included use of the dose concentration to represent the effect concentration, a value not represented by a statistically significant effect, and incorrect values (e.g., paper did not measure concentration in tissue, a lipid normalized value presented as a wet weight value). Due to the high error rate, use of the ERED database would require review of all original data sources, which was beyond the scope of this project. A summary of the results of the ERED QA/QC process can be found in Appendix D-13.

As an alternative, two regional efforts that evaluated tissue residue effects were identified. Both the Lower Duwamish Waterway Group and the Lower Willamette Group recently completed final and draft, Remedial Investigation Baseline Ecological Risk Assessments respectively, which included review and evaluation of tissue residue effects data (Windward 2010, Windward 2009). Both groups identified numerous tissue residue effects concentrations that were subsequently reviewed by toxicologists from various agencies and groups. Since these data had been previously reviewed and vetted by numerous professionals, they were identified as a readily available reliable source of tissue residue effects data for this assessment.

The tissue residue effects concentrations are intended to estimate the direct effect of a COC on an organism via waterborne or dietary exposure. Although considerable effort has been expended over the years to relate tissue metal residues to effects, with the exception of selenium, mercury and tributyl-tin, these efforts have achieved only limited success (Adams et al. 2010).

Due to the disparate physical/chemical characteristics of metals, their environmental presence in multiple forms and states, the fact that some are essential micronutrients and some are controlled by metabolic processes, metals and inorganics as a group continue to be more toxicologically challenging than organics when trying to apply the tissue residue approach. Residue approaches for metals require detailed consideration of metal specific and species specific details and determination of the toxicologically active fraction of the total body/organ tissue residue (Luoma and Rainbow 2005 in McCarty 2010).

The development of the Biotic Ligand Model (BLM) for some metals demonstrates the successful use of a tissue residue based approach for metals that can be used when the target organ and receptors have been identified and the amount of metal necessary to produce toxicity has been established. However, this is not necessarily the case for whole-body tissue residue concentrations for most metals. Aquatic organisms use a variety of storage, detoxification and excretion mechanisms to address metal exposure. As a result, measuring the total metal in an organism provides limited information regarding the biologically active metal concentrations within an organism (Adams et al. 2010; Meador et al. 2008). Due to the complexity of this type of assessment, a meaningful evaluation of metal tissue residues requires a much more detailed evaluation of the available toxicity data than could be conducted here. Therefore, tissue residue data for metals were not evaluated in this hazard prioritization process.

Although there are similar limitations in the use of tissue residue effects concentrations for organic chemicals, the relationships for some compounds (e.g., bioaccumulative and persistent) are much more established (Meador et al. 2008). Thus, the tissue assessment was restricted to bioaccumulative organic compounds that are not readily metabolized and for which data (effects and observed environmental) were available (mercury, PCBs, PBDEs, DDTs, and dioxins). When available, whole-body tissue residue effects data for fish, non-decapod invertebrates and decapods were used in the assessment. All of the available tissue residue effects data were based on wet weight concentrations. Where possible, a qualitative assessment of regionally based lipid normalized effects thresholds are discussed as part of the WOE discussion. A summary of the effects data used in this assessment can be found in Appendix D-11.

Wildlife

Four wildlife receptors were selected for evaluation by this assessment; harbor seal, osprey, river otter and great blue heron (A detailed description of species selection is described in the subsequent section on wildlife receptor and COC selection). The wildlife effects thresholds are based on the daily dose (mg chemical/kg-body weight/day) of a COC known to cause adverse effects to test species of birds or mammals. There are no state or federal standards to evaluate contaminants in wildlife; wildlife effects doses were obtained from published dose-response studies. These studies typically expose test animals to a COC through ingestion of food or water containing known contaminant concentrations and observe any effects on growth, reproduction, development or survival.

Effect doses for this assessment were obtained from multiple publications, some being compilations of effect doses from EPA efforts and included the Great Lakes Water Quality Initiative Criteria Documents (EPA 1995), the Ecological Soil Screening Levels (EPA 2007), Toxicological Benchmarks for Wildlife (Sample et al. 1996), the Draft Lower Willamette River Remedial Investigation Baseline Ecological Risk Assessment (Windward 2009) and the Lower Duwamish Waterway Remedial Investigation Baseline Ecological Risk Assessment (Windward 2010). Individual publications supplemented these sources as available. Effects doses were applied as they were presented in the source documents unless errors of interpretation were found (e.g., the dose causing an effect is incorrect, typographical errors, unit conversion errors). Safety or uncertainty factors were not used to estimate potentially hazardous levels in the assessment.

Due to data availability issues, it is common to use data from published dose-response studies conducted on test species (birds or mammals) other than those of interest in an assessment. All daily doses associated with either bird or mammal species were grouped for use with the appropriate bird or mammal receptor identified for this study. For the effects daily doses calculated directly from published data, safety factors were not applied to adjust for interspecies, lowest effect to no effect value, or any other uncertainty. This decision was made because there is no knowledge of which direction, and to what magnitude uncertainty would be biased. For example, the sensitivity of one species to chemical exposure may be greater or lesser than another. Until each species is tested, it is impossible to predict which species will be more sensitive and the degree of difference in sensitivity between species. In addition, safety factors are not standardized and therefore, when applied, are not consistent in magnitude.

A number of field studies have documented bioaccumulation of PCBs and dioxins/furans in Puget Sound harbor seals and orcas, conducted biopsies and examined immune suppression in these organisms (Ross et al. 1995, de Swart et al. 1996, Ross et al. 1996, Ross et al. 2004, Levin et al. 2005, Cullon et al. 2009). However, to date, a dose-response study has not been conducted to provide the necessary information to develop a toxicity-based daily ingestion dose for marine mammals. Because these results are not dose-response studies, they could not be used in the quantitative part of this assessment. They are instead discussed qualitatively as part of the WOE discussion. Published research on wildlife exposure and effects to COCs conducted in or near Puget Sound are summarized in the Results Section. A summary of the quantitative effects data used in the wildlife assessment can be found in Appendix D-12.

Human Health

The effect threshold used for the human health assessment was based on the National Toxics Rule (NTR) 40CFR§131.36. A number of national and regional fish consumption rates (Table 5) were calculated using the same methods to provide additional perspective and because the NTR specified rate is considered under protective for certain populations and ethnic groups such as Asians, Pacific Islanders and Native Americans. The tissue thresholds were derived by back calculating intake rates from existing water quality criteria using the applicable bioconcentration factors (BCFs) presented in the original water quality criteria development documents. COCs not part of the NTR were not assessed for human health hazards, e.g. lead, triclopyr, and the sum of cPAHs although individual PAHs were prioritized.

Table 5. List of consumption limits assessed in this document.

Guidance/Reference	Rate
NTR Standard Rate(64 FR 61184)	6.5 gm/day
EPA Recreational Rate (EPA 2000)	17.5 gm/day
EPA Subsistence Rate (EPA 2000)	142.4 gm/day
Tulalip Tribal/King County Asian Pacific Islander Rate (Toy 1996; Sechena 1999)	242.5 gm/day
Suquamish Tribal Rate (Suquamish Tribe 2000)	769 gm/day

There are no applicable human health standards for sediment. Both the Washington Sediment Management Standards and the Model Toxics Control Act (MTCA) use site specific assessments of exposure to assess human health risk; however, this process was not practical to conduct on a Puget Sound regional scale. Potential effects associated with exposure to sediment through recreational, shell fishing, or beach use would require parameterizing a human health risk assessment which was beyond the scope of this project. Similarly, water was not evaluated because recreational or consumptive water uses would require developing regional estimates of lifetime human water exposures which was also beyond the scope of this project.

Petroleum

Total petroleum hydrocarbons (TPH) is a term used to describe a large family of chemical compounds that originate from crude oils, coal tars, oil shales, and similar materials. The specific composition of petroleum products varies depending upon (1) the source of the crude oil and (2) the refining practices used to produce the product. TPH and "TPH gasoline" represent a mixture of petroleum compounds and serve as coarse estimates of the presence of the individual constituents that may cause toxicity to aquatic organisms. The ECOTOX database used for the water assessment only includes data for individual chemical components and does not include toxicity data for complex mixture compounds such as TPH. As a result, it was necessary to use a slightly different approach to assess TPH mixtures.

Toxicological evaluation of petroleum mixtures have historically been conducted in the aftermath of oil spills and similar events. Sources consulted for toxicity information on TPH and petroleum products were API, 1994; Barron, et al. 1999a; Barron, et al. 1999b; Tsvetnenko, 1998; and Woodward et al. 1983. The majority of the available toxicity data were for crude oils; however, these studies were deemed unsuitable since none of the available observed environmental data were for crude oils.

Based on availability of both observed and effects data, four classifications of petroleum products from the available environmental data were evaluated: heavy fuel/bunker oil, diesel fuel, gasoline, lube oil. Only toxicity results assessing the water soluble fraction (without free product) were used to assess these data. A more complete evaluation of petroleum would require analysis of parent and alkyl PAHs as well as issues such as phototoxicity which were beyond the scope of this assessment. In addition to the specific assessment for petroleum described here, a suite of individual and high/low molecular weight PAHs were evaluated in both the water and sediment assessments previously described above.

Selection of Wildlife Receptors and COCs

The following section describes the process used to select wildlife species and COCs evaluated in the wildlife assessment. When conducting a wildlife effects assessment, it is necessary to select a finite number of species or "receptors". In part, this is due to the impracticality of trying to assess effects to all wildlife species that reside in the Puget Sound region.

Receptors are generally assumed to be conservative representatives of other species with similar diets, trophic status and biology. A bird and a mammal species were evaluated in freshwater habitats and marine habitats. Two bird (osprey and great blue heron) and two mammal species (harbor seal and river otter) were selected based on their position as top level predators, a diet consisting primarily of fish, and their use of different feeding strategies, all of which make them at greatest risk of exposure. In addition, a substantial amount of ecological information has been published about these species allowing reasonable exposure modeling assumptions.

The four selected receptors are not intended to represent all wildlife species that may be exposed to COCs in the Puget Sound area. However, these receptors do represent other piscivorous species which tend to bioaccumulate chemicals to a greater degree than lower trophic level species.

The great blue heron was selected as the freshwater bird species because it is a common, piscivorous bird in Puget Sound freshwater and marine habitats. Some populations exclusively reside and feed in freshwater habitats as evidenced by large, established heron rookery sites on lakes and rivers. This large wading bird consumes fish of a variety of sizes and species including large predatory fish such as largemouth bass and trout. Also, some are year-round residents of this region. The river otter was selected as the freshwater mammal species because it is a common mammal in freshwater habitats and consumes primarily fish (EPA 1993). There is also evidence that river otter in Washington State accumulate mercury, PCBs, and dioxins/furans (Grove and Henny 2008). Although river otter may migrate between marine and freshwater habitats, some are exclusive to freshwater habitats. For the purposes of this assessment, it was assumed that both the great blue heron and river otter consume 100% of their prey from freshwater habitats and reside year-round in the Puget Sound region.

Osprey and harbor seal were selected as marine habitat receptors. The osprey was selected over the bald eagle, another common top predator of fish, for a number of reasons. Osprey primarily consume fish as compared to the bald eagle with consumes a large portion of birds and mammals; the osprey is much smaller than the bald eagle, making their relative ingestion rate and exposure higher. Osprey consistently hunt by diving or grasping prey from the water, whereas the bald eagle may scavenge for food, exclusively hunt salmon during salmon runs, or hunt for birds. Osprey migrate south during the winter, but breed in western Washington.

The harbor seal was selected to represent an aquatic marine mammal because it is a top predator feeding exclusively on aquatic prey, primarily fish, and has been reported to have elevated tissue concentrations of PCBs. The harbor seal was selected over the orca because the harbor seal is a smaller mammal with relatively higher ingestion rate and exposure, and because much more ecological information is available for the harbor seal. For the purposes of this assessment, it was assumed that the diet of both the osprey and harbor seal was 100% fish and that they reside only in Puget Sound.

The COCs evaluated by the wildlife assessment were limited to bioaccumulative compounds for which sufficient effects and environmental data were available and included mercury, PCBs, DDTs, and dioxins/furans. Many of the COCs are neither detected in fish (wildlife prey) nor bioaccumulative. PAHs are metabolized by fish, and therefore are not bioconcentrated (or analytically detected very frequently). Triclopyr is broken down quickly in the environment, and is not bioaccumulative. Bis(2-ethylhexyl)phthalate (DEHP) was infrequently detected (<10% FOD) in only two species of fish collected from nearshore habitats. Nonylphenol is also not considered to be bioaccumulative. Although nonylphenol is a potential endocrine disruptor, describing the potential endocrine disruption of nonylphenol to wildlife populations has never been done before.

Metals have naturally high FOD in the environment; however, the toxicity of some metals is complicated by their need as essential trace minerals. At the same time, many metals are moderately bioaccumulative and toxic to wildlife. Lead poisoning of birds exposed to lead shot and fishing weights has been a long standing concern. Although lead shot was banned for use in waterfowl hunting in 1991, it continues to be used in upland game hunting, posing risk to non-waterfowl bird species (USGS 2009). Because this assessment is focused on the aquatic environment, assessment of upland exposure of birds to lead shot was outside the scope of this assessment and not evaluated. Based on the chemical characteristics of these COCs, it was assumed that the potential for chronic wildlife exposure was very low and effort was focused on the more persistent and bioaccumulative COCs.

Exposure Model for Wildlife Receptors

Daily doses of COCs were estimated using a simple exposure model that included a body weight normalized sum of daily food intake, drinking water intake and incidental sediment ingestion during foraging and other behaviors. This is represented by the following algorithm:

$$\mathrm{TDD} = \frac{[C_w * IR_w] + [C_s * IR_s] + [C_f * IR_f]}{BW}$$

Where:

TDD = Total daily dose (mg/kg-BW/d)

C_w = 95% UCL of mean chemical concentration in water (mg/L)

C_s = 95% UCL of mean chemical concentration in sediment (mg/kg)

C_f = 95% UCL of mean chemical concentration in food (mg/kg)

IR_w = Ingestion rate of water (L/day)

IR_s = Incidental ingestion rate of sediment (kg/day)

IR_f = Ingestion rate of food (kg/day)

BW = Body weight (kg)

The 95% upper confidence limit of the mean (95% UCL) concentration of COCs in water, sediment and food was used to estimate the amount of each COC ingested by wildlife. The datasets from which the 95% UCL statistic was calculated were the same as those used in the water, sediment, and tissue assessments with the exception of the fish tissue dataset. The 95% UCL fish tissue concentrations are summarized in Appendix D-8. The diet of each receptor was conservatively assumed to be 100% fish. Although a proportion of the receptor's actual diet may include invertebrates, the 95% UCL fish tissue concentration is higher than the invertebrate tissue concentration. Therefore, assuming a diet of 100% fish results in a conservative approach, and meets the screening goal of this wildlife assessment. Data for all fish species, with the exception of six gill sharks, were assumed to be prey. A number of sources were reviewed to characterize the harbor seal (Cullon et al. 2005, EPA 1993), osprey (EPA 1993), great blue heron (EPA 1993, Butler 1992, Alexander 1977), and river otter (EPA 1993) diets.

The wildlife receptors used in this assessment prey on a wide variety of species; based on published information on their prey consumption, none show consistent preference for some prey species over others. Because prey size data were unavailable for observed concentrations, size was not a criterion used to screen fish tissue data for inclusion in the assessment.

The daily food ingestion rates were estimated using the allometric equations of Nagy (1987) which relate food ingestion rate to body weight. These equations are:

Birds: $FI = 0.0582 * BW^{0.651}$

Mammals: $FI = 0.0687 * BW^{0.822}$

Where:

FI = food ingestion rate (kg/day dry weight)

BW = body weight (kg)

Calder and Braun (1983) also use this type of relationship to estimate water ingestion rates.

These allometric equations were used to estimate drinking water intake for receptors and are presented below.

Birds: $WI = 0.0598 * BW^{0.67}$

Mammals: $WI = 0.099 * BW^{0.90}$

Where:

WI = water intake (L)

BW = body weight (Kg)

Sediment ingestion rates have not been empirically measured in wildlife studies, but have been estimated using acid-insoluble ash measurement in scat or digestive tracts of animals. Beyer et al. (1994) used ash measurements in scat to estimate the relative proportion of inorganic solids (i.e. sediments and soils) in the diet of multiple wildlife species. None of the four wildlife receptors were subjects of the Beyer et al. study; however, these data are useful to develop rough estimates of sediment ingestion rates for species that share similar feeding strategies. Empirical measurement of sediment ingestion rate is challenging and difficult to model due to ecological variability between and within species. Thus, the sediment ingestion rates were established using best professional judgment and relied heavily on the Beyer et al. (1994) which published estimates varying from <2% to 9% of the daily food ingestion rate for mammals[1] and <2% to 30% of total food ingestion rate for birds[2].

Since total exposure is sensitive to sediment ingestion, separate daily doses for the species evaluated in this assessment were estimated assuming a low and high sediment ingestion rate based on their similarities in feeding strategy and foraging habitat to species from Beyer et al. (1994). Best professional judgment was used to select a low and a high sediment ingestion rate intended to bound the range of realistic potential sediment ingestion rates for each receptor (Table 6).

Where possible, the body weight assumed for each receptor was based on local information summarized in Table 6. The average body weight for the smaller sex, if applicable, was used in the model, because food intake for smaller-bodied animals is proportionately greater than for the larger-bodied cohorts resulting in a larger daily dose and a more conservative estimate. Body weights and ingestion rates for adult life stages were applied to represent the majority of the animal's reproductive lifetime. However, effects dose studies included dosing of immature

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[1] Only four species of mammals were included in the study and only one, the raccoon, forages in aquatic habitat.

[2] Most species of birds in the study were either shorebirds or herbivorous birds. Sediment ingestion rates for dabbling and diving ducks ranged from <2 to 3% of food ingestion.

individuals. Therefore, the effects doses reflect the most sensitive lifestage and should be protective of younger lifestages.

Table 6. Wildlife body weights and ingestion rate assumptions.

Receptor	Body weight (kg)	Source	Food IR (kg/day dw)	Sediment IR (% of Food IR)	Water IR (L/day)
Osprey	1.45	EPA 1993	0.075	1 (4)	0.078
Harbor Seal	77.0	Assuncao et al. 2007	0.985	2 (4)	1.098
Great Blue Heron	2.1	Simpson 1984 as cited in Butler 1992	0.094	2 (4)	0.098
River Otter	7.9	EPA 1993	0.376	4.5 (9.0)	0.636

IR = ingestion rate. Two different sediment ingestion rates were applied for each receptor while holding all other variables constant because this variable is the greatest source of uncertainty in the daily dose model. The higher rate is in parentheses.
Food ingestion rates are from Nagy (1987); sediment ingestion rates are from Beyer et al. (1994); water ingestion rates are from Calder and Braun (1983).

Hazard Assessment

As previously discussed, the intent of this assessment was to provide a general, high level overview of the potential for the COCs to cause deleterious effects in the matrices evaluated. To conduct the quantitative portion of the hazard evaluation, the observed environmental data were compared to the respective effects concentrations. It should be noted that these comparisons are based on single chemical exposures in a single matrix (water, sediment and tissue) and do not account for any effects associated with exposure to chemical mixtures or other physical stressors or conditions (i.e., temperature, dissolved oxygen, hardness etc.) that may be present and influence bioavailability. Sufficient data for both effects and observed environmental concentrations were not available to evaluate the priority for every COC for each type of evaluation.

Water – Direct Effects to Aquatic Life

To assess potential effects to aquatic life through direct exposure to surface waters, observed surface water concentrations for COCs were presented as box plots of percentiles (5th, 10th, 25th, 50th, 75th, 90th and 95th %iles) plotted adjacent to box plots of percentiles representing the available effects concentrations in a series of figures. If water quality criteria (WQC) were available, these values were also presented. In some cases (e.g., DDT and mercury), the WQCs are well below the available effect concentrations.

Some WQC, particularly those for bioaccumulative chemicals, are derived based on a “final residue value” and the potential to bioaccumulate which typically results in a value that is lower than effects concentrations based on direct exposure. In some cases (e.g., nonylphenol) chronic effects data are limited and the chronic WQC is derived using an acute to chronic ratio (ACR). Use of the ACR can also result in a value that may be below effects concentrations presented in ECOTOX. For a more detailed description of how WQC were derived for these COCs see http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/index.cfm. It is also important to note that water quality criteria are not derived to protect aquatic organisms through the bioaccumulation pathway. The tissue residue assessment described below was intended to help address this pathway for a select group of COCs.

The total number of analytical measurements and number of observed detected concentrations are also presented on each figure. Most freshwater and marine (near- and offshore) data were presented on the separate figures; results for some COCs for which data were limited are combined into a single figure. If a COC was not detected (or measured), or effects data were not available, a figure was not prepared. All data were plotted on a log scale.

Sediment – Direct Effects to Benthic Organisms

To assess the potential for effects to benthic organisms, sediment COC concentrations were presented as box plots of percentiles plotted against the sediment guidelines (represented as horizontal lines on each figure). The standard or guideline use as the primarily comparison is presented as a solid red line, while the remainder of the guidelines provided for additional context are presented as dotted blue lines. When appropriate, based on the guidelines used for comparison, both dry weight and OC normalized concentrations were presented. In general, separate graphics were generated for marine and freshwater sediment data; results for some COCs for which there were limited data are combined into a single figure. If a COC was not detected (or measured), or effects data were not available, a figure was not prepared. All data were plotted on a log scale.

Tissue Residues – Direct Effects to Aquatic Life

The tissue assessment was similar to that described above for water. Observed tissue residue concentrations were presented as box plots of percentiles along with the available tissue residue effects concentrations; all data were plotted on a log scale. Graphics were generated for whole-body tissue types (fish, non-decapod invertebrates, and decapods) where both effects and observed environmental data were available. Marine and freshwater tissue data were graphed separately. If a COC was not detected, or effects data were not available, a figure was not prepared. As discussed above, the tissue residue assessment was limited to four PBTs (DDTs, dioxins, PCBs and mercury). Although PBDEs were not assessed quantitatively, the current effects literature and regional studies are reviewed in the WOE discussion.

Wildlife

The wildlife assessment compared literature-based daily effects doses for birds and mammals to the estimated daily doses of COCs for the four receptors (great blue heron, osprey, river otter and harbor seal). The literature-based daily effects doses were rank ordered and plotted against the estimated daily doses; data were plotted separately for birds and mammals. Two estimated daily doses were calculated for each receptor based on a low and a high estimate of sediment ingestion rates. Both estimates are shown on the figures.

Observed PCBs, DDTs and dioxins/furans data were assessed as sums. PCBs were assessed as Aroclor® sums for tissue and sediment and as PCB congener sums in water because too few Aroclor® detections occurred in the observed water data. DDT sums included DDT, DDE, and

DDD isomers. Dioxins and furans were converted to TEQs and summed to a total TEQ. The effects doses included individual Aroclors®, or DDTs, DDEs, and DDDs and their mixtures. Dioxin and furan effects doses were treated the same as observed data by converting to TEQs and summing to a total TEQ.

Human Health

The human health assessment utilized the National Toxics Rule (NTR) (40CFR§131.36) to establish default assumptions of body weight, toxicity and daily fish/shellfish consumption rates. The NTR uses a national average fish tissue consumption rate of 6.5 gm/day; this consumption rate was used to calculate a screening threshold and used as the primary basis of this assessment. However, this rate is suspected to be under-protective of various other users and ethnic groups (EPA 2007).

To account for different groups who may consume fish/shellfish at higher rates, five consumption rates were also used to derive alternative levels for informational purposes. Two consumption rates (242 gm/day King County API (Sechena 1999) and 243 gm/day Tulalip Tribe (Toy 1996) were almost identical so they were averaged to create one consumption scenario of 242.5 gm/day. In addition to the NTR standard rate and the average of the King County API/Tulalip rate, the EPA recommended recreational and subsistence consumption rates (EAP 2000) and the Suquamish ingestion rate (Suquamish Tribe 2000) were also used. The levels calculated based on these additional consumption rates are presented to provide additional context and are discussed as an additional WOE.

This methodology was used to evaluate bivalve, fish (whole-body and filet) and other invertebrate tissue data for human health consumption risks. The NTR is the only regulatory standard in Washington State applicable for human health risks related to consumption of surface water. However the surface water standards in the NTR are predominantly influenced by bioaccumulation by fresh water fish tissue and not the consumption of water alone. Consumption and/or dermal exposure to water alone would require development of a human health risk assessment for the entire Puget Sound region. A water risk assessment would need to include an estimate of freshwater exposure point concentrations or probabilistic estimates of exposure; such an evaluation was deemed to be beyond the scope of this assessment.

Tissue criteria were backcalculated from the NTR based water quality criteria as shown below in Table 7. The bioconcentration factors (BCFs) shown are from the original criteria documentation. These BCFs and the applicable fresh and marine water quality criteria were used along with the original 6.5 gm/day and modified consumption rates to derive tissue concentrations deemed protective at a range of tissue consumption rates as shown in Table 5.

Table 7. Summary of NTR water quality criteria and bioconcentration factors (BCF) used in the human health assessment.

COC	BCF	NTR Freshwater Human Health Criteria - Water and Organisms (µg/L)	NTR Marine Water Human Health Criteria - Organisms Only (µg/L)
Arsenic	44	0.018	0.14
Mercury (estuarine)	3765	n/a	0.15
Mercury (freshwater)	5500	0.14	n/a
Bis(2-Ethylhexyl)Phthalate	130	1.8	5.9
2,3,7,8-TCDD (Dioxin)	5000	0.000000013	1.4E-08
Total Polychlorinated Biphenyls (PCBs)	31,200	0.00017	0.00017
4,4'-DDT	53,600	0.00059	0.00059
4,4'-DDE	53,600	0.00059	0.00059
4,4'-DDD	53,600	0.00083	0.00084
Anthracene	30	9600	110,000
Benzo(a)Anthracene	30	0.0028	0.031
Benzo(a)Pyrene	30	0.0028	0.031
Benzo(b)Fluoranthene	30	0.0028	0.031
Benzo(k)Fluoranthene	30	0.0028	0.031
Dibenzo(a,h)Anthracene	30	0.0028	0.031
Fluoranthene	1150	300	370
Fluorene	30	1300	14,000
Indeno(1,2,3-cd)Pyrene	30	0.0028	0.031
Pyrene	30	960	11,000

To account for potential rounding errors and changes in estimates of cancer toxicity since the NTR was adopted; cancer slope factors or reference doses were first derived from the NTR calculations for both freshwater and marine waters. These slope factors, or dose for mercury, were then used in the following formulas to derive tissue thresholds.

Following is the calculation of the human health criterion for freshwater organisms along with 2L of drinking water per day consumption:

$$\mathrm{Fresh} - \mathrm{HH} = \frac{\mathrm{RF \ x \ BW \ x \ }(1{,}000\,\frac{\mu\mathrm{g}}{\mathrm{mg}})}{\mathrm{q1} * \mathrm{x}\ [\mathrm{WC} + (\mathrm{FC\ x\ BCF})]}$$

Where:

Fresh-HH = Freshwater criterion in ug/L
RF = Risk Factor = 1 x 10 (-6)
BW = Body Weight = 70 kg
q1* = Cancer slope factor/toxicity (Hg only), chemical specific
WC = Water Consumption = 2 L/day
FC = Fish and Shellfish Consumption varied according to Table 5
BCF = Bioconcentration Factor

Following is the calculation of the human health criterion for marine water organism only consumption:

$$\mathrm{Marine - HH} = \frac{\mathrm{RF\ x\ BW\ x\ (1{,}000\ \frac{\mu g}{mg})}}{\mathrm{q1 * x\ FC\ x\ BCF}}$$

Where:

Marine-HH = Marine criterion in ug/L
RF = Risk Factor = 1 x 10 (-6)
BW = Body Weight = 70 kg
q1* = Cancer slope factor/toxicity (Hg only), chemical specific
FC = Fish and Shellfish Consumption varied according to Table 5
BCF = Bioconcentration Factor

For COCs not included in the NTR, a hazard evaluation was not conducted to evaluate their hazard level for the same reasons that water and sediment hazard evaluation were not conducted.

Petroleum

As previously discussed, due to issues associated with the non-specific nature of petroleum product measurements in surface waters, this COC was evaluated using a slightly different process than the remainder of the COCs in water. Petroleum in freshwater was evaluated using data associated with the release of products to water (spills).

Most available toxicity data were for crude oils, which were not considered applicable for this assessment because no crude oil environmental data were available. Similarly, a large amount of observed oil and grease data were available from the EIM and King County LIMS databases. However, these data do not describe a specific petroleum product; they encompass waxes, greases and other fatty acid substances from both animal, vegetable and petroleum origins. Because these environmental data are non-specific, and potentially toxic components may vary within the same concentration measured by this method; these data were considered unusable for this assessment. Thus, toxicity data and environmental data were both only available for four petroleum products: heavy fuel/bunker oil, diesel fuel, gasoline, and lube oil. Toxicity data for these fours products were almost entirely based on lethal concentrations to 50% of the exposed population (LC50s).

Environmental data for these four products were plotted against the available freshwater toxicity data. Only two petroleum product data results were available for marine waters and these were insufficient to estimate hazard priority levels.

Determination of Priority

Due to the broad screening nature of this assessment, in addition to uncertainties associated with the available data (see Uncertainty Section), a conservative approach was used to determine the potential hazard posed by each COC. While an effort was made to use a consistent approach to classify the priority for each component of the assessment, due to the nature and availability of the data used and variability of methods used for each component, there are differences between some of the approaches.

The reader is urged to use caution when comparing priorities across matrices and type of assessment. The potential for ecological effects for COCs classified as Priority 1 is much higher than that for Priority 2. However, the specific type of ecological effect is not defined for Priority 1 COCs and can vary from mortality to more subtle impacts like physiological changes. The following sections describe the process by which the potential for effects was determined for each element of the assessment. Table 8 summarizes the thresholds used to define priority levels and sufficiency of data.

Water – Direct Effects to Aquatic Life

A conservative approach was used to determine the potential for effects to aquatic life from direct exposure to surface waters. If the 90th %ile of the observed environmental concentrations of a COC was above the 10th %ile concentration of the effect concentrations, the COC was classified as "Priority 1". If the 90th %ile of the observed environmental concentrations was less than the 10th %ile of the effect concentrations, the COC was classified as "Priority 2". If there were insufficient data (<15 effects or <50 observed environmental values) to assess a particular COC, it was classified as "Unknown" or "U". A classification of Priority 2 or "U" is not intended to suggest that this COC is not important. It is assumed that all of these COCs are priorities at some level.

In freshwaters, hardness can have significant influence on the toxicity of metals. Due to the large volume of data used for this assessment it was not practical to evaluate the hardness concentrations associated with each observed or effect metal concentration. The reader is cautioned to take this factor into account when evaluating the findings of the freshwater metals assessment. The WQC were calculated for metals with hardness-based standards using a hardness value of 25 mg/L-CaO_3 which is approximately the average freshwater hardness in Western Washington.

Where available, data from regional studies and other readily available thresholds were used as an additional WOE to qualitatively assess each COC. In general, the available regional data for the direct water exposure were limited to copper and PAHs.

Sediment – Direct Effects to Benthic Organisms

To determine the potential for effects to benthic organisms from direct sediment exposure, the 90th %ile concentration for each COC was compared to the marine SQS or freshwater FP-SQS, in addition to the other sediment guidelines described above.

A process similar to that described above for water was used to assess COC priorities for sediment. If the 90th %ile of the observed sediment concentrations was above the marine SQS or the freshwater FP-SQS the COC was classified as Priority 1; if the 90th %ile concentration was less than the sediment standard/guideline is was classified as Priority 2. COCs for which there were insufficient data (effects or observed concentrations data) to assess were classified as "Unknown" or "U". Sediment COCs were classified as "U" if a FP-SQS or SQS value was not available or if the number of observed environmental concentrations was low (<30). As previously discussed, classification of a COC as a Priority 2 or "U" does not indicate the COC is not potentially important.

It is assumed that all of these COCs are priorities at some level. Where available, data from regional studies and other readily available thresholds were used as an additional WOE to qualitatively assess each COC. In general, the available regional data for the direct sediment exposure were limited to PAHs and PCBs.

The level of uncertainty associated with data availability for each COC was also summarized. Data uncertainty was based on the total number of measurements and the availability of sediment thresholds for each COC. As indicated for water above, this assessment assumes that the available environmental data are representative of the overall region; however, the lower the number of measurements for each COC, the greater the uncertainty that these data are representative.

Tissue –Direct Effects to Aquatic Life

The approach used to determine priorities in the tissue assessment was the same as that described above for water. The data for this element of the assessment were very limited; when interpreting the tissue assessment results, the reader is also encouraged to take into account the amount and type of both tissue residue effects and observed data available. A COC was classified as “Priority 2” if the 90th %ile observed concentration was below the 10th %ile effects concentration. A “U” or “Unknown” priority indicates there was insufficient effects data (<5 effects or >20 observed values) to allow assessment.

Where available, data from regional studies and other readily available thresholds were used as an additional WOE to qualitatively assess each COC. In general, the available regional data for tissue residue related impacts was limited to PAHs and PCBs.

Wildlife

A COC was classified as “Priority 1” when the estimated daily dose was greater than or within 0.1 times the lowest effect dose. Because there are far fewer published effects doses for wildlife than aquatic life, there is greater uncertainty in estimating the lowest effect threshold. For this reason, a COC was classified as “Priority 2” if its estimated daily dose was less than an order of magnitude (i.e., a factor of 10) of the lowest effect dose. A “U” or “Unknown” priority indicates there was insufficient effects data (<5 effects values) to allow assessment. Only one published effects dose was available for PBDEs in birds (Fernie et al. 2011), and none for mammals. Thus, a discussion of the estimated total PBDE daily doses for the avian receptors compared to this published effects dose is included in the WOE discussion in lieu of the full quantitative evaluation.

Human Health

If the 90th %ile of the observed tissue concentrations exceeded the NTR screening criteria the COC was classified at Priority 1; if the NTR value was below the 90th %ile concentration, the COC was classified as Priority 2. Some COCs had many environmental measurements for one tissue type, but few of other tissue types. In these instances, best professional judgment was used to determine the adequacy of all the tissue data within the fresh, near, or offshore environment to develop a hazard ranking for the COC in tissue on the whole. As discussed above, classification as a Priority 2 does not indicate that a COC is not a priority. It is assumed that all COCs are priorities at some level. Results of the comparison to other consumption rate data were used as an additional WOE and discussed qualitatively below. Most COCs were found at comparable concentrations across the bivalve, fish, and other invertebrate tissue groups suggesting that prioritization rankings are relatively robust regardless of tissue type evaluated.

Table 8. Thresholds used to define priorities and sufficiency of data.

Line of Evidence	Threshold for Priority	Threshold for Sufficient Data
Surface Water	90th%ile Observed Conc. > *10th %ile Effects Conc.* *or* *Acute WQC or Chronic WQC*	n ≥ 15 for Effects Data n ≥ 50 for Observed Data
Sediment	90th%ile Observed Conc. > *SQS*	n ≥ 100 for Observed Data
Tissue Residue Effects	90th%ile Observed Conc. > *10% of 10th%ile Effects Conc.*	n ≥ 5 for Effects Data n ≥ 20 for Observed Data
Wildlife	Daily Dose >*10% of Lowest Effects Dose*	n ≥ 5 for Effects Data
Human Health	90th%ile Observed Conc. >*NTR Criterion*	Best Professional Judgment

Results and Discussion

The following sections provide an overview of the availability of both the environmental occurrence data and effects data in addition to the outcome of the individual effects assessments and a summary of the overall outcome of the assessment.

Environmental and Effects Data Availability

Water

Surface water data were used to evaluate direct effects to aquatic life, and in the wildlife assessment as appropriate to estimate exposure through water ingestion. The number of measurements for COCs in freshwater ranged from over 5000 for copper to less than 10 for dioxins. With the exception of PCB and PBDE congeners, dioxins/furans and nonylphenol, there were more than 1200 measurements for each COC in freshwater.

Relative to freshwater data, the number of measurements in marine (near- and offshore) surface waters was significantly less; nearshore data were most limited. With the exception of copper, there were less than 50 measurements (often less than 15) for each COC in nearshore waters. In general, there were less than 100 measurements for each COC in offshore waters. Marine data were not available for petroleum, triclopyr and dioxins. The water data are summarized in Appendix D-8.

The relatively low number of measurements for many of the COCs in marine waters suggests that the spatial coverage for these data is limited and these data may not be representative of the region.

Effects data were considered “sufficient” when a range of values (at least 15 effect concentrations) representing a variety of endpoint types other than mortality were available. It is generally uncommon for ambient concentrations of COCs to be present at levels that would cause mortality; organisms are typically exposed to concentrations likely to cause more subtle effects (e.g., effects to growth and reproduction). If the effects data were limited to mortality based endpoints, it is possible that priority rank may have been underestimated because the potential for effects other than mortality could not be evaluated. For example, most of the available effects data for PCBs in marine water were based on mortality; and this COC was classified as Priority 2. However, exposure to low levels of PCBs can result in food web biomagnification and cause effects to the immune systems of higher trophic level organisms. As such, it should be noted that direct water exposure is not the most sensitive approach to assess this COC.

In freshwater, there were sufficient effects data for most of the COCs with the exception of some individual PAHs, dioxins and PBDEs. Effects data for these COCs were limited, particularly for endpoints other than mortality.

Effects data for aquatic life in marine waters were sufficient for some COCs, but were limited (especially non-mortality effect data) for a number of COCs. In marine waters effects data for arsenic, cadmium, PCBs, PBDEs and a number of individual PAHs were limited.

Sediment

Sediment data were used to evaluate direct effects to benthic organisms and were also incorporated into the wildlife assessment where appropriate to estimate exposure from incidental sediment ingestion. Sediment data were available for all COCs with the exception of triclopyr and petroleum. All sediment data are summarized in Appendix D-8. With the exception of PCB and PBDE congeners, nonylphenol and a few individual PAHs, there were more than 300 measurements for each COC in both freshwater and marine (near- and offshore) sediments.
Of the 3 sets of freshwater sediment guidelines used in this assessment, threshold values were available for the majority of sediment COCs. Only one set of freshwater guidelines was available for a number of individual PAHs, LPAHs, HPAHs and dioxin/furans; two sets of guidelines were available for DDT and some individual PAHs and only a single threshold was available for nonylphenol.

Of the 3 sets of marine sediment guidelines used in this assessment, threshold values were available for the majority of sediment COCs. However, only 2 sets of guidelines were available for some individual PAHs and one set for dioxins/furans; only one sediment guideline was available for nonylphenol.

Tissue

Tissue data were used to evaluate direct effects to aquatic life (limited to PBTs) and wildlife (select organic chemicals only) and to assess human health (select organic chemicals, mercury and arsenic only). The different assessments required the various combinations of tissue types. A summary of the tissue data used for each assessment type can be found in Appendix D-8. The number of measurements for some COCs and tissue types was very low and limited the degree to which these chemicals could be assessed.

Effects data to evaluate the direct impact of tissue residues on aquatic life were very limited for most COCs, particularly for marine fish; effects data for these tissue types were not available for mercury, dioxins/furans and DDTs. The number of tissue residue effects concentrations for some tissue types and COCs was often less than 5. The lack of tissue residue effects data poses limitations on this element of the assessment. As a result, the reader is cautioned to evaluate the available data when interpreting these results.

Wildlife

Generally, the available environmental data were sufficient to meet the needs of the wildlife assessment. Far greater uncertainty exists with the effects data due to the limited number of dose-response data for wildlife species from published studies. The low number of effect dose-response data available for birds and mammals poses limitations on the assessment, particularly for dioxins/furans. The lack of dose-response data for PBDEs precludes an estimation of potential adverse effects to wildlife from exposure to this COC.

Human Health

A number of known or potentially bioaccumulative COCs were not evaluated in the human health portion of this assessment because they are not part of the human health standards in the NTR. These chemicals include:

1. Acenaphthene
2. Acenaphthylene
3. Inorganic arsenic
4. Benzo(g,h,i)perylene
5. Cadmium
6. Chrysene
7. Lead
8. Nonylphenol
9. Phenanthrene
10. Polybrominated diphenyl ethers (PBDEs)

Generally, environmental data were sufficient to meet the needs of this assessment. All chemicals without NTR criteria were classified as “unknown” due to the lack of standards against which to compare.

Effects Prioritization

The results of the quantitative assessments for water, sediment, tissue media and effects on wildlife and human health are presented in Appendix D-2. The remainder of this section summarizes the results for each COC, including any additional evidence provided by studies of regional significance.

Metals

With the exception of mercury, the assessment of metals was limited to water, sediment and human health. The availability of NTR criteria for metals limited the assessment to mercury and arsenic. Due to data availability and scope limitations, metals were not evaluated in wildlife and tissue residue.

Arsenic

Water

Freshwater

Arsenic was classified as ”U” because there were limited effects data for dissolved arsenic. The 90th %ile observed freshwater arsenic concentration is below both the acute and chronic WQC.

Marine Water

Arsenic in nearshore and offshore waters was classified as “U” because no effect data were available for arsenic in marine waters.

Sediment

Freshwater Sediment

Arsenic was classified as Priority 1 based on comparison of the 90th %ile observed sediment concentration to the FP-SQS. The 50th %ile observed sediment arsenic concentrations is below all additional guidelines used in this assessment, suggesting that only the highest concentrations are of greatest concern.

Marine Sediment

Arsenic was classified as Priority 2 based on comparison of the 90th %ile observed near and offshore sediment copper concentrations to the SMS SQS. The 90th %ile observed arsenic concentrations in both near and offshore sediment are below additional guidelines evaluated except for the TEL.

Tissue

Arsenic was not assessed in tissues.

Wildlife

Arsenic was not assessed for wildlife.

Human Health

The NTR is based on inorganic arsenic however; most of the environmental data were for total arsenic which includes less toxic organic forms like arsenobetaine. Both inorganic and total arsenic exceeded the NTR by several orders of magnitude; however, the inorganic dataset was extremely limited with only 15 measurements in all tissue type. Thus, arsenic was classified as "U" in both fresh and marine tissue.

Cadmium

Water

Freshwater

Cadmium was classified as Priority 2 because the 90th %ile observed freshwater concentration is below the 10th %ile of the effects data. The 95%ile observed cadmium concentration was above the chronic WQC.

Marine Water

There were insufficient observed data to prioritize cadmium in nearshore and offshore marine waters and it was categorized as "U".

Sediment

Freshwater Sediment

Cadmium was classified as Priority 1 based on comparison of the 90th %ile observed sediment concentration to the FP-SQS. The 50th %ile observed sediment cadmium concentration is below all additional guidelines used in this assessment, suggesting that only the highest concentrations are of concern.

Marine Sediment

Cadmium was classified as Priority 2 based on comparison of the 90th %ile observed near and offshore sediment concentrations to the SMS SQS. The 90th %ile observed concentration of cadmium in both near and offshore sediment are below all of the additional guidelines evaluated.

Tissue

Cadmium was not assessed in tissue.

Wildlife

Cadmium was not assessed for wildlife.

Human Health

Cadmium was not assessed for human health because it is not included in the NTR.

Copper

Water

Freshwater

Copper in freshwater was classified as Priority 1 because the 90th %ile copper concentration exceeded both the 10th %ile effects concentration and the chronic copper WQC. The 95th %ile observed copper concentration also exceeds the acute WQC.

Marine Water

Copper in offshore waters was classified as Priority 2 because the 90th %ile observed offshore concentration is below the 10th %ile concentration of the effects data. Copper in nearshore waters was classified as Priority 1 because the 90th %ile observed nearshore concentration is above the 10th %ile effect concentration. In addition the acute and chronic water quality criteria exceeded the 90th %ile observed concentration. The 95th %ile observed offshore copper concentration was above the chronic WQC.

Sediment

Freshwater Sediment

Copper was classified as Priority 1 based on the comparison of the 90th %ile observed sediment concentration to the FP-SQS. The 50th %ile observed sediment copper concentration is below all additional guidelines used in this assessment, suggesting that only the highest concentrations are of greatest concern.

Marine Sediment

Copper was classified as Priority 2 based on comparison of the 90th %ile observed near and offshore sediment concentrations to the SMS SQS. The 90th %ile observed copper concentrations in both near and offshore sediment are below all of the additional guidelines evaluated.

Tissue

Copper was not assessed in tissue.

Wildlife

Copper was not assessed for wildlife.

Human Health

Copper was not assessed for human health because it is not included in the NTR.

Additional Evidence from Regional Studies

Aquatic Life

Copper is one of the most far-reaching potential priority toxicants in the Puget Sound region. This is due to its ability to alter the sensory capacity and behavior of a wide variety of aquatic organisms. A number of researchers have documented effects on regional species. Tierney et al. (2010) reviewed over 150 papers and found that avoidance behaviors were common in a variety of fresh and salt water fishes at less the 1 ug/L to concentrations ranging up to 20-30 ug/L.

Tested species included coho and Chinook salmon, as well as rainbow trout and golden shiner. Hecht et al. (2007) compiled a similar body of evidence for the disruptive effects of copper on juvenile salmonids. They used US EPA methodologies to calculate benchmark concentrations predicted to represent 10% and 50% reductions in chemosensory response at 0.18 ug/L and 2.1 ug/L respectively. These concentrations bracket a variety of other regional primary literature sources which confirm that the environmentally relevant range of <1.0 ug/L to 5.0 ug/L copper adversely impacts a variety of Puget Sound basin fish, particularly salmonids. Similar neurologic impacts were found by Linbo et al. (2006) on the mechanosensory lateral line of fish.

Sandahl et al. (2004) found copper concentrations of 4.4 ug/L produced sublethal neurotoxicity in coho salmon. In this laboratory study, copper reduced the ability of coho salmon to detect the natural oderants taurcholic acid and L-serine. Further study by Sandahl et al. (2007) confirmed that concentrations as low as 2 ug/L copper are not only affecting the neurologic systems of fish but also alter their behavioral responses to alarm pheromones. Baldwin et al. (2003) also found olfactory inhibition at the comparable, environmentally relevant, concentration of 2.3 ug/L.

Hansen et al. (1999) produced a seminal work which was utilized by several of the subsequent reviews discussed above. In it they documented Chinook salmon avoidance behaviors at concentrations as low as 0.7 ug/L dissolved copper. However, Chinook also failed to avoid concentrations >44 ug/L due to the extensive neural saturation. This window of affect potentially contributes to mortality from prolonged copper exposure or impairment of olfactory dependent behaviors such as homing.

Additional local studies by McIntyre et al. (2008) found that water hardness had little impact on copper's ability to alter olfactory function in coho salmon despite water hardness being a variable influencing the Washington State water quality standards. These regional reviews and studies provide an additional line of evidence suggesting that copper is a very important toxicant at concentrations well within the range found it the Puget Sound regional environment.

Lead

Water

Freshwater

Lead was classified as Priority 2 because the 90th %ile observed freshwater concentration is below the 10th %ile of the effects data.

Marine Water

Lead in offshore marine waters was classified as Priority 2 because the 90th %ile observed concentrations are below the 10th %ile of the effects data. In nearshore marine waters, lead was classified as "U" due to the insufficient amount of observed data.

Sediment

Freshwater Sediment

Lead was classified as Priority 2 because the 90th %ile observed freshwater sediment concentration is below the FP-SQS.

Marine Sediment

Lead was classified as Priority 2 based on the comparison of the 90th %ile observed near and offshore sediment concentrations to the SMS SQS. The 90th %ile observed lead concentrations in both near and offshore sediment are below all of the additional guidelines evaluated.

Tissue

Lead was not assessed in tissue.

Wildlife

Lead was not assessed for wildlife.

Human Health

Lead was not assessed for human health because it is not included in the NTR.

Mercury

Water

Freshwater

The 90th %ile mercury concentration was below the 10th %ile of the effects concentration, and also exceeded the chronic WQC. Mercury in freshwater was classified as Priority 2.

Marine Water

Mercury in nearshore and offshore waters was classified as “U” because there were a limited number of environmental measurements (n = 13 and 7, respectively).

Sediment

Freshwater Sediment

Mercury was classified as a Priority 1 COC based on the comparison of the 90th %ile observed sediment concentration to the FP-SQS. The 50th %ile observed sediment lead concentrations is below all additional guidelines used in this assessment, suggesting that only the highest concentrations are of greatest concern.

Marine Sediment

Mercury was classified as Priority 1 based on comparison of the 90th %ile observed near and offshore sediment concentrations to the SMS SQS. The 90th %ile observed mercury concentrations in both near and offshore sediments are below all of the additional guidelines evaluated.

Tissue

Freshwater

Mercury is classified as “U” for freshwater non-decapod invertebrates and fish because insufficient observed and effects data are available for the assessment.

Marine Water

Mercury is classified as “U” for all three tissue types in near and offshore marine waters mainly due to a lack of effects concentrations. No marine effects concentrations were available for non-decapod invertebrates and fish and only one marine decapod effect concentration was available. There are observed concentrations for all tissue types although only five for offshore decapods.

Wildlife

Mercury was classified as Priority 1 for all four wildlife receptors because the estimated daily doses are at or above the lowest effect doses. Estimated daily doses of mercury to great blue heron and river otter are above 2 or more effects doses, whereas those of osprey and harbor seal are at or just above the lowest effect dose. Generally, mercury is estimated to bioaccumulate more in receptors living in freshwater habitats than marine habitats around Puget Sound.

Human Health

Freshwater

Mercury was classified as Priority 2 because the 90th percentile tissue concentration for bivalves, fish and other invertebrates did not exceed the NTR.

Marine Water

Mercury was classified as Priority 2 because the 90th percentile tissue concentration for bivalves, fish and other invertebrates did not exceed the NTR.

Additional Evidence from Regional Studies

Wildlife

Regional evaluations of mercury residues in Puget Sound wildlife in the Puget Sound are limited. Johnson et al. (2009) measured mercury concentrations in osprey eggs from the Lower Duwamish River in 2003 and again in 2006/2007. These data demonstrated that mercury concentrations in osprey eggs decreased between these sample periods.

Grove and Henny (2008) measured contaminants in the livers of river otter carcasses collected by trappers in western Oregon and western Washington, including Puget Sound. Mercury liver concentrations were higher in adult river otters from Puget Sound (mean of 7.89 mg/kg dry) than those from the northwest Washington area (mean of 5.85 mg/kg dry weight), located just east of Puget Sound and including the greater Seattle urban area. Mercury levels in Willamette River otter livers and coastal Oregon were slightly higher (mean of 9.2-9.3 mg/kg dw), but similar to Puget Sound levels. This study demonstrates that river otters living in the Puget Sound area are exposed to and bioaccumulate mercury.

Zinc

Water

Freshwater

Zinc was classified as Priority 2 because the 90th %ile observed freshwater concentration is below the 10th %ile of the effects data.

Marine Water

Zinc in offshore waters was classified as Priority 1 because the 90th %ile observed nearshore zinc concentrations is above the 10th %ile concentration of the effects data. Insufficient observed data for zinc in nearshore waters was available; zinc in nearshore waters was classified as “U”.

Sediment

Freshwater Sediment

Zinc was classified as Priority 1 based on the comparison of the 90th %ile observed sediment concentration to the FP-SQS. The 50th %ile observed sediment zinc concentration was below all additional guidelines used in this assessment, suggesting that only the highest concentrations are of greatest concern.

Marine Sediment

Zinc was classified as Priority 2 based on comparison of the 90th %ile observed near and offshore sediment concentrations to the SMS SQS. The 90th %ile observed sediment zinc concentration is above the TEL; the 90th %ile observed nearshore concentration was below the TEL.

Tissue

Zinc was not assessed in tissue.

Wildlife

Zinc was not assessed for wildlife.

Human Health

Zinc was not assessed for human health because it is not included the NTR.

PCBs

The potential for effects associated with PCB exposure was assessed for all media and pathways (water, sediment, tissue, human health and wildlife). Observed environmental PCB concentrations were assessed as the sum of Aroclors® and the sum of congeners. In general, the majority of the available toxicity data were based on individual Aroclor® exposures. It was not practical to compare observed individual Aroclor® and congener data to available effects data for individual compounds. Caution is advised in the use of Aroclor® data; these data may not be optimal due to shifts in the congener composition associated with weathering. It is also important to note that the PCB WQC is not protective of aquatic life through the bioaccumulation pathway.

Water

Freshwater

The 90th %ile observed concentrations of both PCB congeners and Aroclors® were below the 10th %ile concentration of the available effects data. However, the 90th %ile PCB Aroclor® concentration exceeded the chronic WQC. PCB Aroclors® were classified as Priority 1; PCB congeners were classified as Priority 2.

Marine Water

Extremely limited PCB concentration data are available for marine nearshore waters, with only 11 PCB Aroclor® concentrations and no PCB Congener data available; PCBs in nearshore waters were classified as “U”. Similarly, PCB Aroclor® data in offshore marine waters were not available. However, sufficient PCB Congener data were available in marine offshore waters, where the 90th %ile concentration of total PCB congeners was below the 10th %ile of the available effects concentrations; PCB congeners in offshore marine waters were classified as Priority 2.

Sediment

Freshwater Sediment

PCB Aroclors® in freshwater sediments were classified as Priority 1. The 90th %ile observed concentrations of both PCB congeners and Aroclors® were above the FP-SQS, in addition to 3 of the 5 additional guidelines evaluated. Only the PEC fell above the 90th %ile concentration of both PCB congeners and Aroclors®. With the exception of the TEL, the 50th %ile PCB Aroclor® concentration was below all remaining guidelines evaluated. In general, this suggests that areas with the highest concentrations are of concern. Sediment congener data were limited (n=26); as such they were classified as “U”.

Marine Sediment

PCB Aroclors® in marine offshore sediment were classified as Priority 1 because the 90th %ile OC normalized PCB Aroclor® concentrations in marine offshore sediments exceeded the marine SQS. The 90th %ile concentrations of OC normalized PCB Congeners in offshore sediments and PCB Aroclors® in nearshore sediments did not exceed the SQS, resulting in a Priority 2 classification. Insufficient data were available to evaluate PCB congeners in nearshore sediments.

Tissue

Freshwater

PCB Aroclors® and PCB congeners in freshwater non-decapod invertebrates are classified as Priority 1 because the 90th %ile observed concentrations are higher than the 10th %ile of the effects data. All other freshwater tissues are classified as “U” for both PCB Aroclors® and congeners due to the limited number of effects values and/or environmental concentrations. There were no observed data available for PCB congeners in decapods.

Marine

PCB Aroclors® and congeners in nearshore decapods are classified as Priority 2 because the 90th %ile observed concentration is below the 10th %ile effects concentration. PCB Aroclors® and congeners in nearshore non-decapod invertebrates are also classified as Priority 2. PCBs in fish are classified as "U" due to the limited amount of available effects data.

PCB Aroclors® and congeners in offshore decapods and fish were classified as "U" due to a lack of effects values or insufficient quantity of observed concentrations. PCB Aroclors® in offshore non-decapod invertebrates were classified as Priority 2 but PCB congeners are classified as "U" because of insufficient numbers of observed and effect concentrations in non-decapod invertebrates (< 20 and < 5 respectively).

Wildlife

PCBs were classified as Priority 1 for all four wildlife receptors because the estimated daily doses are more than 10 times lower than the lowest effect doses. Generally, PCBs are estimated to bioaccumulate to a greater degree in receptors living in marine habitats than freshwater habitats around Puget Sound. Estimated daily PCB doses to osprey, river otter and harbor seal are above several effects doses. Those of the great blue heron hover near the three lowest effect doses.

Human Health

PCBs were classified as a Priority 1 human health concern; multiple freshwater and near- and offshore tissues types exceeded the NTR PCB concentration standard. The range of observed PCB concentrations analyzed by Aroclor® and congener methods vary from one another. This variability is likely the result of multiple projects using different analytical methods for different suspected levels of contamination.

Additional Evidence from Regional Studies

Aquatic Life

PCBs have been detected in outmigrant juvenile salmon (Johnson et al., 2007) from multiple northwest estuaries and hatcheries, including three in the Puget Sound. Whole-body juvenile Chinook salmon from the Duwamish River contained the highest PCB concentration (103 ng/g wet weight or 3100 ng/g lipid) of any of the locations tested. Johnson et al. (2007) note that this concentration is higher than NOAA's estimated threshold for adverse health effects of 2400 ng/g lipid. Separately, juvenile salmonid PCB exposures were documented as occurring via food source by an analysis of stomach content of outmigrants at three locations in Puget Sound (Stein et al. 1995). Meador et al. (2010) found that PCB tissue concentrations in outmigrant juvenile Chinook from the Duwamish estuary varied by time and location within the estuary, suggesting that localized heterogeneity of sediment concentrations may substantially impact accumulation in fishes.

PCB concentrations in adult Puget Sound Chinook salmon tissues were found to be 3 – 5 times higher than those measured in six other populations of Chinook salmon on the West Coast of North America (O'Neill and West 2009). O'Neill and West note that these elevated tissue concentrations have resulted in consumption advisories, and have implications for the viability of these fish and southern resident killer whales. Cullon et al. (2009) found PCBs in adult Chinook returning to the Duwamish River, as well as in Puget Sound Chinook smolts.

PCBs concentrations in Puget Sound herring and Puget Sound flatfish have also been evaluated. Puget Sound herring were found to contain 3 to 9 times higher concentrations of PCBs than herring from the Strait of Georgia, with Puget Sound whole-body concentrations ranging from about 120 to 160 ng/g wet weight (West et al. 2008). Analyses of various biomarkers of pollution exposures in benthic flatfish were shown to successfully differentiate between sites with differing degrees of sediment contamination (Stein et al. 1992). Cullon et al. (2005) also found about seven times higher levels of PCBs in a mixture of fishes designed to represent the diet of Puget Sound harbor seals than in a similar mixture of fish designed to represent the diet of harbor seals from the Strait of Georgia. Sol et al. (2008) found a statistically significant correlation between PCB concentrations in English sole livers and two biological effects parameters.

Wildlife

A number of studies have been conducted in the Puget Sound region investigating exposure and/or effects of PCBs and other persistent and bioaccumulative contaminants on wildlife, particularly marine mammals. The salient information on PCBs in wildlife is summarized here.

Johnson et al. (2009) measured PCB concentrations in osprey eggs from the Lower Duwamish River and compared them to those sampled from the upper Willamette River. Total PCB residues were significantly higher in Lower Duwamish River osprey eggs (geometric mean = 897 ug/kg wet weight) compared to those from the Willamette River (geometric mean = 182 ug/kg ww). These results demonstrate that adult osprey bioaccumulation and maternal transfer of PCBs is occurring in osprey nesting in PCB contaminated areas of Puget Sound. This study also compared egg residues over time and determined that PCB concentrations in osprey eggs from the Lower Duwamish River had decreased 53% between 2003 and 2007.

Grove and Henny (2008) also demonstrated the bioaccumulation of PCBs in river otter livers from Puget Sound. The Puget Sound area river otters accumulated more PCBs (as total PCBs) than otters from other areas in western Washington.

PCBs and other organochlorines have been shown to cause immunosuppression, thyroid disruption and possibly cancer in harbor seals (Tabuchi et al. 2006, Ylitalo et al. 2005; Simms et al. 2000; Ross et al. 1996; Ross et al. 1995; de Swart et al. 1996; de Swart et al. 1995; Van Loveren et al. 1994). Vitamin A disruption has also been observed in harbor seal pups found on the Washington State coast whose mothers contained high PCB residues in their blubber (Simms et al. 2000). This effect on seal pups is suspected to result from exposure to contaminated milk.

There is substantial evidence that Puget Sound harbor seals and killer whales are bioaccumulating PCBs at very high concentrations in their blubber. The prey items of Puget Sound harbor seals were measured to have 7 times higher concentrations of PCBs than prey from Strait of Georgia on a lipid basis (Cullon et al. 2005), which corresponds to PCB concentrations measured in harbor seal blubber.

PCB tissue concentrations are often reported as dioxin toxicity equivalents (i.e. TEQs) which represent the toxicity of dioxin-like PCBs, dioxins and furans relative to the most toxic dioxin - 2,3,7,8-TCDD. Puget Sound harbor seals have significantly higher TEQs in blubber (158 ng/kg lipid weight) compared to seals from the Strait of Georgia (33 ng/kg lipid weight) (Ross et al. 2004); the TEQ contribution was greater from PCBs than dioxins and furans. Levin et al. (2005) also found that the majority of TEQs in harbor seal pups (from southern B.C.) were from PCBs, not dioxins and furans.

Ross et al. (2000) reported measured mean total PCB concentrations in transient and Southern resident male killer whales of 251 and 146 mg/kg -lipid, respectively. The authors concluded these marine mammals are among most contaminated in the world. Further research on the northern, southern and transient killer whale communities have discovered that males bioaccumulate more PCBs than females; female offload a portion of their tissue burden to their young through maternal transfer (Krahn et al. 2007; Krahn et al. 2009). PCB concentrations in the blubber of mothers decrease temporarily during nursing and can reach concentrations below those in their calves. Mothers initiate bioaccumulation again after calves are weaned. Total PCB concentrations in southern resident killer whales range from about 5,000 to 180,000 µg /kg lipid. For all but three recent mothers, the measured concentrations exceed a marine mammal threshold for blubber concentrations (17,000 µg /kg lipid) (Krahn et al. 2007).

Although environmental concentrations of PCBs are gradually declining, one modeled estimate of southern resident killer whale recovery projects that blubber concentrations will not decrease to the marine mammal threshold until 2063 (Hickie et al. 2007). The reviewed studies suggest that marine mammals in Puget Sound are accumulating PCBs in their blubber to very high concentrations. The results of the quantitative assessment are congruent and classify PCBs as Priority 1.

PBDEs

The PBDE assessment was limited due to the lack of effects data, guidelines or criteria. While PBDEs have been measured in a variety of media, appropriate effects data were insufficient to fully asses this COC.

Water

Surface water data for PBDEs in freshwater (n=255) and marine offshore waters (n=126) were available; however, appropriate effects data were not available in the ECOTOX database, nor is there a WQC for PBDEs. Due to the lack of effects data, PBDEs in both fresh and marine waters were classified as “U”.

Sediment

PBDEs in freshwater and marine sediments were classified as “U”. A limited number of observed concentration data for PBDEs in marine (n=46) and freshwater (n=77) sediments were available. However sediment guidelines are not available for PBDEs in either fresh or marine sediments.

Tissue

PBDEs were not assessed in tissue due to a lack of effects thresholds.

Wildlife

PBDEs were not assessed quantitatively in wildlife due to a lack of effects doses. See the Additional Evidence from Regional Studies below for a discussion of available effects information.

Human Health

PBDEs are prioritized as unknown, “U” because NTR criteria are not available.

Additional Evidence from Regional Studies

Aquatic Life

Sloan et al. (2010) detected PBDEs in outmigrant Chinook salmon tissue and stomach content from four sites in Puget Sound. Concentrations in wild outmigrant juveniles were higher than in hatchery fish. PBDE concentrations in Puget Sound juvenile fishes ranged from 67 to 13,000 µg /kg lipid, which was generally comparable to those measured in the Lower Columbia River and Estuary. Sloan et al. (2010) conclude that PBDEs may be contributing to reduced health and fitness in outmigrant juvenile Chinook salmon.

PBDEs have also been detected in adult Chinook salmon returning to the Duwamish River; however, they were not detected in adult Chinook returning to the Johnstone Strait, Lower Fraser River, or the Deschutes River (Cullon et al. 2009). Lema et al. (2008) demonstrated that dietary exposures of certain PBDEs by adult fathead minnows alter thyroid status and thyroid hormone-regulated gene transcription. Arkoosh et al. (2010) found that juvenile Chinook salmon exposed to moderate doses of PBDEs through their diet may be at increased risk of disease relative to those exposed to higher or lower doses of PBDEs in their diet potentially indicative of a complex U-shaped dose response curve for PBDEs in Chinook salmon. PBDE levels in a mixture of fishes designed to represent the diet of Puget Sound harbor seals were found to be about four to five times higher than in a similar mixture of fish designed to represent the diet of harbor seals from the Strait of Georgia (Cullon et al. 2005).

Wildlife

Because little information on PBDE toxicity to wildlife is available and a quantitative assessment could not be conducted, the publications available are reviewed here regardless of their geographic location. Few studies have been conducted examining effects of PBDEs on birds.

The studies reviewed indicate that PBDEs impact the reproduction and endocrine system similarly to PCBs. Fernie et al. 2005 showed that American kestrel egg injection and oral gavage exposure to PBDE congeners caused hepatic oxidative stress and altered thyroid hormone and vitamin A concentrations and glutathione metabolism. Exposure to PBDE congener 71 for 75 days adversely impacted courtship and mating behavior of American kestrels (Fernie et al. 2008). These birds also displayed significant delays in clutch initiation and produced smaller eggs (Fernie et al. 2009). Eggshell thinning and reduced hatching success also resulted.

A study of species sensitivity to PBDEs (PBDE-71) observed that pentabrominated diphenyl ether (Penta BDE) exposure to eggs at 0.01 to 20 mg/kg caused decreased pipping and hatching success in American kestrels but not chickens or Mallard ducks (McKernan et al. 2009). Species sensitivity was concluded to be Mallard ducks <chickens <American kestrels.

Total PBDE concentrations in osprey eggs and nestling plasma were significantly lower in birds from the Lower Duwamish River (eggs: 321 ug/kg ww; plasma: 6 ppb ww) compared to (Johnson et al. 2009) those from the upper Willamette River (eggs: 897 ug/kg ww; plasma: 22 ug/kg ww). The total PBDE concentrations in the osprey eggs did not change significantly between 2003 and 2007. Reproductive failure was observed in four of nine nests in the Lower Duwamish area. A small dataset from this study suggests that some nestlings may have experienced immunosuppression. However, the results were inconclusive due to the small sample size.

One study (Fernie et al. 2011) was acquired for which a dietary effect dose could be determined. Fernie et al. (2011) exposed American kestrels to PBDEs (Hexa-BDE) via dietary exposure and measured reproductive parameters. Adult kestrels exposed to 0.51 mg/kg/d PBDE, an environmentally relevant dose, through their diet displayed less courtship behaviors, earlier egg laying, a greater clutch size and smaller eggs; however, there were no significant differences in the fledging or hatching rates compared to control.

To compare exposures of birds feeding in Puget Sound, a PBDE daily dose was estimated using the same methods as the other COCs for wildlife. At the higher sediment ingestion rate (4%), the estimated daily dose of total PBDEs for the osprey is 0.006 mg/kg/d. The estimated daily dose for the great blue heron is also 0.006 mg/kg/d. If the threshold from Fernie et al. 2011 is considered an effect dose, piscivorous birds in the Puget Sound watershed are estimated to experience lower exposure by approximately a factor of 100.

Compared to birds, a larger but still limited number of publications exist on the effects of PBDEs in mammals. Rodent exposure studies have demonstrated thyroid hormone disruption (Hallgren et al. 2001, Zhou et al. 2002), developmental neurotoxic and behavioral effects (Ericksson et al. 2001, Viberg et al. 2003a, Viberg et al. 2003b). A study of grey seal pups and juveniles observed a relationship between circulating thyroid hormones, transport proteins and PBDE uptake (Hall et al. 2003).

Similar to PCBs, there is evidence of PBDE bioaccumulation in the blubber of marine mammals at high concentrations. However, absolute total PBDEs concentrations appear to be lower than total PCBs. Cullon et al. (2005) measured PBDE concentrations 5 times higher in harbor seal prey from Puget Sound than the Strait of Georgia; however, the mean PBDE concentration was 5 times lower than that measured for PCBs. Krahn et al. (2009) and Rayne et al. (2004) found the same pattern of killer whale blubber concentrations in males, mothers and calves as they found for PCBs with males having the highest concentrations and females experiencing fluctuations due to maternal transfer. Krahn et al. (2005) measured total PBDE concentrations in killer whale blubber ranging from 680 to 15,000 ug/kg lipid. Mean PBDE concentrations in northern male killer whale blubber have been found to be significantly lower (203 ug/kg lw) than those of southern resident (942 ug/kg lw) and transient males (1015 ug/kg lw).

Although a full quantitative effects assessment was not conducted for PBDE exposure to wildlife, published research demonstrates that PBDEs are bioaccumulating to high concentrations in Puget Sound marine mammals. This coupled with the growing evidence that PBDE exposure can cause thyroid and developmental effects in mammals strongly suggest that PBDEs should be classified Priority 1.

Dioxins and Furans

Both observed environmental concentrations and effects data for dioxins and furans (PCDD/Fs) were limited. As a result the assessment was limited to evaluation of potential effects to wildlife and human health.

Water

Observed surface water data for PCDD/Fs were limited to 7 measurements in freshwater for 3 compounds (1,2,3,4,7,8 HxCDD, 1,2,3,7,8 PeCDD and 2,3,7,8 TCDD). No observed data were available for marine waters; effects data for these compounds were very limited. Due to the lack of data to assess these compounds, dioxins and furans in surface waters were classified as “U”.

Sediment

PCDD/Fs in freshwater and marine sediments were classified as “U”. A moderate number (n >700) of observed concentration data for PCDD/Fs in marine and freshwater sediments were available. However, FP SQS and SQS values are not available for PCDD/Fs. The 90th %ile observed freshwater sediment concentration exceeded both the PEL and TEL; while the 50th %ile concentration was below both the PEL and TEL. The 90th %ile observed nearshore marine sediment concentration was just above the PEL; while the 50th %ile concentration was above the TEL. The 90th %ile observed offshore was below the PEL, but above the TEL.

Tissue

PCDD/Fs were not evaluated in freshwater or marine tissues due to the lack of effects data or the lack of observed concentrations. No observed PCDD/Fs concentrations are available in freshwater or marine tissues.

Wildlife

PCDD/Fs were classified as Priority 1 for the great blue heron and river otter because the estimated daily dose was greater than 0.1 times the lowest effects dose. For harbor seal, PCDD/Fs were classified as Priority 2 because adequate effects data were available and the estimated daily doses are more than 10 times lower than the lowest effects dose. The osprey daily doses are estimated to be almost 1,000 times lower than the lowest effects dose; however, substantial uncertainty exists around the effects of PCDD/Fs on birds so the resulting classification was “U”. The estimated daily doses for great blue heron are close to one of the two existing effects doses for birds, so the assumption was made that reproductive effects were likely occurring.

Human Health

2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8 TCDD) was classified as Priority 1; NTR criteria were not available for other PCDD/Fs. The 90th %ile of the observed 2,3,7,8 TCDD concentrations exceeded the NTR criteria for all three tissue groups (bivalves, fish and other invertebrates). Tissue from both near and offshore areas exceeded the NTR criteria for one or more tissue types, although sample sizes were generally smaller than for freshwater tissues.

Additional Evidence from Regional Studies

Aquatic Life

Generally similar concentrations of PCDD/Fs were found in adult Chinook salmon returning to the Duwamish River, Johnstone Strait, Lower Fraser River, and the Deschutes River (Cullon et al. 2009).

Wildlife

PCDD/Fs TEQ residues in river otter livers from Puget Sound contributed one third to the total TEQs (Grove and Henny, 2008) indicating that PCBs accumulate in river otter livers to a concentration that is twice as toxic as dioxins and furans.

Studies in Puget Sound of harbor seal and southern resident killer whale prey items have shown that prey of these marine mammals are higher in dioxins and furans compared to the same prey from the Strait of Georgia and British Columbia coast (Cullon et al. 2005, Cullon et al. 2009). PCBs in Harbor seal prey were 3-4 times higher on a lipid basis than prey from the Strait of Georgia (Cullon et al. 2005). However, Ross et al. (2000) found that dioxin and furan concentrations in killer whale blubber were much lower than PCBs and there were no differences between whales from the northern and southern resident and transient communities. This was suspected to be due to metabolic removal of dioxins and furans.

DDTs and metabolites

Observed environmental data for DDTs were available for water, sediment and tissue; data in marine waters were very limited. Effects data were available for water, marine sediment, tissue residue, wildlife and human health. Freshwater sediment guidelines were not available.

Water

Freshwater

The 90th %ile observed concentration of DDTs and metabolites was below the 10th %ile of the available effects data; however, the 90th %ile concentration was above both the acute and chronic DDT WQC. DDTs in freshwater were classified as Priority 1.

Marine

DDTs were measured, but not detected, in a limited number of samples (n=11) in marine nearshore waters; there were no DDT measurements in offshore waters. DDTs in marine waters were classified as “U”.

Sediment

Freshwater Sediment

A FP-SQS is not available for DDT in freshwater sediment; as such this COC was classified as “U”. The 90th %ile observed DDT freshwater sediment concentration was well below both the PEL and PEC, while the 50th %ile concentration was above both the TEC and TEL.

Marine Sediment

A SQS is not available for DDT; as such, this COC was classified as “U”. The 90th %ile observed concentration in nearshore marine sediment was above the PEL, 2LAET, LAET and TEL; the 50th %ile concentration was below all four of these guidelines. In offshore sediments, both the 90th %ile and 50th %ile were below the PEL, 2LAET and LAET; and above the TEL.

Tissue

Freshwater

Total DDTs are classified as Priority 2 in freshwater non-decapod and fish tissue because the 90th %ile concentration is below the 10th %ile effects data. DDTs could not be assessed in freshwater decapods due to a lack of observed concentrations.

Marine

Total DDTs are classified as “U” in all marine nearshore and offshore tissues due to insufficient (< 5 values) effects data.

Wildlife

DDT and metabolites were assessed as the sum of DDT, DDE, and DDD isomers and were classified as Priority 1 for great blue heron and osprey because the estimated daily doses are greater than 0.1 times the lowest effect dose. The mammals, river otter and harbor seal, were both classified as Priority 2 because the estimated daily doses are more than 10 times lower than the lowest effect dose.

Human Health

4,4’ DDT was classified as Priority 2 in all freshwater and offshore tissues types. In the nearshore area, the 90th %ile concentration of 4,4’ DDT for both fish and other invertebrates exceeded the NTR threshold and were classified as Priority 1. For the DDT metabolite 4,4’ DDE, only the 90th %ile of other invertebrate tissues in freshwater exceeded the NTR threshold and was classified as Priority 1. All tissues in near and offshore areas were classified as Priority 2. For the DDT metabolite 4,4’ DDD, other invertebrates tissues in freshwater were classified as Priority 1, while all other areas and tissues were classified as Priority 2.

Additional Evidence from Regional Studies

Aquatic Life

Total DDT (sum of DDT, DDE, and DDD) concentrations in stomach contents of outmigrant juvenile Chinook salmon from the Duwamish Estuary and Commencement Bay were found to be elevated relative to the stomach content concentrations of fish from the Nisqually Estuary (Stein et al. 1995). Whole-body total DDT (sum of DDT, DDE, and DDD) concentrations in juvenile Chinook salmon were found to be relatively high (over 1000 ng/g lipid or 25 ng/g wet weight) in fish from the Nisqually, Duwamish and Columbia River Estuaries (Johnson et al. 2007).

Johnson et al. (2007) also found detectable levels of DDTs in stomach contents, with stomach content concentrations substantially higher in Columbia River and Grays Harbor juvenile Chinook than in Duwamish and Nisqually Estuary juvenile Chinook. Johnson et al. (2007) suggest that at the observed levels, DDTs are unlikely to cause adverse effect by themselves; however, they may contribute via additive or synergistic effects with other contaminants. Substantially higher levels of DDTs were found in adult Chinook salmon returning to the Duwamish River than in adult Chinook returning to the Johnstone Strait, Lower Fraser River, or Deschutes River (Cullon et al. 2009).

Analysis of DDT concentrations in Pacific herring indicated that concentrations from Puget Sound herring were 1.5 to 2.5 times higher than those from Strait of Georgia (West et al. 2008), with Puget Sound concentrations ranging from 19 to 27 ng/g wet weight (240 to 330 ng/g lipid).

Cullon et al. (2005) found similar levels of DDTs in a mixture of fishes designed to represent the diets of Puget Sound and Strait of Georgia harbor seals.

Wildlife

Grove and Henny (2008) evaluated DDTs in river otters. They did not detect DDT and detected only low concentrations of DDE (mean of 0.004-0.28 mg/kg ww) in river otter livers from Puget Sound which were much lower than those found in animals residing near the Columbia River (mean of 0.12-1.65 mg/kg ww).

Lipid based concentrations of total DDT concentrations in Harbor seal prey in Puget Sound are 1.6 times higher than those from the Strait of Georgia (Cullon et al. 2005). Puget Sound Chinook, the primary prey of southern resident killer whales, have higher body residues of DDTs and lower lipids compared to Chinook from British Columbia coast (Cullon et al. 2009). Krahn et al. (2009) found the same pattern of killer whale blubber concentrations as found for PCBs in males, mothers and calves. That is, males have the highest DDT concentrations in their blubber and female blubber concentrations vary with their maternity status due to maternal transfer. Total DDT concentrations in killer whales ranged from 1,000 to 160,000 ug/kg lipid.

PAHs

PAHs were evaluated in water, sediment and for human health.

Water

The majority of the toxicity data available for PAHs in surface waters is based on individual PAHs. As such, Total PAHs, HPAH and LPAH were not directly evaluated here.

Freshwater

While there were sufficient observed concentration data (N>1500 measurements) for the individual PAHs evaluated here, there were limited effects data for a number of PAH compounds. The 90th %ile observed concentrations of acenaphthene, anthracene, benzo(a)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene were below the 10th %ile of the available effects concentrations; these COC s were classified as Priority 2. Effects data were insufficient to evaluate benzo(a)anthracene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, and dibenzo(a,h)anthracene; these COCs were classified as “U”.

Marine Water

Observed concentrations of individual PAHs in nearshore waters were very limited (N=12). Due to the lack of sufficient measured concentrations, in addition to the limited availability of effects data, individual PAHs in nearshore waters were classified as “U”.

While there were sufficient observed nearshore marine concentration data for some individual PAHs, marine effects data were limited for a number of COCs. The 90th %ile observed concentrations of acenaphthene, fluoranthene, naphthalene and phenanthrene in nearshore waters were below the 10th %ile of the available effects data; these COCs were classified as “U”. The remainder of the individual PAHs in nearshore waters (anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, dibenzo(a,h,)anthracene, fluorene and pyrene) were classified as “U” due to insufficient data to fully assess these COCs. There were insufficient data to evaluate individual PAHS in offshore waters; these COCs were classified as “U”.

Sediment

Freshwater Sediment

Both LPAH and HPAHs in freshwater sediments were classified as Priority 1. The 90th %ile observed LPAH concentration was also above the FP-CSL; however, the 75th %ile concentration was below both the FP SQS and FP CSL. The 90th %ile HPAH concentration was below the FP-CSL and the 75th %ile concentration was below .both the FP-CSL and FP-SQS. These data suggest that only some of the highest detected concentrations are likely to be of concern. With the exception of benzo(a)anthracene which was classified as Priority 2, all of the individual PAHs evaluate were classified as Priority 1.

Marine Sediment

Both LPAH and HPAH in near and offshore sediments were classified as Priority 2; the 90th %ile observed concentrations were below the SQS. All of the individual PAHS in near and offshore sediments were also classified as Priority 2.

Tissue

Tissue residue concentrations of PAHs were not evaluated because these chemicals typically to not accumulate in the tissue of vertebrates and are rapidly metabolized in fish. It was beyond the scope of this effort to evaluate PAHs in those invertebrates that are not capable of metabolizing PAHs.

Wildlife

PAHs were not evaluated because these chemicals typically do not bioaccumulate in wildlife.

Human Health

Five if the nine individual PAHS (benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene) evaluated in freshwater tissue exceeded the NTR criteria and were classified as Priority 1. Concentrations of the remaining (anthracene, fluorene, fluoranthene, and pyrene) PAHs evaluated were below the NTR criteria and classified as Priority 2.

The same pattern of Priority classification was observed in nearshore tissues as was found for the freshwater tissues. Tissue data from nearshore waters was limited; as a result, five of the individual PAHS were classified as “U” (benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene). The remainder of offshore marine tissue was classified as Priority 2 for human consumption.

Additional Evidence from Regional Studies

Aquatic Life

Multiple investigations have identified biomarkers of PAH exposure in various Puget Sound fishes.

Bile and stomach content of outmigrant juvenile Chinook salmon were found to contain various PAHs (Johnson et al. 2007), demonstrating that diet pathways are important PAH exposure pathways. The authors suggest that exposure may result in immunosuppression and other health effects. These results expanded and confirmed previously documented PAH exposures (Stein et al. 1992; Stein et al. 1995). A dietary feeding study on juvenile Chinook documented growth and physiological responses from dietary exposures to PAHs at concentrations that were environmentally realistic in the Puget Sound (Meador et al. 2006).

Biomarkers of PAH exposure were confirmed in Puget Sound English sole, rock sole, and starry flounder collected from up to five sites in Puget Sound (Stein et al. 1992). Stein et al. found that biomarkers of exposure were related to the degree of sediment contamination. Further field study (Johnson 2000) resulted in recommended a sediment threshold of 1000 ppb total PAHs to protect English sole against liver lesions, DNA adducts in liver, and other effects. The causal relationship between elevated sediment PAH concentrations and English sole liver effects was confirmed by Meyers et al. (2003). In a study of English sole from the Hylebos Waterway and Colvos Passage, Sol et al. (2008) found no correlation between PAH exposure and age and little correlation between reproductive end points and PAH exposure. Pacific herring embryos were found to be affected by tricyclic PAHs in weathered crude oil (Incardona et al. 2009; Carls et al. 1999).

Several laboratory studies have documented that developmental defects in fish are associated with exposure to PAHs released by the weathered crude oil, notably the tricyclic-PAHs (Incardona et al. 2005; Incardona et al. 2006; Carls et al. 2008). Carls and Meador (2009) developed a description of the oil weathering, PAH toxicity, and embryo exposures to explain the observed toxicity of PAHs in weathered oil at relatively low levels. Driscoll et al. (2010) developed a framework for describing PAH exposure as a dose to fishes in order to understand the mechanisms of exposure and toxicity.

Bis(2-Ethylhexyl) Phthalate

The assessment of bis(2-ethylhexyl) phthalate was limited to water and sediment.

Water

The 90th %ile observed concentration of bis(2-ethylhexyl) phthalate in freshwater was below the 10th %ile of the available effects data; this COC was classified as Priority 2. Insufficient observed and effects data for bis(2-ethylhexyl) phthalate in marine nearshore waters were available; as such it was classified as “U”. The 90th %ile observed concentration of bis(2-ethylhexyl) phthalate in offshore marine water was below the 10th %ile of the available effects data; as such it was classified as Priority 2.

Sediment

The 90th %ile observed concentration of bis(2-ethylhexyl) phthalate in freshwater sediments was above the FP-SQS and the FP-CSL; this COC was classified as Priority 1. The OC-normalized 90th %ile concentrations in both marine nearshore and offshore sediments exceeded the marine SQS, resulting in Priority 1 classification.

Tissue

Bis(2-ethylhexyl)phthalate tissue concentrations were not evaluated because phthalates typically do not accumulate to a significant degree in tissues.

Wildlife

Bis(2-ethylhexyl) phthalate was not evaluated.

Human Health

The 90th %ile of the observed freshwater bivalve tissue concentration of bis(2-ethylhexyl) phthalate exceeded the NTR criteria. While there were a number of measurements (>100) for the other tissue types in marine and freshwaters, there were too few detections to calculate a 90th percentile. Thus for freshwater, bis(2-ethylhexyl)phthalate was classified as Priority 1, while for marine tissues bis(2-ethylhexyl)phthalate was classified as priority “U”.

Triclopyr

The assessment of triclopyr was limited to water.

Water

The 90th %ile observed triclopyr concentration in freshwater was below the 10th %ile concentration of the available effects concentrations and was classified as Priority 2. No observed triclopyr data were available in marine nearshore or offshore waters, resulting in a classification of “U”.

Sediment

No observed concentrations of triclopyr are available in freshwater or marine sediments. This COC was classified as “U” in sediments.

Tissue

Tissue concentrations were not evaluated because these types of pesticides typically do not accumulate in tissues.

Wildlife

Triclopyr was not evaluated because it is not bioaccumulative in wildlife.

Human Health

Triclopyr is not listed in the NTR and was not evaluated.

Nonylphenol

The assessment of nonylphenol was limited to water and sediment. Effects data are limited for this COC.

Water

Nonylphenol was classified as Priority 2 in freshwater because the 90th %ile concentration is below the acute and chronic WQC and below the 10th %ile of the available effects data. However, the 95th %ile observed concentration was above the chronic WQC for nonylphenol. Nonylphenol was classified as “U” in marine nearshore water because insufficient effects and observed data were available. Nonylphenol was classified as Priority 2 in offshore marine water because the 90th %ile concentration is below the acute and chronic WQC and below the 10th %ile of the available effects data.

Sediment

Nonylphenol was classified as “U” in sediments because no FP-SQS is available for freshwater sediments and no SQS or CSL are available for marine sediments.

Tissue

Nonylphenol tissue concentrations were not evaluated because this COC does not typically bioaccumulate to a significant degree in tissues.

Wildlife

Nonylphenol was not evaluated because it is not bioaccumulative in wildlife.

Human Health

Nonylphenol is not listed on the NTR and was not evaluated.

Petroleum

Water

All four of the individual petroleum products were classified as “U” because the number of effect concentrations for each product was insufficient (< 15) and the number of observed concentrations for heavy fuel/bunker oil was insufficient (< 50).

Sediment

Petroleum was not assessed in sediment because there are no sediment guidelines nor observed sediment data.

Tissue

Petroleum was not assessed for tissue residues because there are no effects nor observed tissue data.

Wildlife

Petroleum could not be evaluated for wildlife because there are no effects data.

Human Health

Petroleum was not evaluated because it is not listed on the NTR.

Combined Prioritization for all Elements of the Assessment

The specific COCs evaluated in the quantitative assessments varied; a summary of the media and pathways evaluated for each COC is presented in Table 9. The chemicals assessed in this report were placed into three groups based on the likelihood that they may currently be causing widespread environmental effects (Table 10). This grouping was based on a review of the individual priority classification for each line of evidence evaluated.

COCs with multiple Priority 1 and different lines of evidence

Those chemicals with two or more Priority 1 classifications for the different lines of evidence were categorized as “Multiple Priority 1”. These chemicals represent the COCs with the most compelling evidence that they may be causing widespread environmental effects in the Puget Sound region. Chemicals in “Multiple Priority 1” are likely to warrant action to reduce the potential for widespread environmental affects.

COCs with a single Priority 1 or line of evidence

Those chemicals with one priority 1 classification were placed in “Single Priority 1”. These COCs represent those with strong evidence that they may be causing widespread environmental effects in the Puget Sound region, but where the evidence is limited to one line evidence from the many evaluated. Chemicals in “Single Priority 1” are likely to warrant action to reduce the potential for widespread environmental affects.

COCs with no Priority 1 and no additional lines of evidence

COCs that were not classified in any media for pathway were categorized as “No Priority 1”. These COCs represent those with ongoing concern about their effects, but for which limited evidence is available to indicate they may be causing widespread environmental impacts in the Puget Sound region. Some “No Priority 1” COCs were not evaluated for some lines of evidence due to limited availability of observed data and/or the lack of effects data. Chemicals in “No Priority 1” may warrant action based on existing concerns that the current assessment was unable to capture and the extent and nature of the potential effects from these chemicals.

Table 9. Summary of COCs Assessed.

COC	Water	Sediment	Tissue	Wildlife	Human Health
Arsenic	X	X	NA	NA	X[1]
Cadmium	X	X	NA	NA	NA
Copper	X	X	NA	NA	NA
Lead	X	X	NA	NA	NA
Mercury	X	X	X	X	X
Zinc	X	X	NA	NA	NA
PCBs[2]	X	X	X	X	X
PBDEs	NA	NA	NA	X[3]	NA
PCDD/Fs[4]	X	NA	NA	X	X
DDT and Metabolites[5]	X	X	X	X	X
LPAHs[6]	NA	X	NA	NA	NA
HPAH[6]	NA	X	NA	NA	NA
Acenaphthene	X	X	NA	NA	NA
Anthracene	X	X	NA	NA	X
Benzo(a) anthracene	X	X	NA	NA	X
Benzo(a)pyrene	X	X	NA	NA	X
Benzo(b) fluoranthene[7]	NA	X	NA	NA	X
Benzo(k) fluoranthene[7]	X	X	NA	NA	X
Chrysene	X	X	NA	NA	NA
Dibenzo(a,h) anthracene	X	X	NA	NA	X
Fluoranthene	X	X	NA	NA	X
Fluorene	X	X	NA	NA	X
Indeno(1,2,3)pyrene	X	X	NA	NA	X
Naphthalene	X	X	NA	NA	NA
Phenanthrene	X	X	NA	NA	NA
Pyrene	X	X	NA	NA	X
Bis(2-Ethylhexyl) Phthalate	X	X	NA	NA	X
Triclopyr	X	NA	NA	NA	NA
Nonylphenol	X	NA	NA	NA	NA
Petroleum - Heavy Fuel Oil	X	NA	NA	NA	NA
Petroleum - Diesel Fuel Oil	X	NA	NA	NA	NA
Petroleum - Gasoline	X	NA	NA	NA	NA
Petroleum - Lube Oil	X	NA	NA	NA	NA

NA - not evaluated in the hazard assessment for one or more reasons.

[1] Specifically the inorganic arsenic form was assessed for human health.

[2] Assessed as individual Aroclors and/or congeners or total PCBs.

[3] In the WOE discussion for PBDEs, limited effects data are discussed in the context of estimated daily doses for wildlife.

[4] Assessed as individual congeners, 2,3,7,8-TCDD or TEQs.

[5] Assessed as DDT, DDE, and DDD or as a sum.

[6] LPAHs and HPAHs are assessed as individual PAHs in all assessments except sediment.

[7] Assessed as part of total benzofluoranthenes in sediment assessment.

Table 10. Overall chemical groupings based on evaluation of all lines of evidence, including regional studies.

Multiple Priority 1 Classifications	Single Priority 1 Classifications		No Priority 1 Classifications
Copper	Arsenic*	Chrysene*	Lead*
Mercury*	Cadmium*	Fluoranthene*	Benzo(a)anthracene*
Zinc*	PBDEs*	Fluorene*	Triclopyr* ’
PCBs*	LPAHs	Naphthalene*	Nonylphenol*
Dioxins/Furans*	HPAHs	Phenanthrene*	Petroleum – Diesel*
DDT/DDE/DDD*	Anthracene*	Pyrene*	Petroleum – Heavy Fuel Oil*
Bis(2-ethylhexyl)phthalate*	Benzo(ghi)perylene*		Petroleum – Gasoline*
Benzo(a)pyrene*	Acenaphthene*		Petroleum – Lube Oil*
Dibenzo(ah)anthracene*	Acenaphthylene		
Indeno(123-cd)pyrene*			
Benzo(b)fluoranthene*			
Benzo(k)fluoranthene*			

Notes: COCs with an "*" were not prioritized in at least one media or pathway due to insufficient data (observed or effect data). It is important to note that not all COCs were evaluated in all media or pathways; the reader is encouraged to review Table 9 which summarizes the assessments that were conducted on each COC.

Uncertainty

While this hazard evaluation provides a broad general overview of the potential for the COCs evaluated to cause adverse ecological and human health effects, a number of uncertainties associated with the assessment process should be taken into consideration when interpreting the results. The following sections highlight the key uncertainties associated with the various elements of the assessment.

Environmental Data

This assessment included collection of a large number of environmental measurements for COCs in sediment, water and tissue from throughout the region. The EIM database likely includes the majority of observed ambient environmental data available for the Puget Sound region. Combined with the additional data included in this assessment, the dataset likely represents a reasonable representation of conditions in the Puget Sound region for many of the COCs. However, as previously indicated, there are likely data associated with special studies and research that have not been incorporated into readily accessible databases that were not included here.

Due to the broad nature of this assessment, the appropriateness of the analytical detection limits for the available environmental data were not evaluated. It is not anticipated that detection limits are a significant source of uncertainty for most COCs. However, for some COCs, such as PCB Aroclors® in surface waters, insufficient detection limits are a likely significant source of uncertainty. While there were a relatively large number of measurements for PCB Aroclors® (N>1200 in freshwater) the FOD was very low (3.5%). Based on a comparison to the much higher FOD for PCB congeners in water (58%), it is likely that Aroclor® measurements in water may represent an underestimate of the observed water concentration of this COC and PCBs as congeners better represents PCB concentrations and thus priority.

The assessment methodology is focused on COCs, which due to high concentrations (90th %ile) in some areas may pose a threat to Puget Sound. Including estimates of non-detected concentrations (e.g. detection limits, ½ detection limits, or zero) would result in lowering the 90th %ile for infrequently detected compounds, although it would not likely influence 90th %iles for frequently detected chemicals. Thus, commonly measured but rarely detected COCs such as DDT/DDD/DDE in water would be less likely to rank as Priority 1, while the rank of commonly detected COCs such as zinc in water would be unchanged. By considering only detected concentrations, some COCs with low FODs may be conservatively included in Priority 1.

For the Human Health priority classifications, the greatest source of uncertainty is associated with COCs that were not evaluated because there are no NTR criteria for these chemicals; the priority for these COCS is unknown. An additional uncertainty is associated with the exposure pathways that were not assessed here (e.g., dermal water exposures as well as air, inhalation, and dust exposures). These various other exposure pathways result in an additive exposure to COCs.

Ecological Data

The wildlife assessment required a number of ecological parameters to estimate daily doses of COC s for wildlife receptors. The most important of these parameters are the food and sediment ingestion rates because bioaccumulation is driven mainly by prey and sediment ingestion. Although a model was applied to estimate prey ingestion rates, the uncertainty associated with this parameter is small relative to the sediment ingestion rates. This is due to the significant relationship between body size and food ingestion rate. However, sediment ingestion is less predictable from body size and is more dependent on feeding strategies and foraging habitat. The total daily dose estimated using the upper and lower sediment ingestion rates for each receptor in the wildlife assessment demonstrated that there is little relative sensitivity to this parameter. Thus, the high uncertainty associated with sediment ingestion rates appears to have minimal impact on the results of this assessment.

Effects Data

Due to the variety of effects data used for this assessment there are a number of uncertainties that should be considered when interpreting the results. The water assessment relied primarily on the effect data obtained from the ECOTOX database. While an effort was made to screen out effects data that were inappropriate for use, the sheer volume of effect concentrations precluded a detailed review of these data. The QA/QC process used to evaluate the accuracy of the ECOTOX data base suggests that the use of these data is likely a source of uncertainty. It is unclear if the errors associated with the ECOTOX database would result in an over- or underestimate of the potential for effects to occur.

Some of the greatest uncertainty in the surface water assessment was associated with lack of effects data for some COCs, particularly for marine organisms and some dissolved metals. Uncertainties associated with the effects data used for the surface water assessment include, but are not limited to differences in the following variables: species sensitivity, exposure conditions (water quality - hardness and pH, light regime, temperature, feeding regime if any, chemical form of the COC and whether the test was static or flow through), test duration, appropriateness of endpoints evaluated and type of endpoint. These differences make comparability of effects data challenging at best.

An additional source of uncertainty was the lack of non-mortality based effects data for some COCs; this was especially an issue for some of the marine COCs. Only evaluating effects associated with COC exposure at concentrations that cause mortality may underestimate the potential for these COCs to cause more subtle impacts (e.g., growth, reproduction etc.) to some aquatic organisms. Uncertainty is also associated with the comparison of surface water concentrations of bioaccumulative COCs (PCBs, mercury, DDTs) to effects data based on direct water exposure only. This comparison does not account for indirect impacts associated with bioaccumulation; the potential for adverse effects is likely underestimated for these COCs. The reader is encouraged to evaluate the types of effects data available for each COC when drawing conclusions about these results.

Hardness can have a significant influence on the toxicity of metals in freshwater; however, due to the large volume of data evaluated here it was not practical to account for study specific hardness. Due to the large number of effects data that were available for most metals, it is not expected that this would have a significant impact on the outcome of the assessment. In general, hardness in the Puget Sound region tends to be low; therefore, it is unlikely that the effects data would have significantly underestimated metal toxicity.

The sediment assessment relied on a variety of established sediment guidelines thresholds. While these guidelines have been reviewed by others and some have undergone regulatory scrutiny, there are still some uncertainties associated with their use. For some COCs the concentration of OC and sulfides in the sediment can have a significant influence on bioavailability and toxicity. While some of the thresholds used here incorporated organic carbon, most did not account for site specific conditions that could influence bioavailability and toxicity. This assumption could have resulted in both an over- or under estimate of the potential for effects. The sediment guidelines were developed based on impacts to benthic organisms. Therefore, they do not provide a direct assessment of how sediment associated COCs can indirectly impact other aquatic organisms through bioaccumulation.

There are significant uncertainties associated with the effects data used for the tissue assessment. While use of tissue residues to assess toxicity can be a useful tool in some cases, care must be taken when using these data to estimate the potential for effects, particularly when used in a screening approach. In many cases, the available tissue residue data are not based on experiments designed to directly relate tissue residue to an effect and as a result they lack dose response data. An additional limitation results from the way much of the residue effects data are reported; unlike water based toxicity data which is reported in the context of a dose response, relatively little of the tissue residue data is reported as such (Meador et al. 2008).

For some organisms and COCs, lipid content can be an important factor in interpreting the toxic response. Due to the nature of this assessment and the limited availability of data, lipid content was not incorporated into the data interpretation.

In addition, there is also significant uncertainty associated with the number and type of tissue residue effect concentrations available for some COCs and tissue types; in some cases there were only one or two tissue residue effects levels available for a COC and tissue type. Some of the tissue residue effects data were limited to data only for mortality endpoints; which likely underestimated the prioritization for these COCs and tissue types. Typically, elevated tissue levels of bioaccumulative compounds will result in more subtle effects to growth or reproduction before they cause mortality. These factors contribute to the high level of uncertainty associated with the tissue residue assessment.

The petroleum effects concentrations were limited to fuel and lubricating oils. It is suspected that actual toxicity can vary substantially based on product additives, weathering, and phototoxicity. Additionally, the studies that served as a source of effects data utilized various water-product mixtures. For the purposes of this assessment only dissolved fractions were utilized. However, there is anecdotal evidence that product spills are common and sheens of product can often be found in the environment in selected areas. Waters with free product are potentially more toxic and/or present physical hazards to organisms. These issues create a high level of uncertainty for the petroleum assessment.

As previously discussed, the limited number of published effect doses for the wildlife receptors assessed here poses the greatest level of uncertainty in assessing potential effects in wildlife. In comparison to the volume of effects data available for aquatic life, the data available for wildlife may seem very weak; however, it should be noted that the dose-response studies for wildlife are frequently very comprehensive in examining effects. In comparison to a 30-day aquatic study that measures lethal doses, wildlife dose-response studies often include exposure over a reproductive cycle and examine everything from changes in adult body weight to egg size, time to hatch, female menses, and fertility of offspring. All these observations get lumped into broad categories. Considering the relative number of effects doses available for wildlife, the greatest uncertainty is associated with the dioxin/furan effects doses, particularly for birds.

Only about one-half of the COCs in this assessment were also listed in the NTR. The remaining chemicals were not evaluated, and thus pose a significant uncertainty regarding the potential for these COCs to cause human health effects. As previously discussed, none of the COCs were evaluated to estimate potential risk from water ingestion or dermal exposure. The same issue applies to sediment exposures, as there are no adopted and published standards for human exposure to sediments. Systemic human toxicity was also not evaluated for any of the COCs.

Data Gaps

It was assumed that the data identified for this assessment would be relatively representative of the region. However, due to the broad nature of this effort, the spatial distribution of data for a given COC within an assessment area (freshwater, near and offshore areas) is not well understood. This is a key gap in the current analytical approach when making broad generalizations regarding the priority on a sound wide basis.

For some matrices and spatial areas (e.g., freshwater metals where N was >3000) the assumption that the data are representative is likely true; however, data were limited for some COCs in some matrices and spatial areas (e.g., offshore COCs where many Ns were <20). This is not to suggest that thousands of measurements are necessary to provide a reasonable estimate of priority; in some cases other factors can be taken into account to increase the confidence of this assumption. For example, since the source of many COCs to offshore waters is via upland or nearshore inputs it can be reasonably assumed that if a COC is not Priority 1 in the nearshore it is not likely to be of Priority 1 in the offshore marine waters. There may be some exceptions to this logic; for example, bioaccumulative and hydrophobic chemicals tend to be present in freshwater streams at relatively low levels, but are subsequently biomagnified to high levels in upper trophic level organisms.

Potential gaps in data availability and spatial distribution should be taken into account when interpreting these data and using them to prioritize future efforts. A spatial analysis of existing data to identify regions or areas with high and low data densities would be a first step in understanding the magnitude and distribution of environmental data gaps.

As presented in the uncertainty discussion above, there were limited effects data for a number of COCs and matrices. This data gap is particularly significant for a number COCs in marine matrices. In water, there were limited effects data for many of the COCs evaluated; in some cases the available data were primarily based on mortality effects. This data gap limited the ability to fully assess the potential for these COCs to cause effects in marine waters and was compounded by the limited number of marine surface water measurements, particularly nearshore waters, for many COCs where the number of measurements was typically less than 15. Very few surface water PCB measurements in both marine and freshwaters were available; this limited the ability to fully assess this COC in this matrix.

In comparison to surface water, the sediment dataset (both effects and observed) was more robust. The most significant sediment data gap was the lack of multiple sediment guidelines for some COCs and a lack of nonylphenol environmental data. Only one guideline was available to evaluate nonylphenol in both marine and freshwater sediments. Only one set of guidelines were available for HPAH and LPAH and a number of individual PAHs in freshwater sediments and for dioxins/furans in both freshwater and marine sediments. Sediment guidelines were also lacking for triclopyr and PBDEs.

There were significant data gaps associated with the tissue assessment. Tissue residue effects data were limited for a number of the COCs and tissue types evaluated. In some cases there were less than five tissue residue effect values (e.g., mercury in marine tissues; PCBs in freshwater decapods and marine fish; dioxins/furans in all tissue types except freshwater fish; DDTs in marine tissues). There were very few measurements of dioxins/furans in tissue; no data were available for freshwater tissue types. There were limited PBDE tissue data and no readily available effects data for this COC. These data gaps limited the ability to fully assess the potential effects of these COCs.

As previously indicated, the lack of NTR criteria limited the number of COCs that could be evaluated for human health effects. Although there were invertebrate inorganic arsenic data, there were no inorganic arsenic data for freshwater or marine fish, which limited the ability to fully assess the human health priority for this COC. Additionally triclopyr, PBDEs and the sum of cPAHs are not part of the NTR and could not be prioritized.

The limited amount of effects data for PBDEs limited the ability to assess them in tissue and wildlife.

Recommendations for Further Assessment

- The spatial distribution of data used in this assessment was not assessed beyond the general habitat types (freshwater, marine near and offshore). The data for some COCS in all matrices are not likely evenly distributed throughout the region. As a result it is unknown if the data used in this assessment are truly representative of the region or only limited areas. This is of greatest concern for those COCs for which data were limited (see data gaps listed above). To fully understand if the priority identified for a COC applies on a regional basis, or is limited to a discrete area, additional data analysis that examines the spatial distribution of the data could be done. This analysis would provide additional information to focus future hazard reduction efforts to areas of greatest concern.

- Marine surface water data were limited for a number of COCs. Expansion of the number and type of parameters measured by ambient surface water monitoring programs would provide a means to fill this environmental data gap. The parameter list should focus on COCs that were Priority 1 in freshwaters; in addition to those likely to be bioaccumulated in the marine food web (e.g., nonylphenol, mercury, PCBs, HPAHs, PBDEs, and DDTs).

- Petroleum product data was not available for marine waters and the degree to which individual PAHs represent spilled and degraded petroleum products is unknown. Future investigations targeting a more complete suite of alkylated PAHS, other PAH and petroleum products, and their degradates could more fully characterize petroleum hazards.

- Sediment data for nonylphenol, particularly in marine sediment was limited. Sediment data for PCB congeners and PBDEs was also limited, particularly in marine nearshore areas. PCB Aroclor data is likely sufficient to identify priority; however additional PBDE and nonylphenol data would improve the ability to determine the priority for these COCs

- Tissue data for inorganic arsenic were very limited. Collection of inorganic arsenic data in edible seafood tissue would provide more certainty in determining human health priority for this COC.

- Effects data to assess surface waters were limited for a number of COCs, particularly for effects other than mortality. It is possible that additional data may be identified through a literature search and review for those COCs that are of greatest concern (this was beyond the scope of the current assessment). Additional effects data for some COCs would provide better certainty in determining the priority.

- Sediment guidelines were not available or limited for a number of COCs (PBDEs, dioxins, and nonylphenol). It is possible that additional effects data may be identified through a literature search. Additional effects data for these COCs would provide better certainty in determining priority.

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Appendix E. Glossary, Acronyms, and Abbreviations

Glossary

Ambient area: Un-impacted area; away from point sources of contamination.

Anthropogenic: Human-caused.

Aquatic life: Aquatic life refers to any organism which spends all of, the majority of, or significant portions of its life stage in water.

Attenuation: The reduction in the concentration, mass, toxicity, mobility, or volume of a chemical due to chemical, biological, or physical processes.

Baseflow: Groundwater discharge to a surface stream or river. The component of total streamflow that originates from direct groundwater discharges to a stream.

Basin: A drainage area or watershed in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Benthic: Bottom-dwelling.

Bioaccumulative chemicals: Chemicals that build up and become concentrated in organisms.

Bivalves: Mollusks having a shell consisting of two hinged valves. Examples are clams, mussels, and oysters.

Built-up roof: A general term that can be applied to many flat, membrane, or torch-down roof types.

Catch basin: Large underground container for the collection of sediment and other debris from stormwater run-off. Designed to catch or collect the dirt and debris, and prevents it from entering surface water.

Congener: In chemistry, congeners are related chemicals. For example, polychlorinated biphenyls (PCBs) are a group of 209 related chemicals that are called congeners.

Constrained systems: Physical systems that generally do not allow chemicals to become mobilized in other environmental compartments or environmental pathways (e.g., sanitary sewer systems).

Dry season: In this study, May through September.

Effects data: In this study and specifically for the hazard evaluation, data from toxicity testing or derived otherwise to indicate chemical concentrations where effects are elicited.

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Enrichment: Natural or human-caused enhancement of chemical concentrations in environmental media such as water or soils.

Exceeds (or is above) guidelines or standards: Does not meet guidelines or standards.

First flush: A rain event following an extended dry period. Runoff from a first flush can contain elevated concentrations of contaminants.

Flux: Amount that flows through a unit area in a unit of time.

Guilds: In this study, groups distinguished by their trophic level.

Hazard evaluation: A screening-level assessment of relative toxic hazards posed by chemicals at observed concentrations.

Land cover types: In this study, commercial/industrial, residential, agricultural, and forests.

Load pathways: In this study, groundwater, air deposition, surface water runoff, publicly-owned treatment works, and ocean exchange.

Loading: The input of pollutants into a waterbody.

Marine water: Saltwater

Micronutrient: Nutrients required by organisms at very low concentrations.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Observed data: In this study and specifically for the hazard evaluation, data on chemical concentrations in various media sampled since January 1, 2000.

Ocean boundary: Approximate area or space – theoretically defined by a vertical plane, a series of planes, or polygons – where Pacific Ocean waters are exchanged with the waters of Puget Sound.

Ocean exchange: The flux of Pacific Ocean waters and the waters of Puget Sound across the ocean boundary.

Organics: Shorthand for organic chemicals (those which contain carbon).

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Pelagic: Open-water.

Personal care products (or toiletries): Products used for personal hygiene or beautification. Personal care includes products as diverse as chapstick, colognes, cotton swabs, deodorant, eye liner, facial tissue, hair clippers, lipstick, lotion, makeup, mouthwash, nail files, pomade, perfumes, personal lubricant, razors, shampoo, shaving cream, skin cream, toilet paper, cleansing pads and wipes, lip gloss, toothbrushes, and toothpaste, to give a few examples.

Piscivorous: Fish-eating.

Point source: Sources of pollution that discharge at a specific location from stacks, pipes, outfalls, or conveyance channels to a surface water.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char.

Sediment: Solid fragmented material (soil and organic matter) that is transported and deposited by water and covered with water (example, river or lake bottom).

Sill: A relatively shallow area of the seabed.

Source: For the purpose of the present project, the term *source* is strictly defined as: the object or activity from which a COC is initially released to environmental media (air, water, or soil) or released in a form which can be mobilized and transported in an environmental pathway.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Study Area: The geographical study area for this *Assessments* study is Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits.

Surface runoff: In this study, surface runoff is broadly defined to include stormwater, nonpoint source overland flow, and groundwater discharge to surface waters that flow into marine waters.

Toxicant: Toxic contaminant.

Toxics: Shorthand for toxic chemical.

Water column: In a waterbody, a conceptual cylinder of water extending from the top of the sediment layer to the surface of the water.

Watershed: Basin. A drainage area in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Wet season: In this study, October through April.

Acronyms and Abbreviations

a.k.a.	also known as
ABS	acrylonitrile butadiene styrene
AOP	Air Operating Permit
API	American Petroleum Institute or [King County] Asian and Pacific Islander
ATSDR	Agency for Toxic Substances and Disease Registry
BEE	butoxyethyl ester
CAP	Chemical Action Plan
CCA	chromated copper arsenate
COC	chemical of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
DBP	di-n-butyl phthalate
DDT	dichlorodiphenyltrichloroethane
DEHP	di(2-ethylhexyl) phthalate [a.k.a. bis(2-ethylhexyl) phthalate]
DEP	diethyl phthalate
ECB	European Chemicals Bureau
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
Hg	mercury
HPAH	high-molecular weight polycyclic aromatic hydrocarbon
LAET	lowest apparent effects threshold
LCR	Lead and Copper Rule

LPAH	low-molecular weight polycyclic aromatic hydrocarbon
N	number
NOAA	National Oceanic Atmospheric Administration
NTR	National Toxics Rule
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PBT	persistent, bioaccumulative, and toxic substance
PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzo-*p*-dioxin and dibenzofuran
PEC	probable effects concentration
PEL	probable effects level
POP	persistent organic pollutant
POTW	Publicly-owned treatment works
PSP	Puget Sound Partnership
PSTLA	Puget Sound Toxics Loading Analysis
PVC	polyvinyl chloride
SQS	Sediment Quality Standards
TEA	triethylamine
TEC	threshold effects concentration
TEL	thresholds effects level
TEQ	toxic equivalent
TRI	Toxics Release Inventory
UC	University of California
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
WQC	water quality criteria

Units of Measurement

°C	degrees Celsius
d	day
dw	dry weight
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams.
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters.
m	meter
mg	milligrams
mg/kg	milligrams per kilogram (parts per million)
mg/l	milligrams per liter (parts per million)
ng/g	nanograms per gram (parts per billion)
ng/kg	nanograms per kilogram (parts per trillion)
ng/l	nanograms per liter (parts per trillion)
pg/l	picograms per liter (parts per quadrillion)

t	tonne (metric ton, equal to 1,000 kg); appr. 2.2 tons
t/yr	tonnes (metric tons) per year
ug/kg	micrograms per kilogram (parts per billion)
ug/l	micrograms per liter (parts per billion)
ww	wet weight

Treatment Technology Review and Assessment

Association of Washington Business
Association of Washington Cities
Washington State Association of Counties

December 4, 2013

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Acronyms

Acronym	Definition
AACE	Association for the Advancement of Cost Engineering
AOP	advanced oxidation processes
AWB	Association of Washington Businesses
BAC	biological activated carbon
BAP	benzo(a)pyrene
BOD	biochemical oxygen demand
BTU	British thermal unit
CEPT	Chemically-enhanced primary treatment
cf	cubic feet
CIP	clean in place
CRITFC	Columbia River Inter-Tribal Fish Commission
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
FCR	fish consumption rate
g/day	grams per day
GAC	granular activated carbon
gal	gallon
gfd	gallons per square foot per day
GHG	greenhouse gas
gpd	gallons per day
gpm	gallons per minute
GWh	giga watt hours
HDR	HDR Engineering, Inc.
HHWQC	human health water quality criteria
HRT	hydraulic residence time
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
KWh/MG	kilowatt-hours per million gallons
lb	pound
MBR	membrane bioreactor
MCL	maximum contaminant level
MF	microfiltration
mgd	million gallons per day
mg/L	milligrams per liter
MMBTU	million British thermal units
MWh/d	megawatt-hours per day
NF	nanofiltration
ng/L	nanograms per liter
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
O&M	operations and maintenance
ODEQ	Oregon Department of Environmental Quality
PAC	powdered activated carbon
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PE	population equivalents
PIX	potable ion exchange

Acronym	Definition
ppm	parts per million
RO	reverse osmosis
SDWA	Safe Drinking Water Act
sf	square feet
SGSP	salinity gradient solar pond
SRT	solids retention time
Study Partners	Association of Washington Businesses/Association of Washington Cities and Washington State Association of Counties consortium
TDS	total dissolved solids
TMDL	total maximum daily load
TSS	total suspended solids
UF	ultrafiltration
µg/L	micrograms per liter
USDA	U.S. Department of Agriculture
UV	ultraviolet
WAC	Washington Administrative Code
WAS	waste activated sludge
WLA	waste load allocation
WWTP	wastewater treatment plant
ZLD	zero liquid discharge

Executive Summary

This study evaluated treatment technologies potentially capable of meeting the State of Washington Department of Ecology's (Ecology) revised effluent discharge limits associated with revised human health water quality criteria (HHWQC). HDR Engineering, Inc. (HDR) completed a literature review of potential technologies and an engineering review of their capabilities to evaluate and screen treatment methods for meeting revised effluent limits for four constituents of concern: arsenic, benzo(a)pyrene (BAP), mercury, and polychlorinated biphenyls (PCBs). HDR selected two alternatives to compare against an assumed existing baseline secondary treatment system utilized by dischargers. These two alternatives included enhanced secondary treatment with membrane filtration/reverse osmosis (MF/RO) and enhanced secondary treatment with membrane filtration/granulated activated carbon (MF/GAC). HDR developed capital costs, operating costs, and a net present value (NPV) for each alternative, including the incremental cost to implement improvements for an existing secondary treatment facility.

Currently, there are no known facilities that treat to the HHWQC and anticipated effluent limits that are under consideration. Based on the literary review, research, and bench studies, the following conclusions can be made from this study:

- Revised HHWQC based on state of Oregon HHWQC (2001) and U.S. Environmental Protection Agency (EPA) "National Recommended Water Quality Criteria" will result in very low water quality criteria for toxic constituents.
- There are limited "proven" technologies available for dischargers to meet required effluent quality limits that would be derived from revised HHWQC.
  - Current secondary wastewater treatment facilities provide high degrees of removal for toxic constituents; however, they are not capable of compliance with water quality-based National Pollutant Discharge Elimination System (NPDES) permit effluent limits derived from the revised HHWQC.
  - Advanced treatment technologies have been investigated and candidate process trains have been conceptualized for toxics removal.
    - Advanced wastewater treatment technologies may enhance toxics removal rates; however, they will not be capable of compliance with HHWQC-based effluent limits for PCBs. The lowest levels achieved based on the literature review were between <0.00001 and 0.00004 micrograms per liter (µg/L), as compared to a HHWQC of 0.0000064 µg/L.
    - Based on very limited performance data for arsenic and mercury from advanced treatment information available in the technical literature, compliance with revised criteria may or may not be possible, depending upon site specific circumstances.
      - Compliance with a HHWQC for arsenic of 0.018 µg/L appears unlikely. Most treatment technology performance information available in the literature is based on drinking water treatment applications targeting a much higher Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 10 µg/L.
      - Compliance with a HHWQC for mercury of 0.005 µg/L appears to be potentially attainable on an average basis, but perhaps not if effluent limits are structured on a maximum monthly, maximum weekly or maximum daily basis. Some secondary treatment facilities attain average effluent mercury levels of 0.009 to 0.066 µg/L. Some treatment facilities with effluent filters attain average effluent mercury levels of 0.002 to 0.010 µg/L. Additional

        advanced treatment processes are expected to enhance these removal rates, but little mercury performance data is available for a definitive assessment.

        - Little information is available to assess the potential for advanced technologies to comply with revised BAP criteria. A municipal wastewater treatment plant study reported both influent and effluent BAP concentrations less than the HHWQC of 0.0013 ug/L (Ecology, 2010).

    - Some technologies may be effective at treating identified constituents of concern to meet revised limits while others may not. It is therefore even more challenging to identify a technology that can meet all constituent limits simultaneously.
    - A HHWQC that is one order-of-magnitude less stringent could likely be met for mercury and BAP; however, it appears PCB and arsenic limits would not be met.
- Advanced treatment processes incur significant capital and operating costs.
    - Advanced treatment process to remove additional arsenic, BAP, mercury, and PCBs would combine enhancements to secondary treatment with microfiltration membranes and reverse osmosis or granular activated carbon and increase the estimated capital cost of treatment from $17 to $29 in dollars per gallon per day of capacity (based on a 5.0-million-gallon-per-day (mgd) facility).
    - The annual operation and maintenance costs for the advanced treatment process train will be substantially higher (approximately $5 million - $15 million increase for a 5.0 mgd capacity facility) than the current secondary treatment level.
- Implementation of additional treatment will result in additional collateral impacts.
    - High energy consumption.
    - Increased greenhouse gas emissions.
    - Increase in solids production from chemical addition to the primaries. Additionally, the membrane and GAC facilities will capture more solids that require handling.
    - Increased physical space requirements at treatment plant sites for advanced treatment facilities and residuals management including reverse osmosis reject brine processing.
- It appears advanced treatment technology alone cannot meet all revised water quality limits and implementation tools are necessary for discharger compliance.
    - Implementation flexibility will be necessary to reconcile the difference between the capabilities of treatment processes and the potential for HHWQC driven water quality based effluent limits to be lower than attainable with technology

Table ES-1 indicates that the unit NPV cost for baseline conventional secondary treatment ranges from $13 to $28 per gallon per day of treatment capacity. The unit cost for the advanced treatment alternatives increases the range from the low $20s to upper $70s on a per gallon per-day of treatment capacity. The resulting unit cost for improving from secondary treatment to advanced treatment ranges between $15 and $50 per gallon per day of treatment capacity. Unit costs were also evaluated for both a 0.5 and 25 mgd facility. The range of unit costs for improving a 0.5 mgd from secondary to advanced treatment is $60 to $162 per gallon per day of treatment capacity. The range of unit costs for improving a 25 mgd from secondary to advanced treatment is $10 to $35 per gallon per day of treatment capacity.

Table ES-1. Treatment Technology Costs in 2013 Dollars for a 5-mgd Facility

Alternative	Total Construction Cost, 2013 dollars ($ Million)	O&M Net Present Value, 2013 dollars ($ Million)***	Total Net Present Value, 2013 dollars ($ Million)	NPV Unit Cost, 2013 dollars ($/gpd)
Baseline (Conventional Secondary Treatment)*	59 - 127	5 - 11	65 - 138	13 - 28
Incremental Increase to Advanced Treatment - MF/RO	48 - 104	26 - 56	75 - 160	15 - 32
Advanced Treatment - MF/RO**	108 - 231	31 - 67	139 - 298	28 - 60
Incremental Increase to Advanced Treatment - MF/GAC	71 - 153	45 - 97	117 - 250	23 - 50
Advanced Treatment - MF/GAC	131 - 280	50 - 108	181 - 388	36 - 78

* Assumed existing treatment for dischargers. The additional cost to increase the SRT to upwards of 30-days is about $12 - 20 million additional dollars in total project cost for a 5 mgd design flow.

** Assumes zero liquid discharge for RO brine management, followed by evaporation ponds. Other options are available as listed in Section 4.4.2.

*** Does not include the cost for labor.

mgd=million gallons per day
MG=million gallons
MF/RO=membrane filtration/reverse osmosis
MF/GAC=membrane filtration/granulated activated carbon
O&M=operations and maintenance
Net Present Value = total financed cost assuming a 5% nominal discount rate over an assumed 25 year equipment life.

Costs presented above are based on a treatment capacity of 5.0 mgd, however, existing treatment facilities range dramatically across Washington in size and flow treated. The key differences in cost between the baseline and the advanced treatment MF/RO are as follows:

- Larger aeration basins than the baseline to account for the longer SRT (>8 days versus <8 days).
- Additional pumping stations to pass water through the membrane facilities and granulated activated carbon facilities. These are based on peak flows.
- Membrane facilities (equipment, tanks chemical feed facilities, pumping, etc.) and replacement membrane equipment.
- Granulated activated carbon facilities (equipment, contact tanks, pumping, granulated activated carbon media, etc.)
- Additional energy and chemical demand to operate the membrane and granulated activated carbon facilities
- Additional energy to feed and backwash the granulated activated carbon facilities.
- Zero liquid discharge facilities to further concentrate the brine reject.
    - Zero liquid discharge facilities are energy/chemically intensive and they require membrane replacement every few years due to the brine reject water quality.
- Membrane and granulated activated carbon media replacement represent a significant maintenance cost.

- Additional hauling and fees to regenerate granulated activated carbon off-site.

The mass of pollutant removal by implementing advanced treatment was calculated based on reducing current secondary effluent discharges to revised effluent limits for the four pollutants of concern. These results are provided in Table ES-2 as well as a median estimated unit cost basis for the mass of pollutants removed.

Table ES-2. Unit Cost by Contaminant for a 5-mgd Facility Implementing Advanced Treatment using Membrane Filtration/Reverse Osmosis

Component	PCBs	Mercury	Arsenic	BAPs
Required HHWQC based Effluent Quality (µg/L)	0.0000064	0.005	0.018	0.0013
Current Secondary Effluent Concentration (µg/L)	0.002	0.025	7.5	0.006
Total Mass Removed (lbs) over 25 year Period	0.76	7.6	2,800	1.8
Median Estimated Unit Cost (NPV per total mass removed in pounds over 25 years)	$290,000,000	$29,000,000	$77,000	$120,000,000

µg/L=micrograms per liter
lbs=pounds
NPV=net present value

Collateral adverse environmental impacts associated with implementing advanced treatment were evaluated. The key impacts from this evaluation include increased energy use, greenhouse gas production, land requirements and treatment residuals disposal. Operation of advanced treatment technologies could increase electrical energy by a factor of 2.3 to 4.1 over the baseline secondary treatment system. Direct and indirect greenhouse gas emission increases are related to the operation of advanced treatment technologies and electrical power sourcing, with increases of at least 50 to 100 percent above the baseline technology. The energy and air emission implications of advanced treatment employing granulated activated carbon construction of advanced treatment facilities will require additional land area. The availability and cost of land adjacent to existing treatment facilities has not been included in cost estimates, but could be very substantial. It is worthwhile noting residual materials from treatment may potentially be hazardous and their disposal may be challenging to permit. Costs assume zero liquid discharge from the facilities.

1.0 Introduction

Washington's Department of Ecology (Ecology) has an obligation to periodically review waterbody "designated uses" and to modify, as appropriate, water quality standards to ensure those uses are protected. Ecology initiated this regulatory process in 2009 for the human health-based water quality criteria (HHWQC) in Washington's *Surface Water Quality Standards* (Washington Administrative Code [WAC] 173-201A). HHWQC are also commonly referred to as "toxic pollutant water quality standards." Numerous factors will influence Ecology's development of HHWQC. The expectation is that the adopted HHWQC will be more stringent than current adopted criteria. National Pollutant Discharge Elimination System (NPDES) effluent limits for permitted dischargers to surface waters are based on U.S. Environmental Protection Agency (EPA) and state guidance. Effluent limits are determined primarily from reasonable potential analyses and waste load allocations (WLAs) from total maximum daily loads (TMDLs), although the permit writer may use other water quality data. Water quality-based effluent limits are set to be protective of factors, including human health, aquatic uses, and recreational uses. Therefore, HHWQC can serve as a basis for effluent limits. The presumption is that more stringent HHWQC will, in time, drive lower effluent limits. The lower effluent limits will require advanced treatment technologies and will have a consequent financial impact on NPDES permittees. Ecology anticipates that a proposed revision to the water quality standards regulation will be issued in first quarter 2014, with adoption in late 2014.

The Association of Washington Businesses (AWB) is recognized as the state's chamber of commerce, manufacturing and technology association. AWB members, along with the Association of Washington Cities and Washington State Association of Counties (collectively referred to as Study Partners), hold NPDES permits authorizing wastewater discharges. The prospect of more stringent HHWQC, and the resulting needs for advanced treatment technologies to achieve lower effluent discharge limits, has led this consortium to sponsor a study to assess technology availability and capability, capital and operations and maintenance (O&M) costs, pollutant removal effectiveness, and collateral environmental impacts of candidate technologies.

The "base case" for the study began with the identification of four nearly ubiquitous toxic pollutants present in many industrial and municipal wastewater discharges, and the specification of pollutant concentrations in well-treated secondary effluent. The pollutants are arsenic, benzo(a)pyrene (BAP), mercury and polychlorinated biphenyls (PCBs), which were selected for review based on available monitoring data and abundant presence in the environment. The purpose of this study is to review the potential water quality standards and associated treatment technologies able to meet those standards for four pollutants.

A general wastewater treatment process and wastewater characteristics were used as the common baseline for comparison with all of the potential future treatment technologies considered. An existing secondary treatment process with disinfection at a flow of 5 million gallons per day (mgd) was used to represent existing conditions. Typical effluent biochemical oxygen demand (BOD) and total suspended solids (TSS) were assumed between 10 and 30 milligrams per liter (mg/L) for such a facility and no designed nutrient or toxics removal was assumed for the baseline existing treatment process.

Following a literature review of technologies, two advanced treatment process options for toxics removal were selected for further evaluation based on the characterization of removal effectiveness from the technical literature review and Study Partners' preferences. The two tertiary treatment options are microfiltration membrane filtration (MF) followed by either reverse osmosis (RO) or granular activated carbon (GAC) as an addition to an existing secondary treatment facility.

The advanced treatment technologies are evaluated for their efficacy and cost to achieve the effluent limitations implied by the more stringent HHWQC. Various sensitivities are examined, including for less stringent adopted HHWQC, and for a size range of treatment systems. Collateral environmental impacts associated with the operation of advanced technologies are also qualitatively described.

2.0 Derivation of the Baseline Study Conditions and Rationale for Selection of Effluent Limitations

2.1 Summary of Water Quality Criteria

Surface water quality standards for toxics in the State of Washington are being updated based on revised human fish consumption rates (FCRs). The revised water quality standards could drive very low effluent limitations for industrial and municipal wastewater dischargers. Four pollutants were selected for study based on available monitoring data and abundant presence in the environment. The four toxic constituents are arsenic, BAP, mercury, and PCBs.

2.2 Background

Ecology is in the process of updating the HHWQC in the state water quality standards regulation. Toxics include metals, pesticides, and organic compounds. The human health criteria for toxics are intended to protect people who consume water, fish, and shellfish. FCRs are an important factor in the derivation of water quality criteria for toxics.

The AWB/City/County consortium (hereafter "Study Partners") has selected four pollutants for which more stringent HHWQC are expected to be promulgated. The Study Partners recognize that Ecology probably will not adopt more stringent arsenic HHWQC so the evaluation here is based on the current arsenic HHWQC imposed by the National Toxics Rule. Available monitoring information indicates these pollutants are ubiquitous in the environment and are expected to be present in many NPDES discharges. The four pollutants include the following:

- Arsenic
    - Elemental metalloid that occurs naturally and enters the environment through erosion processes. Also widely used in batteries, pesticides, wood preservatives, and semiconductors. Other current uses and legacy sources in fungicides/herbicides, copper smelting, paints/dyes, and personal care products.
- Benzo(a)pyrene (BAP)
    - Benzo(a)pyrene is a polycyclic aromatic hydrocarbon formed by a benzene ring fused to pyrene as the result of incomplete combustion. Its metabolites are highly carcinogenic. Sources include wood burning, coal tar, automobile exhaust, cigarette smoke, and char-broiled food.
- Mercury
    - Naturally occurring element with wide legacy uses in thermometers, electrical switches, fluorescent lamps, and dental amalgam. Also enters the environment through erosion processes, combustion (especially coal), and legacy industrial/commercial uses. Methylmercury is an organometallic that is a bioaccumulative toxic. In aquatic systems, an anaerobic methylation process converts inorganic mercury to methylmercury.
- Polychlorinated Biphenyls (PCBs)
    - Persistent organic compounds historically used as a dielectric and coolant in electrical equipment and banned from production in the U.S. in 1979. Available information indicates continued pollutant loadings to the environment as a byproduct from the use of some pigments, paints, caulking, motor oil, and coal combustion.

2.3 Assumptions Supporting Selected Ambient Water Quality Criteria and Effluent Limitations

Clean Water Act regulations require NPDES permittees to demonstrate their discharge will "not cause or contribute to a violation of water quality criteria." If a "reasonable potential analysis" reveals the possibility of a standards violation, the permitting authority is obliged to develop "water quality-based effluent limits" to ensure standards achievement. In addition, if ambient water quality monitoring or fish tissue assessments reveal toxic pollutant concentrations above HHWQC levels, Ecology is required to identify that impairment ("303(d) listing") and develop corrective action plans to force reduction in the toxic pollutant discharge or loading of the pollutant into the impaired water body segment. These plans, referred to as total maximum daily loads (TMDLs) or water cleanup plans, establish discharge allocations and are implemented for point discharge sources through NPDES permit effluent limits and other conditions.

The effect of more stringent HHWQC will intuitively result in more NPDES permittees "causing or contributing" to a water quality standards exceedance, and/or more waterbodies being determined to be impaired, thus requiring 303(d) listing, the development of TMDL/water cleanup plans, and more stringent effluent limitations to NPDES permittees whose treated wastewater contains the listed toxic pollutant.

The study design necessarily required certain assumptions to create a "baseline effluent scenario" against which the evaluation of advanced treatment technologies could occur. The Study Partners and HDR Engineering, Inc (HDR) developed the scenario. Details of the baseline effluent scenario are presented in Table 1. The essential assumptions and rationale for selection are presented below:

- Ecology has indicated proposed HHWQC revisions will be provided in first quarter 2014. A Study Partners objective was to gain an early view on the treatment technology and cost implications. Ecology typically allows 30 or 45 days for the submission of public comments on proposed regulations. To wait for the proposed HHWQC revisions would not allow sufficient time to complete a timely technology/cost evaluation and then to share the study results in the timeframe allowed for public involvement/public comments.
- Coincident with the issuance of the proposed regulation, Ecology has a statutory obligation to provide a Significant Legislative Rule evaluation, one element of which is a "determination whether the probable benefits of the rule are greater than its probable costs, taking into account both the qualitative and quantitative benefits and costs and the specific directives of the statute being implemented" (RCW 34.05.328(1)(d)). A statutory requirement also exists to assess the impact of the proposed regulation to small businesses. The implication is that Ecology will be conducting these economic evaluations in fourth quarter 2013 and early 2014. The Study Partners wanted to have a completed technology/cost study available to share with Ecology for their significant legislative rule/small business evaluations.
- The EPA, Indian tribes located in Washington, and various special interest groups have promoted the recently promulgated state of Oregon HHWQC (2011) as the "model" for Washington's revisions of HHWQC. The Oregon HHWQC are generally based on a increased FCR of 175 grams per day (g/day) and an excess cancer risk of 10^{-6}. While the Study Partners do not concede the wisdom or appropriateness of the Oregon criteria, or the selection of scientific/technical elements used to derive those criteria, the Study Partners nevertheless have selected the Oregon HHWQC as a viable "starting point" upon which this study could be based.

- The scenario assumes generally that Oregon's HHWQC for ambient waters will, for some parameters in fact, become effluent limitations for Washington NPDES permittees. The reasoning for this important assumption includes:
    - The state of Washington's NPDES permitting program is bound by the *Friends of Pinto Creek vs. EPA* decision in the United States Court of Appeals for the Ninth Circuit (October 4, 2007). This decision held that no NPDES permits authorizing new or expanded discharges of a pollutant into a waterbody identified as impaired; i.e., listed on CWA section 303(d), for that pollutant, may be issued until such time as "existing dischargers" into the waterbody are "subject to compliance schedules designed to bring the (waterbody) into compliance with applicable water quality standards." In essence, any new/expanded discharge of a pollutant causing impairment must achieve the HHWQC at the point of discharge into the waterbody.
    - If a waterbody segment is identified as "impaired" (i.e., not achieving a HHWQC), then Ecology will eventually need to produce a TMDL or water cleanup plan. For an existing NPDES permittee with a discharge of the pollutant for which the receiving water is impaired, the logical assumption is that any waste load allocation granted to the discharger will be at or lower than the numeric HHWQC (to facilitate recovery of the waterbody to HHWQC attainment). As a practical matter, this equates to an effluent limit established at the HHWQC.
    - Acceptance of Oregon HHWQC as the baseline for technology/cost review also means acceptance of practical implementation tools used by Oregon. The HHWQC for mercury is presented as a fish tissue methyl mercury concentration. For the purposes of NPDES permitting, however, Oregon has developed an implementation management directive which states that any confirmed detection of mercury is considered to represent a "reasonable potential" to cause or contribute to a water quality standards violation of the methyl mercury criteria. The minimum quantification level for total mercury is presented as 0.005 micrograms per liter (µg/L) (5.0 nanograms per liter (ng/L)).
    - The assumed effluent limit for arsenic is taken from EPA's *National Recommended Water Quality Criteria* (2012) (inorganic, water and organisms, 10^{-6} excess cancer risk). Oregon's 2011 criterion is actually based on a less protective excess cancer risk (10^{-4}). This, however, is the result of a state-specific risk management choice and it is unclear if Washington's Department of Ecology would mimic the Oregon approach.
    - The assumption is that no mixing zone is granted such that HHWQC will effectively serve as NPDES permit effluent limits. Prior discussion on the impact of the Pinto Creek decision, 303(d) impairment and TMDL Waste Load Allocations processes, all lend support to this "no mixing zone" condition for the parameters evaluated in this study.
- Consistent with Ecology practice in the evaluation of proposed regulations, the HHWQC are assumed to be in effect for a 20-year period. It is assumed that analytical measurement technology and capability will continue to improve over this time frame and this will result in the detection and lower quantification of additional HHWQC in ambient water and NPDES dischargers. This knowledge will trigger the Pinto Creek/303(d)/TMDL issues identified above and tend to pressure NPDES permittees to evaluate and install advanced treatment technologies. The costs and efficacy of treatment for these additional HHWQC is unknown at this time.

Other elements of the Study Partners work scope, as presented to HDR, must be noted:

- The selection of four toxic pollutants and development of a baseline effluent scenario is not meant to imply that each NPDES permittee wastewater discharge will include those pollutants at the assumed concentrations. Rather, the scenario was intended to represent a composite of many NPDES permittees and to facilitate evaluation of advanced treatment technologies relying on mechanical, biological, physical, chemical processes.
- The scalability of advanced treatment technologies to wastewater treatment systems with different flow capacities, and the resulting unit costs for capital and O&M, is evaluated.
- Similarly, a sensitivity analysis on the unit costs for capital and O&M was evaluated on the assumption the adopted HHWQC (and effectively, NPDES effluent limits) are one order-of-magnitude less stringent than the Table 1 values.

Table 1: Summary of Effluent Discharge Toxics Limits

Constituent	Human Health Criteria based Limits to be met with no Mixing Zone (µg/L)	Basis for Criteria	Typical Concentration in Municipal Secondary Effluent (µg/L)	Typical Concentration in Industrial Secondary Effluent (µg/L)	Existing Washington HHC (water + org.), NTR (µg/L)
PCBs	0.0000064	Oregon Table 40 Criterion (water + organisms) at FCR of 175 grams/day	0.0005 to 0.0025[b,c,d,e,f]	0.002 to 0.005[i]	0.0017
Mercury	0.005	DEQ IMD[a]	0.003 to 0.050[h]	0.010 to 0.050[h]	0.140
Arsenic	0.018	EPA National Toxics Rule (water + organisms)[k]	0.500 to 5.0[j]	10 to 40[j]	0.018
Benzo(a)Pyrene	0.0013	Oregon Table 40 Criterion (water + organisms) at FCR of 175 grams/day	0.00028 to 0.006[b,g]	0.006 to1.9	0.0028

[a] Oregon Department of Environmental Quality (ODEQ). Internal Management Directive: Implementation of Methylmercury Criterion in NPDES Permits. January 8, 2013.

[b] Control of Toxic Chemicals in Puget Sound, Summary Technical Report for Phase 3: Loadings from POTW Discharge of Treated Wastewater, Washington Department of Ecology, Publication Number 10-10-057, December 2010.

[c] Spokane River PCB Source Assessment 2003-2007, Washington Department of Ecology, Publication No. 11-03-013, April 2011.

[d] Lower Okanogan River Basin DDT and PCBs Total Maximum Daily Load, Submittal Report, Washington Department of Ecology, Publication Number 04-10-043, October 2004.

[e] Palouse River Watershed PCB and Dieldrin Monitoring, 2007-2008, Wastewater Treatment Plants and Abandoned Landfills, Washington Department of Ecology, Publication No. 09-03-004, January 2009

[f] A Total Maximum Daily Load Evaluation for Chlorinated Pesticides and PCBs in the Walla Walla River, Washington Department of Ecology, Publication No. 04-03-032, October 2004.

[g] Removal of Polycyclic Aromatic Hydrocarbons and Heterocyclic Nitrogenous Compounds by A POTW Receiving Industrial Discharges, Melcer, H., Steel, P. and Bedford, W.K., Water Environment Federation, 66th Annual Conference and Exposition, October 1993.

[h] Data provided by Lincoln Loehr's summary of WDOE Puget Sound Loading data in emails from July 19, 2013.

[i] NCASI memo from Larry Lefleur, NCASI, to Llewellyn Matthews, NWPPA, revised June 17, 2011, summarizing available PCB monitoring data results from various sources.

[j] Professional judgment, discussed in August 6, 2013 team call.

[k] The applicable Washington Human Health Criteria cross-reference the EPA National Toxics Rule, 40 CFR 131.36. The EPA arsenic HHC is 0.018 ug/L for water and organisms.

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3.0 Wastewater Characterization Description

This section describes the wastewater treatment discharge considered in this technology evaluation. Treated wastewater characteristics are described, including average and peak flow, effluent concentrations, and toxic compounds of concern.

3.1 Summary of Wastewater Characterization

A general wastewater treatment process and wastewater characteristics were developed as the common baseline to represent the existing conditions as a starting point for comparison with potential future advanced treatment technologies and improvements. A secondary treatment process with disinfection at a flow of 5 mgd as the current, baseline treatment system for existing dischargers was also developed. Typical effluent biochemical oxygen demand (BOD) and total suspended solids (TSS) were assumed between 10 to 30 mg/L from such a facility and no nutrient or toxics removal was assumed to be accomplished in the existing baseline treatment process.

3.2 Existing Wastewater Treatment Facility

The first step in the process is to characterize the existing wastewater treatment plant to be evaluated in this study. The goal is to identify the necessary technology that would need to be added to an existing treatment facility to comply with revised toxic pollutant effluent limits. Rather than evaluating the technologies and costs to upgrade multiple actual operating facilities, the Study Partners specified that a generalized municipal/industrial wastewater treatment facility would be characterized and used as the basis for developing toxic removal approaches. General characteristics of the facility’s discharge are described in Table 2.

Table 2. General Wastewater Treatment Facility Characteristics

Average Annual Wastewater Flow, mgd	Maximum Month Wastewater Flow, mgd	Peak Hourly Wastewater Flow, mgd	Effluent BOD, mg/L	Effluent TSS, mg/L
5.0	6.25	15.0	10 to 30	10 to 30

mgd=million gallons per day
mg/L=milligrams per liter
BOD=biochemical oxygen demand
TSS=total suspended solids

In the development of the advanced treatment technologies presented below, the capacity of major treatment elements are generally sized to accommodate the maximum month average wastewater flow. Hydraulic elements, such as pumps and pipelines, were selected to accommodate the peak hourly wastewater flow.

The general treatment facility incorporates a baseline treatment processes including influent screening, grit removal, primary sedimentation, suspended growth biological treatment (activated sludge), secondary clarification, and disinfection using chlorine. Solids removed during primary treatment and secondary clarification are assumed to be thickened, stabilized, dewatered, and land applied to agricultural land. The biological treatment process is assumed to be activated sludge with a relatively short (less than 10-day) solids retention time. The baseline secondary treatment facility is assumed not to have processes dedicated to removing nutrients or toxics. However, some coincident removal of toxics will occur during conventional treatment.

3.3 Toxic Constituents

As described in Section 2.3, the expectation of more stringent HHWQC will eventually trigger regulatory demands for NPDES permittees to install advanced treatment technologies. The Study Group and HDR selected four specific toxic pollutants reflecting a range of toxic constituents as the basis for this study to limit the constituents and technologies to be evaluated to a manageable level.

The four toxic pollutants selected were PCBs, mercury, arsenic, and BAP, a polycyclic aromatic hydrocarbon (PAH). Mercury and arsenic are metals, and PCBs and PAHs are organic compounds. Technologies for removing metals and organic compounds are in some cases different. Key information on each of the compounds, including a description of the constituent, the significance of each constituent, proposed HHWQC, basis for the proposed criteria, typical concentration in both municipal and industrial secondary effluent, and current Washington state water quality criteria, are shown in Table 1. It is assumed that compliance with the proposed criteria in the table would need to be achieved at the “end of pipe” and Ecology would not permit a mixing zone for toxic constituents. This represents a “worst–case,” but a plausible assumption about discharge conditions.

4.0 Treatment Approaches and Costs

4.1 Summary of Treatment Approach and Costs

Two advanced treatment process options for toxics removal for further evaluation based on the characterization of removal effectiveness from the technical literature review and Study Group preferences. The two tertiary treatment options are microfiltration MF followed by either RO or GAC as an addition to an existing secondary treatment facility. Based on the literature review, it is not anticipated that any of the treatment options will be effective in reducing all of the selected pollutants to below the anticipated water quality criteria. A summary of the capital and operations and maintenance costs for tertiary treatment is provided, as well as a comparison of the adverse environmental impacts for each alternative.

4.2 Constituent Removal – Literature Review

The evaluation of treatment technologies relevant to the constituents of concern was initiated with a literature review. The literature review included a desktop search using typical web-based search engines, and search engines dedicated to technical and research journal databases. At the same time, HDR's experience with the performance of existing treatment technologies specifically related to the four constituents of concern, was used in evaluating candidate technologies. A summary of the constituents of concern and relevant treatment technologies is provided in the following literature review section.

4.2.1 Polychlorinated Biphenyls

PCBs are persistent organic pollutants that can be difficult to remove in treatment. PCB treatment in wastewater can be achieved using oxidation with peroxide, filtration, biological treatment or a combination of these technologies. There is limited information available about achieving ultra-low effluent PCB concentrations near the 0.0000064 µg/L range under consideration in the proposed rulemaking process. This review provides a summary of treatment technology options and anticipated effluent PCB concentrations.

Research on the effectiveness of ultraviolet (UV) light and peroxide on removing PCBs was tested in bench scale batch reactions (Yu, Macawile, Abella, & Gallardo 2011). The combination of UV and peroxide treatment achieved PCB removal greater than 89 percent, and in several cases exceeding 98 percent removal. The influent PCB concentration for the batch tests ranged from 50 to 100 micrograms per liter (µg/L). The final PCB concentration (for the one congener tested) was <10 µg/L (10,000 ng/L) for all tests and <5 µg/L (5,000 ng/L) for some tests. The lowest PCB concentrations in the effluent occurred at higher UV and peroxide doses.

Pilot testing was performed to determine the effectiveness of conventional activated sludge and a membrane bioreactor to remove PCBs (Bolzonella, Fatone, Pavan, & Cecchi 2010). EPA Method 1668 was used for the PCB analysis (detection limit of 0.01 ng/L per congener). Influent to the pilot system was a combination of municipal and industrial effluent. The detailed analysis was for several individual congeners. Limited testing using the Aroclor method (total PCBs) was used to compare the individual congeners and the total concentration of PCBs. Both conventional activated sludge and membrane bioreactor (MBR) systems removed PCBs. The effluent MBR concentrations ranged from <0.01 ng/L to 0.04 ng/L compared to <0.01 ng/L to 0.88 ng/L for conventional activated sludge. The pilot testing showed that increased solids retention time (SRT) and higher mixed liquor suspended solids concentrations in the MBR system led to increased removal in the liquid stream.

Bench scale studies were completed to test the effectiveness of GAC and biological activated carbon (BAC) for removing PCBs (Ghosh, Weber, Jensen, & Smith 1999). The effluent from the

GAC system was 800 ng/L. The biological film in the BAC system was presumed to support higher PCB removal with effluent concentrations of 200 ng/L. High suspended sediment in the GAC influent can affect performance. It is recommended that filtration be installed upstream of a GAC system to reduce solids and improve effectiveness.

Based on limited available data, it appears that existing municipal secondary treatment facilities in Washington state are able to reduce effluent PCBs to the range approximately 0.10 to 1.5 ng/L. It appears that the best performing existing municipal treatment facility in Washington state with a microfiltration membrane is able to reduce effluent PCBs to the range approximately 0.00019 to 0.00063 µg/L. This is based on a very limited data set and laboratory blanks covered a range that overlapped with the effluent results (blanks 0.000058 to 0.00061 µg/L).

Addition of advanced treatment processes would be expected to enhance PCB removal rates, but the technical literature does not appear to provide definitive information for guidance. A range of expected enhanced removal rates might be assumed to vary widely from level of the reference microfiltration facility of 0.19 to 0.63 ng/L.

Summary of PCB Technologies

The literature review revealed there are viable technologies available to reduce PCBs **but no research was identified with treatment technologies capable of meeting the anticipated human health criteria based limits for PCB removal**. Based on this review, a tertiary process was selected to biologically reduce PCBs and separate the solids using tertiary filtration. Alternately, GAC was investigated as an option to reduce PCBs, although it is not proven that it will meet revised effluent limits.

4.2.2 Mercury

Mercury removal from wastewater can be achieved using precipitation, adsorption, filtration, or a combination of these technologies. There is limited information available about achieving ultra-low effluent mercury concentrations near the 5 ng/L range under consideration in the proposed rulemaking process. This review provides a summary of treatment technology options and anticipated effluent mercury concentrations.

Precipitation (and co-precipitation) involves chemical addition to form a particulate and solids separation, using sedimentation or filtration. Precipitation includes the addition of a chemical precipitant and pH adjustment to optimize the precipitation reaction. Chemicals can include metal salts (ferric chloride, ferric sulfate, ferric hydroxide, or alum), pH adjustment, lime softening, or sulfide. A common precipitant for mercury removal is sulfide, with an optimal pH between 7 and 9. The dissolved mercury is precipitated with the sulfide to form an insoluble mercury sulfide that can be removed through clarification or filtration. One disadvantage of precipitation is the generation of a mercury-laden sludge that will require dewatering and disposal. The mercury sludge may be considered a hazardous waste and require additional treatment and disposal at a hazardous waste site. The presence of other compounds, such as other metals, may reduce the effectiveness of mercury precipitation/co-precipitation. For low-level mercury treatment requirements, several treatment steps will likely be required in pursuit of very low effluent targets.

EPA compiled a summary of facilities that are using precipitation/co-precipitation for mercury treatment (EPA 2007). Three of the full-scale facilities were pumping and treating groundwater and the remaining eight facilities were full-scale wastewater treatment plants. One of the pump and treat systems used precipitation, carbon adsorption, and pH adjustment to treat groundwater to effluent concentrations of 300 ng/L.

Adsorption treatment can be used to remove inorganic mercury from water. While adsorption can be used as a primary treatment step, it is frequently used for polishing after a preliminary treatment step (EPA 2007). One disadvantage of adsorption treatment is that when the adsorbent is saturated, it either needs to be regenerated or disposed of and replaced with new adsorbent. A common adsorbent is GAC. There are several patented and proprietary adsorbents on the market for mercury removal. Adsorption effectiveness can be affected by water quality characteristics, including high solids and bacterial growth, which can cause media blinding. A constant and low flow rate to the adsorption beds increases effectiveness (EPA 2007). The optimal pH for mercury adsorption on GAC is pH 4 to 5; therefore, pH adjustment may be required.

EPA compiled a summary of facilities that are using adsorption for mercury treatment (EPA 2007). Some of the facilities use precipitation and adsorption as described above. The six summarized facilities included two groundwater treatment and four wastewater treatment facilities. The reported effluent mercury concentrations were all less than 2,000 ng/L (EPA 2007).

Membrane filtration can be used in combination with a preceding treatment step. The upstream treatment is required to precipitate soluble mercury to a particulate form that can be removed through filtration. According to the EPA summary report, ultrafiltration is used to remove high-molecular weigh contaminants and solids (EPA 2007). The treatment effectiveness can depend on the source water quality since many constituents can cause membrane fouling, decreasing the effectiveness of the filters. One case study summarized in the EPA report showed that treatment of waste from a hazardous waste combustor treated with precipitation, sedimentation, and filtration achieved effluent mercury concentrations less than the detection limit of 200 ng/L.

Bench-scale research performed at the Oak Ridge Y-12 Plant in Tennessee evaluated the effectiveness of various adsorbents for removing mercury to below the NPDES limit of 12 ng/L and the potential revised limit of 51 ng/L (Hollerman et al. 1999). Several proprietary adsorbents were tested, including carbon, polyacrylate, polystyrene, and polymer adsorption materials. The adsorbents with thiol-based active sites were the most effective. Some of the adsorbents were able to achieve effluent concentrations less than 51 ng/L but none of the adsorbents achieved effluent concentrations less than 12 ng/L.

Bench-scale and pilot-scale testing performed on refinery wastewater was completed to determine treatment technology effectiveness for meeting very low mercury levels (Urgun-Demirtas, Benda, Gillenwater, Negri, Xiong & Snyder 2012) (Urgun-Demirtas, Negri, Gillenwater, Agwu Nnanna & Yu 2013). The Great Lakes Initiative water quality criterion for mercury is less than 1.3 ng/L for municipal and industrial wastewater plants in the Great Lakes region. This research included an initial bench scale test including membrane filtration, ultrafiltration, nanofiltration, and reverse osmosis to meet the mercury water quality criterion. The nanofiltration and reverse osmosis required increased pressures for filtration and resulted in increased mercury concentrations in the permeate. Based on this information and the cost difference between the filtration technologies, a pilot-scale test was performed. The 0.04 um PVDF GE ZeeWeed 500 series membranes were tested. The 1.3 ng/L water quality criterion was met under all pilot study operating conditions. The mercury in the refinery effluent was predominantly in particulate form which was well-suited for removal using membrane filtration.

Based on available data, it appears that existing municipal treatment facilities are capable of reducing effluent mercury to near the range of the proposed HHWQC on an average basis. Average effluent mercury in the range of 1.2 to 6.6 ng/L for existing facilities with secondary treatment and enhanced treatment with cloth filters and membranes. The Spokane County plant data range is an average of 1.2 ng/L to a maximum day of 3 ng/L. Addition of advanced treatment processes such as GAC or RO would be expected to enhance removal rates. Data from the West Basin treatment facility in California suggests that at a detection limit of 7.99 ng/L mercury is not detected in the effluent from this advanced process train. A range of expected enhanced removal rates from the advanced treatment process trains might be expected to ranged from meeting the proposed standard at 5 ng/L to lower concentrations represented by the Spokane County performance level (membrane filtration) in the range of 1 to 3 ng/L, to perhaps even lower levels with additional treatment. For municipal plants in Washington, this would suggest that effluent mercury values from the two advanced treatment process alternatives might range from 1 to 5 ng/L (0.001 to 0.005 µg/L) and perhaps substantially better, depending upon RO and GAC removals. It is important to note that industrial plants may have higher existing mercury levels and thus the effluent quality that is achievable at an industrial facility would be of lower quality.

Summary of Mercury Technologies

The literature search revealed limited research on mercury removal technologies at the revised effluent limit of 0.005 µg/L. Tertiary filtration with membrane filters or reverse osmosis showed the best ability to achieve effluent criteria less than 0.005 µg/L.

4.2.3 Arsenic

A variety of treatment technologies can be applied to capture arsenic (Table 3). Most of the information in the technical literature and from the treatment technology vendors is focused on potable water treatment for compliance with a Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 10 µg/L. The most commonly used arsenic removal method for a wastewater application (tertiary treatment) is coagulation/ flocculation plus filtration. This method by itself could remove more than 90 to 95 percent of arsenic. Additional post-treatment through adsorption, ion exchange, or reverse osmosis is required for ultra-low arsenic limits in the 0.018 µg/L range under consideration in the proposed rulemaking process. In each case it is recommended to perform pilot-testing of each selected technology.

Table 3: Summary of Arsenic Removal Technologies[1]

Technology	Advantages	Disadvantages
Coagulation/filtration	• Simple, proven technology • Widely accepted • Moderate operator training	• pH sensitive • Potential disposal issues of backwash waste • As^{+3} and As^{+5} must be fully oxidized
Lime softening	• High level arsenic treatment • Simple operation change for existing lime softening facilities	• pH sensitive (requires post treatment adjustment) • Requires filtration • Significant sludge operation
Adsorptive media	• High As^{+5} selectivity • Effectively treats water with high total dissolved solids (TDS)	• Highly pH sensitive • Hazardous chemical use in media regeneration • High concentration SeO_4^{-2}, F^-, Cl^-, and SO_4^{-2} may limit arsenic removal

Table 3: Summary of Arsenic Removal Technologies[1]

Technology	Advantages	Disadvantages
Ion exchange	• Low contact times • Removal of multiple anions, including arsenic, chromium, and uranium	• Requires removal of iron, manganese, sulfides, etc. to prevent fouling • Brine waste disposal
Membrane filtration	• High arsenic removal efficiency • Removal of multiple contaminants	• Reject water disposal • Poor production efficiency • Requires pretreatment

[1] Adapted from WesTech

The removal of arsenic in activated sludge is minimal (less than 20 percent) (Andrianisa et al. 2006), but biological treatment can control arsenic speciation. During aerobic biological process As (III) is oxidized to As (V). Coagulation/flocculation/filtration removal, as well as adsorption removal methods, are more effective in removal of As(V) vs. As (III). A combination of activated sludge and post-activated sludge precipitation with ferric chloride (addition to MLSS and effluent) results in a removal efficiency of greater than 95 percent. This combination could decrease As levels from 200 µg/L to less than 5 µg/L (5,000 ng/L) (Andrianisa et al. 2008) compared to the 0.018 µg/L range under consideration in the proposed rulemaking process.

Data from the West Basin facility (using MF/RO/AOP) suggests effluent performance in the range of 0.1 to 0.2 µg/L, but it could also be lower since a detection limit used there of 0.15 µg/l is an order of magnitude higher than the proposed HHWQC. A range of expected enhanced removal rates might be assumed to equivalent to that achieved at West Basin in 0.1 to 0.2 µg/L range.

Review of Specific Technologies for Arsenic Removal

Coagulation plus Settling or Filtration

Coagulation may remove more than 95 percent of arsenic through the creation of particulate metal hydroxides. Ferric sulfite is typically more efficient and applicable to most wastewater sources compared to alum. The applicability and extent of removal should be pilot-tested, since removal efficiency is highly dependent on the water constituents and water characteristics (i.e., pH, temperature, solids).

Filtration can be added after or instead of settling to increase arsenic removal. Example treatment trains with filtration are shown in Figures 1 and 2, respectively.

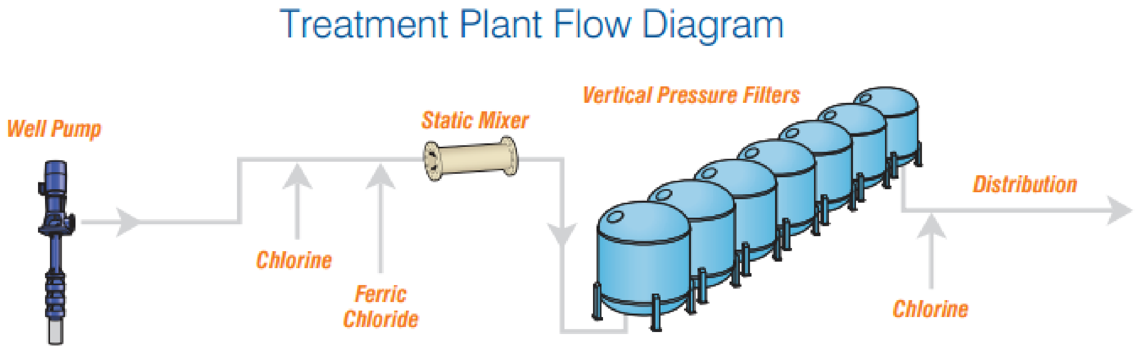

Figure 1. Water Treatment Configuration for Arsenic Removal (WesTech)

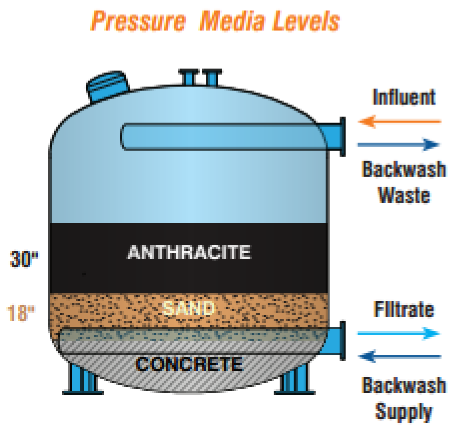

Figure 2. WesTech Pressure Filters for Arsenic Removal

One system for treatment of potable water with high levels of arsenic in Colorado (110 parts per million [ppm]) consists of enhanced coagulation followed by granular media pressure filters that include anthracite/silica sand/garnet media (WesTech). The arsenic levels were reduced to less than the drinking water MCL, which is 10 µg/L (10,000 ng/L). The plant achieves treatment by reducing the pH of the raw water to 6.8 using sulfuric acid, and then adding approximately 12 to 14 mg/L ferric sulfate. The water is filtered through 16 deep bed vertical pressure filters, the pH is elevated with hydrated lime and is subsequently chlorinated and fed into the distribution system. (http://www.westechinc.com/public/uploads/global/2011/3/Fallon%20NV%20Installation%20ReportPressureFilter.pdf).

Softening (with lime)

Removes up to 90 percent arsenic through co-precipitation, but requires pH to be higher than 10.2.

Adsorption processes

Activated alumina is considered an adsorptive media, although the chemical reaction is an exchange of arsenic ions with the surface hydroxides on the alumina. When all the surface hydroxides on the alumina have been exchanged, the media must be regenerated. Regeneration consists of backwashing, followed by sodium hydroxide, flushing with water and neutralization with a strong acid. Effective arsenic removal requires sufficient empty bed contact time. Removal efficiency can also be impacted by the water pH, with neutral or slightly acidic conditions being considered optimum. If As (III) is present, it is generally advisable to increase empty bed contact time, as As (III) is adsorbed more slowly than As (V). Alumina dissolves slowly over time due to contact with the chemicals used for regeneration. As a result, the media bed is likely to become compacted if it is not backwashed periodically.

Granular ferric hydroxide works by adsorption, but when the media is spent it cannot be regenerated and must be replaced. The life of the media depends upon pH of the raw water, the concentrations of arsenic and heavy metals, and the volume of water treated daily. Periodic backwashing is required to prevent the media bed from becoming compacted and pH may need to be adjusted if it is high, in order to extend media life. For maximum arsenic removal, filters operate in series. For less stringent removal, filters can operate in parallel.

One type of adsorption media has been developed for application to non-drinking water processes for arsenic, phosphate and for heavy metals removal by sorption (Severent Trent Bayoxide® E IN-20). This granular ferric oxide media has been used for arsenic removal from mining and industrial wastewaters, selenium removal from refinery wastes and for phosphate polishing of municipal wastewaters. Valley Vista drinking water treatment with Bayoxide® E IN-20 media achieves removal from 31-39 µg/L (31,000-39,000 ng/L) to below 10 µg/L MCL (http://www.severntrentservices.com/News/Successful_Drinking_Water_Treatment_in_an_Arsenic__Hot_Spot__nwMFT_452.aspx).

Another adsorptive filter media is greensand. Greensand is available in two forms: as glauconite with manganese dioxide bound ionically to the granules and as silica sand with manganese dioxide fused to the granules. Both forms operate in pressure filters and both are effective. Greensand with the silica sand core operates at higher water temperatures and higher differential pressures than does greensand with the glauconite core. Arsenic removal requires a minimum concentration of iron. If a sufficient concentration of iron is not present in the raw water, ferric chloride is added.

WesTech filters with greensand and permanganate addition for drinking water systems can reduce As from 15-25 µg/L to non-detect. Sodium hypochlorite and/or potassium permanganate are added to the raw water prior to the filters. Chemical addition may be done continuously or intermittently, depending on raw water characteristics. These chemicals oxidize the iron in the raw water and also maintain the active properties of the greensand itself. Arsenic removal is via co-precipitation with the iron.

Ion Exchange

Siemens offers a potable ion exchange (PIX) arsenic water filtration system. PIX uses ion exchange resin canisters for the removal of organic and inorganic contaminants, in surface and groundwater sources to meet drinking water standards.

Filtronics also uses ion exchange to treat arsenic. The technology allows removal for below the SWDA MCL for potable water of 10 µg/L (10,000 ng/L).

Reverse osmosis

Arsenic is effectively removed by RO when it is in oxidative state As(V) to approximately 1,000 ng/L or less (Ning 2002).

Summary of Arsenic Technologies

The current state of the technology for arsenic removal is at the point where all the processes target the SWDA MCL for arsenic in potable water. Current EPA maximum concentration level for drinking water is 10 ug/l; much higher than 0.0018 µg/L target for arsenic in this study. The majority of the methods discussed above are able to remove arsenic to either EPA maximum contaminant level or to the level of detection. The lowest detection limit of one of the EPA approved methods of arsenic measurements is 20 ng/l (0.020 µg/l) (Grosser, 2010), which is comparable to the 0.018 µg/L limit targeted in this study.

4.2.1 Polycyclic Aromatic Hydrocarbons

BAP During Biological Treatment

During wastewater treatment process, BAP tends to partition into sludge organic matter (Melcer et al. 1993). Primary and secondary processing could remove up to 60 percent of incoming PAHs and BAP in particular, mostly due to adsorption to sludge (Kindaichi et al., NA, Wayne et al. 2009). Biodegradation of BAP is expected to be very low since there are more than five benzene rings which are resistant to biological degradation. Biosurfactant addition to biological process could partially improve biodegradation, but only up to removal rates of 50 percent (Sponza et al. 2010). Existing data from municipal treatment facilities in Washington state have influent and effluent concentrations of BAP of approximately 0.30 ng/L indicating that current secondary treatment has limited effectiveness at BAP removal.

Methods to Enhance Biological Treatment of BAP

Ozonation prior to biological treatment could potentially improve biodegradability of BAP (Zeng et al. 2000). In the case of soil remediation, ozonation before biotreatment improved biodegradation by 70 percent (Russo et al. 2012). The overall removal of BAP increased from 23 to 91 percent after exposure of water to 0.5 mg/L ozone for 30 minutes during the simultaneous treatment process and further to 100 percent following exposure to 2.5 mg/L ozone for 60 minutes during the sequential treatment mode (Yerushalmi et al. 2006). In general, to improve biodegradability of BAP, long exposure to ozone might be required (Haapea et al. 2006).

Sonication pre-treatment or electronic beam irradiation before biological treatment might also make PAHs more bioavailable for biological degradation..

Recent studies reported that a MBR is capable of removing PAHs from wastewater (Rodrigue and Reilly 2009; Gonzaleza et al. 2012). None of the studies listed the specific PAHs constituents removed.

Removal of BAP from Drinking Water

Activated Carbon

Since BAP has an affinity to particulate matter, it is removed from the drinking water sources by means of adsorption, such as granular activated carbon (EPA). Similarly, Oleszczuk et al. (2012) showed that addition of 5 percent activated carbon could remove 90 percent of PAHs from the wastewater.

Reverse Osmosis

Light (1981) (referenced by Williams, 2003) studied dilute solutions of PAHs, aromatic amines, and nitrosamines and found rejections of these compounds in reverse osmosis to be over 99 percent for polyamide membranes. Bhattacharyya et al. (1987) (referenced by Williams, 2003) investigated rejection and flux characteristics of FT30 membranes for separating various pollutants (PAHs, chlorophenols, nitrophenols) and found membrane rejections were high (>98 percent) for the organics under ionized conditions.

Summary of BAP Technologies

Current technologies show that BAP removal may be 90 percent or greater. The lowest detection limit for BAP measurements is 0.006 µg/L, which is also the assumed secondary effluent BAP concentration assumed for this study. If this assumption is accurate, it appears technologies may exist to remove BAP to a level below the proposed criteria applied as an effluent limit of 0.0013 µg/L; however, detection limits exceed this value and it is impossible to know this for certain. A municipal wastewater treatment plant study reported both influent and effluent BAP concentrations less than the HHWQC of 0.0013 ug/L (Ecology, 2010).

4.3 Unit Processes Evaluated

Based on the results of the literature review, a wide range of technologies were evaluated for toxic constituent removal. A listing of the technologies is as follows:

- Chemically enhanced primary treatment (CEPT): this physical and chemical technology is based on the addition of a metal salt to precipitate particles prior to primary treatment, followed by sedimentation of particles in the primary clarifiers. This technology has been shown to effectively remove arsenic but there is little data supporting the claims. As a result, the chemical facilities are listed as optional.

- Activated sludge treatment (with a short SRT of approximately 8 days or less): this biological technology is commonly referred to as secondary treatment. It relies on converting dissolved organics into solids using biomass. Having a short SRT is effective at removing degradable organics referred to as BOD compounds for meeting existing discharge limits. Dissolved constituents with a high affinity to adsorb to biomass (e.g., metals, high molecular weight organics, and others) will be better removed compared to smaller molecular weight organics and recalcitrant compounds which will have minimal removal at a short SRT.
- Enhanced activated sludge treatment (with a long SRT of approximately 8 days or more): this technology builds on secondary treatment by providing a longer SRT, which enhances sorption and biodegradation. The improved performance is based on having more biomass coupled with a more diverse biomass community, especially nitrifiers, which have been shown to assist in removal of some of the more recalcitrant constituents not removed with a shorter SRT (e.g., lower molecular weight PAHs). There is little or no data available on the effectiveness of this treatment for removing BAP.

  Additional benefits associated with having a longer SRT are as follows:

  - Lower BOD/TSS discharge load to receiving water
  - Improved water quality and benefit to downstream users
  - Lower effluent nutrient concentrations which reduce algal growth potential in receiving waters
  - Reduced receiving water dissolved oxygen demand due to ammonia removal
  - Reduced ammonia discharge, which is toxic to aquatic species
  - Improved water quality for habitat, especially as it relates to biodiversity and eutrophication
  - Secondary clarifier effluent more conditioned for filtration and disinfection
  - Greater process stability from the anaerobic/anoxic zones serving as biological selectors
- Coagulation/Flocculation and Filtration: this two-stage chemical and physical process relies on the addition of a metal salt to precipitate particles in the first stage, followed by the physical removal of particles in filtration. This technology lends itself to constituents prone to precipitation (e.g., arsenic).
- Lime Softening: this chemical process relies on increasing the pH as a means to either volatilize dissolved constituents or inactivate pathogens. Given that none of the constituents being studied are expected to volatilize, this technology was not carried forward.
- Adsorptive Media: this physical and chemical process adsorbs constituents to a combination of media and/or biomass/chemicals on the media. There are several types of media, with the most proven and common being GAC. GAC can also serve as a coarse roughing filter.
- Ion Exchange: this chemical technology exchanges targeted constituents with a resin. This technology is common with water softeners where the hard divalent cations are

exchanged for monovalent cations to soften the water. Recently, resins that target arsenic and mercury removal include activated alumina and granular ferric hydroxides have been developed. The resin needs to be cleaned and regenerated, which produces a waste slurry that requires subsequent treatment and disposal. As a result, ion exchange was not considered for further.

- Membrane Filtration: This physical treatment relies on the removal of particles larger than the membranes pore size. There are several different membrane pore sizes as categorized below.
    - Microfiltration (MF): nominal pore size range of typically between 0.1 to 1 micron. This pore size targets particles, both inert and biological, and bacteria. If placed in series with coagulation/flocculation upstream, dissolved constituents precipitated out of solution and bacteria can be removed by the MF membrane.
    - Ultrafiltration (UF): nominal pore size range of typically between 0.01 to 0.1 micron. This pore size targets those solids removed with MF (particles and bacteria) plus viruses and some colloidal material. If placed in series with coagulation/flocculation upstream, dissolved constituents precipitated out of solution can be removed by the UF membrane.
    - Nanofiltration (NF): nominal pore size range of typically between 0.001 to 0.010 micron. This pore size targets those removed with UF (particles, bacteria, viruses) plus colloidal material. If placed in series with coagulation/flocculation upstream, dissolved constituents precipitated out of solution can be removed by the NF membrane.
- MBR (with a long SRT): this technology builds on secondary treatment whereby the membrane (microfiltration) replaces the secondary clarifier for solids separation. As a result, the footprint is smaller, the mixed liquor suspended solids concentration can be increased to about 5,000 – 10,000 mg/L, and the physical space required for the facility reduced when compared to conventional activated sludge. As with the activated sludge option operated at a longer SRT, the sorption and biodegradation of organic compounds are enhanced in the MBR process. The improved performance is based on having more biomass coupled with a more diverse biomass community, especially nitrifiers which have been shown to assist in removal of persistent dissolved compounds (e.g., some PAHs). There is little or no data available on effectiveness at removing BAP. Although a proven technology, MBRs were not carried further in this technology review since they are less likely to be selected as a retrofit for an existing activated sludge (with a short SRT) secondary treatment facility. The MBR was considered to represent a treatment process approach more likely to be selected for a new, greenfield treatment facility. Retrofits to existing secondary treatment facilities can accomplish similar process enhancement by extending the SRT in the activated sludge process followed by the addition of tertiary membrane filtration units.
- RO: This physical treatment method relies on the use of sufficient pressure to osmotically displace water across the membrane surface while simultaneously rejecting most salts. RO is very effective at removing material smaller than the size ranges for the membrane filtration list above, as well as salts and other organic compounds. As a result, it is expected to be more effective than filtration and MBR methods described above at removing dissolved constituents. Although effective, RO produces a brine reject water that must be managed and disposed.

- Advanced Oxidation Processes (AOPs): this broad term considers all chemical and physical technologies that create strong hydroxyl-radicals. Examples of AOPs include Fenton's oxidation, ozonation, ultraviolet/hydrogen peroxide (UV-H2O2), and others. The radicals produced are rapid and highly reactive at breaking down recalcitrant compounds. Although effective at removing many complex compounds such as those evaluated in this study, AOPs does not typically have as many installations as membranes and activated carbon technologies. As a result, AOPs were not carried forward.

Based on the technical literature review discussed above, a summary of estimated contaminant removal rated by unit treatment process is presented in Table 4.

Table 4. Contaminants Removal Breakdown by Unit Process

Unit Process	Arsenic	BAP	Mercury	Polychlorinated Biphenyls
Activated Sludge Short SRT	No removal	Partial Removal by partitioning		80% removal; effluent <0.88 ng/L
Activated Sludge Long SRT	No removal	Partial removal by partitioning and/or partially biodegradation; MBR could potentially remove most of BAP		>90% removal with a membrane bioreactor, <0.04 ng/L (includes membrane filtration)
Membrane Filtration (MF)	More than 90 % removal (rejection of bound arsenic)	No removal	<1.3 ng/L	>90% removal with a membrane bioreactor, <0.04 ng/L (includes membrane filtration)
Reverse Osmosis (RO)	More than 90% removal (rejection of bound arsenic and removal of soluble arsenic)	More than 98% removal		
Granular Activated Carbon (GAC)	No removal, removal only when carbon is impregnated with iron	90 % removal	<300 ng/L (precipitation and carbon adsorption) <51 ng/L (GAC)	<800 ng/L Likely requires upstream filtration
Disinfection	--	--	--	--

4.4 Unit Processes Selected

The key conclusion from the literature review was that there is limited, to no evidence, that existing treatment technologies are capable of simultaneously meeting all four of the revised discharge limits for the toxics under consideration. Advanced treatment using RO or GAC is expected to provide the best overall removal of the constituents of concern. It is unclear whether these advanced technologies are able to meet revised effluent limits, however these processes may achieve the best effluent quality of the technologies reviewed. This limitation in the findings is based on a lack of an extensive dataset on treatment removal effectiveness in the technical literature for the constituents of interest at the low levels relevant to the proposed criteria, which approach the limits of reliable removal performance for the technologies. As Table 4 highlights, certain unit processes are capable of removing a portion, or all, of the removal requirements for each technology. The removal performance for each constituent will vary from facility to facility and require a site-specific, detailed evaluation because the proposed criteria are such low concentrations. In some cases, a facility may only have elevated concentrations of a single constituent of concern identified in this study. In other cases, a discharger may have elevated concentrations of the four constituents identified in this study, as well as others not identified in this study but subject to revised water quality criteria. This effort is intended to describe a planning level concept of what treatment processes are required to comply with discharge limits for all four constituents. Based on the literature review of unit processes above, two different treatment trains were developed for the analysis that are compared against a baseline of secondary treatment as follows:

- Baseline: represents conventional secondary treatment that is most commonly employed nationwide at wastewater treatment plants. A distinguishing feature for this treatment is the short solids residence time (SRT) (<8 days) is intended for removal of BOD with minimal removal for the toxic constituents of concern.
- Advanced Treatment – MF/RO: builds on baseline with the implementation of a longer SRT (>8 days) and the addition of MF and RO. The longer SRT not only removes BOD, but it also has the capacity to remove nutrients and a portion of the constituents of concern. This alternative requires a RO brine management strategy which will be discussed in sub-sections below.
- Advanced Treatment – MF/GAC: this alternative provides a different approach to advanced treatment with MF/RO by using GAC and avoiding the RO reject brine water management concern. Similar to the MF/RO process, this alternative has the longer SRT (>8 days) with the capacity to remove BOD, nutrients, and a portion of the toxic constituents of concern. As a result, the decision was made to develop costs for both advanced treatment options.

A description of each alternative is provided in Table 5. The process flowsheets for each alternative are presented in Figure 3 to Figure 5.

4.4.1 Baseline Treatment Process

A flowsheet of the baseline treatment process is provided in Figure 3. The baseline treatment process assumes the current method of treatment commonly employed by dischargers. For this process, water enters the headworks and undergoes primary treatment, followed by conventional activated sludge (short SRT) and disinfection. The solids wasted in the activated sludge process are thickened, followed by mixing with primary solids prior to entering the anaerobic digestion process for solids stabilization. The digested biosolids are dewatered to produce a cake and hauled off-site. Since the exact process for each interested facility in Washington is unique, this baseline treatment process was used to establish the baseline capital and O&M costs. The baseline costs will be compared against the advanced treatment alternatives to illustrate the magnitude of the increased costs and environmental impacts.

Table 5. Unit Processes Description for Each Alternative

Unit Process	Baseline	Advanced Treatment – MF/RO	Advanced Treatment - GAC
Influent Flow	5 mgd	5 mgd	5 mgd
Chemically Enhanced Primary Treatment (CEPT); Optional	--	• Metal salt addition (alum) upstream of primaries	• Metal salt addition (alum) upstream of primaries
Activated Sludge	• Hydraulic Residence Time (HRT): 6 hrs • Short Solids Residence Time (SRT): <8 days	• Hydraulic Residence Time (HRT): 12 hrs (Requires more tankage than the Baseline) • Long Solids Residence Time (SRT): >8 days (Requires more tankage than the Baseline)	• Hydraulic Residence Time (HRT): 12 hrs (Requires more tankage than the Baseline) • Long Solids Residence Time (SRT): >8 days (Requires more tankage than the Baseline)
Secondary Clarifiers	Hydraulically Limited	Solids Loading Limited (Larger clarifiers than Baseline)	Solids Loading Limited (Larger clarifiers than Baseline)
Microfiltration (MF)	--	Membrane Filtration to Remove Particles and Bacteria	Membrane Filtration to Remove Particles and Bacteria
Reverse Osmosis (RO)	--	Treat 50% of the Flow by RO to Remove Metals and Dissolved Constituents. Sending a portion of flow through the RO and blending it with the balance of plant flows ensures a stable non-corrosive, non-toxic discharge.	--
Reverse Osmosis Brine Reject Mgmt	--	Several Options (All Energy or Land Intensive)	--
Granular Activated Carbon (GAC)	--	--	Removes Dissolved Constituents
Disinfection	Not shown to remove any of the constituents	Not shown to remove any of the constituents	Not shown to remove any of the constituents

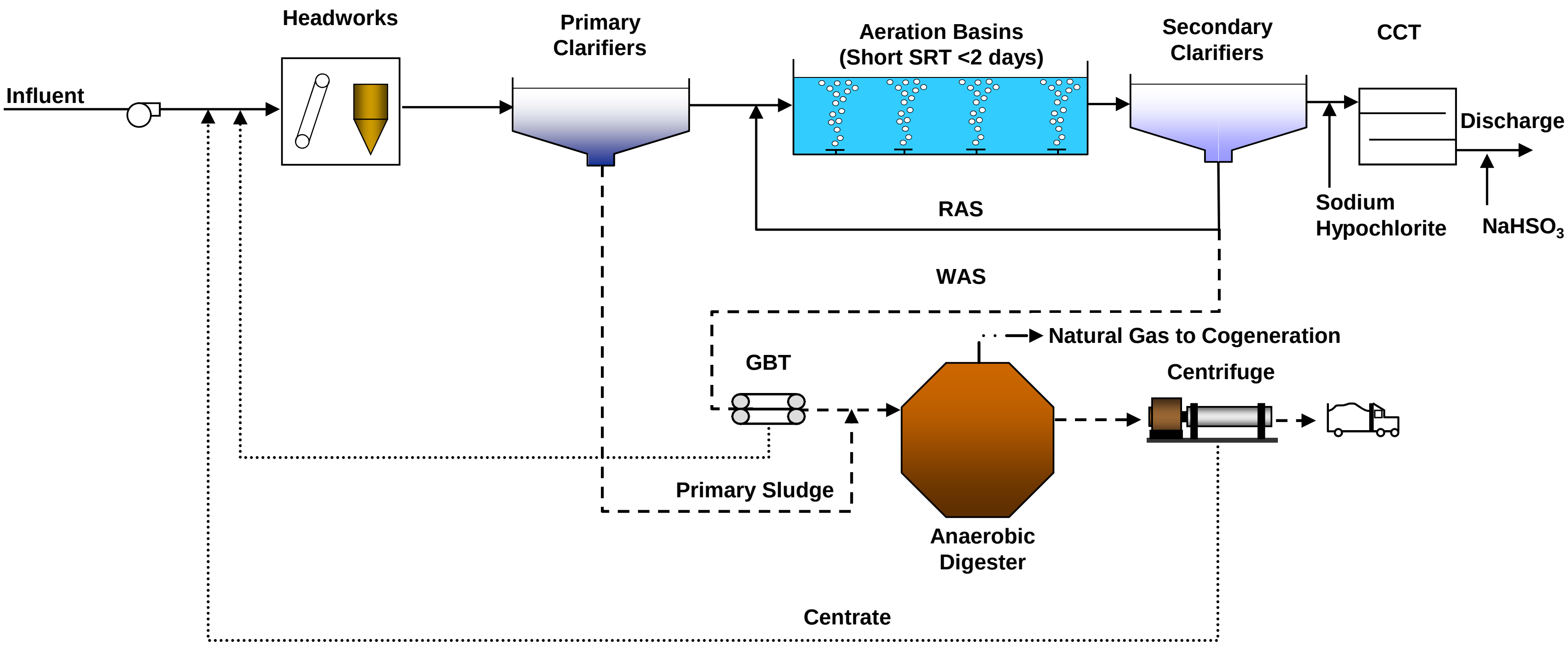

Figure 3. Baseline Flowsheet – Conventional Secondary Treatment

4.4.2 Advanced Treatment – MF/RO Alternative

A flowsheet of the advanced treatment – MF/RO alternative is provided in Figure 4. This alternative builds on the baseline secondary treatment facility, whereby the SRT is increased in the activated sludge process, and MF and RO are added prior to disinfection. The solids treatment train does not change with respect to the baseline. Additionally, a brine management strategy must be considered.

The RO process concentrates contaminants into a smaller volume reject stream. Disposing of the RO reject stream can be a problem because of the potentially large volume of water involved and the concentration of contaminants contained in the brine. For reference, a 5 mgd process wastewater flow might result in 1 mgd of brine reject requiring further management. The primary treatment/handling options for RO reject are as follows:

- Zero liquid discharge
- Surface water discharge
- Ocean discharge
- Haul and discharge to coastal location for ocean discharge
- Sewer discharge
- Deep well injection
- Evaporate in a pond
- Solar pond concentrator

Many of the RO brine reject management options above result in returning the dissolved solids to a “water of the state” such as surface water, groundwater, or marine waters. Past rulings in Washington State have indicated that once pollutants are removed from during treatment they are not to be re-introduced to a water of the state. As a result, technologies with this means for disposal were not considered viable options for management of RO reject water in Washington.

Zero Liquid Discharge

Zero liquid discharge (ZLD) is a treatment process that produces a little or no liquid brine discharge but rather a dried residual salt material. This process improves the water recovery of the RO system by reducing the volume of brine that must be treated and disposed of in some manner. ZLD options include intermediate treatment, thermal-based technologies, pressure driven membrane technologies, electric potential driven membrane technologies, and other alternative technologies.

Summary

There are many techniques which can be used to manage reject brine water associated with RO treatment. The appropriate alternative is primarily governed by geographic and local constraints. A comparison of the various brine management methods and potential costs are provided in Table 6.

Of the listed options, ZLD was considered for this analysis as the most viable approach to RO reject water management. An evaporation pond was used following ZLD. The strength in this combination is ZLD reduces the brine reject volume to treat, which in turn reduces the required evaporation pond footprint. The disadvantage is that evaporation ponds require a substantial amount of physical space which may not be available at existing treatment plant sites. It is also important to recognize that the greenhouse gas (GHG) emissions vary widely for the eight brine management options listed above based on energy and chemical intensity.

Table 6. Brine Disposal Method Relative Cost Comparison

Disposal Method	Description	Relative Capital Cost	Relative O&M Cost	Comments
Zero Liquid Discharge (ZLD)	Further concentrates brine reject for further downstream processing	High	High	This option is preferred as an intermediate step. This rationale is based on the reduction in volume to handle following ZLD. For example, RO reject stream volume is reduced on the order of 50-90%.
Surface Water Discharge	Brine discharge directly to surface water. Requires an NPDES permit.	Lowest	Lowest	Both capital and O&M costs heavily dependent on the distance from brine generation point to discharge. Not an option for nutrient removal.
Ocean Discharge	Discharge through a deep ocean outfall.	Medium	Low	Capital cost depends on location and availability of existing deep water outfall.
Sewer Discharge	Discharge to an existing sewer pipeline for treatment at a wastewater treatment plant.	Low	Low	Both capital and O&M costs heavily dependent on the brine generation point to discharge distance. Higher cost than surface water discharge due to ongoing sewer connection charge. Not an option for wastewater treatment.
Deep Well Injection	Brine is pumped underground to an area that is isolated from drinking water aquifers.	Medium	Medium	Technically sophisticated discharge and monitoring wells required. O&M cost highly variable based on injection pumping energy.
Evaporation Ponds	Large, lined ponds are filled with brine. The water evaporates and a concentrated salt remains.	Low – High	Low	Capital cost highly dependent on the amount and cost of land.
Salinity Gradient Solar Ponds (SGSP)	SGSPs harness solar power from pond to power an evaporative unit.	Low – High	Lowest	Same as evaporation ponds plus added cost of heat exchanger and pumps. Lower O&M cost due to electricity production.
Advanced Thermal Evaporation	Requires a two-step process consisting of a brine concentrator followed by crystallizer	High	Highest	Extremely small footprint, but the energy from H_2O removal is by far the most energy intensive unless waste heat is used.

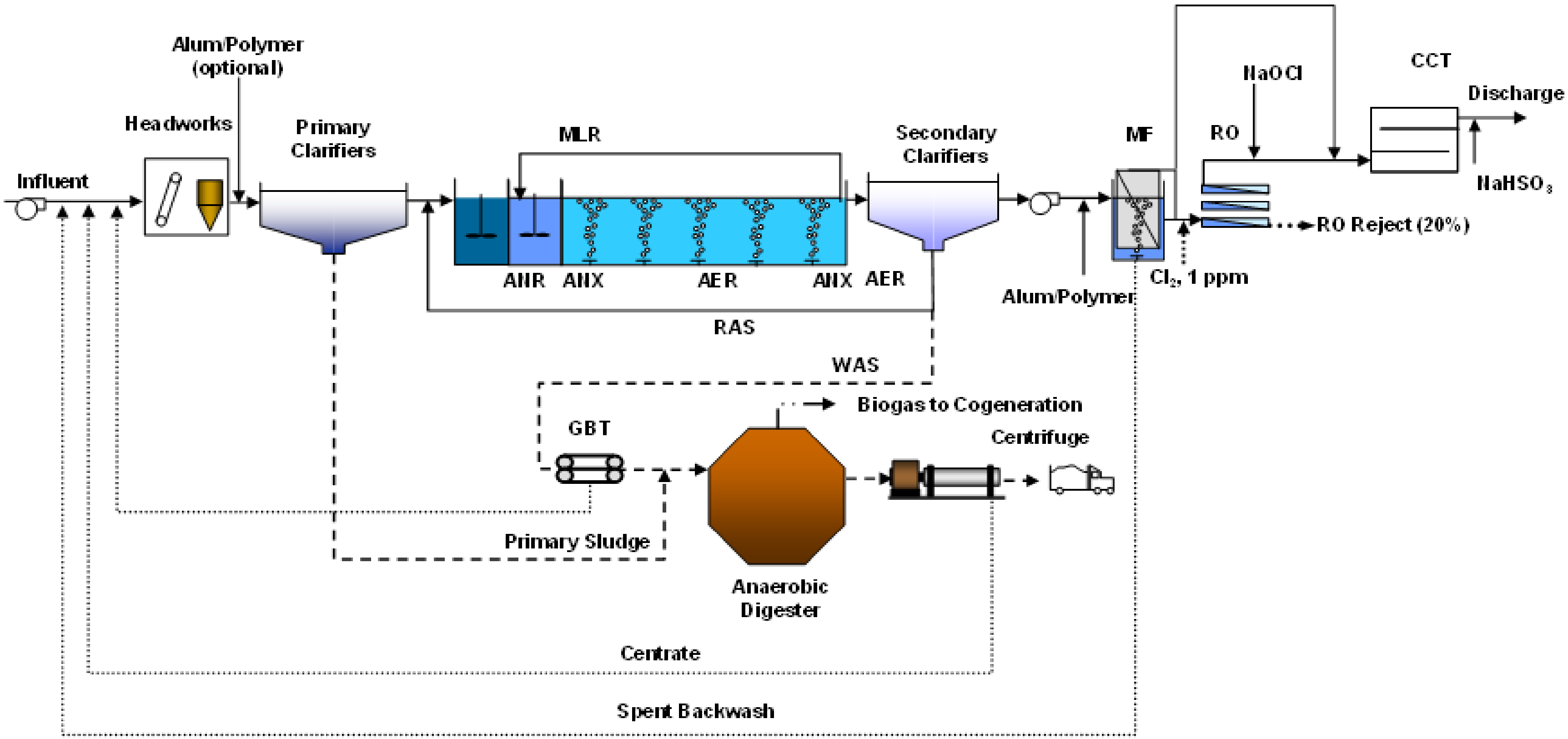

Figure 4. Advanced Treatment Flowsheet – Tertiary Microfiltration and Reverse Osmosis

4.4.3 Advanced Treatment – MF/GAC Alternative

A flowsheet of the advanced treatment – MF/GAC alternative is provided in Figure 5. Following the MF technology, a GAC contactor and media are required.

This alternative was developed as an option that does not require a brine management technology (e.g., ZLD) for comparison to the MF/RO advanced treatment alternative. However, this treatment alternative does require that the GAC be regenerated. A baseline secondary treatment facility can be retrofitted for MF/GAC. If an existing treatment facility has an extended aeration lagoon, the secondary effluent can be fed to the MF/GAC. The longer SRT in the extended aeration lagoon provides all the benefits associated with the long SRT in an activated sludge plant as previously stated:

- Lower BOD/TSS discharge load
- Higher removal of recalcitrant constituents and heavy metals
- Improved water quality and benefit to downstream users
- Less downstream algal growth
- Reduced receiving water dissolved oxygen demand due to ammonia removal
- Reduced ammonia discharge loads, which is toxic to several aquatic species
- Improved water quality for habitat, especially as it relates to biodiversity and eutrophication
- Secondary clarifier effluent more conditioned for filtration and disinfection
- Greater process stability from the anaerobic/anoxic zones serving as a selector

If an existing treatment facility employs a high rate activated sludge process (short SRT) similar to the baseline, it is recommended that the activated sludge process SRT be increased prior to the MF/GAC unit processes. The longer SRT upstream of the MF is preferred to enhance the membrane flux rate, reduce membrane biofouling, increase membrane life, and reduce the chemicals needed for membrane cleaning.

The key technical and operational challenges associated with the tertiary add-on membrane filtration units are as follows:

- The membrane filtration technology is a proven and reliable technology. With over 30 years of experience, it has made the transition in recent years from an emerging technology to a proven and reliable technology.
- Membrane durability dependent on feed water quality. The water quality is individual facility specific.
- Membranes are sensitive to particles, so upstream screening is critical. The newer generations of membranes have technical specifications that require a particular screen size.
- Membrane area requirements based on peak flows as water must pass through the membrane pores. Additionally, membranes struggle with variable hydraulic loading. Flow equalization upstream can greatly reduce the required membrane surface area and provide uniform membrane loading.

- Membrane tanks can exacerbate any foam related issues from the upstream biological process. Foam entrapment in the membrane tank from the upstream process can reduce membrane filtration capacity and in turn result in a plant-wide foam problem.
- Reliable access to the membrane modules is key to operation and maintenance. Once PLC is functionary properly, overall maintenance requirements for sustained operation of the system are relatively modest.
- The membranes go through frequent membrane relaxing or back pulse and a periodic deep chemical clean in place (CIP) process.
- Sizing of membrane filtration facilities governed by hydraulic flux. Municipal wastewaters have flux values that range from about 20 to 40 gallons per square foot per day (gfd) under average annual conditions. The flux associated with industrial applications is wastewater specific.

Following the MF is the activated carbon facilities. There are two kinds of activated carbon used in treating water: powdered activated carbon (PAC) and GAC. PAC is finely-ground, loose carbon that is added to water, mixed for a short period of time, and removed. GAC is larger than PAC, is generally used in beds or tanks that permit higher adsorption and easier process control than PAC allows, and is replaced periodically. PAC is not selective, and therefore, will adsorb all active organic substances making it an impractical solution for a wastewater treatment plant. As a result, GAC was considered for this analysis. The type of GAC (e.g., bituminous and subbituminous coal, wood, walnut shells, lignite or peat), gradation, and adsorption capacity are determined by the size of the largest molecule/ contaminant that is being filtered (AWWA, 1990).

As water flows through the carbon bed, contaminants are captured by the surfaces of the pores until the carbon is no longer able to adsorb new molecules. The concentration of the contaminant in the treated effluent starts to increase. Once the contaminant concentration in the treated water reaches an unacceptable level (called the breakthrough concentration), the carbon is considered "spent" and must be replaced by virgin or reactivated GAC.

The capacity of spent GAC can be restored by thermal reactivation. Some systems have the ability to regenerate GAC on-site, but in general, small systems haul away the spent GAC for off-site regeneration (EPA 1993). For this study, off-site regeneration was assumed.

The basic facilities and their potential unit processes included in this chapter are as follows:

- GAC supply and delivery
- Influent pumping
    - Low head feed pumping
    - High head feed pumping (assumed for this study as we have low limits so require high beds)
- Contactors and backwash facilities
    - Custom gravity GAC contactor
    - Pre-engineered pressure GAC contactor (Used for this study)
    - Backwash pumping
- GAC transport facilities
    - Slurry pumps
    - Eductors (Used for this study)

- Storage facilities
  - Steel tanks
  - Concrete tanks (Used for this study; larger plants would typically select concrete tanks)
- Spent carbon regeneration
  - On-site GAC regeneration
  - Off-Site GAC regeneration

Following the MF is the GAC facility. The GAC contactor provides about a 12-min hydraulic residence time for average annual conditions. The GAC media must be regenerated about twice per year in a furnace. The constituents sorbed to the GAC media are removed during the regeneration process. A typical design has full redundancy and additional storage tankage for spent and virgin GAC. Facilities that use GAC need to decide whether they will regenerate GAC on-site or off-site. Due to challenges associated with receiving air emission permits for new furnaces, it was assumed that off-site regeneration would be evaluated.

The key technical and operational challenges associated with the tertiary add-on GAC units are as follows:

- Nearest vendor to acquire virgin GAC – How frequently can they deliver virgin GAC and what are the hauling costs?
- Contactor selection is typically based on unit cost and flow variation. The concrete contactor is typically more cost effective at higher flows so it was used for this evaluation. The pre-engineered pressure contactor can handle a wider range of flows than a concrete contactor. Additionally, a pressure system requires little maintenance as they are essentially automated
- Periodical contactor backwashing is critical for maintaining the desired hydraulics and control biological growth
- Eductors are preferred over slurry pumps because they have fewer mechanical components. Additionally, the pump with eductors is not in contact with the carbon, which reduces wear.
- Off-site GAC regeneration seems more likely due to the challenges with obtaining an air emissions permit.

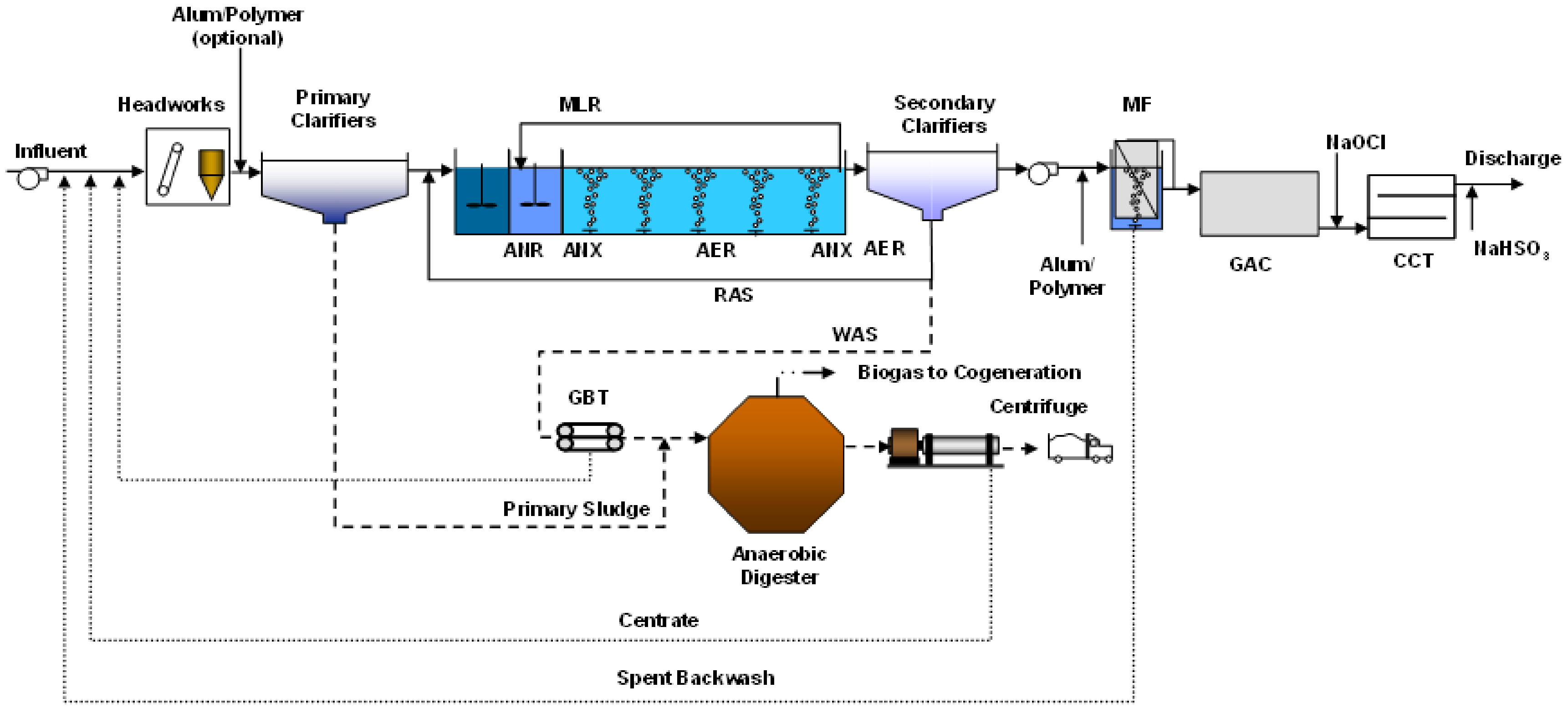

Figure 5. Advanced Treatment Flowsheet – Tertiary Microfiltration and Granular Activated Carbon

4.5 Steady-State Mass Balance

HDR used its steady-state mass balance program to calculate the flows and loads within the candidate advanced treatment processes as a means to size facilities. The design of wastewater treatment facilities are generally governed by steady-state mass balances. For a steady-state mass balance, the conservation of mass is calculated throughout the entire wastewater treatment facility for defined inputs. Dynamic mass balance programs exist for designing wastewater facilities, but for a planning level study such as this, a steady state mass balance program is adequate. A dynamic program is generally used for detailed design and is site-specific with associated requirements for more detailed wastewater characterization.

The set of model equations used to perform a steady-state mass balance are referred to as the model. The model equations provide a mathematical description of various wastewater treatment processes, such as an activated sludge process, that can be used to predict unit performance. The program relies on equations for each unit process to determine the flow, load, and concentration entering and leaving each unit process.

An example of how the model calculates the flow, load, and concentration for primary clarifiers is provided below. The steady-state mass balance equation for primary clarifiers has a single input and two outputs as shown in the simplified Figure 6. The primary clarifier feed can exit the primary clarifiers as either effluent or sludge. Solids not removed across the primaries leave as primary effluent, whereas solids captured leave as primary sludge. Scum is not accounted for.

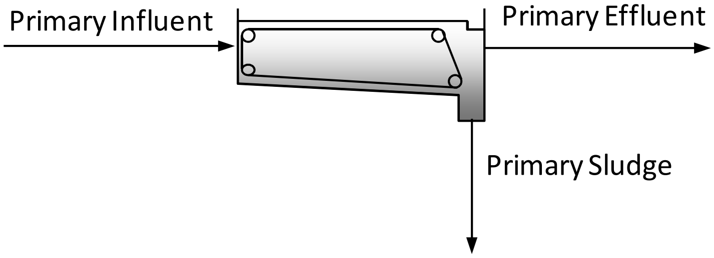

Figure 6. Primary Clarifier Inputs/Outputs

The mass balance calculation requires the following input:

- Solids removal percentage across the primaries (based on average industry accepted performance)
- Primary solids thickness (i.e., percent solids) (based on average industry accepted performance)

The steady-state mass balance program provides a reasonable first estimate for the process performance, and an accurate measure of the flows and mass balances at various points throughout the plant. The mass balance results were used for sizing the facility needs for each alternative. A listing of the unit process sizing criterion for each unit process is provided in Appendix A. By listing the unit process sizing criteria, a third-party user could redo the analysis and end up with comparable results. The key sizing criteria that differ between the baseline and treatment alternatives are as follows:

- Aeration basin mixed liquor is greater for the advanced treatment alternatives which in turn requires a larger volume
- The secondary clarifiers are sized based on hydraulic loading for the baseline versus solids loading for the advanced treatment alternatives

- The MF/GAC and MF/RO sizing is only required for the respective advanced treatment alternatives.

4.6 Adverse Environmental Impacts Associated with Advanced Treatment Technologies

The transition from the baseline (conventional secondary treatment) to either advanced treatment alternatives has some environmental impacts that merit consideration, including the following:

- Land area for additional system components (which for constrained facility sites, may necessitate land acquisition and encroachment into neighboring properties with associated issues and challenges, etc.).
- Increased energy use and atmospheric emissions of greenhouse gases and criteria air contaminants associated with power generation to meet new pumping requirements across the membrane filter systems (MF and RO) and GAC.
- Increased chemical demand associated with membrane filters (MF and RO).
- Energy and atmospheric emissions associated with granulated charcoal regeneration.
- RO brine reject disposal. The zero liquid discharge systems are energy intensive energy and increase atmospheric emissions as a consequence of the electrical power generation required for removing water content from brine reject.
- Increase in sludge generation while transitioning from the baseline to the advanced treatment alternatives. There will be additional sludge captured with the chemical addition to the primaries and membrane filters (MF and RO). Additionally, the GAC units will capture more solids.
- Benefits to receiving water quality by transitioning from a short SRT (<2 days) in the baseline to a long SRT (>8 days) for the advanced treatment alternatives (as previously stated):
    - Lower BOD/TSS discharge load
    - Higher removal of recalcitrant constituents and heavy metals
    - Improved water quality and benefit to downstream users
    - Reduced nutrient loadings to receiving waters and lower algal growth potential
    - Reduced receiving water dissolved oxygen demand due to ammonia removal
    - Reduced ammonia discharge loads, which is toxic to aquatic species
    - Improved water quality for habitat, especially as it relates to biodiversity and eutrophication
    - Secondary clarifier effluent better conditioned for subsequent filtration and disinfection
    - Greater process stability from the anaerobic/anoxic zones serving as a biological selectors

HDR calculated GHG emissions for the baseline and advanced treatment alternatives. The use of GHG emissions is a tool to normalize the role of energy, chemicals, biosolids hauling, and fugitive emissions (e.g., methane) in a single unit. The mass balance results were used to quantify energy demand and the corresponding GHG emissions for each alterative. Energy demand was estimated from preliminary process calculations. A listing of the energy demand for each process stream, the daily energy demand, and the unit energy demand is provided in Table 7. The advanced treatment options range from 2.3 to 4.1 times greater than the baseline. This large increase in energy demand is attributed to the energy required to pass water through the membrane barriers and/or the granular activated carbon. Additionally, there is energy required to handle the constituents removed as either regenerating the GAC or handling the RO brine reject water. This additional energy required to treat the removed constituents is presented in Table 7.

Table 7. Energy Breakdown for Each Alternative (5 mgd design flow)

Parameter	Units	Baseline	Advanced Treatment – MF/GAC	Advanced Treatment – MF/RO
Daily Liquid Stream Energy Demand	MWh/d	11.6	23.8	40.8
Daily Solids Stream Energy Demand	MWh/d	-1.6	-1.1	-1.1
Daily Energy Demand	MWh/d	10.0	22.7	39.7
Unit Energy Demand	kWh/MG Treated	2,000	4,500	7,900

MWh/d = megawatt hours per day
kWh/MG = kilowatt hours per million gallons

Details on the assumptions used to convert between energy demand, chemical demand and production, as well as biologically-mediated gases (i.e., CH4 and N2O) and GHG emissions are provided in Appendix B.

A plot of the GHG emissions for each alternative is shown in Figure 7. The GHG emissions increase from the baseline to the two advanced treatment alternatives. The GHG emissions increase about 50 percent with respect to baseline when MF/GAC is used and the GHG emissions increase over 100 percent with respect to baseline with the MF/RO advanced treatment alternative.

The MF/GAC energy demand would be larger if GAC regeneration was performed on-site. The GHG emissions do not include the energy or air emissions that result from off-site GAC regeneration. Only the hauling associated with moving spent GAC is included. The energy associated with operating the furnace would exceed the GHG emissions from hauling spent GAC.

The zero liquid discharge in the MF/RO alternative alone is comparable to the Baseline. This contribution to increased GHG emissions by zero liquid discharge brine system highlights the importance of the challenges associated with managing brine reject.

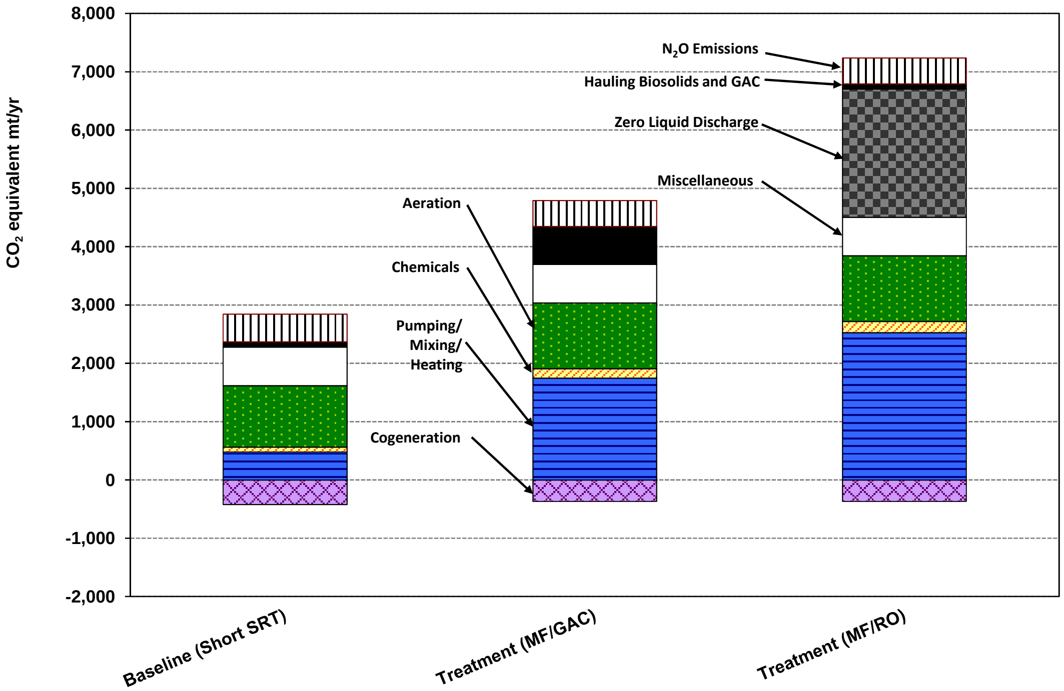

Figure 7. Greenhouse Gas Emissions for Each Alternative

The use of GHG emissions as a measure of sustainability does not constitute a complete comparison between the baseline and advanced treatment alternatives. Rather, it is one metric that captures the impacts of energy, chemical demand and production, as well as biologically-mediated gases (i.e., CH_4 and N_2O). The other environmental impacts of advanced treatment summarized in the list above should also be considered in decision making beyond cost analysis.

4.7 Costs

Total project costs along with the operations and maintenance costs were developed for each advanced treatment alternative for a comparison with baseline secondary treatment.

4.7.1 Approach

The cost estimates presented in this report are planning level opinions of probable construction costs for a nominal 5 mgd treatment plant design flow representing a typical facility without site specific details about local wastewater characteristics, physical site constraints, existing infrastructure, etc. The cost estimates are based on wastewater industry cost references, technical studies, actual project cost histories, and professional experience. The costs presented in this report are considered planning level estimates. A more detailed development of the advanced treatment process alternatives and site specific information would be required to further refine the cost estimates. Commonly this is accomplished in the preliminary design phase of project development for specific facilities following planning.

The cost opinion includes a range of costs associated with the level of detail used in this analysis. Cost opinions based on preliminary engineering can be expected to follow the Association for the Advancement of Cost Engineering (AACE International) Recommended Practice No. 17R-97 Cost Estimate Classification System estimate Class 4. A Class 4 estimate is based upon a 5 to 10 percent project definition and has an expected accuracy range of -30 to +50 percent and typical end usage of budget authorization and cost control. It is considered an “order-of-magnitude estimate.” The life-cycle costs were prepared using the net present value (NPV) method.

The cost associated for each new unit process is based on a unit variable, such as required footprint, volume, demand (e.g., lb O_2/hr), and others. This approach is consistent with the approach developed for the EPA document titled “Estimating Water Treatment Costs: Volume 2- Cost Curves Applicable to 1 to 200 mgd Treatment Plants” dated August 1979. The approach has been updated since 1979 to account for inflation and competition, but the philosophy for estimating costs for unit processes has not changed. For example, the aeration system sizing/cost is governed by the maximum month airflow demand. Additionally, the cost associated constructing an aeration basin is based on the volume. The cost considers economies of scale.

The O&M cost estimates were calculated from preliminary process calculations. The operations cost includes energy and chemical demand. For example, a chemical dose was assumed based on industry accepted dosing rates and the corresponding annual chemical cost for that particular chemical was accounted for. The maintenance values only considered replacement equipment, specifically membrane replacement for the Advanced Treatment Alternatives.

4.7.2 Unit Cost Values

The life-cycle cost evaluation was based on using the economic assumptions shown in Table 8. The chemical costs were based on actual values from other projects. To perform detailed cost evaluations per industry, each selected technology would need to be laid out on their respective site plan based on the location of the existing piping, channels, and other necessary facilities.

Table 8. Economic Evaluation Variables

Item	Value
Nominal Discount Rate	5%
Inflation Rate:	
General	3.5%
Labor	3.5%
Energy	3.5%
Chemical	3.5%
Base Year	2013
Project Life	25 years
Energy	$0.06/kWh
Natural Gas	$0.60/therm
Chemicals:	
Alum	$1.1/gal
Polymer	$1.5/gal
Hypochlorite	$1.5/gal
Salt	$0.125/lb
Antiscalant	$12.5/lb
Acid	$0.35/lb
Deionized Water	$3.75/1,000 gal
Hauling:	

Table 8. Economic Evaluation Variables

Item	Value
Biosolids Hauling Distance	100 miles (one way)
Biosolids Truck Volume	6,000 gal/truck
Biosolids Truck Hauling	$250/truck trip
GAC Regeneration Hauling Distance	250 miles (round trip)
GAC Regeneration Truck Volume	$20,000 lb GAC/truck
GAC Regeneration Truck Hauling	Included in cost of Virgin GAC

kWh= kilowatt hours; lbs=pounds; GAC=granulated activated carbon; gal=gallon

4.7.3 Net Present Value of Total Project Costs and Operations and Maintenance Cost in 2013 Dollars

An estimate of the net present value for the baseline treatment process and the incremental cost to implement the advanced treatment alternatives is shown in Table 9. The cost for the existing baseline treatment process was estimated based on new construction for the entire conventional secondary treatment process (Figure 3). The incremental cost to expand from existing baseline secondary treatment to advanced treatment was calculated by taking the difference between the baseline and the advanced treatment alternatives. These values serve as a benchmark for understanding the prospective cost for constructing advanced treatment at the planning level of process development.

Table 9. Treatment Technology Total Project Costs in 2013 Dollars for a 5 mgd Facility

Alternative	Total Construction Cost, 2013 dollars ($ Million)	O&M Net Present Value, 2013 dollars ($ Million)*	Total Net Present Value, 2013 dollars ($ Million)	NPV Unit Cost, 2013 dollars ($/gpd)
Baseline (Conventional Secondary Treatment)*	59 - 127	5 - 11	65 – 138	13 - 28
Advanced Treatment – MF/RO**	108 - 231	31 - 67	139 - 298	28 - 60
Advanced Treatment – MF/GAC	131 - 280	50 - 108	181 - 388	36 - 78
Incremental Increase to Advanced Treatment MF/RO	48 - 104	26 - 56	75 - 160	15 - 32
Incremental Increase to Advanced Treatment MF/GAC	71 - 153	45 - 97	117 - 250	23 - 50

* The additional cost to increase the SRT to upwards of 30-days is about $12 - 20 million additional dollars in total project cost for a 5 mgd design flow

** Assumes zero liquid discharge for RO brine management, followed by evaporation ponds. Other options are available as listed in Section 4.4.2.

O&M=operations and maintenance; MF/RO=membrane filtration/reverse osmosis; MF/GAC=membrane filtration/granulated activated carbon; gpd=gallons per day

4.7.4 Unit Cost Assessment

Costs presented above are based on a treatment capacity of 5.0 mgd, however, existing treatment facilities range dramatically across Washington in size and flow treated. Table 9 indicates that the unit capital cost for baseline conventional secondary treatment for 5.0 mgd ranges between $13 to 28 per gallon per day of treatment capacity. The unit cost for the advanced treatment alternatives increases the range from the low $20s to upper $70s on a per-gallon per-day of capacity. The increase in cost for the advanced treatment alternatives is discussed in the sub-sections below.

Advanced Treatment MF/RO

The advanced treatment MF/RO alternative has a total present worth unit cost range of $28 to $60 million in per gallon per day of capacity. This translates to an incremental cost increase with respect to the baseline of $15 to $32 million dollars in per gallon per day treatment capacity. The key differences in cost between the baseline and the advanced treatment MF/RO are as follows:

- Larger aeration basins than the baseline to account for the longer SRT (<8 days versus >8 days).
- Additional pumping stations to pass water through the membrane facilities (MF and RO). These are based on peak flows.
- Membrane facilities (MF and RO; equipment, tanks chemical feed facilities, pumping, etc.) and replacement membrane equipment.
- Additional energy and chemical demand to operate the membrane facilities (MF and RO) and GAC.
- Zero liquid discharge facilities to further concentrate the brine reject.
- Zero liquid discharge facilities are energy/chemically intensive and they require membrane replacement every few years due to the brine reject water quality.
- An evaporation pond to handle the brine reject that has undergone further concentration by zero liquid discharge.

The advanced treatment MF/RO assumes that 100 percent of the flow is treated by MF, followed by 50 percent of the flow treated with RO. Sending a portion of flow through the RO and blending it with the balance of plant flows ensures a stable water to discharge. The RO brine reject (about 1.0 mgd) undergoes ZLD pre-treatment that further concentrates the brine reject to about 0.1-0.5 mgd. The recovery for both RO and ZLD processes is highly dependent on water quality (e.g., silicate levels).

ZLD technologies are effective at concentrating brine reject, but it comes at a substantial cost ($17.5 per gallon per day of ZLD treatment capacity of brine reject). The zero liquid discharge estimate was similar in approach to the demonstration study by Burbano and Brandhuber (2012) for La Junta, Colorado. The ability to further concentrate brine reject was critical from a management standpoint. Although 8 different options were presented for managing brine reject in Section 4.4.2, none of them is an attractive approach for handling brine reject. ZLD provides a viable pre-treatment step that requires subsequent downstream treatment. Evaporation ponds following ZLD were used for this study. Without ZLD, the footprint would be 3-5 times greater.

Roughly 30 acres of evaporation ponds, or more, may be required to handle the ZLD concentrate, depending upon concentrator effectiveness, local climate conditions, residuals accumulation, residual removal, etc. Precipitation throughout Washington is highly variable which can greatly influence evaporation pond footprint. The approach for costing the evaporation pond was in accordance with Mickley et al. (2006) and the cost was about $2.6 million.

Recent discussions with an industry installing evaporation ponds revealed that they will use mechanical evaporators to enhance evaporation rates. The use of mechanical evaporators was not included in this study, but merits consideration if a facility is performing a preliminary design that involves evaporation ponds. The mechanical evaporators have both a capital costs and annual energy costs.

Advanced Treatment MF/GAC

The advanced treatment MF/GAC alternative has a total present worth unit cost range of $36 to $78 million in per gallon per day capacity. This translates to an incremental cost increase with respect to the baseline of $23 to $50 million dollars on a per gallon per day of treatment capacity basis. The key differences in cost between the baseline and the advanced treatment MF/GAC are as follows:

- Larger aeration basins than the baseline to account for the longer SRT (<8 days versus >8 days).
- Additional pumping stations to pass water through the MF membrane and GAC facilities. These are based on peak flows.
- GAC facilities (equipment, contact tanks, pumping, GAC media, etc.)
- Additional energy to feed and backwash the GAC facilities.
- GAC media replacement was the largest contributor of any of the costs.
- Additional hauling and fees to regenerate GAC off-site.

The advanced treatment MF/GAC assumes that 100 percent of the flow is treated by MF, followed by 100 percent of the flow treated with GAC. The GAC technology is an established technology. The costing approach was in accordance with EPA guidelines developed in 1998.

The critical issue while costing the GAC technology is whether a GAC vendor/regeneration facility is located within the region. On-site regeneration is an established technology with a furnace.

However, there are several concerns as listed in Section 4.4.3:

- Ability to obtain an air emissions permit
- Additional equipment to operate and maintain
- Energy and air emissions to operate a furnace on-site
- Operational planning to ensure that furnace is operating 90-95 percent of the time. Otherwise, operations is constantly starting/stopping the furnace which is energy intensive and deleterious to equipment
- If not operated properly, the facility has the potential to create hazardous/toxic waste to be disposed

If located within a couple hundred miles, off-site regeneration is preferred. For this study, off-site regeneration was assumed with a 250-mile (one-way) distance to the nearest vendor that can provide virgin GAC and a regeneration facility.

Incremental Treatment Cost

The difference in costs between the baseline and the advanced treatment alternatives is listed in Table 10. The incremental cost to retrofit the baseline facility to the advanced treatment was calculated by taking the difference between the two alternatives. These values should serve as a planning level benchmark for understanding the potential cost for retrofitting a particular facility. The incremental cost is unique to a particular facility. Several reasons for the wide range in cost in retrofitting a baseline facility to advanced treatment are summarized as follows:

- Physical plant site constraints. A particular treatment technology may or may not fit within the constrained particular plant site. A more expensive technology solution that is more compact may be required. Alternately, land acquisition may be necessary to enlarge a plant site to allow the addition of advanced treatment facilities. An example of the former is stacking treatment processes vertically to account for footprint constraints. This is an additional financial burden that would not be captured in the incremental costs presented in Table 10.
- Yard piping. Site specific conditions may prevent the most efficient layout and piping arrangement for an individual facility. This could lead to additional piping and pumping to convey the wastewater through the plant. This is an additional financial burden that would not be captured in the incremental costs presented in Table 10.
- Pumping stations. Each facility has unique hydraulic challenges that might require additional pumping stations not captured in this planning level analysis. This is an additional financial burden that would not be captured in the incremental costs presented in Table 10.

A cursory unit cost assessment was completed to evaluate how costs would compare for facilities with lower (0.5 mgd) and higher capacity (25 mgd), as presented in Table 10. Capital costs were also evaluated for a 0.5 mgd and 25 mgd facility using non-linear scaling equations with scaling exponents. The unit capital cost for baseline conventional secondary treatment for 0.5 mgd and 25 mgd is approximately $44 and $10 per gallon per day of treatment capacity, respectively. The incremental unit costs to implement an advanced treatment retrofit for 0.5 mgd would range between $30 to $96 per gallon per day of treatment capacity and would be site and discharger specific. The incremental unit costs to implement an advanced treatment retrofit for 25 mgd would range between $10 to 35 per gallon per day of treatment capacity and would be site and discharger specific. The larger flow, 25 mgd, is not as expensive on a per gallon per day of treatment capacity. This discrepancy for the 0.5 and 25 mgd cost per gallon per day of treatment capacity is attributed to economies of scale. Cost curve comparisons (potential total construction cost and total net present value) for the baseline and the two tertiary treatment options (MF/RO and MF/GAC) are shown in Figure 8 and Figure 9 between the flows of 0.5 and 25 mgd. It is important to note that while the economies of scale suggest lower incremental costs for the larger size facilities, some aspects of the advanced treatment processes may become infeasible at larger capacities due to factors such as physical space limitations and the large size requirements for components such as RO reject brine management.

Table 10. Treatment Technology Total Project Costs in 2013 Dollars for a 0.5 mgd Facility and a 25 mgd Facility

Alternative	Total Construction Cost, 2013 dollars ($ Million)	O&M Net Present Value, 2013 dollars ($ Million)*	Total Net Present Value, 2013 dollars ($ Million)	NPV Unit Cost, 2013 dollars ($/gpd)
0.5 mgd:				
Baseline (Conventional Secondary Treatment)	15 - 32	0.5 - 1.1	15 - 33	31 - 66
Advanced Treatment – MF/RO**	27 - 58	3.2 - 6.8	30 - 65	60 - 130
Advanced Treatment – MF/GAC	33 - 70	5 - 10.8	38 - 81	76 - 162
Incremental Increase to Advanced Treatment MF/RO	12 - 26	2.7 - 5.7	15 - 32	30 - 64
Incremental Increase to Advanced Treatment MF/GAC	18 - 38	4.6 - 9.8	22 - 48	45 - 96
25 mgd:				
Baseline (Conventional Secondary Treatment)	156 - 335	25 - 54	182 - 389	7 - 16
Advanced Treatment – MF/RO**	283 - 606	157 - 336	440 - 942	18 - 38
Advanced Treatment – MF/GAC	343 - 735	252 - 541	595 - 1276	24 - 51
Incremental Increase to Advanced Treatment MF/RO	127 - 272	131 - 281	258 - 553	10 - 22
Incremental Increase to Advanced Treatment MF/GAC	187 - 401	226.9 - 486	414 - 887	17 - 35

* Does not include the cost for labor.
** Assumes zero liquid discharge for RO brine management, followed by evaporation ponds. Other options are available as listed in Section 4.4.2.
MF/RO=membrane filtration/reverse osmosis
MF/GAC=membrane filtration/granulated activated carbon
O&M=operations and maintenance
gpd=gallons per day

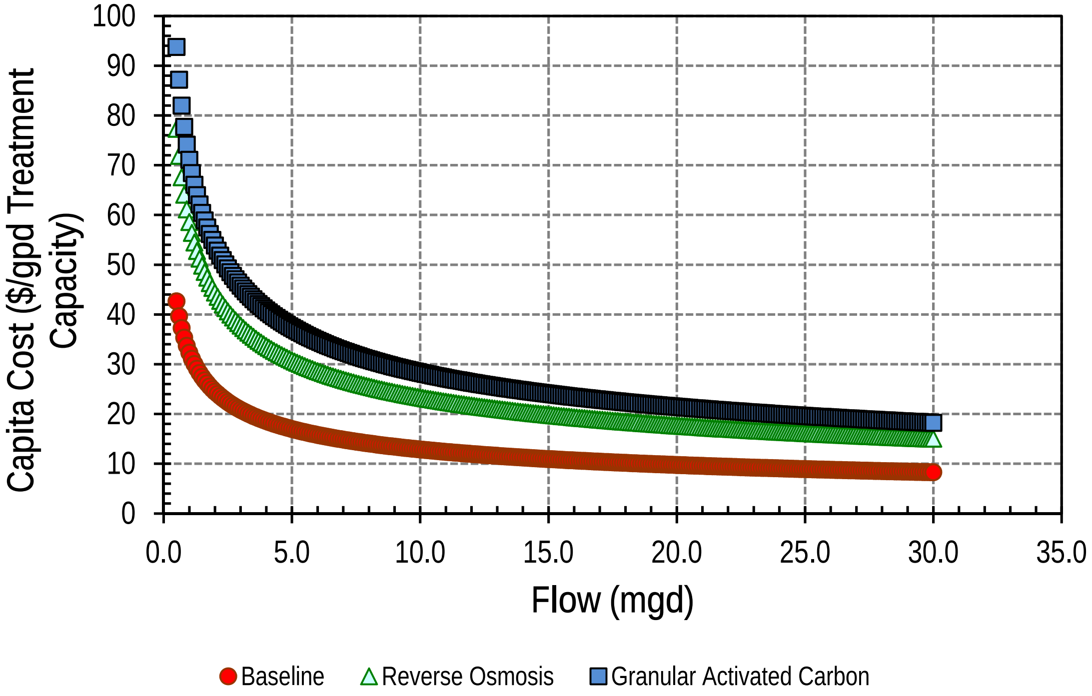

Figure 8: Capital Cost Curve Comparison for Baseline Treatment, MF/RO, and MF/GAC

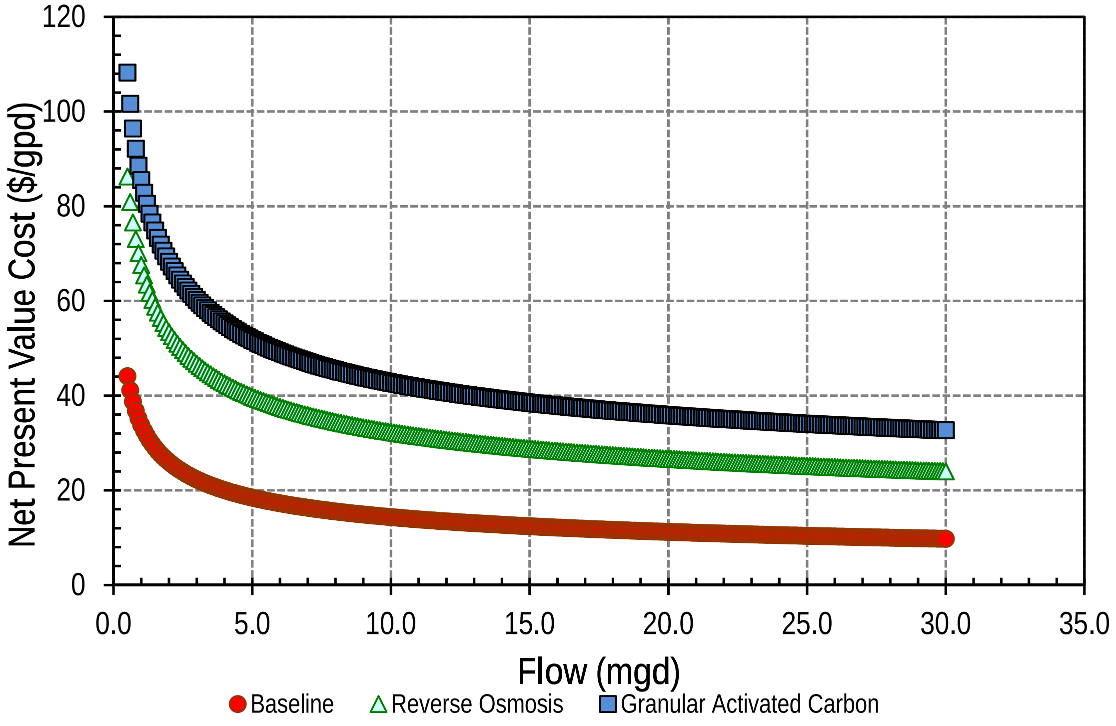

Figure 9: NPV Cost Curve Comparison for Baseline Treatment, MF/RO, and MF/GAC

4.8 Pollutant Mass Removal

An estimate of the projected load removal for the four constituents of concern was developed and is presented in Table 11. The current secondary effluent and advanced treatment effluent data is based on the only available data to HDR and is from municipal treatment plant facilities. Data is not available for advanced treatment facilities such as MF/RO or MF/GAC. Due to this lack of data, advanced treatment using MF/RO or MF/GAC was assumed to remove an additional zero to 90 percent of the constituents presented resulting in the range presented in Table 11. It is critical to note these estimates are based on limited data and are presented here simply for calculating mass removals. Current secondary effluent for industrial facilities would likely be greater than the data presented here and as a result, the projected effluent quality for industrial facilities would likely be higher as well. Based on the limited actual data from municipal treatment facilities, Table 11 indicates that mercury and BAP effluent limits may potentially be met using advanced treatment at facilities with similar existing secondary effluent quality.

Table 11. Pollutant Mass Removal by Contaminant for a 5 mgd Facility

Component	PCBs	Mercury	Arsenic	BAP
Required HHWQC based Effluent Quality (µg/L)	0.0000064	0.005	0.018	0.0013
Current Secondary Effluent Concentration (µg/L)*	0.0015	0.025	7.5	0.00031
Projected Effluent Quality (µg/L) from Advanced Treatment (MF/RO or MF/GAC)*	0.000041 – 0.00041	0.00012 – 0.0012	0.38 – 3.8	0.000029 - 0.00029
Mass Removed (mg/d)**	21 - 28	451 - 471	71,000 – 135,000	0.4 – 5.0
Mass Removed (lb/d)**	0.000045 – 0.000061	0.00099 – 0.0010	0.16 – 0.30	0.0000010 – 0.0000012

* Based on or estimated for actual treatment plant data from municipal facilities. Data sets are limited and current secondary effluent for industrial facilities would likely be greater than the data presented here.
** 1 lb = 454,000 mg
HHWQC=human health-based water quality criteria
MF/RO=membrane filtration/reverse osmosis
MF/GAC=membrane filtration/granulated activated carbon
µg/L=micrograms per liter
mg/d=milligrams per day
lb/d=pounds per day

Unit costs were developed based on required mass removal from a 5 mgd facility for each of the four constituents of concern to reduce discharges from current secondary effluent quality to the assumed required effluent quality (HHWQC). It important to note that this study concludes it is unclear if existing technology can meet the required effluent quality, however, the information presented in Table 12 assumes HHWQC would be met for developing unit costs. The unit costs are expressed as dollars in NPV (over a 25 year period) per pound of constituent removed over the same 25 year period using advanced treatment with MF/RO. The current secondary effluent quality data presented are based on typical secondary effluent quality expected for a municipal/industrial discharger. Table 12 suggests unit costs are most significant in meeting the PCB, mercury, and PAH required effluent quality.

Table 12. Unit Cost by Contaminant for a 5 mgd Facility Implementing Advanced Treatment using MF/RO

Component	PCBs	Mercury	Arsenic	PAHs
Required HHWQC based Effluent Quality (µg/L)	0.0000064	0.005	0.018	0.0013
Current Secondary Effluent Concentration (µg/L)*	0.002	0.025	7.5	0.006
Total Mass Removed (lbs) over 25-year Period	0.76	7.6	2,800	1.8
Unit Cost (NPV per total mass removed in pounds over 25 years)	$290,000,000	$29,000,000	$77,000	$120,000,000

*Derived from data presented in Table 3.
**Based on assumed 25-year NPV of $219,000,000 (average of the range presented in Table 10) and advanced treatment using MF/RO.
NPV=net present value
HHWQC=human health-based water quality criteria
µg/l=micrograms per liter

4.9 Sensitivity Analysis

The ability of dischargers to meet a HHWQC one order of magnitude less stringent (than HHWQC presented in Table 3 and used in this report) was considered. The same advanced treatment technologies using MF/RO or MF/GAC would still be applied to meet revised effluent quality one order-of-magnitude less stringent despite still not being able to meet less stringent effluent limits. As a result, this less stringent effluent quality would not impact costs. Based on available data, it appears the mercury and BAP limits would be met at a less stringent HHWQC. PCB effluent quality could potentially be met if advanced treatment with RO or GAC performed at the upper range of their projected treatment efficiency. It does not appear the less stringent arsenic HHWQC would be met with advanced treatment. It is important to note that a discharger's ability to meet these less stringent limits depends on existing secondary effluent characteristics and is facility specific. Facilities with higher secondary effluent constituent concentrations will have greater difficulty meeting HHWQC.

5.0 Summary and Conclusions

This study evaluated treatment technologies potentially capable of meeting revised effluent discharge limits associated with revised HHWQC. HDR completed a literature review of potential technologies and engineering review of their capabilities to evaluate and screen treatment methods for meeting revised effluent limits for four constituents of concern: arsenic, BAP, mercury, and PCBs. HDR selected two alternatives to compare against a baseline, including enhanced secondary treatment, enhanced secondary treatment with MF/RO, and enhanced secondary treatment with MF/GAC. HDR developed capital costs, operating costs, and a NPV for each alternative, including the incremental cost to implement from an existing secondary treatment facility.

The following conclusions can be made from this study.

- Revised HHWQC based on state of Oregon HHWQC (2001) and EPA “National Recommended Water Quality Criteria” will result in very low water quality criteria for toxic constituents.
- There are limited “proven” technologies available for dischargers to meet required effluent quality limits that would be derived from revised HHWQC.
  - Current secondary wastewater treatment facilities provide high degrees of removal for toxic constituents; however, they will not be capable of compliance with water quality-based NPDES permit effluent limits derived from revised HHWQC.
  - Advanced treatment technologies have been investigated and candidate process trains have been conceptualized for toxics removal.
    - Advanced wastewater treatment technologies may enhance toxics removal rates, however they will not be capable of compliance with HHWQC based effluent limits for PCBs. The lowest levels achieved based on the literature review were between <0.00001 and 0.00004 µg/L, as compared to a HHWQC of 0.0000064 µg/L.
    - Based on very limited performance data for arsenic and mercury from advanced treatment information available in the technical literature, compliance with revised criteria may or may not be possible, depending upon site specific circumstances.
      - Compliance with a HHWQC for arsenic of 0.018 µg/L appears unlikely. Most treatment technology performance information available in the literature is based on drinking water treatment applications targeting a much higher SDWA MCL of 10 µg/L.
      - Compliance with a HHWQC for mercury of 0.005 µg/L appears to be potentially attainable on an average basis but perhaps not if effluent limits are structured on a maximum monthly, weekly or daily basis. Some secondary treatment facilities attain average effluent mercury levels of 0.009 to 0.066 µg/L. Some treatment facilities with effluent filters attain average effluent mercury levels of 0.002 to 0.010 µg/L. Additional advanced treatment processes are expected to enhance these removal rates, but little mercury performance data is available for a definitive assessment.
    - Little information is available to assess the potential for advanced technologies to comply with revised benzo(a)pyrene criteria. A municipal wastewater treatment plant study reported both influent and effluent BAP concentrations less than the HHWQC of 0.0013 ug/L (Ecology, 2010).

  - Some technologies may be effective at treating identified constituents of concern to meet revised limits while others may not. It is therefore even more challenging to identify a technology that can meet all constituent limits simultaneously.
  - A HHWQC that is one order-of-magnitude less stringent could likely be met for mercury and PAHs however it appears PCB and arsenic limits would not be met.
- Advanced treatment processes incur significant capital and operating costs.
  - Advanced treatment process to remove additional arsenic, benzo(a)pyrene, mercury, and PCBs would combine enhancements to secondary treatment with microfiltration membranes, reverse osmosis, and granular activated carbon and increase the estimated capital cost of treatment from $17 to $29 in dollars per gallon per day of capacity (based on a 5.0 mgd facility).
  - The annual operation and maintenance costs for the advanced treatment process train will be substantially higher (approximately $5 million - $15 million increase for a 5.0 mgd capacity facility) than the current secondary treatment level.
- Implementation of additional treatment will result in additional collateral impacts.
  - High energy consumption.
  - Increased greenhouse gas emissions.
  - Increase in solids production from chemical addition to the primaries. Additionally, the membrane and GAC facilities will capture more solids that require handling.
  - Increased physical space requirements at treatment plant sites for advanced treatment facilities and residuals management including reverse osmosis reject brine processing.
- It appears advanced treatment technology alone cannot meet all revised water quality limits and implementation tools are necessary for discharger compliance.
  - Implementation flexibility will be necessary to reconcile the difference between the capabilities of treatment processes and the potential for HHWQC driven water quality based effluent limits to be lower than attainable with technology

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7.0 Appendices

- Appendix A - Unit Process Sizing Criteria
- Appendix B - Greenhouse Gas Emissions Calculation Assumptions

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APPENDIX A - UNIT PROCESS SIZING CRITERIA

Table A-1. Unit Processes Sizing Criteria for Each Alternative

Unit Process	Units	Baseline Treatment	Advanced Treatment	Comment
Influent Pumping Station	unitless	3 Times Ave Flow	3 Times Ave Flow	This is peaking factor used to size the pumps (peak flow:average flow)
Alum Dose for CEPT (optional)	mg/L	20	20	This is the metal salt upstream of the primaries
Primary Clarifiers	gpd/sf	1000	1000	This is for average annual flows
Primary Solids Pumping Station	unitless	1.25 Times Ave Flow	1.25 Times Ave Flow	This is peaking factor used to size the pumps (maximum month flow:average flow)
Aeration System Oxygen Uptake Rate (OUR)	mg/L/hr	25	25	Average annual OUR is used in tandem with mixed liquor to determine the required aeration basin volume (the limiting parameter governs the activated sludge basin volume)
Aeration Basin Mixed Liquor	mg/L	1250	2500	Average annual mixed liquor is used in tandem with OUR (see next row) to determine the required aeration basin volume (the limiting parameter governs the activated sludge basin volume)
Secondary Clarifiers Hydraulic Loading	gpd/sf	650	--	Only use for Baseline as clarifiers governed hydraulically with short SRT (<2 days)
Secondary Clarifiers Solids Loading	lb/d/sf	--	24	Only use for Advanced Treatment as clarifiers governed by solids with long SRT (>8 days)
Return Activated Sludge (RAS) Pumping Station	unitless	1.25 Times Ave Flow	1.25 Times Ave Flow	RAS must have capacity to meet 100% influent max month Flow. The influent flow is multiplied by this peaking factor to determine RAS pumping station capacity.
Waste Activated Sludge (WAS) Pumping Station	gpm	1.25 Times Ave Flow	1.25 Times Ave Flow	WAS must have capacity to meet max month WAS flows. The average annual WAS flow is multiplied by this peaking factor to determine WAS pumping station capacity.
Microfiltration (MF) Flux	gfd	--	25	Based on average annual pilot experience in Coeur D'Alene, ID
MF Backwash Storage Tank	unitless	--	1.25	Storage tanks must have capacity to meet maximum month MF backwash flows. The average annual MF backwash volume is multiplied by this peaking factor to determine required volume.

Table A-1. Unit Processes Sizing Criteria for Each Alternative

Unit Process	Units	Baseline Treatment	Advanced Treatment	Comment
MF Backwash Pumps	unitless	--	1.25	Backwash pumps must have capacity to meet maximum month MF backwash flows. The average annual MF backwash flow is multiplied by this peaking factor to determine required flows.
Reverse Osmosis (RO)	gallon per square foot per day (gfd)	--	10	
RO Reject	%	--	20	This represents the percentage of feed flow that is rejected as brine
Chlorination Dose	mg/L	15	15	
Chlorination Storage Capacity	days	14	14	
Chlorine Contact Tank	min	30	30	This is for average annual conditions.
Dechlorination Dose	mg/L	15	15	
Dechlorination Storage Capacity	days	14	14	
Gravity Belt Thickener	gpm/m	200	200	This is for maximum month conditions using the 1.25 peaking factor from average annual to maximum month
Anaerobic Digestion	Hydraulic residence time (HRT)	18	18	This is for average annual conditions
Dewatering Centrifuge	gpm	120	120	This is for maximum month conditions using the 1.25 peaking factor from average annual to maximum month

gpd=gallons per day; sf=square feet; gpm=gallons per minute

Appendix B – Greenhouse Gas Emissions Calculation Assumptions

The steady state mass balance results were used to calculate GHG emissions. The assumptions used to convert between energy demand, chemical demand and production, as well as biologically-mediated gases (i.e., CH4 and N2O) and GHG emissions are provided in Table B-1. The assumptions are based on EPA (2007) values for energy production, an adaptation of the database provided in Ahn et al. (2010) for N2O emissions contribution, Intergovernmental Panel on Climate Change (IPCC) (2006) for fugitive CH4 emissions, and various resources for chemical production and hauling from production to the wastewater treatment plant (WWTP). Additionally, the biogas produced during anaerobic digestion that is used as a fuel source is converted to energy with MOP8 (2009) recommended waste-to-energy values.

Table B-1. Greenhouse Gas Emissions Assumptions

Parameters	Units	Value	Source
N_2O to CO_2 Conversion	lb CO_2/lb N_2O	296	IPCC, 2006
CH_4 to CO_2 Conversion	lb CO_2/lb CH_4	23	IPCC, 2006
Energy Production			
CO_2	lb CO_2/MWh	1,329	USEPA (2007)
N_2O	lb N_2O/GWh	20.6	USEPA (2007)
CH_4	lb CO_2/GWh	27.3	USEPA (2007)
Sum Energy Production	lb CO_2/MWh	1336	USEPA (2007)
GHGs per BTU Natural Gas			
CO_2	lb CO_2/MMBTU Natural Gas	52.9	CA Climate Action Registry Reporting Tool
N_2O	lb N_2O/MMBTU Natural Gas	0.0001	CA Climate Action Registry Reporting Tool
CH_4	lb CO_2/MMBTU Natural Gas	0.0059	CA Climate Action Registry Reporting Tool
Sum Natural Gas		53.1	CA Climate Action Registry Reporting Tool
Non-BNR N_2O Emissions	g N_2O/PE/yr	32	Ahn et al. (2010)
BNR N_2O Emissions	g N_2O/PE/yr	30	Ahn et al. (2010)
Biogas Purity	% Methane	65	WEF, 2009
Biogas to Energy	BTU/cf CH4	550	WEF, 2009
Digester Gas to Electrical Energy Transfer Efficiency	%	32	HDR Data

Table B-1. Greenhouse Gas Emissions Assumptions

Parameters	Units	Value	Source
Chemical Production			
Alum	lb CO_2/lb Alum	0.28	SimaPro 6.0 - BUWAL250, Eco-indicator 95
Polymer	lb CO_2/lb Polymer	1.18	Owen (1982)
Sodium Hypochlorite	lb CO_2/lb Sodium Hypochlorite	1.07	Owen (1982)
Building Energy Efficiency	kBTU/sf/yr	60	Calif. Commercial End-Use Survey (2006)
Hauling Distance		-	
Local	miles	100	-
Hauling Emissions			
Fuel Efficiency	miles per gallon	8	
CO_2	kg CO_2/gal diesel	10.2	CA Climate Action Registry Reporting Tool
N_2O	kg N_2O/gal diesel	0.0001	CA Climate Action Registry Reporting Tool
CH_4	kg CH_4/gal diesel	0.003	CA Climate Action Registry Reporting Tool
Sum Hauling Fuel	kg CO_2/gal diesel	10.2	CA Climate Action Registry Reporting Tool

GWh = Giga Watt Hours
MWh = Mega Watt Hours
MMBTU = Million British Thermal Units
BTU = British Thermal Unit
PE = Population Equivalents
kBTU/sf/yr = 1,000 British Thermal Units per Square Foot per Year
cf = cubic feet
lb = pound
kg = kilogram
gal = gallon

street roots news

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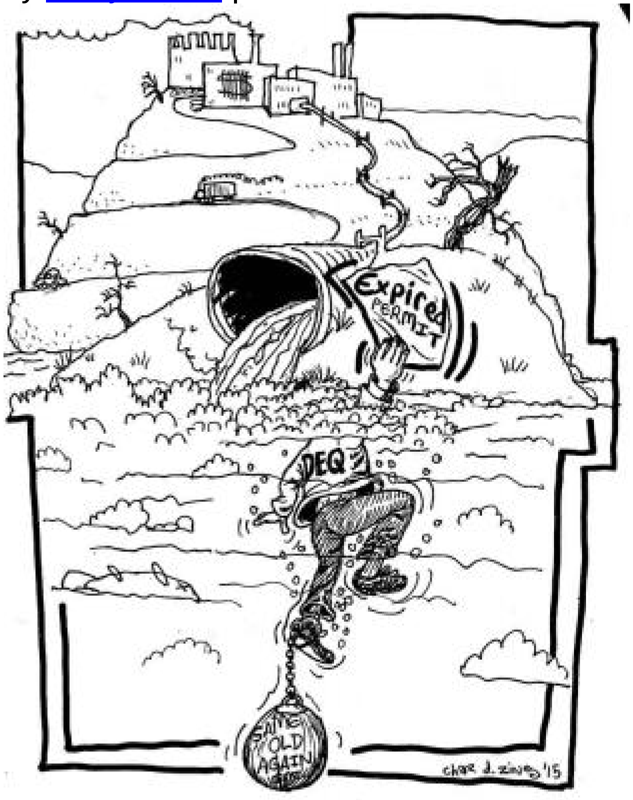
http://news.streetroots.org/2015/02/24/underwater-oregons-agency-responsible-monitoring-waterway-polluters-most-backlogged

Underwater: Oregon's agency responsible for monitoring waterway polluters is the most backlogged in the country

by Emily Green | 24 Feb 2015



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Oregon has the stiffest water pollution regulations of any state in the U.S.

Sounds impressive, right?

Think again.

Oregon is dead last nationwide when it comes to keeping wastewater permits current with state regulations. According to the EPA's most recent data on the status of each state's stormwater and wastewater permits, Oregon has the highest percentage of expired state-issued permits nationwide.

Most of the state-issued permits polluters operate under have long-passed their original expiration dates — in some cases by 20 years or more.

This means these permit holders have to be in compliance only with laws that existed when their permits were written, not with current laws. In the past two decades, numerous changes to state regulations have reduced permissible levels of toxics and temperature in wastewater.

Under the Clean Water Act of 1972, facilities and municipalities releasing wastewater directly into U.S. waterways must adhere to limits outlined in EPA or state-issued wastewater and stormwater permits. The Oregon Department of Environmental Quality issues these permits in Oregon, under the oversight of the EPA. Under the Clean Water Act, DEQ is supposed to revise water-quality standards every three years and renew each permit every five years.

But according to DEQ's current backlog count, 63 percent of existing state-issued permits for releasing stormwater and treated wastewater directly into streams and rivers are expired. An alarming 76 percent of major wastewater permits – issued to facilities with more than 1 million gallons of wastewater flowing through their treatment plants every day – also are operating on administrative extensions. Because permits are written five years before they expire, there are many municipal sewage facilities and several large industrial facilities operating under permits written in the late 1980s and early 1990s, when regulations were much less stringent than they are today.

For example, TDY Industries in Albany – a metals manufacturer that is one of the state's top polluters according to the EPA – is operating under the parameters of a wastewater permit that was written in 1988. Most of the state's municipal sewage treatment plants are operating under expired permits as well. Klamath Falls' is the oldest, written in 1990.

The amount of pollution a permit allows is based on many factors, including the number and size of other facilities contributing to the pollution of a waterway, the temperature of the water and the condition of wildlife living in the area.

"It's very circumstantial, and those circumstances can change, and they do change, as well as the scientific knowledge," says Nina Bell, an attorney who specializes in the implementation of Clean Water Act programs as the executive director of Northwest Environmental Advocates. She says when the Clean Water Act was written, Congress understood that science was going to be changing rapidly and that permits needed to keep up with it – that's why permits are supposed to be rewritten every five years.

"We have a much better idea of the science behind what pollution does to people, fish and wildlife. And that change in our scientific understanding is supposed to be reflected in our water quality standards," says Bell. "In that course of time you could also have species that have come to the brink of extinction and are listed as threatened or endangered and need the protection a new permit might afford. There could be studies that show there's contamination in fish or water that we didn't know about the last time the permit was issued. The amount of water in the stream that dilutes the pollution could change over that period of time as well – whether because there are more withdrawals or from the effects of climate change," she says.

In 2012, Oregon's waterways were ranked the 33rd most polluted in the nation, according to the Environmental Protection Agency's Toxics Release Inventory.
So why is DEQ allowing polluters to operate under such outdated parameters? It's not because polluters are failing to reapply for new permits. They are applying on time, which removes their liability. According to DEQ, it just doesn't have the resources it needs to do its job.

Greg Aldrich has worked for DEQ for 15 years and is the former head of its water quality program. He's seen backlogs like the one DEQ is experiencing before. He says the program was the most backlogged in the nation in the early 2000s as well, but then DEQ ramped the water program's funding, creating more positions, and it started to catch up.

Then the recession hit.

"We took huge cuts – 19 percent cuts," says Aldrich. "It is frustrating. We get an agreement, we start ramping up, we add a stormwater program that people support, and then you start seeing cuts. Some of it is a loss of general funds, some of it is a loss of federal funds. And then the stormwater (program) – because a lot of it is paid for by industry – as they shrank, you just see the program shrink," he says.

DEQ's $52 million Water Quality Program suffered a $5.7 million reduction in the 2011-13 budget, which represented a loss of about 37 full-time positions. These cuts included seven employees among wastewater permitting and stormwater programs.

But budget isn't the only factor contributing to DEQ's backlog. Aldrich says tighter regulations make the permit writing process increasingly complex, which requires a lot more water testing and analysis. DEQ is also experiencing high turnover rates as its experts, many of whom joined the program in the early 1970s when it was created, are retiring.

Litigation in 2012 surrounding DEQ's temperature requirements added to the backlog because DEQ stopped issuing permits involving temperature regulation during that time.

Now Aldrich is DEQ's policy and analysis manager. He hopes the Legislature will help figure out a way to increase funding to the water quality program in the next biennium, because the budget package DEQ is seeking will merely sustain the program, not help it catch up, he says.

As things are, DEQ prioritizes which permits get renewed and which ones continue to be extended based on risk factors and economic needs. Aldrich says the agency always prioritizes permits for new facilities and expansions.

The last time DEQ was this far behind on water permits, it stopped inspecting and monitoring permit holders entirely and focused only on writing permits. Aldrich says this time DEQ is approaching things differently.

“We’ve been putting more effort into the compliance part,” he says. But with the workload, his environmental engineers are not always able to review all the water testing data that permit holders self-report to DEQ.

“I think what’s been challenging for us is we sometimes have this data presented to us, and we’ve not spent time looking at it to say, ‘Oh, well you even reported a problem and we didn’t follow up on it.’ That’s where it looks incredibly bad for us,” he says.

Because DEQ hasn’t been able to do its job fully, river-watching nonprofits and their attorneys have stepped in to fill the void.

Doug Quirke, founder of Oregon Clean Water Project, has been bringing litigation against facilities violating the terms of their DEQ water quality permits since 1999. He often works with nonprofits such as the Willamette Riverkeepers.

“We track permit compliance, and we bring citizen enforcement action when we find noncompliance,” says Quirke. But he can enforce only the terms of the permit any particular polluter is operating under, not current regulations.

“In a general sense, the regulations under the Clean Water Act tend to get more stringent over time, so any of these facilities with expired permits would have more stringent permits if they were issued today.” He says older permits issued in the 1990s are of particular concern. “You don’t really need to do an analysis to know that a permit that old would definitely be more stringent if it were issued today,” he says.

DEQ’s current Water Quality Program Manager Jennifer Wigal says in the last 15 years, DEQ has seen tighter regulations in several areas.

“Temperature standards have been done and redone several times over the years, which is a concern for a lot of dischargers,” she says.

Most notably, in 2011 toxic pollutants standards changed significantly, specifically regarding reductions on pollutants that affect fish and people drinking the water, she says.

The changes in 2011 came about when Oregon found that its fish consumption rate was much higher than previously thought, says Teresa Huntsinger, water program director at Oregon Environmental Council. She sits on a committee that was formed to help find solutions to DEQ’s tremendous water permit backlog in 2001. “For many years they were making progress and catching up with that backlog, but in the last few years things have been getting worse again,” she says.

Huntsinger says part of DEQ’s resource issues have to do with water permit fees.

“The wastewater plants pay an annual fee, and the increase in that fee hasn’t ever been commensurate with the staffing cost,” she says. “DEQ has a proposal this year to increase those fees, and they're increasing them more than they usually do to catch up. The permitees have been really balking at that, which you can understand. Partly because, from their perspective, they're saying, 'We're getting poor service, it's taking you a long time to deal with our issues, and what are we going to get in response for paying increased fees? We're still going to be getting poor service.' So I can see that point of view, but also at the same time they're not paying the cost of writing their permits, so their fees need to be increased."

DEQ's air and land programs are not backlogged in the way its water quality program is, and this is in part because funding for those programs is more reliant on fees, says Aldrich.

While most of Oregon's water quality permits are expired, Indiana leads the nation with nearly 100 percent of its permits up to date. But it too has experienced significant backlogs. Back in 2005, there were 263 administratively extended water quality permits across the state. According to Bruno Pigott, assistant commissioner to Indiana's Office of Water Quality, it took a statewide commitment to fixing the problem to get his department to where it is today.

When Mitch Daniels became Indiana's governor in 2005, he made the water quality permit backlog a top priority, meeting with Indiana's water program his second day in office. "He was very concerned about our agency's backlog," says Pigott. He appointed a new commissioner and required the agency report its progress to his office. "Our individual performances as well as our agency performances were judged on our ability to reduce and eliminate that backlog," says Pigott. "We made a concerted effort – it came from the very top and came down to an organizational commitment to getting it done," he says. His organization also ceased extended negotiation with permitees over the parameters of permits. "If they said they were going to appeal a permit, we said OK, go ahead,'" he says.

But Oregon has not given DEQ the funding that would be necessary to see the kind of progress that states like Indiana have made in reducing backlogs. And that means stringent water quality requirements are an unreachable ideal, not a reality.

Last year Siltronic Corp., a semiconductor manufacturer in Portland, made headlines when the EPA listed it as the top waterway polluter in the state for 2012. Its wastewater permit expired in June, and the DEQ regulator responsible for its permit, Mer Wiren, says she has no idea when it will be renewed.

Wiren, is one of only two employees charged with monitoring, inspecting and writing permits for all 55 major industrial wastewater permit holders in DEQ's Northwest Region of Oregon. She says Siltronic applied for the renewal six months ahead of time like it was supposed to, and she issued an "indefinite administrative renewal" that will keep it legal until she rewrites the permit. Additionally, as a major facility, Siltronic is supposed to receive an on-sight inspection every two years, but received no inspection between 2010 and 2014.

But the pollutant that earned Siltronic its place at the top of Oregon's polluters, nitrate compounds, isn't even limited under the terms of its current permit.

When told about the EPA's ranking of Siltronic due to nitrates, Wiren says, "That's a new piece of information to me, but if it's a concern, we can look at that."

Wiren says in the five years she's worked as an environmental engineer at DEQ, she's never seen a water quality permit renewed on time.

Siltronic spokesman Christof Bachmair says Siltrnoic has been working at reducing its pollution. He said the company has effectively reduced nitrate compound emissions by 90 percent since 2000.

Bachmair also pointed out that many facilities with wastewater permits discharge to wastewater treatment plants, not directly into the river.

"Some of these companies are discharging more nitrates than Siltronic," he says. "In addition, the water treatment plants receive residential waste, which also contain nitrates. Again, these nitrates are typically not treated, nor are they reported to EPA as a part of the Toxic Release Reporting program. So in our view, the true picture of discharge rankings is not clearly portrayed by the EPA reports," he says.

Portland's Environmental Services spokesman Linc Mann confirmed that there are no specific requirements at the Columbia Boulevard and Tryon Creek wastewater treatment plants to remove nitrates and other nitrogen compounds. According to the EPA, nitrates can cause people to become seriously ill if high levels are present in drinking water. Nitrate compounds can also be harmful to the health of aquatic organisms and fish.

In DEQ's Northwest Region, covering Multnomah, Clackamas, Washington, Columbia, Tillamook and Clatsop counties, the most outdated permits belong to the Port of St. Helens, written in 2003, and StarLink Logistics Inc., a Portland agricultural chemicals manufacturer that's permit was renewed in 2003.

The EPA ultimately is responsible for Oregon's permit backlog. It oversees DEQ, and gave it the authority to issue and monitor water quality permits. Quirke says any lawsuit resulting from someone getting sick from pollution emitted under the parameters of an old permit ultimately would be directed at the EPA.

"The main plan of attack for this sort of thing that I've seen is to try to get EPA to pull the approval of the state program, and if it actually did happen, that means that the administration of the program would get taken away and kicked back to EPA," says Quirke.

The EPA has never fully revoked a state's authority to issue permits, and to do so in this case wouldn't be in Oregon's best interest, says Christine Psyk, associate director of the EPA's regional wastewater permitting unit. "We've had conversations with Oregon about their backlog," she says, "but we don't have a standing workforce to come in and take over permitting." She says the EPA is working with Oregon to find ways to get caught up.

As the permitting process becomes more and more complex, with some wastewater permits filling an entire six-inch binder, looking at ways to streamline the process and providing roadmaps to permit writers are areas of focus, she says.

While Oregon may be the farthest behind on issuing permits, it’s backlog problem is not unique. “Everyone has somewhat of a backlog,” says Psyk. “The EPA has a backlog, too.”

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
15 W Yakima Ave, Ste 200 • Yakima, WA 98902-3452 • (509) 575-2490

January 7, 2010

Al Jensen
Facility Manager
U.S. Fish and Wildlife Service
12790 Fish Hatchery Road
Leavenworth, WA 98826

RE: Final 401 Certification for the Leavenworth National Fish Hatchery
Order No. 7192

Dear Mr. Jensen:

Enclosed is Order number 7192, in the matter of granting a Water Quality Certification to U.S. Fish and Wildlife Service. The certification includes limits and treatment requirements for wastewater discharges, and monitoring and reporting requirements pertaining to water temperature and fish habitat in Icicle Creek affected by hatchery operations.

All correspondence relating to this document should be directed to Pat Irle, Department of Ecology, 15 W. Yakima Avenue, Suite 200, Yakima, WA 98902. If you have any questions concerning the content of the document, please call Pat, at 509/454-7864.

Sincerely,

Charles McKinney

Charles McKinney, Section Manager
Water Quality Program
Central Regional Office

Enclosure: Order No. 7192
1-30-09 Flow Management Plan
Schedule of required studies and reports (Table 1)

By Registered Mail

cc: Steve Croci, Leavenworth National Fish Hatchery
Michael Lidgard, Environmental Protection Agency, Region 10
Tom Tebb, Ecology-Central

IN THE MATTER OF GRANTING A WATER QUALITY CERTIFICATION TO
U.S. Fish and Wildlife Service
1790 Fish Hatchery Road
Leavenworth, WA 98826
in accordance with 33 U.S.C. 1341 (FWPCA § 401), RCW 90.48.120, RCW 90.48.260 and Chapter 173-201A WAC

ORDER No. 7192
Certification of the Leavenworth National Fish Hatchery (NPDES Permit No. WA-000-190-2) on Icicle Creek, Chelan County, Washington.

TO: **Al Jensen, Facility Manager**
U.S. Fish and Wildlife Service
12790 Fish Hatchery Road
Leavenworth, WA 98826

The Leavenworth National Fish Hatchery (Leavenworth NFH) is required to have a Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDES) Permit issued by the U.S. Environmental Protection Agency (EPA) authorizing the discharge of wastewater. In 2005, the U.S. Fish and Wildlife Service (USFWS), which manages and operates the Leavenworth NFH, applied to EPA to renew its NPDES Permit. On June 26, 2006, EPA issued a draft NPDES Permit and associated fact sheet for the Leavenworth NFH. On January 15, 2008, Washington State Department of Ecology (Ecology) received an application from the USFWS requesting a CWA Section 401 water quality certification (401 Certification), 33 USC §1341, for the draft NPDES permit. Pursuant to Ecology's request, the USFWS prepared a Tier II Water Quality Analysis for the Leavenworth NFH and submitted it to Ecology on April 30, 2008. On January 9, 2009, Ecology received a request from the USFWS to withdraw and re-apply for a 401 Certification. Ecology has determined that the project has and is likely to continue to violate water quality standards. This Order is intended to ensure that its continued operation does not create future violations. If operated consistent with the terms of this Order, Ecology has reasonable assurance that the project will meet water quality standards. This document represents Ecology's Section 401 water quality certification and ch. 90.48 RCW order (Order) for the Leavenworth NFH. For purposes of this Order, USFWS and Leavenworth NFH will be referred to as Leavenworth NFH.

PROJECT DESCRIPTION

The Leavenworth NFH is located on Icicle Creek, a tributary to the Wenatchee River, at river mile (RM) 3.0 near Leavenworth, Washington. The Leavenworth NFH was authorized as mitigation for the construction of Grand Coulee Dam and is used to capture, spawn, and rear approximately 1.2 million spring Chinook salmon at 70,000 pounds and acclimate coho salmon for a total weight gain of less than 10,000 pounds annually. According to the draft NPDES permit, the Project has had a total daily average discharge of 26 million gallons per day and the main pollutants of concern are nitrogen, phosphorus, settleable solids (SS), total suspended solids (TSS), dissolved oxygen (DO), pH, temperature, and total residual chlorine (EPA, draft NPDES permit). Water is discharged from the hatchery operations at two locations: (1) from the rearing ponds and raceways via combined Outfalls 001 and 004; and (2) from the Pollution Abatement Pond, Outfall 002.

AUTHORITIES

In exercising authority under 33 U.S.C. § 1341, RCW 90.48.120, and RCW 90.48.260, Ecology has reviewed this application pursuant to the following:

1. Conformance with applicable water quality-based, technology-based, and toxic or pretreatment effluent limitations as provided under 33 U.S.C. §§1311, 1312, 1313, 1316, and 1317 (FWPCA §§ 301, 303, 306 and 307);
2. Conformance with the state water quality standards contained in Chapter 173-201A WAC and authorized by 33 U.S.C. §1313 and by Chapter 90.48 RCW, and with other applicable state laws; and
3. Conformance with the provision of using all known, available and reasonable methods to prevent and control pollution of state waters as required by RCW 90.48.010.
4. Conformance with RCW 90.54.020(3)(a) and (b).

WATER QUALITY CERTIFICATION CONDITIONS

Through issuance of this Order, Ecology certifies that it has reasonable assurance that the activity as proposed and conditioned will be conducted in a manner that will comply with applicable water quality standards and other appropriate requirements of state law. In view of the foregoing and in accordance with 33 U.S.C. §1341, RCW 90.48.120, RCW 90.48.260, Chapter 173-200 WAC and Chapter 173-201A WAC, water quality certification is granted to the Leavenworth NFH subject to the conditions within this Order.

Certification of this project does not authorize the Leavenworth NFH to exceed applicable state water quality standards (Chapter 173-201A WAC), ground water quality standards (Chapter 173-200 WAC) or sediment quality standards (Chapter 173-204 WAC). Furthermore, nothing in this certification shall absolve Leavenworth NFH from liability for contamination and any subsequent cleanup of surface waters, ground waters or sediments occurring as a result of project operations.

A. General Conditions

1. For purposes of this Order, the term "Applicant" shall mean the Leavenworth NFH and its agents, assignees and contractors.
2. For purposes of this Order, all submittals required as conditions shall be sent to the Section Manager, Water Quality Program, Washington State Department of Ecology, Central Regional Office, 15 West Yakima Ave., Suite 200, Yakima, WA 98902 or via e-mail (preferred), if possible, to the Section Manager, Water Quality Program for Ecology's Central Regional Office. Notifications shall be made via phone or e-mail (preferred). All submittals and notifications shall be identified with Order No. 7192 and include the Applicant's name, project name, project location, the project contact and the contact's phone number.

3. Conditions B.6, B.7, B.8, and B.9 shall be deemed denied if the EPA does not issue a NPDES Permit for the Leavenworth NFH within two years from the date of the Order.

4. Copies of this Order shall be kept on the site and readily available for reference by staff of the Leavenworth NFH, its contractors and consultants, Ecology personnel, and state and local government inspectors.

5. The Leavenworth NFH shall ensure that all project staff and other workers at the project site with authority to direct work have read and understand relevant conditions of this Order and all permits, approvals, and documents referenced in this Order.

6. The Leavenworth NFH shall provide access to the project site and all monitoring sites upon request by Ecology personnel for site inspections, monitoring, necessary data collection, and/or to ensure that conditions of this Order are being met.

7. Nothing in this Order waives Ecology's authority to issue additional orders if Ecology determines that further actions are necessary to implement the water quality laws of the state. Further, Ecology retains continuing jurisdiction to make modifications hereto through supplemental order, if additional impacts due to project operation are identified (*e.g.*, violations of water quality standards, downstream erosion, etc.), or if additional conditions are necessary to further protect water quality.

8. All applications, reports, or information submitted to Ecology shall be signed and certified.

   a. All permit applications shall be signed by the project staff or manager with authority to act for USFWS.

   b. All reports required by this permit and other information requested by Ecology shall be signed by a person described above or by a duly authorized representative of that person. A person is a duly authorized representative only if:

      i. The authorization is made in writing by a person described above and submitted to Ecology.

      ii. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility, such as the position of plant manager, superintendent, position of equivalent responsibility, or an individual or position having overall responsibility for environmental matters. (A duly authorized representative may thus be either a named individual or any individual occupying a named position.)

   c. Changes to authorization. If an authorization under paragraph A.8.b.ii. is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of paragraph A.8.b.ii. shall be submitted to Ecology prior to or together with any reports, information, or applications to be signed by an authorized representative.

   d. Certification. Any person signing a document under this section shall make the following certification:

> I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

9. This Order does not authorize direct, indirect, permanent, or temporary impacts to waters of the state or related aquatic resources, except as specifically provided for in conditions of this Order.

10. Failure of any person or entity to comply with the Order may result in the issuance of civil penalties or other actions, whether administrative or judicial, to enforce the terms of this Order.

B. Specific Conditions

1. Icicle Creek Stream Flow

   a. Flow Management. The Leavenworth NFH shall comply with all of the provisions of the Leavenworth National Fish Hatchery Proposed Flow Management Operations 2009-2014 (Proposed Flow Management Plan), dated January 30, 2009, until replaced with a final plan approved by Ecology in writing. A copy of the Flow Management Plan is attached as Appendix A. Compliance shall include completion of all studies to address the information needs identified in the Proposed Flow Management Plan. All studies required by the Proposed Flow Management Plan shall be submitted to Ecology for its review.

   b. Ramping Rates. When adjusting Structure 2, flow ramping rates shall not exceed one inch per hour. If the condition or capability of Structure 2 does not reliably allow stage adjustments as fine as one inch per hour, adjustments should be made in the finest increment possible and field observation of the historical channel or the hatchery canal, as appropriate, should be performed to verify that fish stranding is minimized.

   c. Flow Monitoring. The Leavenworth NFH shall prepare the following flow monitoring plans, in accordance with the approved Quality Assurance Project Plan (QAPP), described in paragraph D, and implement them upon Ecology's approval.

      i. Historic channel and hatchery canal. Within four months of issuance of this Order, the Leavenworth NFH shall prepare a plan describing how stream flow will be monitored in the hatchery canal and the historic Icicle Creek channel. The plan shall include a description of the monitoring equipment to be used, the monitoring frequency, and the procedures for such monitoring. The plan shall be submitted to Ecology for its review and written approval. The plan shall be implemented within 90 days of its approval by Ecology.

ii. Snow/Nada Lake. Within four months of issuance of this Order, the Leavenworth NFH shall prepare a plan for monitoring releases from Snow and Nada Lakes to supplement Icicle Creek flow below USGS Gage 12458000. The plan shall be submitted to Ecology for its review and written approval. The plan shall be implemented within 90 days of its approval by Ecology.

d. Annual Flow Monitoring Report. By December 31 of each year following approval of the flow monitoring plans, the Leavenworth NFH shall submit an annual report to Ecology compiling the flow monitoring data for the prior water year (October 1 – September 30).

e. Implementation. Within four years of the issuance of this Order, the Leavenworth NFH shall submit a Final Flow Management Plan. Once approved by Ecology, Leavenworth NFH shall implement the Final Flow Management Plan on the schedule set forth in the approved plan.

2. IFIM Study.

a. Within 18 months of issuance of this Order, the Leavenworth NFH shall prepare an Instream Flow Incremental Methodology (IFIM) study plan (IFIM Study Plan) for the historic channel consistent with the requirements of "Instream Flow Guidelines: Technical and Habitat Suitability Issues," Publication No. 04-11-007 (WDFW and Ecology, updated 2/12/2008), or an equivalent method or methodology approved by Ecology. The IFIM Study Plan shall include an implementation schedule. Upon completion, the IFIM Study Plan shall be submitted to Ecology for its review and written approval.

b. Within three months of approval by Ecology, the Leavenworth NFH shall implement the IFIM Study Plan.

c. Within three years of the issuance of this Order, the Leavenworth NFH shall submit a report of the IFIM study results to Ecology. The study results shall include flow recommendations. Once approved by Ecology, USFWS shall incorporate the flow recommendations into the proposed Final Flow Management Plan.

3. Fish Passage.

a. Within one year of issuance of this Order, the Leavenworth NFH shall submit a plan to investigate stream flow management and structural options for improving fish passage at (a) the intake structure, (b) Structure 2, and (c) Structure 5.

The investigation shall address the following:

- Determine flows needed for upstream and downstream passage of all swimming stages of native species;
- Investigate a long-term solution for year-round passage that may include modifications to the structure; and

- Analyze the potential for fish stranding due to ramping rates employed for operating Structure 2.

b. Within three years of issuance of this Order, the Leavenworth NFH shall submit a report summarizing the results of the study and recommending flow management and structural options for improving fish passage.

c. Implementation. Once approved by Ecology, USFWS shall incorporate the flow recommendations from the plan into the Final Flow Management Plan and implement the fish passage plan in accordance with the schedule set forth in the approved plan.

4. Hatchery Canal Hydrologic Functions.

a. Aquifer Recharge. The Leavenworth NFH shall prepare a plan to quantify the timing, rate, and volume of water needed in the hatchery canal to provide sufficient recharge to maintain water levels in the shallow aquifer within the range of variation exhibited during the 1945-1980 period. The Aquifer Recharge Plan shall be submitted to Ecology for its review and written approval.

b. Flood Control. The aquifer recharge plan shall also include a description of the operation of Structure 2 for the purpose of flood control.

c. Within three years of the issuance of this Order, Leavenworth NFH shall submit the Aquifer Recharge Plan and the Flood Control operating rules to Ecology for its review and approval. Once approved by Ecology, USFWS shall incorporate the flow recommendations from these two plans into the Final Flow Management Plan.

5. Navigation and Boating.

Within 24 months of issuance of this order, the Leavenworth NFH shall submit a report evaluating approaches or methods to provide navigation and boating through the natural channel reach from structure 2 through structure 5.

6. Temperature and Flow Monitoring.

a. Water used in hatchery operations. In accordance with the Quality Assurance Project Plan prepared pursuant to the requirements of paragraph D, the Leavenworth NFH shall monitor the temperature and flow of (a) each groundwater well; (b) surface water entering the hatchery; and (c) hatchery discharges to Icicle Creek. To the extent that flow monitoring required by this section coincides with or duplicates flow monitoring required in section B.1, the monitoring frequencies and locations should be reconciled with the flow monitoring plans required in section B.1.c.

i. Monitoring frequency. Temperature shall be monitored hourly from October 1st through September 30th.

ii. Monitoring report. By December 31st of each year, the Leavenworth NFH shall prepare and submit to Ecology an annual report summarizing its monitoring results. In addition to the temperature and flow data collected, the report shall include an analysis comparing the measured temperature of discharged water to the temperature calculated by flow-averaging the well water and surface water used by the hatchery.

b. Instream Temperature. Within two years of the issuance of this Order, the Leavenworth NFH shall submit a Temperature Study Plan to evaluate measures to reduce temperatures in Icicle Creek. The Temperature Study Plan shall include a QAPP consistent with the requirements of paragraph D for monitoring water temperatures at appropriate locations and frequencies and shall be submitted to Ecology for its review and written approval.

i. Plan Contents. The Temperature Study Plan shall include an evaluation of measures to:

- Lower temperatures in Icicle Creek to temperatures that would occur under natural conditions, focusing on the critical period between June and October.

- Meet the site-potential shade throughout the length of the historic river channel and hatchery canal.

ii. Plan Review and Approval. Within four years of the issuance of this Order, the Leavenworth NFH shall submit a report describing the results of the above study, including the environmental impacts, feasibility, costs, and potential schedules for implementation of each feasible alternative. Once approved by Ecology, the Leavenworth NFH shall within 180 days prepare and submit an Implementation Plan for review and written approval by Ecology.

iii. Implementation. Upon Ecology's approval of the Implementation Plan, Leavenworth NFH shall implement it in accordance with the schedule set forth in the approved Implementation plan.

7. Dissolved Oxygen and pH. Portions of the Wenatchee River, lower Icicle Creek, and other tributaries do not meet water quality standards for Dissolved Oxygen and pH during the critical period identified in the Wenatchee River pH and Dissolved Oxygen TMDL, Ecology Publication No. 08-10-062, August 2009. Phosphorus levels in the Wenatchee River watershed must be reduced to improve DO and pH levels to protect aquatic resources and designated uses. In the TMDL, the Leavenworth NFH was allocated a waste load of 0.52 kg/day total phosphorous.

a. Standards. The Leavenworth NFH shall meet a discharge limit of 0.52 kg/day total phosphorous within five years of permit issuance.

b. Monitoring. The Leavenworth NFH shall prepare and implement a QAPP consistent with the requirements of paragraph D to monitor phosphorus levels in its effluent and Icicle Creek flows upstream of the hatchery. Icicle Creek flow monitoring for calculating total phosphorous concentrations and mass should be reflected in the development of the flow monitoring required in paragraph B.5. Results shall be provided in both concentrations and total mass.

8. Toxics. The Leavenworth NFH shall prepare and implement a QAPP consistent with the requirements of paragraph D to monitor sediment deposited through hatchery operations for the presence of toxic pollutants. The QAPP shall include the following elements:

    a. Every 12 months, sample and analyze sediment in the pollution abatement pond for total PCBs, hexacholorcyclohexanes and endrin.

    b. Once during the five years subsequent to issuance of this order, sample and analyze the sediment in the pollution abatement pond, above the hatchery intake, and below the hatchery outfall for total PCB, endrin, endosulfan II and DDT.

    c. Provisions for the removal and proper disposal of all sediment in the pollution abatement pond in the event that any sample exceeds its Apparent Effects Threshold (Ecology 2003) for the identified parameter.

9. Turbidity. The Leavenworth NFH shall conduct turbidity monitoring when cleaning sediments from (a) the sand settling basin, (b) conveyance channel, (c) behind the fish screens, and (d) the pollution abatement pond.

    a. Sampling analysis and method. Turbidity analysis shall be performed with a calibrated turbidity meter (turbidimeter), either on-site or at an accredited lab. The results shall be recorded in a site log book in Nephelometric Turbidity Units (NTU).

    b. Sampling locations. Sampling is required at all discharge points where water used to clean sediments is being discharged back into surface waters. Background samples shall also be gathered to ensure that the discharge meets the requirements of WAC 173-201A-200 (discharge not to exceed five NTU above background if turbidity is 50 NTU or less, or 10 percent above background if background turbidity is greater than 50 NTU).

    c. Reporting. A copy of sampling results shall be submitted to Ecology within one month of each cleaning event.

C. Aquatic Workgroup.

1. Aquatic Workgroup Participation. Ecology will periodically convene a workgroup of federal, state, and tribal fisheries co-managers for consultation prior to its approval of the several flow- and aquatic resource-related studies, plans, or reports required by this Order. Workgroup members are not obligated to participate. A proposed workgroup member may request Ecology to consult with them separately.

2. Workgroup Composition. Members of the workgroup are USFWS, Ecology, the Yakama Nation, the Colville Confederated Tribes, National Marine Fisheries Service, and Washington Department of Fish and Wildlife.

3. Facilitation. Ecology, or another member of the workgroup, may serve as facilitator for the workgroup.

4. Study Procedures. A summary of the study plans, study reports and implementation plans required under this subsection is provided in Table 1. These documents shall be prepared according to the schedule provided in Table 1 or as modified by Ecology in writing. Where possible, the studies may be done in conjunction with other EPA-required plans and reports associated with the NPDES permit.

5. Plan Preparation. The Leavenworth NFH shall be responsible for preparing proposed study plans and study reports, with any proposed implementation measures, required by this Order. Ecology reserves the right to make the final determination as to the adequacy of the final products required by this 401 Certification.

D. Quality Assurance Project Plan

1. Plan Preparation. The Leavenworth NFH shall prepare a Quality Assurance Project Plan (QAPP) for monitoring of each parameter required to be monitored under this Order, including flow, temperature, phosphorus, turbidity and toxics.

2. QAPP Contents. The QAPP shall be prepared in accordance with the Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology Publication Number 04-03-030, July 2004) or its successor. The QAPP shall contain, at a minimum, the list of parameters to be monitored, a map of sampling locations, and descriptions of the purpose of the monitoring, sampling frequency, sampling procedures and equipment, analytical methods, quality control procedures, data handling and data assessment procedures, and reporting protocols.

3. Use of Best Available Science. In preparing the study plans and study reports, and in developing implementation measures to address Project impacts, the Leavenworth NFH shall use the most current and best available scientific information and analysis. When all implementation options are approximately equal in their biologic and hydrologic effectiveness, the Leavenworth NFH may also consider, in evaluating the options, (a) time required to achieve that success, and (b) cost effectiveness of solution.

4. Submittal to Ecology. The draft QAPPs shall be submitted to Ecology for its review and written approval. Once approved, Leavenworth NFH shall follow the approved QAPP for the collection and management of data and analyses for the reports and studies required in section B of this Order.

E. Appeal Process

You have a right to appeal this Order. To appeal this you must:

- File your appeal with the Pollution Control Hearings Board within 30 days of the "date of receipt" of this document. Filing means actual receipt by the Board during regular office hours.
- Serve your appeal on the Department of Ecology within 30 days of the "date of receipt" of this document. Service may be accomplished by any of the procedures identified in WAC 371-08-305(10). "Date of receipt" is defined at RCW 43.21B.001(2).

Be sure to do the following:

- Include a copy of this document that you are appealing with your Notice of Appeal.

- Serve and file your appeal in paper form; electronic copies are not accepted.

1. To file your appeal with the Pollution Control Hearings Board

Mail appeal to:		Deliver your appeal in person to:
The Pollution Control Hearings Board PO Box 40903 Olympia, WA 98504-0903	OR	The Pollution Control Hearings Board 4224 – 6th Ave SE Rowe Six, Bldg 2 Lacey, WA 98503

2. To serve your appeal on the Department of Ecology

Mail appeal to:		Deliver your appeal in person to:
The Department of Ecology Appeals & Application for Relief Coordinator PO Box 47608 Olympia, WA 98504-7608	OR	The Department of Ecology Appeals & Application for Relief Coordinator 300 Desmond Dr SE Lacey, WA 98503

3. And send a copy of your appeal to:

Section Manager
Department of Ecology
Central Regional Office
15 W. Yakima Avenue, Suite 200
Yakima, WA 98902

For additional information visit the Environmental Hearings Office Website: http://www.eho.wa.gov
To find laws and agency rules visit the Washington State Legislature Website: http://www.leg.wa.gov/CodeReviser

Your appeal alone will not stay the effectiveness of this Order. Stay requests must be submitted in accordance with RCW 43.21B.320. These procedures are consistent with Ch. 43.21B RCW.

DATED this 7th day of January, 2010 at Yakima, WA 98902.

Charles McKinney

Charles McKinney, Section Manager
Water Quality Program
Central Regional Office

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries

April 2006

Publication No. 06-03-017

04681

This report is available on the Department of Ecology home page on the World Wide Web at www.ecy.wa.gov/biblio/0603017.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, DSER0015.

Ecology's Project Code for this study is 05-056.

For a printed copy of this report, contact:

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Refer to Publication Number 06-03-017

Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries

by
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Environmental Assessment Program
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in cooperation with

Washington Department of Fish and Wildlife
Fish Program, Hatcheries Division
Olympia, Washington 98501-1091

April 2006

Waterbody numbers: Statewide

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Abstract

During 2005, persistent organic pollutants (POPs) were analyzed in fish feed and catchable rainbow trout from ten Washington Department of Fish and Wildlife (WDFW) hatcheries and the fish purchased by WDFW from one private hatchery operator. Fish originating from the same hatchery populations were also sampled approximately 2½ months following planting into unpolluted lakes in order to assess contaminant depuration or uptake. All feed and tissue (fillet) samples were analyzed for a variety of chlorinated pesticides, polychlorinated biphenyls (PCBs), a select group of polybrominated diphenyl ethers (PBDEs), and lipid content. A subset of feed and tissue samples was also analyzed for polychlorinated dioxins and furans (PCDD/Fs).

Feed samples had the following mean wet weight concentrations: ΣPCBs[1] – 13.8 ng/g, ΣDDT – 8.2 ng/g, ΣPBDEs – <0.25 ng/g, PCDD/F toxic equivalent – 0.75 pg/g. Fish tissue samples had the following respective mean wet weight concentrations in hatchery and planted rainbow trout: ΣPCBs – 13.0 and 3.1 ng/g, ΣDDT – 3.9 and 8.8 ng/g, ΣPBDEs – 0.66 ng/g for both. PCDD/F toxic equivalent averaged 0.032 pg/g in hatchery fish but was not analyzed in trout collected from lakes.

Other pesticides found in feed (f), hatchery fish (h), and planted fish (p) were: DDMU (f,h,p), dieldrin (f,h,p), hexachlorobenzene (f,h,p), pentachloroanisole (f,h,p), trans-nonachlor (f,h), cis-chlordane (f,h), trans-chlordane (f), methoxychlor (f), and toxaphene (f).

Results suggest that some portion of POP concentrations in trout from unpolluted waters may originate from hatcheries. In addition, some catchable trout contain POP concentrations above regulatory criteria when they are planted in lakes.

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[1] Σ = Total

Acknowledgements

The authors would like to thank the following individuals for their contributions:

Staff with the Washington Department of Fish and Wildlife:

- John Kerwin, Hatchery Division Manager, helped conceive and develop this project
- Managers and staff of the trout hatcheries provided samples and answered our inquiries
- District biologists provided valuable suggestions and information on lakes and their trout populations
- Jeff Korth and Patrick Verhey helped collect fish in Warden Lake
- John Sneva aged the specimens
- John Kerwin and Sandie O'Neill reviewed the report

Staff with the Washington State Department of Ecology:

- Karin Feddersen contracted and reviewed the dioxin/furan analysis
- Dean Momohara conducted the lipid analysis
- Will White and Pam Covey handled and tracked samples
- Paul Anderson, Randy Coots, Casey Deligeannis, Brandee Era-Miller, Brandi Lubliner, Brenda Nipp, Brian Reese, Kirk Sinclair, and Trevor Swanson assisted with the collection and processing of fish samples
- Dale Norton and Art Johnson reviewed the report
- Carol Norsen and Joan LeTourneau edited and formatted the sampling plan and final report, respectively

Other contributors:

- Corey Bray assisted with fish collection
- Dave McBride, Washington State Department of Health, provided useful comments

Introduction

Recent reports have indicated that commercially farmed salmon, hatchery-raised trout, and the feed used to grow them may contain polychlorinated biphenyls (PCBs) and other persistent organic pollutants (POPs). For instance, Hites et al. (2004) showed that salmon raised in net-pens had substantially higher PCBs than those caught wild, presumably due to PCB-contaminated feed. Carline et al. (2004) found that concentrations of PCBs in hatchery rainbow trout (*Oncorhynchus mykiss*) fillets were correlated to concentrations in feed, and nearly all the body burden was due to PCBs in the diet. Other investigations have revealed detectable concentrations of dioxins, dieldrin, and endrin as well as PCBs in hatchery broodstock salmon and trout (Millard et al., 2004). In Pennsylvania, PCB contamination of edible tissues accumulated through dietary uptake in hatcheries exceeded thresholds for issuance of consumption advisories (Carline et al., 2004).

Currently there is no statewide program in Washington to evaluate toxic chemicals in hatchery feed or hatchery fish. At the same time, low levels of POPs in fish from lakes and streams across the state are being detected at an increasing rate (e.g., Seiders 2003; Seiders and Kinney, 2004) due to increased sampling coverage and better analytical detection limits. These waterbodies are often added to the list of impaired waters as required by the federal Clean Water Act section 303(d), and subsequently require a plan to control or clean up the contaminants. Many of the POPs found in fish tissue (e.g., PCBs, dioxins) are ubiquitous environmental contaminants and may be found globally through atmospheric deposition, historical releases, or food-web cycling. Fish may accumulate low concentrations of these chemicals through one or more of these pathways, although it is nearly impossible to distinguish and quantify these diffuse sources, and control and clean-up is often unrealistic. Due to recent data, however, contamination stemming from hatcheries is now considered a possible source of POPs in fish.

Study Description

Catchable rainbow trout – fish approximately six inches or more released into lakes and streams just prior to the opening of fishing season – were sampled from ten Washington Department of Fish and Wildlife (WDFW) hatcheries. Approximately 2½ months following planting, samples from un-mixed hatchery populations were sampled from stocked lakes. All feed and tissue (fillet) samples were analyzed for a variety of chlorinated pesticides, PCB aroclors, a select group of polybrominated diphenyl ethers (PBDEs), and lipid content. A subset of feed and tissue samples was also analyzed for polychlorinated dioxins and furans (PCDD/Fs). Specific project objectives were to:

- Measure concentrations of POPs in catchable rainbow trout released to lakes by WDFW.
- Measure concentrations of POPs in feed used to raise catchable rainbow trout in WDFW hatcheries to assess the correlation between diet and contaminant burdens in fish tissue.
- Estimate the degree of contaminant depuration or uptake in catchable rainbow trout following their release into lakes.

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Methods

Study Design

Fish feed and catchable rainbow trout were sampled from ten WDFW hatcheries during March 29 - April 5, 2005. Hatchery selection was made based on consultation with John Kerwin, Hatchery Division Manager with the WDFW Fish Program. Figure 1 shows locations of hatcheries. All ten hatcheries use well or spring water for hatching and rearing, although Tucannon River water is used in the final six-month rearing phase at the Tucannon Hatchery. Vancouver and Puyallup Hatchery personnel have also observed surface runoff entering hatcheries during rainy periods, but the extent of the exposure to fish is minor. POPs are much less likely to be present in groundwater and surface water due to their low solubility and immobility in soils.

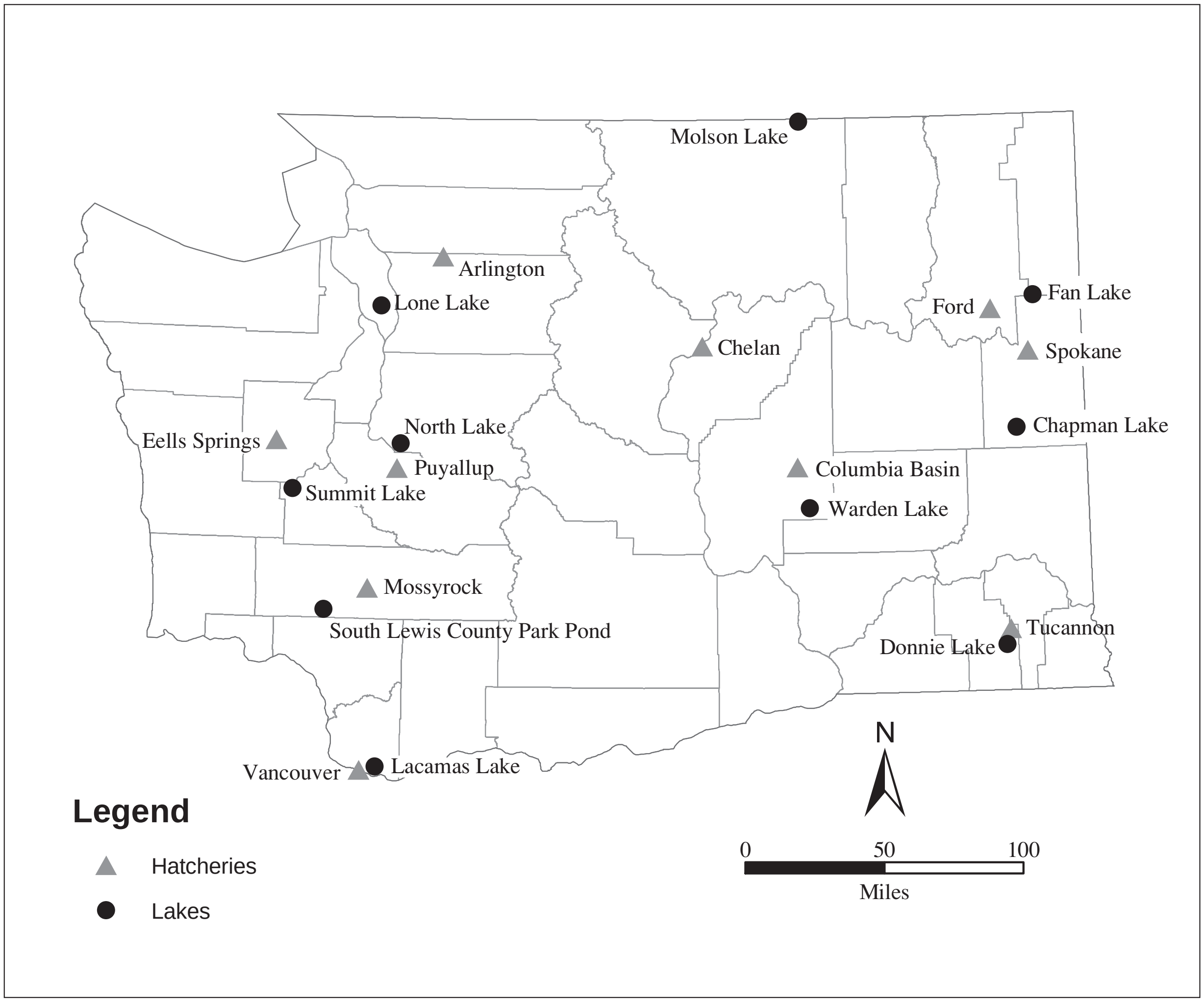

Figure 1. Locations of Hatcheries and Lakes Sampled for the 2005 Study of Persistent Organic Pollutants in Hatchery Feed and Hatchery Fish.

Hatchery personnel were interviewed about the feed used, schedule for changes in feed size and type, weight growth obtained using the sampled feed, hatchery water source, planting schedules, and other pertinent information related to the project. Feed samples consisted of material being fed to the trout at the time of sampling. In most cases, fish had been on the feed sampled for at least four months during which they had gained 50% - 80% of their mass (Table 1).

Table 1. Feed Analyzed from WDFW Hatcheries.

Hatchery	Feed Sampled	Pellet Size (mm)	Manufacturer	Period of use	Weight Gain
Arlington	Rangen	3.2	Rangen, Inc. Buhl, ID	6 mo.	76%
Chelan	Silver Cup Trout	3.0	Nelson & Sons, Inc., Murray, UT	6 mo.	76%
Columbia Basin	Silver Cup Fish Feed	3.2	Nelson & Sons, Inc., Murray, UT	6 mo.	80%
Eells Springs	Rangen	4.0	Rangen, Inc. Buhl, ID	4 mo.(a)	56%
Ford	Orient	4.0	Skretting, Vancouver, B.C.	na	50%
Mossyrock	Silver Cup Salmon	3.0	Nelson & Sons, Inc., Murray, UT	10 mo.	na
Puyallup	EWOS Vita	3.0	EWOS, Surrey, B.C.	na	na
Spokane	Silver Cup Fish Feed	3.2	Nelson & Sons, Inc., Murray, UT	na	78%
Tucannon	EWOS Pacific	3.0	EWOS, Surrey, B.C.	1 mo.(b)	70% (c)
Vancouver	Rangen	4.0	Rangen, Inc. Buhl, ID	6 mo.	82%

(a) fish fed Rangen since fry stage
(b) fish fed EWOS 2.0 for preceding 4 months, and EWOS 1.2 for 2 months prior to that
(c) weight gain during diet of EWOS 1.2, EWOS 2.0, and EWOS 3.0
na - not available

Ten rainbow trout specimens from each hatchery were randomly selected for sampling. They were from the general catchable populations which were in the process of being planted or were planned to be stocked within the subsequent weeks.

Ten triploid rainbow trout from Troutlodge, a private facility that supplies trout to WDFW, were provided by WDFW staff. Triploid trout are fish with three sets of chromosomes produced by pressure-treating the newly dividing fertilized eggs. Since they are sterile, more energy is used for somatic growth than gamete production, and the resulting triploid trout is larger than diploid fish of the same age. No feed samples or post-plant fish associated with Troutlodge were sampled for this study.

Lakes selected for sampling were based on the following criteria:

1. No known contaminant sources and low potential for appreciable contamination
2. Little or no natural rainbow trout production
3. Rainbow trout originating from a single hatchery planted between late-March and mid-April, 2005
4. Geographically dispersed to reflect a variety of ecosystem types, water chemistry, aquatic environments, and regions of the state containing differing preponderance of land use types.

Few of the approximately 380 lakes stocked annually with catchable trout have any contaminant data. Therefore, criterion 1 was assumed to be met unless a potential contaminant source was obvious. District WDFW biologists were interviewed to satisfy criterion 2. Criterion 3 was the most difficult to meet due to the common practice of multiple plantings of fish from different hatcheries. Lakes are also often planted at various intervals throughout the spring, which would yield uncertainties in fish residence periods; these lakes were avoided. Planting reports provided weekly by WDFW were reviewed in order to find lakes with single hatchery plants and fish residence times of approximately 2½ months. Criterion 4 was easily satisfied due to the geographic separation of the hatcheries and their associated lakes. Table 2 lists lakes where rainbow trout were sampled and their hatcheries of origin.

Table 2. Lakes Sampled and 2005 Rainbow Trout Plants.

Lake	County	Area (hect.)	Mean Depth (meters)	2005 Stock Date	Number	Mean Weight (grams)	Hatchery
Lone	Island	41	2.7	30-Mar	4,060	114	Arlington
				18-Apr	593*	649	Troutlodge
Molson	Okanogan	9.3	1.8	12-Apr	4,160	142	Chelan
Warden	Grant	81	8.2	15-Mar	12,723	116	Columbia Basin
				18-Mar	11,596	108	
				5-Apr	685	123	
Summit	Thurston	214	16	28-Mar	400	1,746	Eells Springs
				29-Mar	402	1,681	
				14-Apr	10,048	142	
				15-Apr	646	825	
				22-Apr	15,097	138	
				25-Apr	9,810	153	
				26-Apr	5,056	142	
Fan	Pend Oreille	32	7.6	22-Mar	3,021	86	Ford
S. Lewis Co. Park Pond	Lewis	4.5	2.7	14-Apr	3,043	134	Mossyrock
North	King	23	4.3	20-Apr	8,500	114	Puyallup
Chapman	Spokane	61	20	15-Mar	5,925	91	Spokane
Donnie	Columbia	0.4	0.9	14-Apr	420	108	Tucannon
Lacamas	Clark	129	7.3	7-Mar	2,000	227	Vancouver
				8-Apr	3,000	267	
				26-Apr	4,000	197	

*Triploid fish

Sampling Procedures

Hatchery feed and pre-plant catchable rainbow trout samples were collected with assistance of hatchery staff. Fish averaged 235 mm total length and 152 gm in weight (excluding Troutlodge samples). Feed samples were placed directly in 1-liter organics-free glass jars with Teflon lid liners and certificates of analysis. Fish from hatcheries were killed with a blow to the skull, double-wrapped in aluminum foil, sealed in zip-lock polyethylene bags, and transported on ice to Ecology headquarters where they were weighed and measured prior to being stored frozen at –20° C.

Rainbow trout from lakes were collected by hook-and-line or electrofishing. Following capture, fish were observed for signs confirming previous hatchery residence. Specimens were then killed with a blow to the skull, weighed to the nearest gram and measured to the nearest millimeter, assigned a sample number, double-wrapped in aluminum foil, placed in zip-lock polyethylene bags, and transported on ice to Ecology headquarters where they were stored frozen at –20° C. Rainbow trout collected from lakes averaged 270 mm total length and 211 gm in weight.

When ready for processing, fish were partially thawed then scales were removed for aging by WDFW. Composite samples of homogenate tissue were prepared by methods described by EPA and the Washington State Toxics Monitoring Program (EPA, 2000; Seiders, 2003). Briefly, fish were scaled, skin-on fillets removed, and equal mass aliquots of tissue were homogenized with three passes through a Kitchen-Aid food processor for each composite. Homogenates were placed in a 4-oz organics-free glass jar with Teflon lid liner and certificate of analysis and stored frozen.

All resection was done with non-corrosive stainless steel implements on a clean aluminum foil surface. Persons preparing samples wore non-talc polyethylene or nitrile gloves changed between samples. Resection and homogenizing equipment was cleaned using Liquinox® detergent and hot tap water, followed by rinses with deionized water, pesticide grade acetone, and pesticide grade hexane, then air-dried in a fume hood before use.

Laboratory Analysis and Data Quality

Sample Preparation

Feed

Feed samples were first Soxhlet extracted using 1:1 methylene chloride/hexane, then solvent exchanged into hexane and adjusted to 10 ml. Extracts were split, half for PCB/chlorinated pesticide and half for PBDE and lipid analysis.

Extracts for PCB and chlorinated pesticide analysis were eluted through 2 gm micro Florisil® columns first with 100% hexane and collected as the “0% Florisil fraction”, followed by elution with 1:1 hexane/preserved diethyl ether, collected as the “50% Florisil fraction”. When the

"0% Florisil fractions" were solvent-reduced, the remaining extracts were as much as 50% lipids, unsuitable for gas chromatography (GC) analysis, and were therefore added to the "50% Florisil fraction". The combined extracts were then back-extracted with acetonitrile to remove lipids and re-eluted through 2 gm micro Florisil® columns with 100% hexane ("0% Florisil fraction") and 1:1 hexane/preserved diethyl ether ("50% Florisil fraction"). Each fraction was solvent-exchanged to iso-octane and concentrated to 1 ml. One-half of the "50% Florisil fraction" and the "0% Florisil fraction" were treated with concentrated sulfuric acid prior to analysis. The remainder of the "50% fraction" was analyzed without acid treatment.

Fish Tissue

Tissue samples were first Soxhlet extracted using 1:1 methylene chloride/hexane, then solvent exchanged into hexane and adjusted to 10 ml. Extracts were split, half for PCB/chlorinated pesticide and half for PBDE and lipid analysis.

Extracts for some PCB analyses (sample nos. 05248100 – 05248109) were eluted through 2 gm micro Florisil® columns with 100% hexane, solvent-exchanged to iso-octane, and concentrated to 1 ml. Extracts were treated with concentrated sulfuric acid prior to analysis.

For chlorinated pesticide analysis and some PCB analyses (sample nos. 05144080 – 05144090), extracts were eluted through 2 gm micro Florisil® columns with 100% hexane and collected as the "0% Florisil fractions", followed by elution with 1:1 hexane/preserved diethyl ether. The hexane/ether fractions were adjusted to 5 ml and back-extracted with acetonitrile to remove lipids and re-eluted through 2 gm micro Florisil® columns with 1:1 hexane/preserved diethyl ether, and collected as the "50% Florisil fraction". Each fraction was solvent-exchanged to iso-octane and concentrated to 1 ml. One-half of the "50% Florisil fraction" and the "0% Florisil fraction" were treated with concentrated sulfuric acid prior to analysis. The remainder of the "50% fraction" was analyzed without acid treatment.

Analyses for PCBs, chlorinated pesticides, and PBDEs were conducted at the Manchester Environmental Laboratory (MEL) using dual column GC/ECD. Sample preparation and analysis methods were modifications of EPA SW-846 Methods 3540, 3620, and 8081/8082.

Samples for PCDDs/PCDFs were analyzed at Pacific Rim Laboratories, Inc. (Surrey, B.C.) using high resolution GC/MS isotope dilution methodology of EPA Method 1613B. Percent lipid was analyzed gravimetrically at MEL. The complete list of analytes is in Appendix B.

Data Quality

Overall quality of the data was fair. Precision for Aroclor analysis was 11% relative percent difference. Analysis was also performed with a high degree of precision for DDT compounds (14%), other chlorinated pesticides (17%), PBDEs (17%), and PCDD/Fs (13%).

One standard reference material was analyzed along with feed and tissue; NIST 1974b – Organics in Frozen Mussel Tissue (https://srmors.nist.gov/tables/view_table.cfm?table=109-2.htm). Chlorinated pesticide analytes, including DDT compounds, were only 67% of certified concentrations on average. Total PCBs were 82% of the reference concentration. These results indicate a possible low bias for these analyte groups.

Data Analysis

PCB, DDT, PBDE, and lipid concentrations were compared between hatchery and lake rainbow trout using the Wilcoxon signed-rank test, a non-parametric equivalent of the paired t-test (Zar, 1984). Spearmann ranked correlations among contaminant groups and sample types were done using SYSTAT 9.01 software program (SPSS, 1998). Non-detected values were treated as zero for statistical tests to avoid misinterpretation of comparisons between hatchery tissue samples and the lake tissue samples, which had different detection limits for the same analytes.

Non-detects were also treated as zero for samples analyzed in duplicate. Therefore, values presented as the mean of duplicate analyses may be biased low. The complete set of chemistry data is in Appendix C.

Results

Field Observations

Physical observations of rainbow trout collected from lakes indicated that they originated from hatcheries sampled earlier in the year. Most specimens had gnawed pectoral fins, or dorsal and caudal fin erosion. Scale annuli patterns also indicated fish were from the year's stock of catchables (John Sneva, WDFW, written communication, 8/10/2005). This physical evidence, coupled with local knowledge from WDFW District Biologists and WDFW plant records, supports the conclusion that the trout had been raised as catchables from known hatcheries.

Rainbow trout collected from lakes in June were larger on average than just prior to their release from hatcheries (Table 3). Increases in total length averaged 15%, and weight gain was 39% on average. Mean condition factors in hatchery and planted trout were 1.11 and 1.02, respectively. Condition factors fell below 1.0 in half the lakes, suggesting food supply was limited. Gut contents were not examined, but aside from the fin erosion mentioned previously, the fish collected from lakes appeared healthy and took bait and lures readily in most cases.

Contaminants in Feed and Fish

PCBs, DDT, and PBDEs

Most feed and fish tissue samples contained measurable concentrations of PCBs (Table 4). Aroclor-1254 was the most commonly detected, followed by 1260, 1242, and 1248; none of the other Aroclors were detected.

All samples contained DDT compounds, with 4,4'-DDE comprising 74% of the ΣDDT on average. All but one of the tissue samples contained low levels of PBDEs; none of the feed samples had detectable PBDEs. PBDE-47 was the most common congener detected, followed by 99, 71/100, and 138/209.

Mean concentrations of lipids in feed were high (16.8%) compared to tissue. This high fat diet resulted in high lipid levels in hatchery rainbow trout fillet tissue (mean of 3.2%). Although the catchable rainbow trout increased in size following planting, it appears that muscle lipid was depleted to meet their energy requirements, with an average 60% decrease in lipid content (1.2%).

Table 3. Length and Weight of Rainbow Trout Collected from Hatcheries and Lakes.

Hatchery/Lake	2005 Collection Date	N	Total Length (mm, mean ± SD)	Weight (gm, mean ± SD)	Condition Factor (mean ± SD)
Arlington Hatchery	29-Mar	10	245 ± 16	165 ± 34	1.11 ± 0.09
Lone Lake	16-Jun	10	306 ± 12	334 ± 37	1.17 ± 0.06
Chelan Hatchery	5-Apr	10	253 ± 16	178 ± 37	1.08 ± 0.11
Molson Lake	13-Jun	10	296 ± 20	303 ± 59	1.16 ± 0.08
Columbia Basin Hatchery	5-Apr	10	230 ± 15	140 ± 31	1.15 ± 0.08
Warden Lake	9-Jun	10	251 ± 10	147 ± 23	0.93 ± 0.08
Eells Springs Hatchery	1-Apr	10	230 ± 8	142 ± 19	1.16 ± 0.07
Summit Lake	13-Jun	7	259 ± 13	160 ± 16	0.92 ± 0.12
Ford Hatchery	4-Apr	10	197 ± 15	83 ± 15	1.09 ± 0.06
Fan Lake	14-Jun	8	290 ± 14	271 ± 47	1.11 ± 0.15
Mossyrock Hatchery	5-Apr	10	260 ± 14	190 ± 31	1.08 ± 0.06
S. Lewis Co. Park Pond	14-Jun	8	259 ± 10	176 ± 24	1.01 ± 0.07
Puyallup Hatchery	1-Apr	10	218 ± 20	111 ± 31	1.04 ± 0.11
North Lake	13-Jun	10	245 ± 12	141 ± 21	0.96 ± 0.08
Spokane Hatchery	4-Apr	10	210 ± 13	98 ± 21	1.04 ± 0.08
Chapman Lake	15-Jun	4	243 ± 10	125 ± 13	0.87 ± 0.04
Tucannon Hatchery	4-Apr	10	206 ± 18	108 ± 30	1.21 ± 0.06
Donnie Lake	16-Jun	10	254 ± 19	145 ± 33	0.87 ± 0.07
Vancouver Hatchery	5-Apr	10	298 ± 24	303 ± 91	1.12 ± 0.10
Lacamas Lake	17-Jun	9	285 ± 14	249 ± 37	1.07 ± 0.06
Troutlodge Hatchery	4-Apr	10	374 ± 22	678 ± 133	1.29 ± 0.19

Condition Factor = (W[g] x 100/L[cm]^3)
N = number
SD = standard deviation

Table 4. Lipid, ΣPCB, ΣDDT, and ΣPBDE Concentrations in Feed and Rainbow Trout Fillet Tissue (ng/g, ww).

Sample Type/Location	% Lipid	ΣPCB	ΣDDT	ΣPBDE
Hatchery Feed				
Arlington	18.19	**13.8**	**6.3**	U(0.25-1.2)
Chelan	13.75	**34.8**	**9.4**	U(0.25-1.2)
Columbia Basin	14.47	**11.6**	**6.3**	U(0.24-1.2)
Eells Spring	12.70	**12.5**	**5.9**	U(0.24-1.2)
Ford*	25.85	U(2.5)	**3.7**	U(0.25-1.2)
Mossyrock	19.64	**27.6**	**11.0**	U(0.25-1.2)
Puyallup*	16.14	U(2.5)	**6.6**	U(0.25-1.2)
Spokane	15.79	**16.4**	**5.9**	U(0.25-1.2)
Tucannon	15.01	**8.2**	**21**	U(0.25-1.2)
Vancouver	16.08	**13.3**	**5.8**	U(0.25-1.2)
Hatchery Rainbows				
Arlington	3.97	**12.1**	**4.8**	**0.64**
Chelan	3.05	**67**	**4.1**	**1.09 J**
Columbia Basin	4.10	**18.5**	**6.5**	**0.90 J**
Eells Spring*	2.42	U(2.4)	**2.7**	**0.52**
Ford	2.35	U(2.5)	**2.5**	**0.24 J**
Mossyrock	2.69	**15.8**	**3.9**	**0.89 J**
Puyallup	3.07	U(2.3)	**2.4**	**0.24**
Spokane	2.48	**11.7**	**2.9**	**1.10 J**
Tucannon	3.69	U(2.4)	**5.3**	**0.27**
Vancouver*	4.00	**4.8**	**4.0**	**0.71 J**
Troutlodge	5.39	**14.4**	**5.7**	**0.84 J**
Planted Rainbows				
Lone Lake*	1.67	U(4.8)	**1.9**	**0.96 J**
Molson Lake	2.05	**8.6**	**5.8**	U(0.49-2.4)
Warden Lake	0.61	U(4.9)	**3.7**	**0.46 J**
Summit Lake*	0.40	**5.0**	**3.2**	**0.56**
Fan Lake	2.66	U(5.0)	**57**	**0.40 J**
South Lewis Co. Park Pond	0.77	**5.9**	**2.4**	**1.33 J**
North Lake	0.65	U(4.9)	**2.9**	**1.23 J**
Chapman Lake	0.44	**11.8**	**5.0**	**1.01 NJ**
Donnie Lake	1.29	U(5.0)	**3.6**	**0.25 J**
Lacamas Lake	1.50	U(5.0)	**3.0**	**0.42 J**

ΣPCB = the sum of detected Aroclors
ΣDDT = the sum of detected 4,4' and 2,4' homologues of DDD, DDE, and DDT
ΣPBDE = the sum of detected PBDE congeners analyzed
Detected concentrations in **bold**
* Samples analyzed in duplicate. Results shown are mean of laboratory analyses.
U - The analyte was not detected at or above the reported result
J - The analyte was positively identified. The associated numerical value is an estimate.
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

Lipid catabolism in muscle and consequent contaminant mobilization may explain higher mean ΣPCB in hatchery fish compared to fish from lakes (13 and 3.1 ng/g, respectively; Figure 2). Differences between contaminant concentrations in hatchery and planted rainbow trout appear to be regulated by more than lipid decreases, however. Mean ΣDDT concentrations in tissue were higher in lakes (8.8 ng/g) compared to tissues from hatchery fish (3.9 ng/g), although concentrations were nearly identical when the outlier from Fan Lake was removed.

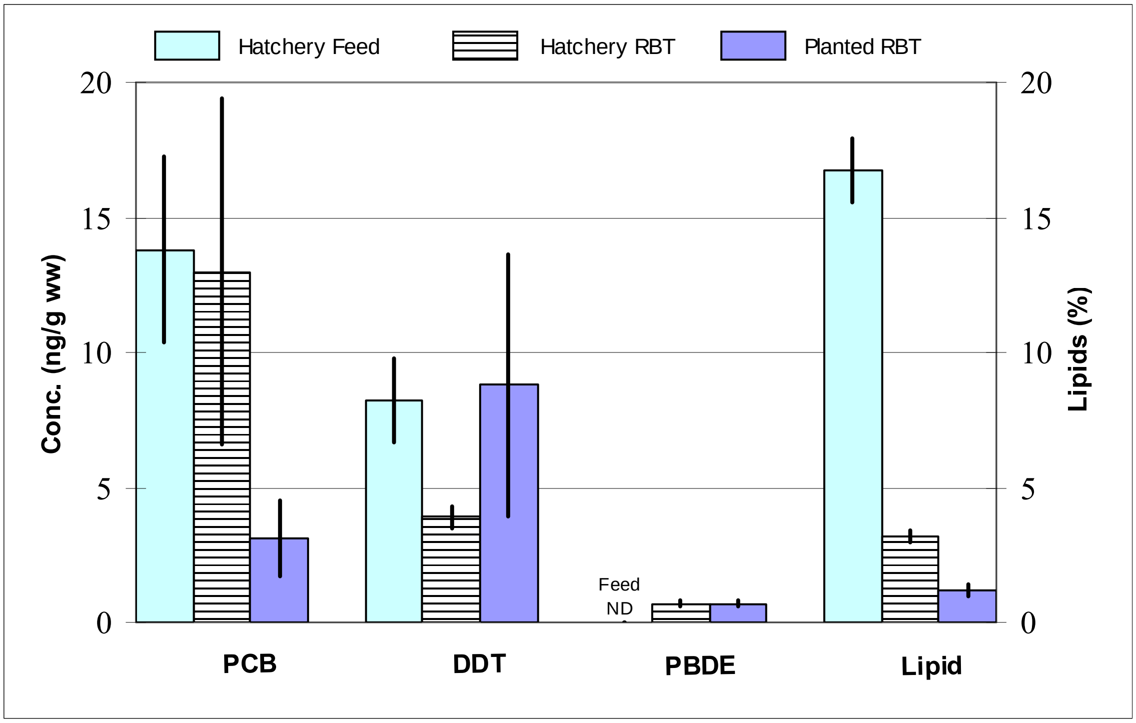

Figure 2. Mean (SE) Concentrations of ΣPCBs, ΣDDT, ΣPBDE, and Percent Lipid in Hatchery Feed, Hatchery Rainbow Trout, and Planted Rainbow Trout.

Neither ΣPCB nor ΣDDT were significantly different in hatchery fish compared to planted fish (Wilcoxon signed-rank test, α=0.05). There was also no significant difference in PBDEs between groups, although this was not surprising since mean concentrations were identical (0.66 ng/g, respectively).

PCBs tended to be highest in hatchery fish whose food had comparatively high PCB concentrations. For example, the Chelan Hatchery had high ΣPCB in both feed and fish, while Ford and Puyallup Hatcheries had no detectable PCBs in either feed or fish. However, this pattern was not true for ΣDDT and ΣPBDE in hatchery samples.

To examine possible relationships among sample types and contaminants, a ranked correlation analysis was performed on major variables in hatchery and lake samples (Table 5). There were no strong correlations between contaminants in hatchery fish and their lake counterparts. With the exception of lipids and ΣDDT in hatchery fish, lipids were not highly correlated with ΣPCB, ΣDDT, or ΣPBDE, a somewhat surprising finding but lending support to the notion that factors other than lipid may be the primary determinants in contaminant residue levels, particularly for DDT compounds and PBDEs.

Table 5. Spearman Ranked Correlation Matrix of Major Variables in Feed and Tissue Samples.

	Hatch. Feed Lipid									
Hatch. Feed ΣPCB	-0.182	Hatch. Feed ΣPCB								
Hatch. Feed ΣDDT	-0.159	0.226	Hatch. Feed ΣDDT							
Hatch. Fish Lipid	-0.139	-0.012	0.256	Hatch. Fish Lipid						
Hatch. Fish ΣPCB	-0.156	**0.753**	0.280	0.356	Hatch. Fish ΣPCB					
Hatch. Fish ΣDDT	-0.333	0.280	0.402	**0.721**	**0.563**	Hatch. Fish ΣDDT				
Hatch. Fish ΣPBDE	-0.365	**0.817**	0.086	0.170	**0.822**	0.426	Hatch. Fish ΣPBDE			
Planted Fish Lipid	0.467	0.030	-0.030	0.042	0.125	0.127	-0.213	Planted Fish Lipid		
Planted Fish ΣPCB	-0.307	**0.753**	0.131	**-0.519**	0.405	-0.171	**0.685**	-0.294	Planted Fish ΣPCB	
Planted Fish ΣDDT	-0.285	-0.109	-0.293	-0.382	0.019	-0.042	0.182	0.176	0.246	Planted Fish ΣDDT
Planted Fish ΣPBDE	0.382	0.103	0.055	-0.103	-0.006	-0.394	0.043	**-0.539**	0.184	**-0.636**

Spearman correlation coefficients ≥|0.500| in **bold**

Dioxins and Furans

Four samples each of hatchery feed and rainbow trout tissue were analyzed for 2,3,7,8-substituted PCDDs and PCDFs (Table 6). Toxic equivalents (TEQs) were calculated using toxic equivalency factors (TEFs) proposed by Van den Berg et al., 1998.

Table 6. TEQ Concentrations (pg/g, ww) in Four Feed and Rainbow Trout Samples and Percent TEQ Contribution by Congener.

	Vancouver	Mossyrock	Ford*	Spokane
Hatchery Feed				
TEQ	0.562	1.226	0.028	1.194
2,3,7,8-TCDD	33%	30%	0%	16%
1,2,3,7,8-PeCDD	38%	44%	0%	53%
1,2,3,4,7,8-HxCDD	0%	0%	0%	0%
1,2,3,6,7,8-HxCDD	4%	4%	0%	4%
1,2,3,7,8,9-HxCDD	0%	3%	0%	3%
1,2,3,4,6,7,8-HpCDD	2%	1%	18%	1%
OCDD	0%	0%	1%	0%
2,3,7,8-TCDF	9%	7%	71%	12%
1,2,3,7,8-PeCDF	2%	2%	10%	1%
2,3,4,7,8-PeCDF	11%	9%	0%	10%
1,2,3,4,7,8-HxCDF	0%	0%	0%	0%
1,2,3,6,7,8-HxCDF	0%	0%	0%	0%
2,3,4,6,7,8-HxCDF	0%	0%	0%	0%
1,2,3,7,8,9-HxCDF	0%	0%	0%	0%
1,2,3,4,6,7,8-HpCDF	0%	0%	0%	0%
1,2,3,4,7,8,9-HpCDF	0%	0%	0%	0%
OCDF	0%	0%	0%	0%
Hatchery Rainbows				
TEQ	0.053	0.041	0.012	0.024
2,3,7,8-TCDD	0%	0%	0%	0%
1,2,3,7,8-PeCDD	0%	0%	0%	0%
1,2,3,4,7,8-HxCDD	0%	0%	0%	0%
1,2,3,6,7,8-HxCDD	0%	0%	0%	0%
1,2,3,7,8,9-HxCDD	0%	0%	0%	0%
1,2,3,4,6,7,8-HpCDD	0%	0%	0%	0%
OCDD	0%	0%	0%	0%
2,3,7,8-TCDF	35%	68%	35%	68%
1,2,3,7,8-PeCDF	11%	17%	0%	0%
2,3,4,7,8-PeCDF	39%	0%	0%	0%
1,2,3,4,7,8-HxCDF	13%	12%	56%	28%
1,2,3,6,7,8-HxCDF	0%	0%	0%	0%
2,3,4,6,7,8-HxCDF	0%	0%	0%	0%
1,2,3,7,8,9-HxCDF	0%	0%	0%	0%
1,2,3,4,6,7,8-HpCDF	2%	2%	9%	3%
1,2,3,4,7,8,9-HpCDF	0%	0%	0%	0%
OCDF	0%	0%	0%	0%

* Samples analyzed in duplicate. Results shown are mean of laboratory analyses.

TEQs were much higher in hatchery feed compared to rainbow trout, with the exception of Ford Hatchery feed which had a TEQ up to 40 times lower than the other hatcheries. Like other contaminants, it appears that TEQ concentrations were not determined primarily by lipid content. Congeners contributing to TEQ were markedly different between high and low TEQ samples, with tetra- and penta-substituted dioxin congeners providing approximately 70% of the toxicity. In contrast, the Ford feed sample had none of these congeners detected.

Congener patterns were even more distinct when feed and fish tissue samples were compared. None of the tissue samples contained detectable concentrations of PCDDs. Most of the toxicity in tissue samples was derived from tetra-, penta-, and hexa-substituted furan congeners.

Other Chlorinated Pesticides

In addition to DDT compounds, nine chlorinated pesticides or breakdown products were detected in feed samples, six were detected in hatchery rainbow trout, and four were found in trout collected from lakes (Figure 3). DDMU, like its parent DDT, was detected in all hatchery feed samples. Although DDMU was much higher in Fan Lake trout (4.4 ng/g) compared to other lakes, feed from the originating hatchery (Ford) had the lowest concentration (0.2 ng/g), and Ford Hatchery rainbow trout did not have a detectable DDMU concentration.

Dieldrin had an unusual detection pattern among samples; it was detected in only 10% (Mossyrock, one of ten) feed samples, and 20% of lake fish tissue samples, but was found in 70% of the hatchery tissue samples. It should be noted, however, that detection limits for dieldrin in feed samples were approximately three-to-five times higher than in tissue samples (see Appendix C). Hexachlorobenzene was found in only one sample from planted rainbow trout (Summit Lake, 0.7 ng/g) but not in fish from the original population at Eells Springs Hatchery. The comparatively high concentration and lack of apparent link to the hatchery suggests these fish may have accumulated hexachlorobenzene from a local source in Summit Lake.

Pentachloroanisole, a degradation product of pentachlorophenol, was the only additional compound detected in planted rainbow tissue. Concentration of pentachloroanisole doubled in Lacamas Lake fish compared with the original hatchery population, suggesting a possible local source. Tucannon hatchery rainbows also apparently accumulated pentachloroanisole from the hatchery feed, although residues in the hatchery fish did not persist while the fish were in a (Donnie) lake environment.

Nonachlor and cis-chlordane, two components of commercial-grade chlordane, were found in at least half of the hatchery feed and fish samples. Another chlordane component, trans-chlordane, was found in 40% of feed samples. Two other chlorinated pesticides, toxaphene and methoxychlor, were found in 30% and 20% of feed samples, respectively.

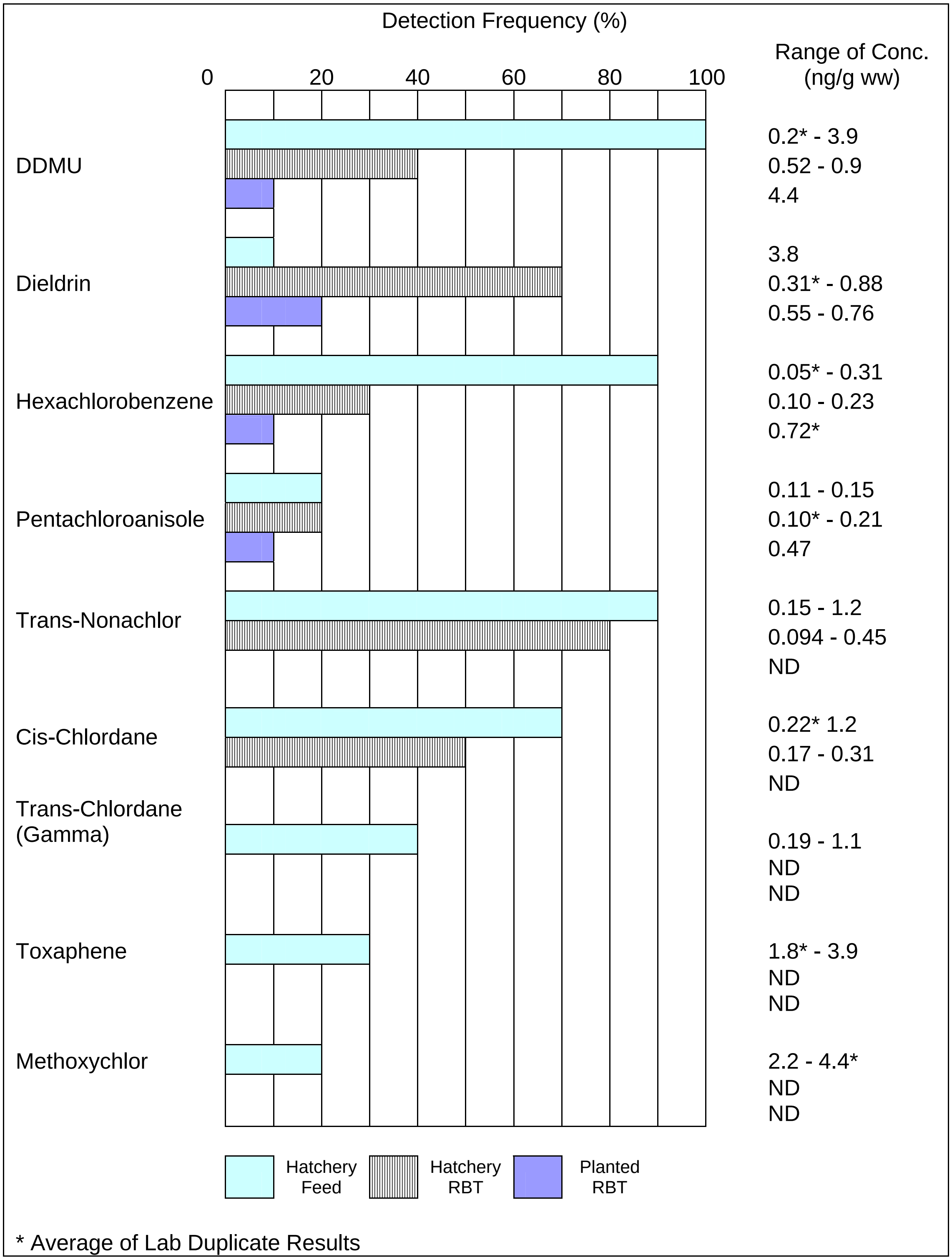

Figure 3. Detection Frequency of Chlorinated Pesticides (Excluding DDT Compounds) and Range of Detected Concentrations.

Discussion

Feed Ingredients and Residue Tolerances

The four brands of feed analyzed during the present 2005 survey have a wide range of contaminant levels. Rainbow trout collected at hatcheries gained approximately 50-80% of their final weight on these feeds, and may have gained most of their initial weight on starter feeds with similar ingredients.

Feed sack labels obtained at the time of sampling indicated that minimum amounts of crude protein (40-45%) were similar among feeds, as were maximum amounts of crude fiber (1.5-5%) and ash (9-12%). Crude fat was the other major component, constituting 10-24% of the weight which generally showed good agreement with lipid analysis in the present study (r^2=0.64).

In terms of contaminant residues, the origin of the lipids in the feed is probably a much greater concern than their percent by weight. All of the feeds sampled advertise fish oil as a major ingredient which is likely to be the major source of PCBs, chlorinated pesticides, PBDEs, PCDD/Fs, and other lipophilic contaminants (Jacobs et al., 2002).

The exact source of the fish oil and fish meal, as well as other major ingredients in hatchery feed (wheat flour, soybean oil, blood meal, feather meal, and poultry by-product), may change from batch to batch, depending on the availability and cost of the raw products. Fishmeal may derive largely from anchovy, menhaden, capelin, and herring, and fish oil is a by-product of the fishmeal manufacturing industry.

The negative correlation between lipids and major contaminants in feed is another indication that the source of fish oil is probably a more important determinant in contaminant residues than lipid content by weight. However, contaminant concentrations in feed apparently play a large role in accumulation by fish, probably due to the high rate of weight conversion from feed to fish (>80%). This is demonstrated by the strong correlation between ΣPCB in hatchery feed and hatchery fish (r=0.75), and a weaker yet positive correlation for ΣDDT (r=0.40).

In the case of the Tucannon hatchery, where the fish are raised in water from the Tucannon River for six months prior to stocking, fish weight gain actually exceeded the weight of feed provided (conversion of 163%) due to availability of natural prey items.

The only domestic regulation concerning POP contaminants is a federal PCB residue tolerance of 2,000 ng/g for feed components of animal origin (21 CFR 109.30). The Canadian Food Inspection Agency has an “actionable level” of 2,000 ng/g for PCBs, but it only applies to fish oil destined for animal feed (CFIA, 2003). In 2001, the European Union (EU) established maximum tolerable levels of PCDD/F TEQs in fish in various fish products and feeds. The maximum levels for fish feed and fish oil for use other than direct human consumption is 2.25 and 6.0 pg TEQ/g, respectively (Directive 2001/102/EC).

Table 7 shows a summary of major contaminants in hatchery feeds and commercial aquaculture feeds for salmonids. Care should be used interpreting the available data since information on the intended species is often not included. For instance, feed for commercial salmon aquaculture typically contains higher fish oil content than trout feed, and some species, such as catfish and tilapia, may be fed entirely vegetable-based feeds.

Table 7. Contaminant Concentrations in Various Hatchery and Commercial Aquaculture Feeds and Applicable Regulations (mean concentrations unless otherwise noted).

Source	ΣPCB (ng/g ww)	ΣDDT (ng/g ww)	ΣPBDE (ng/g ww)	Dioxin TEQ (pg/g ww)	Lipid (%)	Ref.
Contaminant Levels in Feed						
Feeds from 6 manufacturers used in 11 USF&WS National Fish Hatcheries	1.94*	11.33	nr	0.227	16.7	Maule et al., 2006
Mean of 8 commercial salmon aquaculture feeds from Scottish sources	105	12.1	5.1	nr	28.8	Jacobs et al., 2002
Mean of fish feed/fishmeal samples originating from Canada (n=14), U.S. (n=7), Iceland (n=1), Peru (n=1), and Russia (n=1)	Can.–30.7† U.S.–16.5† Ice.–12.1† Peru–0.6† Rus.–12.7†	Can.–21.1 U.S.–23.3 Ice.– <7 Peru–nr Rus.–nr	nr	Can.–1.0 U.S.–1.1 Ice.–0.23 Peru–ND Rus.–0.22	nr	CFIA, 2006
Feed from the 2 largest global suppliers for commercial salmon aquaculture; 9 samples from North and South America and 4 samples from Europe	15 (approx. Amer. median) 60 (approx. Eur. median)	nr	nr	1 (approx. Amer. median) 4 (approx. Eur. median)	nr	Hites et al., 2004
Confidential	nr	nr	nr	1.21	nr	Hermann et al., 2004
WDFW trout hatchery feed	*13.8*	*8.2*	*ND (<0.25)*	*0.75*	*16.8*	*present study, 2005*
Regulatory Levels in Feed						
U.S. Food and Drug Admin.	2,000	ne	ne	ne	ne	21 CFR 109.30(a)(6)
European Union	ne	ne	ne	2.25	ne	Directive 2001/102/EC 21

*sum of 14 dioxin-like congeners
†sum of 72 congeners
nr - not reported
ND – not detected
ne - not established

Maule et al. (2006) analyzed numerous batches of feeds used at eleven U.S. Fish and Wildlife Service (USF&WS) National Fish Hatcheries. They found a lower mean dioxin TEQ and ΣPCB than reported here, although the ΣPCB was derived from only 14 dioxin-like PCB congeners. Interestingly, the bulk of the dioxin TEQ was derived from 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD similar to the feed samples analyzed for the present survey. ΣDDT and percent lipid contents were similar between the two studies.

Comparison of contaminants in feed and salmon fillet from commercial aquaculture operations showed ΣPCB, ΣDDT, and ΣPBDE higher in feed compared to fish tissue at similar proportions to those reported here (Jacobs et al., 2002). Although the mean ΣDDT was similar to results for the present study, ΣPCB was an order of magnitude higher. The feeds, which were from Scottish sources, had much higher lipids (mean of 28.8%) than found here (mean of 16.8%). Hites et al. (2004) reported ΣPCB and dioxin TEQ levels approximately four-fold higher in commercial salmon aquaculture feeds from Europe compared to North and South America. Like other results, the Hites et al. (2004) study found POP concentrations slightly higher in feed compared to fish, on average, but lipid concentrations were not given.

The Canadian Food Inspection Agency (CFIA) analyzed 24 samples originating primarily from Canada and the U.S., but also from Iceland, Peru, and Russia, although little additional information is provided about the samples (CFIA, 2006). ΣPCB for U.S., Icelandic, and Russian samples were similar to those reported here, while Canadian feed had about twice the concentration on average. DDT levels were about twice the levels reported in other samples, while the dioxin TEQs tended to be within ranges reported by other investigators.

The only reported PBDE analysis of feed was done in the Jacobs et al. (2002) study which found ΣPBDE averaging 20 times the analytical reporting limits for the present study. PBDE-47 was the predominant congener found and, although not found in WDFW hatchery feeds, it was the major congener in rainbow trout from hatcheries and lakes and is one of the most abundant congeners found in Washington freshwater fish (Johnson and Olson, 2001).

None of the average POP concentrations reported in these studies violated residue tolerances from the applicable regulations, with the exception of the European median dioxin TEQ reported by Hites et al. (2004). A study by Herrmann et al. (2004), designed specifically to look at compliance with EU standards, found a mean concentration of dioxin TEQ about one-half the EU residue tolerance. However, 95th percentile values for both fish feed (2.71 pg/g) and fish oil (6.30 pg/g) exceeded the dioxin TEQ standards.

Depuration/Uptake of Contaminants in Lakes

One of the underlying goals of this study was to determine if lakes act as purifying environments or if hatchery fish stocked in lakes accumulate additional contaminants. Cursory inspection of the data suggests depuration occurs for PCBs and chlorinated pesticides other than DDT compounds, and no differences are seen for ΣDDT (with the Fan Lake outlier removed) and ΣPBDE. Although pairwise comparisons show no statistical differences between ΣPCB in hatchery and lake rainbow trout, mean ΣPCB in hatchery fish are substantially higher, even when the outlier from Chelan Hatchery (67 ng/g) is removed.

Part of the decrease in ΣPCB may be the significant decrease in lipid content of the planted fish. It is a well-known fact that PCB concentrations are often positively correlated with lipid in tissue. Lipid metabolism, and in particular lipid catabolysis, to meet energy requirements may mobilize lipids from muscle to high lipid organs such as the liver, kidney, and brain, thus decreasing muscle PCB concentrations (Jørgensen et al., 2002). Gamete production is another mechanism for transfer of PCBs due to loss of muscle lipids, although it is unlikely that the fish examined had reached sexual maturity.

As mentioned previously, the absence of a strong correlation between lipids and ΣPCB suggests PCB concentrations are controlled by factors other than the percentage of lipid. One possible explanation for altered PCB concentrations is that some lakes allow PCBs to be shed from muscle tissue while others increase the PCB accumulated by fish. Molson, Warden, South Lewis County Park, and Lone lakes received fish with the highest ΣPCB, and all four lakes had the greatest depuration. Increases in ΣPCB only occurred where concentrations were low-to-moderate in hatchery fish (with the exception of the very small increase in Spokane Hatchery-Chapman Lake fish), suggesting net accumulation only occurs when PCB concentrations in tissue are initially low.

ΣDDT concentrations were low in muscle tissue of hatchery rainbow trout precluding an opportunity to observe substantial depuration. As many lakes had increased levels of ΣDDT as had decreases, all small changes with the exception of Fan Lake.

Fan Lake is a medium-sized (32 hectare) lake approximately 20 miles north of Spokane, situated in a small drainage basin (1,600 hectares). It is one of the lowermost in a chain of lakes along the West Branch of the Little Spokane River. Since the Fan Lake basin is relatively undeveloped and the lake is connected to other lakes only through its outlet, it appears unlikely that high ΣDDT accumulating in Fan Lake rainbow trout is a result of basin-wide or area-wide contamination.

Comparison of Tissue Concentrations to Applicable Criteria

Criteria to protect human health from harmful pollutants in ingested water and fish were issued to Washington State in EPA's 1992 National Toxics Rule (NTR, 40 CFR 131.36). The human health-based criteria, if met, will generally ensure that public health concerns do not arise, and that fish advisories are not needed. Sampling of either water or edible fish tissue may be conducted to assess compliance with the NTR criteria (Ecology, 1992), but tissue is generally preferred because POPs are often found at concentrations in water below reasonably available laboratory detection limits.

It should be recognized that POPs exceeding the NTR criteria in fish tissue do not necessarily signal the need for a fish consumption advisory, nor does it imply the existence of a public health concern. Assessment of risks to the fishing public and consumption advice is carried out by the Washington State Department of Health (DOH), often based on data collected by Ecology and WDFW. While DOH supports Ecology's use of the NTR criteria for identifying potentially contaminated waters and for developing source controls to keep water quality at or below criteria, it does not use the NTR criteria to establish fish advisories. Instead, DOH evaluates contaminants in fish tissue using established risk assessment paradigms. These include tools for:

1. Analysis of risks – calculating allowable meal limits based on known contaminant concentrations, estimates of exposure in specific groups or populations.
2. Risk management – e.g., reduction in contaminants through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations or health risks associated with replacement foods, and cultural importance of fish.
3. Risk communication – the outreach component of a fish advisory or a conclusion that an advisory is unnecessary.

Table 8 shows NTR criteria for chemicals analyzed in the present 2005 survey compared to concentrations in rainbow trout. NTR criteria have not been established either for PBDEs or for some of the chlorinated pesticides analyzed here.

There are 15 instances where contaminants in rainbow trout exceed NTR criteria. Most of the exceedances are for ΣPCB (three lakes and six hatcheries), followed by dieldrin (one lake and four hatcheries) and 4,4'-DDE (one lake). In all, seven of the eleven hatchery samples (including Troutlodge) exceeded NTR criteria for at least one chemical, and five of the ten planted fish samples exceeded the criteria.

When criteria are not met, the waterbody is considered impaired and placed on the federal Clean Water Act section 303(d) list and may require a Total Maximum Daily Load (TMDL) study to address the impairment. TMDLs identify the sources of a pollutant and allocate pollutant loads among sources in order to bring the waterbody in compliance with standards.

One of the questions this study sought to answer is whether contaminants accumulated by fish in hatcheries could contribute, in whole or in part, to the water quality impairment of a waterbody and its consequent addition to the 303(d) list. This question was not intended to be directed at the lakes analyzed in the present survey. Instead, at issue is whether hatchery-derived contamination is worthy of inquiry by investigators who are conducting surveys on individual lakes and streams where the source of contamination is uncertain and where waterbodies may be considered for 303(d) listing.

Table 8. National Toxics Rule Criteria Compared to Contaminant Residues in Hatchery and Planted Rainbow Trout Fillet (ng/g ww except pg/g ww for 2,3,7,8-TCDD).

Contaminant	Criterion	Concentrations in present study	No. of Criterion Exceedances	Location(s) of Criterion Exceedance
ΣPCB	5.3	4.85 - 67	9	Chapman Lake Molson Lake South Lewis Co. Park Pond Chelan Hatchery Columbia Basin Hatchery Mossyrock Hatchery Troutlodge Arlington Hatchery Spokane Hatchery
4,4'-DDT	32	0.14 - 1.9		
4,4'-DDE	32	1.9 - 45	1	Fan Lake
4,4'-DDD	45	0.29 - 9.6		
2,3,7,8-TCDD	0.07	0.011 - 0.053		
Aldrin	0.65	ND		
Dieldrin	0.65	0.32 - 0.88	5	Warden Lake Mossyrock Hatchery Spokane Hatchery Arlington Hatchery Eells Springs Hatchery
Endrin	3,216	ND		
Endrin Aldehyde	3,216	ND		
alpha-BHC	1.7	ND		
beta-BHC	1.6	ND		
gamma-BHC (Lindane)	8.2	ND		
Chlordane (total)	8.3	ND		
Endosulfan I	540	ND		
Endosulfan II	540	ND		
Endosulfan Sulfate	540	ND		
Heptachlor	2.4	ND		
Heptachlor Epoxide	1.2	ND		
Hexachlorobenzene	6.7	0.10 - 0.73		
Toxaphene	9.8	ND		

ND - not detected

To examine this question on a statewide basis, results of the present survey were compared to all of the data on contaminants in tissue in Washington. In order to provide a suitably comparable data set, data that met the following conditions were extracted from Ecology's Environmental Information Management (EIM) database; 1) samples analyzed since 1998, 2) results only for rainbow trout, brown trout, and cutthroat trout since these are the primary resident species raised to catchable size at WDFW hatcheries, and 3) fillet data only. Only results for ΣPCB, 4,4'-DDE, and dieldrin were selected since these were the contaminants found here that exceeded NTR criteria. Waterbodies known to have large sources of these chemicals (e.g., Spokane River for PCBs, Yakima River for 4,4'-DDE and dieldrin) were removed.

Figure 4 shows the cumulative distribution of all ΣPCB data for fish in Washington using the selection process previously described. Sixty percent of the 46 samples exceed the NTR criterion, and approximately 50% of samples statewide had concentrations that fall into the range of detectable ΣPCB concentrations in hatchery rainbow trout, excluding the Chelan Hatchery sample. One hundred percent of samples fall into the hatchery ΣPCB range when all of the hatchery rainbows are considered.

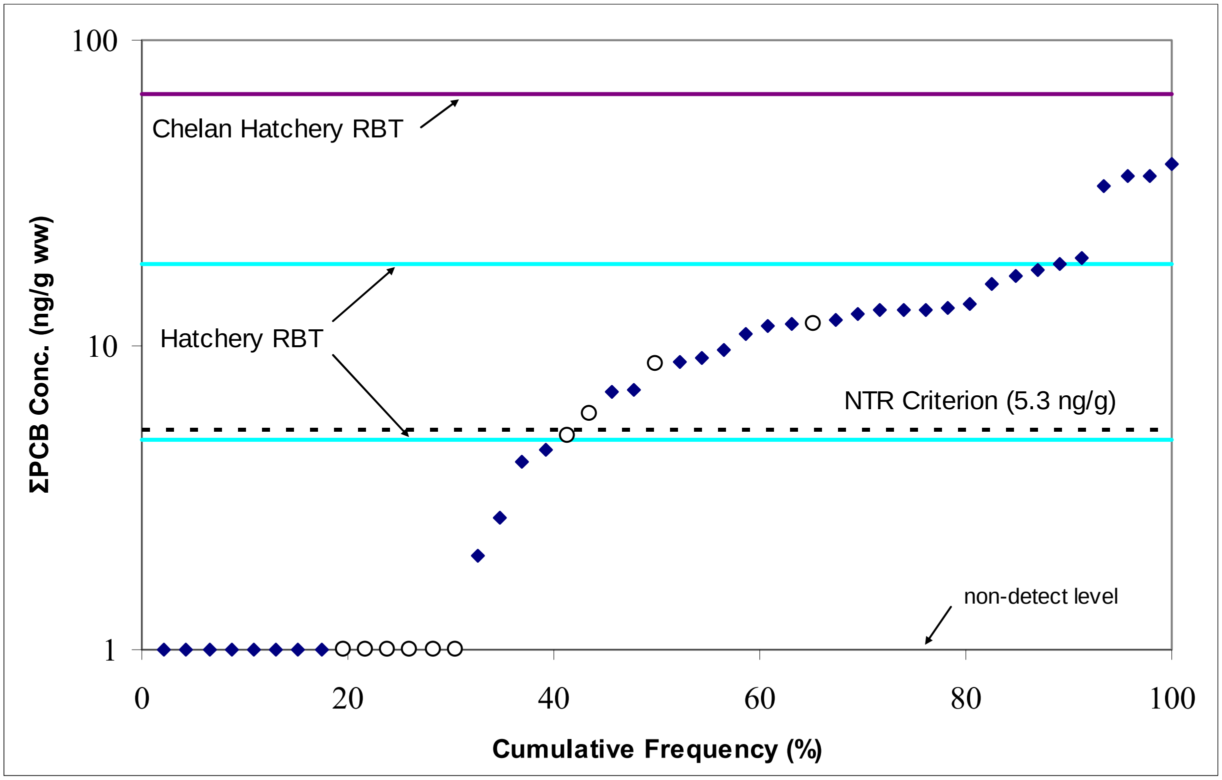

Figure 4. Cumulative Frequency Distribution of ΣPCB Concentrations in Fillet Tissue of Rainbow Trout (RBT), Cutthroat Trout, and Brown Trout from Washington Lakes and Streams. (Open circles represent data from lakes sampled in the present survey. Solid gray lines bound the range of detected ΣPCB concentrations in hatchery fish. Dashed line is the NTR criterion for ΣPCBs.)

Only two of the 38 trout samples (5%) exceed the NTR criterion for 4,4'-DDE, including the Fan Lake result found in the present survey (Figure 5). Approximately 40% of the samples are within the hatchery fish range, with more than 70% falling below the maximum 4,4'-DDE level in hatchery rainbows.

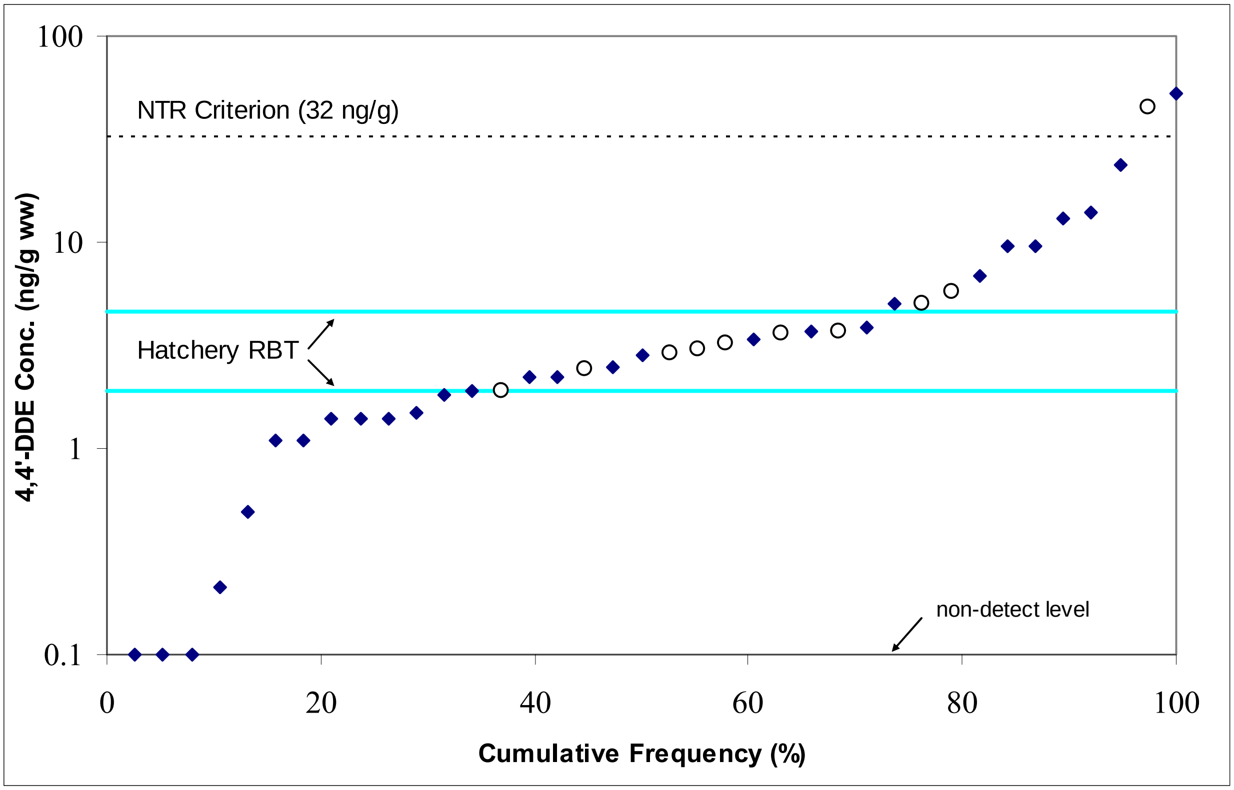

Figure 5. Cumulative Frequency Distribution of 4,4'-DDE Concentrations in Fillet Tissue of Rainbow Trout (RBT), Cutthroat Trout, and Brown Trout from Washington Lakes and Streams. (Open circles represent data from lakes sampled in the present survey. Solid gray lines bound the range of detected 4,4'-DDE concentrations in hatchery fish. Dashed line is the NTR criterion for 4,4'-DDE.)

None of the 38 samples screened from the EIM database had detectable levels of dieldrin; North Lake and Warden Lake are the only "unpolluted" sites where dieldrin has been detected in common trout species (Figure 6). Dieldrin in Warden Lake rainbow trout (0.76 ng/g) exceeds the NTR criterion (0.65 ng/g).

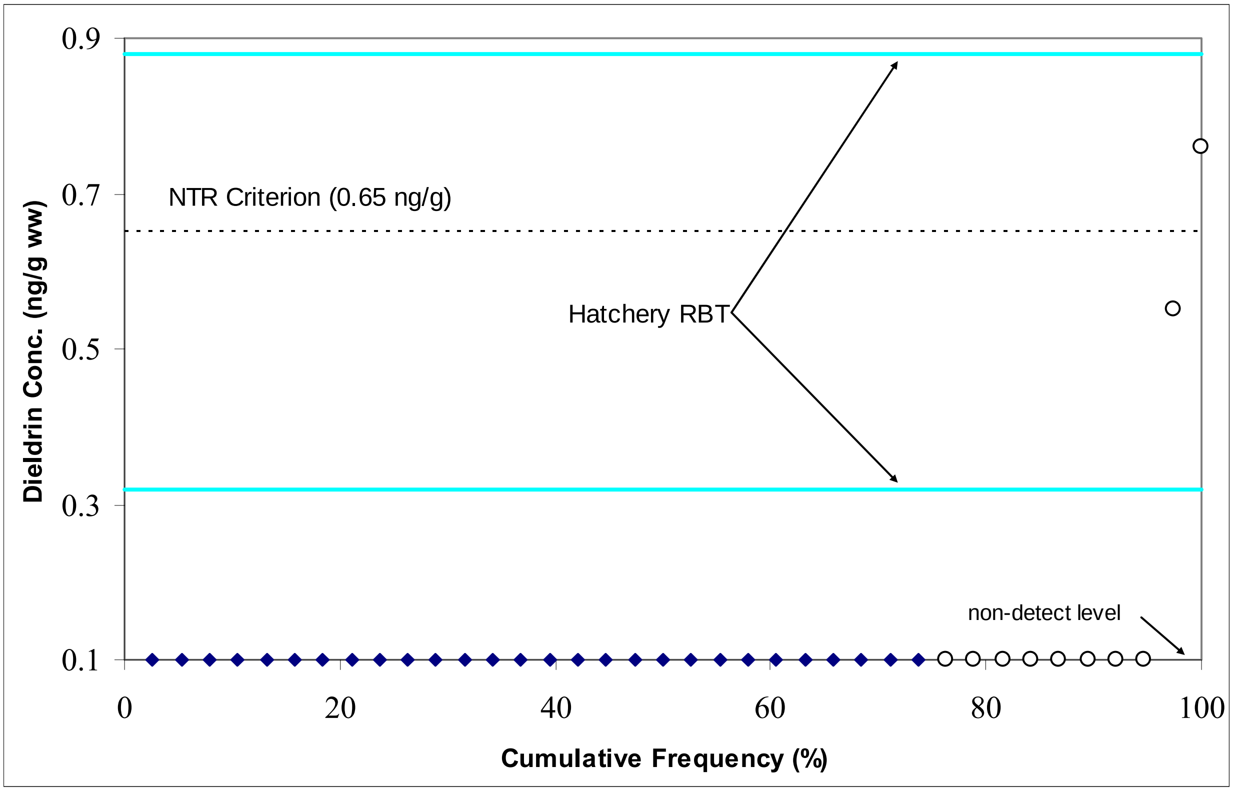

Figure 6. Cumulative Frequency Distribution of Dieldrin Concentrations in Fillet Tissue of Rainbow Trout (RBT), Cutthroat Trout, and Brown Trout from Washington Lakes and Streams. (Open circles represent data from lakes sampled in the present survey. Solid gray lines bound the range of detected dieldrin concentrations in hatchery fish. Dashed line is the NTR criterion for dieldrin.)

There are several inferences that may be drawn from these comparisons to screened data. One supposition is that some portion of POPs found in trout is derived from burdens obtained at a hatchery, although this presumes that the fish were planted. However, there is no concomitant information on the origin of the fish used for these comparisons.

The extent of hatchery-derived POPs remaining in planted fish is variable and appears to depend largely on the amount of time lapsed since stocking. Trout caught around the time of opening day – typically mid-to-late April – will have contaminant concentrations nearly identical to concentrations found in fish just prior to their removal from hatcheries. It appears that as the fishing season progresses, the concentrations in fillet tissue generally decrease, particularly for PCBs and some chlorinated pesticides, although this is a pattern which is less consistent for DDT compounds and PBDEs. Unfortunately, the planted cohorts that were sampled for each hatchery-planted pair could not be sampled further to track fillet concentrations during subsequent periods.

One of the implications of these results, particularly from the practical standpoint of a regulatory agency, is that waterbodies may be included on the 303(d) list due to contamination stemming from hatcheries. Taken further, 303(d) listed waters often require a TMDL to assess contaminant sources. Sources considered for TMDLs are typically point sources (e.g., piped effluent) and nonpoint sources (e.g., agricultural and urban runoff, atmospheric deposition) which normally occur in the vicinity of the impaired waterbody. However, no known TMDLs in Washington have included hatchery fish as a contaminant source. For PCBs, and to a lesser extent dieldrin, hatchery fish may contribute to impairment and, in some cases, may cause the bulk of impairment. Therefore, TMDL investigators may want to consider including hatchery fish as contaminant sources among other sources.

Conclusions

Rainbow trout acquire low-to moderate concentrations of persistent organic pollutants (POPs) while residing at Washington Department of Fish and Wildlife (WDFW) hatcheries. Feed used to raise rainbow trout to catchable size (≥6”) contains concentrations of PCBs, DDT compounds, PCDD/Fs, and several additional chlorinated pesticides at higher wet-weight concentrations than in fillet tissue of the fish specimens analyzed, suggesting that the POP accumulation pathway is primarily through the feed. This is consistent with findings of other aquacultural studies, although other possible pathways of contaminant accumulation were not examined for this study. Low levels of PBDEs were also present in rainbow trout tissue, but were not detected in trout feed.

Fish feed is high in lipids and shows variable amounts of contaminants, but POP concentrations were not correlated with the percent lipid in feed samples. This suggests the source of lipids, largely derived from marine oil, is an important determinant in POP concentrations. The positive correlation between feed and fish ΣPCB and between feed and fish ΣDDT supports the conclusion that feed is the primary contaminant source to hatchery fish. WDFW trout hatchery feed has POP concentrations similar or lower than feeds analyzed in other studies, and appears to have much lower PCB concentrations than feeds used in commercial salmon aquaculture.

It appears that fillet tissue concentrations of some POPs, particularly PCBs, decrease following stocking in lakes, although this finding is inconclusive. ΣDDT concentrations may increase in the lake environment even as fillet lipid concentrations decrease significantly. Fish from only one location – Fan Lake in Pend Oreille County – showed a substantial increase in contaminants (DDT compounds) following residence in the wild.

In the 21 rainbow trout fillet samples analyzed (11 from hatcheries including Troutlodge and 10 from lakes), there are 15 instances where contaminants exceed (do not meet) regulatory criteria. Most of the exceedances are for ΣPCB (three lakes and six hatcheries), followed by dieldrin (one lake and four hatcheries) and 4,4’-DDE (one lake). Considering the POP levels in catchable rainbow trout just prior to planting, it appears likely that at least part of the contaminant burden is hatchery-derived, with the notable exception of DDT compounds in Fan Lake as described previously.

Based on comparisons between waterbodies in Washington State and POP data reported here, it is possible that trout caught in “unpolluted” lakes and streams contain contaminants originating from WDFW hatcheries. It is also possible that some listings for impaired waters, particularly listings for PCBs, may be due to hatchery-contaminated fish. Therefore, Total Maximum Daily Load (TMDL) project managers may want to consider hatchery fish as a source of contaminant loads.

Recommendations

Based on results of this 2005 study, it is recommended that fish feed and trout fillet tissue sampling be expanded to include all 26 WDFW hatcheries raising catchable trout. Samples should be analyzed for the persistent organic pollutants (POPs) in the present study, with PCDD/F analysis included for all samples. Water in hatcheries should also be sampled where contaminant levels in fish are exceptionally high. Any water sampling should be performed using semi-permeable membrane devices or other methods to achieve low detection limits for POPs.

More data are needed to assess depuration or accumulation of contaminants in catchable trout following planting in lakes. Ideally, fish could be sampled during several periods to better track trends in contaminant levels over time. Whole fish analysis should also be considered along with fillet sampling, to determine if contaminant burdens are conserved in fish following mobilization of lipids in muscle tissue.

A review of the current 303(d) list should be conducted to identify cases where tissue data used to assess impairment may have come from WDFW catchable trout plants. TMDL project managers should consider the implications of hatchery fish as a possible source of contaminants to waterbodies being assessed.

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Appendices

Appendix A – Glossary of Acronyms and Units

303(d) – Section 303(d) of the federal Clean Water Act
CFIA – Canadian Food Inspection Agency
DDD – 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane
DDE – 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene
DDT – 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane
DOH – Washington State Department of Health
ECD – electron capture detector
Ecology – Washington State Department of Ecology
EIM – Environmental Information Management
EPA – U.S. Environmental Protection Agency
EU – European Union
GC – gas chromatography
MEL – Manchester Environmental Laboratory
MS – mass spectrometry
NIST – National Institute of Standards and Technology
NTR – National Toxics Rule
PBDE – polybrominated diphenyl ether
PCB – polychlorinated biphenyl
PCDD – polychlorinated dibenzo-*p*-dioxin
PCDF – polychlorinated dibenzofuran
POP – persistent organic pollutant
SRM – standard reference material
TEF – toxic equivalency factor
TEQ – toxic equivalent
TMDL – total maximum daily load (water cleanup plan)
USF&WS – U.S. Fish and Wildlife Service
WDFW – Washington Department of Fish and Wildlife
ww – wet weight
Σ – sum of

Units of measurement

ng/g – nanograms per gram (parts per billion)
pg/g – picograms per gram (parts per trillion)

Appendix B – Target Analytes and Reporting Limits

Table B. Target Analytes and Reporting Limits

Analyte	Reporting Limit (ng/g ww)	Analyte	Reporting Limit (ng/g ww)	Analyte	Reporting Limit (pg/g ww)
PCBs		**Chlorinated Pesticides**		**PCDDs/PCDFs**	
Aroclor-1016	2.3 – 5.0	2,4'-DDE	0.47 – 1.0	2,3,7,8-TCDD	0.03 – 0.05
Aroclor-1221	2.3 – 5.0	2,4'-DDD	0.47 – 1.0	1,2,3,7,8-PeCDD	0.07 – 0.11
Aroclor-1232	2.3 – 5.0	2,4'-DDT	0.47 – 1.0	1,2,3,4,7,8-HxCDD	0.05 – 0.2
Aroclor-1242	2.3 – 5.0	4,4'-DDT	0.47 – 1.0	1,2,3,6,7,8-HxCDD	0.05 – 0.2
Aroclor-1248	2.3 – 5.0	4,4'-DDE	0.47 – 1.0	1,2,3,7,8,9-HxCDD	0.05 – 0.2
Aroclor-1254	2.3 – 5.0	4,4'-DDD	0.47 – 1.0	1,2,3,4,6,7,8-HpCDD	0.05 – 0.2
Aroclor-1260	2.3 – 5.0	DDMU	0.47 – 1.0	OCDD	0.36
PBDEs		Aldrin	0.47 – 1.0	2,3,7,8-TCDF	0.03 – 0.05
		Dieldrin	0.47 – 10	1,2,3,7,8-PeCDF	0.06 – 0.1
PBDE-47	0.23 – 0.65	Endrin	0.96 – 10	2,3,4,7,8-PeCDF	0.04 – 0.12
PBDE-66	0.25 – 0.50	Endrin Aldehyde	0.96 – 10	1,2,3,4,7,8-HxCDF	0.2
PBDE-71	0.25 – 0.50	Endrin Ketone	0.96 – 10	1,2,3,6,7,8-HxCDF	0.05 – 0.1
PBDE-99	0.25 – 0.50	alpha-BHC	0.47 – 1.0	2,3,4,6,7,8-HxCDF	0.05 – 0.2
PBDE-100	0.25 – 0.50	beta-BHC	0.47 – 1.0	1,2,3,7,8,9-HxCDF	0.05 – 0.2
PBDE-138	0.25 – 0.50	gamma-BHC (Lindane)	0.47 – 1.0	1,2,3,4,6,7,8-HpCDF	0.05 – 0.2
PBDE-153	0.25 – 0.50	delta-BHC	0.47 – 1.0	1,2,3,4,7,8,9-HpCDF	0.05 – 0.2
PBDE-154	0.25 – 0.50	cis-Chlordane (alpha)	0.47 – 1.0	OCDF	0.21 – 0.23
PBDE-183	0.25 – 0.50	trans-Chlordane (gamma)	0.47 – 1.0		
PBDE-190	0.25 – 0.50	Oxychlordane	0.47 – 1.0		
PBDE-209	1.2 – 6.2	Chlordane (technical)	0.98 – 5.0		
		Chlorpyriphos	0.96 – 10		
		Dacthal (DCPA)	0.96 – 10		
		Endosulfan I	0.96 – 10		
		Endosulfan II	0.96 – 10		
		Endosulfan Sulfate	0.96 – 10		
		Heptachlor	0.47 – 1.0		
		Heptachlor Epoxide	0.96 – 10		
		Hexachlorobenzene	0.47 – 1.0		
		Methoxychlor	0.47 – 1.0		
		Mirex	0.47 – 1.0		
		cis-Nonachlor	0.47 – 1.0		
		trans-Nonachlor	0.47 – 1.0		
		Pentachloroanisole	0.47 – 1.0		
		Toxaphene	0.98 – 10		

Appendix C – Complete Results of Lipid and Contaminant Analysis

Table C-1. Complete Results of Percent Lipids and PCB Aroclor Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Lipids (%)	PCB-aroclor 1016		PCB-aroclor 1221		PCB-aroclor 1232		PCB-aroclor 1242		PCB-aroclor 1248		PCB-aroclor 1254		PCB-aroclor 1260		PCB-aroclor 1262		PCB-aroclor 1268	
Hatchery Feed																				
Arlington	5144102	18.19	2.5	UJ	2.5	UJ	2.5	UJ	2.7	J	5.5	UJ	8.1	J	3	J	2.5	UJ	2.5	UJ
Chelan	5144096	13.75	2.5	U	2.5	U	2.5	U	5	UJ	8	NJ	18		8.8		2.5	U	2.5	U
Columbia Basin	5144098	14.47	2.4	UJ	2.4	UJ	2.4	UJ	2.4	UJ	4.7	UJ	7.6	J	4	J	2.4	UJ	2.4	UJ
Eells Spring	5144103	12.7	2.4	UJ	2.4	UJ	2.4	UJ	2.6	J	4.6	UJ	6.9	J	3	J	2.4	UJ	2.4	UJ
Ford	5144099	25.75	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ
Ford-Dup	5144099-Dup	25.95	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Mossyrock	5144097	19.64	2.5	UJ	2.5	UJ	2.5	UJ	3.8	J	10	UJ	16	J	7.8	J	2.5	UJ	2.5	UJ
Puyallup	5144104	15.75	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ
Puyallup-Dup	5144104-Dup	16.52	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Spokane	5144100	15.79	2.5	UJ	2.5	UJ	2.5	UJ	2.8	J	6.1	UJ	9.3	J	4.3	J	2.5	UJ	2.5	UJ
Tucannon	5144101	15.01	2.5	UJ	2.5	UJ	2.5	UJ	2.5	UJ	2.8	J	5.4	NJ	2.5	UJ	2.5	UJ	2.5	UJ
Vancouver	5144095	16.08	2.5	UJ	2.5	UJ	2.5	UJ	2.6	J	5.5	UJ	7.7	NJ	3	J	2.5	UJ	2.5	UJ
Hatchery Rainbows																				
Arlington	5144087	3.97	2.5	U	2.5	U	2.5	U	2.1	J	3.5	UJ	6.5	NJ	3.5	J	2.5	U	2.5	U
Chelan	5144081	3.05	2.4	U	2.4	U	2.4	U	8.5	UJ	20	NJ	47		3.4	UJ	2.4	U	2.4	U
Columbia Basin	5144083	4.1	2.5	U	2.5	U	2.5	U	2.5	U	3.5	J	9		6		3.6	UJ	2.5	U
Eells Spring	5144088	2.7	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Eells Spring-Dup	5144088-Dup	2.13	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U
Ford	5144084	2.35	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U
Mossyrock	5144082	2.69	2.4	U	2.4	U	2.4	U	2.4	U	4.8	UJ	9	J	6.8	J	2.4	U	2.4	U
Puyallup	5144089	3.07	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U	2.3	U
Spokane	5144085	2.48	2.5	U	2.5	U	2.5	U	2.5	U	2.6	J	5.2	NJ	3.9	J	2.5	U	2.5	U
Troutlodge	5144090	5.39	2.4	U	2.4	U	2.4	U	2.6	J	5.6	UJ	7.9		3.9	J	2.4	U	2.4	U
Tucannon	5144086	3.69	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U	2.4	U
Vancouver	5144080	4.86	2.5	U	2.5	U	2.5	U	2.5	U	3.2	NJ	3.6	NJ	2.9	NJ	2.5	U	2.5	U
Vancouver-Dup	5144080-Dup	3.14	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U

Table C-1 (cont'd). Complete Results of Percent Lipids and PCB Aroclor Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Lipids (%)	PCB-aroclor 1016		PCB-aroclor 1221		PCB-aroclor 1232		PCB-aroclor 1242		PCB-aroclor 1248		PCB-aroclor 1254		PCB-aroclor 1260		PCB-aroclor 1262		PCB-aroclor 1268	
Planted Rainbows																				
Chapman Lake	5248102	0.44	5	U	5	U	5	U	5	U	5	U	6.7	J	5.1	J	5	U	5	U
Donnie Lake	5248103	1.29	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Fan Lake	5248104	2.66	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Lacamas Lake	5248100	1.5	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Lone Lake	5248108	1.63	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U
Lone Lake-Dup	5248108-Dup	1.71	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U
Molson Lake	5248101	2.05	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	8.6	J	4.9	U	4.9	U	4.9	U
North Lake	5248106	0.65	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U
South Lewis Co. Park Pond	5248105	0.77	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	5.9	J	4.9	U	4.9	U	4.9	U
Summit Lake	5248109	0.35	4.8	U	4.8	U	4.8	U	4.8	U	4.8	U	4.7	J	4.8	U	4.8	U	4.8	U
Summit Lake-Dup	5248109-Dup	0.45	5.0	U	5.0	U	5.0	U	5.0	U	5.0	U	**5.2**	J	5.0	U	5.0	U	5.0	U
Warden Lake	5248107	0.61	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U	4.9	U

U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate
Dup - Duplicate

Table C-2. Complete Results of DDT Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	2,4'-DDD		2,4'-DDE		2,4'-DDT		4,4'-DDD		4,4'-DDE		4,4'-DDT	
Hatchery Feed													
Arlington	5144102	0.37	J	0.49	U	0.49	U	2.3		2.8		0.78	NJ
Chelan	5144096	0.57	UJ	0.5	U	0.5	U	3.1		4.8		1.5	
Columbia Basin	5144098	0.28	J	0.49	U	0.49	U	1.4		4.4		0.21	J
Eells Spring	5144103	0.38	J	0.48	U	0.48	U	2		2.8		0.72	J
Ford	5144099	0.12	J	0.5	U	0.12	J	0.61		2.3		0.31	J
Ford- Dup	5144099-Dup	0.17	J	0.5	U	0.13	J	0.86		2.4		0.38	J
Mossyrock	5144097	0.43	J	0.5	U	0.5	U	3.4		6		1.2	NJ
Puyallup	5144104	0.32	J	0.5	U	0.15	J	1.2		4.3		0.49	J
Puyallup-Dup	5144104-Dup	0.3	J	0.49	U	0.15	J	1.4		4.3	NJ	0.55	
Spokane	5144100	0.2	J	0.5	U	0.5	U	0.77		4.2		0.7	NJ
Tucannon	5144101	0.85		0.5	U	0.16	J	4.4		15		0.7	J
Vancouver	5144095	0.43	J	0.5	U	0.5	U	2.1		2.6		0.69	J
Hatchery Rainbows													
Arlington	5144087	0.12	J	0.49	U	0.49	U	0.84		3.8		0.49	U
Chelan	5144081	0.49	U	0.49	U	0.49	U	0.7		2.8		0.6	NJ
Columbia Basin	5144083	0.5	U	0.61	UJ	0.5	U	1.8		3.9		0.77	NJ
Eells Spring	5144088	0.1	J	0.5	U	0.5	U	0.55		1.8		0.25	J
Eells Spring-Dup	5144088-Dup	0.49	U	0.49	U	0.49	U	0.5		1.9		0.24	J
Ford	5144084	0.49	U	0.49	U	0.49	U	0.33	J	2.2		0.49	U
Mossyrock	5144082	0.48	U	0.48	U	0.48	U	0.91		2.7		0.24	NJ
Puyallup	5144089	0.47	U	0.47	U	0.47	U	0.29	J	2		0.14	J
Spokane	5144085	0.49	U	0.49	U	0.49	U	0.52		2.2		0.2	J
Troutlodge	5144090	0.15	J	0.49	U	0.49	U	1.5		3.4		0.65	J
Tucannon	5144086	0.49	U	0.49	U	0.49	U	0.52		4.6		0.18	J
Vancouver	5144080	0.5	U	0.5	U	0.5	U	0.7		4		0.26	J
Vancouver-Dup	5144080-Dup	0.12	J	0.5	U	0.5	U	0.59		2.1		0.27	J
Planted Rainbows													
Chapman Lake	5248102	1	U	1	U	1	U	1	U	5.1		1	U
Donnie Lake	5248103	1	U	1	U	1	U	1	U	3.6		1	U
Fan Lake	5248104	1	U	1	U	1	U	9.6	J	45		1.9	J
Lacamas Lake	5248100	1	U	1	U	1	U	1	U	3.0		1	U
Lone Lake	5248108	0.98	U	0.98	U	0.98	U	0.98	U	1.9	J	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	U	0.97	U	0.97	U	0.97	U	1.9	J	0.97	U
Molson Lake	5248101	0.98	U	0.98	U	0.98	U	0.98	U	5.8		0.98	U
North Lake	5248106	0.97	U	0.97	U	0.97	U	0.97	U	2.9		0.97	U
South Lewis Co. Park Pond	5248105	0.96	U	0.98	U	0.98	U	0.96	U	2.4		0.96	UJ
Summit Lake	5248109	0.96	U	0.96	U	0.96	U	0.96	U	3.0		0.96	U
Summit Lake-Dup	5248109-Dup	1.0	U	1.0	U	1.0	U	1.0	U	3.3		1.0	U
Warden Lake	5248107	0.97	U	0.97	U	0.97	U	0.97	U	3.7		0.97	U

U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate

Table C-3. Complete Results of PBDE Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	PBDE-047		PBDE-066		PBDE-071		PBDE-099		PBDE-100		PBDE-138	
Hatchery Feed													
Arlington	5144102	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Chelan	5144096	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Columbia Basin	5144098	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ
Eells Spring	5144103	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ
Ford	5144099	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Ford-Dup	5144099-Dup	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Mossyrock	5144097	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Puyallup	5144104	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Puyallup-Dup	5144104-Dup	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Spokane	5144100	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Tucannon	5144101	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Vancouver	5144095	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ
Hatchery Rainbows													
Arlington	5144087	0.64		0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Chelan	5144081	0.95		0.24	U	0.14	J	0.24	U	0.24	U	0.24	U
Columbia Basin	5144083	0.65	J	0.25	U	0.16	J	0.089	NJ	0.25	U	0.25	U
Eells Spring	5144088	0.55		0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Eells Spring-Dup	5144088-Dup	0.49		0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Ford	5144084	0.24	J	0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Mossyrock	5144082	0.73		0.24	U	0.16	J	0.24	U	0.24	U	0.24	U
Puyallup	5144089	0.24		0.23	U	0.23	U	0.23	U	0.23	U	0.23	U
Spokane	5144085	0.55		0.25	U	0.25	U	0.25	U	0.11	J	0.1	J
Troutlodge	5144090	0.62		0.24	U	0.15	J	0.07	J	0.24	U	0.24	U
Tucannon	5144086	0.27		0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Vancouver	5144080	0.72		0.25	U	0.13	J	0.25	U	0.25	U	0.25	U
Vancouver-Dup	5144080-Dup	0.56		0.25	U	0.25	U	0.25	U	0.25	U	0.25	U
Planted Rainbows													
Chapman Lake	5248102	0.91		0.5	U	0.5	U	0.1	NJ	0.5	U	0.5	U
Donnie Lake	5248103	0.25	J	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Fan Lake	5248104	0.4	J	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Lacamas Lake	5248100	0.29	J	0.5	U	0.5	U	0.5	U	0.13	J	0.5	U
Lone Lake	5248108	0.65		0.49	U	0.49	U	0.24	J	0.15	J	0.49	U
Lone Lake-Dup	5248108-Dup	0.54		0.48	U	0.48	U	0.13	J	0.20	J	0.48	U
Molson Lake	5248101	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ
North Lake	5248106	0.78		0.48	U	0.48	U	0.29	J	0.16	J	0.48	U
South Lewis Co. Park Pond	5248105	1		0.49	U	0.49	U	0.33	J	0.49	U	0.49	U
Summit Lake	5248109	0.87		0.48	U	0.48	U	0.12	J	0.14	J	0.48	U
Summit Lake-Dup	5248109-Dup	0.65	U	0.50	U	0.50	U	0.50	U	0.50	U	0.50	U
Warden Lake	5248107	0.46	J	0.48	U	0.48	U	0.48	U	0.48	U	0.48	U

Table C-3 (cont'd). Complete Results of PBDE Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	PBDE-153		PBDE-154		PBDE-183		PBDE-190		PBDE-209	
Hatchery Feed											
Arlington	5144102	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Chelan	5144096	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Columbia Basin	5144098	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	1.2	UJ
Eells Spring	5144103	0.24	UJ	0.24	UJ	0.24	UJ	0.24	UJ	1.2	UJ
Ford	5144099	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Ford-Dup	5144099-Dup	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Mossyrock	5144097	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Puyallup	5144104	0.25	U	0.25	U	0.25	U	0.25	U	1.2	U
Puyallup-Dup	5144104-Dup	0.25	U	0.25	U	0.25	U	0.25	U	1.2	U
Spokane	5144100	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Tucannon	5144101	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Vancouver	5144095	0.25	UJ	0.25	UJ	0.25	UJ	0.25	UJ	1.2	UJ
Hatchery Rainbows											
Arlington	5144087	0.24	U	0.24	U	0.24	U	0.24	U	3.1	U
Chelan	5144081	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Columbia Basin	5144083	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Eells Spring	5144088	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Eells Spring-Dup	5144088-Dup	0.24	U	0.24	U	0.24	U	0.24	U	3.0	U
Ford	5144084	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Mossyrock	5144082	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Puyallup	5144089	0.23	U	0.23	U	0.23	U	0.23	U	2.9	U
Spokane	5144085	0.25	U	0.25	U	0.25	U	0.25	U	0.34	J
Troutlodge	5144090	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Tucannon	5144086	0.24	U	0.24	U	0.24	U	0.24	U	3	U
Vancouver	5144080	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Vancouver-Dup	5144080-Dup	0.25	U	0.25	U	0.25	U	0.25	U	3.1	U
Planted Rainbows											
Chapman Lake	5248102	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Donnie Lake	5248103	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Fan Lake	5248104	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Lacamas Lake	5248100	0.5	U	0.5	U	0.5	U	0.5	U	6.2	U
Lone Lake	5248108	0.49	U	0.49	U	0.49	U	0.49	U	6.1	U
Lone Lake-Dup	5248108-Dup	0.48	U	0.48	U	0.48	U	0.48	U	6.0	U
Molson Lake	5248101	0.49	UJ	0.49	UJ	0.49	UJ	0.49	UJ	2.4	UJ
North Lake	5248106	0.48	U	0.48	U	0.48	U	0.48	U	6.1	U
South Lewis Co. Park Pond	5248105	0.49	U	0.49	U	0.49	U	0.49	U	6.1	U
Summit Lake	5248109	0.48	U	0.48	U	0.48	U	0.48	U	6	U
Summit Lake-Dup	5248109-Dup	0.50	U	0.50	U	0.50	U	0.50	U	6.2	U
Warden Lake	5248107	0.48	U	0.48	U	0.48	U	0.48	U	6.1	U

U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate

Table C-4. Complete Results of PCDD/F Analysis of Feed Samples (pg/g ww)

Sample Number	TEF	Vancouver Hatchery			Mossyrock Hatchery			Ford Hatchery			Ford Hatchery			Spokane Hatchery		
		Sample 05144105		TEQ	Sample 05144106		TEQ	Sample 05144107		TEQ	Sample 05144107-Dup		TEQ	Sample 05144108		TEQ
2,3,7,8-TCDF	0.1	0.525		0.0525	0.798		0.0798	0.182		0.0182	0.222		0.0222	1.4		0.14
1,2,3,7,8-PeCDF	0.05	0.251	J	0.01255	0.591		0.02955	0.1	UJ	0	0.115	J	0.00575	0.218	J	0.0109
2,3,4,7,8-PeCDF	0.5	0.126	J	0.063	0.226	J	0.113	0.12	UJ	0	0.12	UJ	0	0.246	J	0.123
1,2,3,4,7,8-HxCDF	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,6,7,8-HxCDF	0.1	0.1	UJ	0	0.1	UJ	0	0.1	UJ	0	0.1	UJ	0	0.1	UJ	0
2,3,4,6,7,8-HxCDF	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,7,8,9-HxCDF	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,4,6,7,8-HpCDF	0.01	0.2	UJ	0	0.207	J	0.00207	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,4,7,8,9-HpCDF	0.01	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
OCDF	0.0001	0.404	J	0.00004	0.403	J	0.00004	0.32	J	0.00003	0.344	J	0.00003	0.377	J	0.00004
2,3,7,8-TCDD	1	0.186		0.186	0.367		0.367	0.05	UJ	0	0.05	UJ	0	0.192		0.192
1,2,3,7,8-PeCDD	1	0.215	J	0.215	0.534		0.534	0.11	UJ	0	0.11	UJ	0	0.637		0.637
1,2,3,4,7,8-HxCDD	0.1	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0	0.2	UJ	0
1,2,3,6,7,8-HxCDD	0.1	0.235	J	0.0235	0.494		0.0494	0.2	UJ	0	0.2	UJ	0	0.437		0.0437
1,2,3,7,8,9-HxCDD	0.1	0.2	UJ	0	0.333		0.0333	0.2	UJ	0	0.2	UJ	0	0.339		0.0339
1,2,3,4,6,7,8-HpCDD	0.01	0.857		0.00857	1.6		0.016	0.524		0.00524	0.474		0.00474	1.25		0.0125
OCDD	0.0001	8.14		0.00081	16.5		0.00165	3.38		0.00034	3.3		0.00033	11.5		0.00115
TEQ total				0.56197			1.22581			0.02381			0.03305			1.19419

TEF - Toxicity Equivalence Factor from Van den Berg et al., 1998
TEQ - Toxic Equivalent
UJ - The analyte was not detected at or above the reported estimated result
J - The analyte was positively identified. The associated numerical value is an estimate

Table C-5. Complete Results of PCDD/F Analysis of Rainbow Trout Tissue Samples (pg/g ww)

Sample Number	TEF	Vancouver Hatchery			Mossyrock Hatchery			Ford Hatchery			Ford Hatchery			Spokane Hatchery		
		Sample 05144092		TEQ	Sample 05144093		TEQ	Sample 05144091		TEQ	Sample 05144091-Dup		TEQ	Sample 05144094		TEQ
2,3,7,8-TCDF	0.1	0.187		0.0187	0.282		0.0282	0.037	J	0.0037	0.042	J	0.0042	0.163		0.0163
1,2,3,7,8-PeCDF	0.05	0.111	J	0.00555	0.143	J	0.00715	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0
2,3,4,7,8-PeCDF	0.5	0.041	J	0.0205	0.04	UJ	0	0.04	UJ	0	0.04	UJ	0	0.04	UJ	0
1,2,3,4,7,8-HxCDF	0.1	0.07	J	0.007	0.051	J	0.0051	0.075	J	0.0075	0.053	J	0.0053	0.067	J	0.0067
1,2,3,6,7,8-HxCDF	0.1	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0
2,3,4,6,7,8-HxCDF	0.1	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0
1,2,3,7,8,9-HxCDF	0.1	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0	0.06	UJ	0
1,2,3,4,6,7,8-HpCDF	0.01	0.095	J	0.00095	0.078	J	0.00078	0.094	J	0.00094	0.105	J	0.00105	0.082	J	0.00082
1,2,3,4,7,8,9-HpCDF	0.01	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0
OCDF	0.0001	0.31	J	0.00003	0.225	J	0.00002	0.313	J	0.00003	0.289	J	0.00003	0.336	J	0.00003
2,3,7,8-TCDD	1	0.03	UJ	0	0.03	UJ	0	0.03	UJ	0	0.03	UJ	0	0.03	UJ	0
1,2,3,7,8-PeCDD	1	0.07	UJ	0	0.07	UJ	0	0.07	UJ	0	0.07	UJ	0	0.07	UJ	0
1,2,3,4,7,8-HxCDD	0.1	0.10000	UJ	0	0.10000	UJ	0	0.10000	UJ	0	0.10000	UJ	0	0.10000	UJ	0
1,2,3,6,7,8-HxCDD	0.1	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0
1,2,3,7,8,9-HxCDD	0.1	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0	0.05	UJ	0
1,2,3,4,6,7,8-HpCDD	0.01	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0	0.08	UJ	0
OCDD	0.0001	0.36	UJ	0	0.36	UJ	0	0.36	UJ	0	0.36	UJ	0	0.36	UJ	0
TEQ total				0.05273			0.04125			0.01217			0.01058			0.02385

TEF - Toxicity Equivalence Factor from Van den Berg et al., 1998
TEQ - Toxic Equivalent
UJ - The analyte was not detected at or above the reported estimated result
J - The analyte was positively identified. The associated numerical value is an estimate

Table C-5. Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Aldrin		Alpha-BHC		Beta-BHC		Chlordane		Chlor-pyriphos		cis-Chlordane	
Hatchery Feed													
Arlington	5144102	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	UJ	0.52	
Chelan	5144096	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.5	U
Columbia Basin	5144098	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.68	NJ
Eells Spring	5144103	0.48	UJ	0.48	U	0.48	U	2.4	U	2.4	UJ	0.47	NJ
Ford	5144099	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.19	J
Ford-Dup	5144099-Dup	0.50	UJ	0.50	U	0.50	U	2.5	U	2.5	UJ	0.25	J
Mossyrock	5144097	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	1.2	NJ
Puyallup	5144104	0.5	UJ	0.5	U	0.5	U	2.5	U	10	UJ	0.5	U
Puyallup-Dup	5144104-Dup	0.49	UJ	0.49	U	0.49	U	2.5	U	9.9	UJ	0.49	U
Spokane	5144100	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	UJ	0.39	NJ
Tucannon	5144101	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	UJ	0.5	U
Vancouver	5144095	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.52	
Hatchery Rainbows													
Arlington	5144087	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	U	0.24	NJ
Chelan	5144081	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.49	U
Columbia Basin	5144083	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.25	NJ
Eells Spring	5144088	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.5	U
Eells Spring-Dup	5144088-Dup	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.49	U
Ford	5144084	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	U	0.49	U
Mossyrock	5144082	0.48	UJ	0.48	U	0.48	U	2.4	U	2.4	U	0.31	NJ
Puyallup	5144089	0.47	UJ	0.47	U	0.47	U	2.3	U	2.3	U	0.47	U
Spokane	5144085	0.49	UJ	0.49	U	0.49	U	2.5	U	2.5	U	0.49	U
Troutlodge	5144090	0.49	UJ	0.49	U	0.49	U	2.4	U	1.2	J	0.44	NJ
Tucannon	5144086	0.49	UJ	0.49	U	0.49	U	2.4	U	2.4	U	0.17	J
Vancouver	5144080	0.5	UJ	0.5	U	0.5	U	2.5	U	2.5	U	0.2	NJ
Vancouver-Dup	5144080-Dup	0.50	UJ	0.50	U	0.50	U	2.5	U	2.5	U	0.17	NJ
Planted Rainbows													
Chapman Lake	5248102	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Donnie Lake	5248103	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Fan Lake	5248104	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Lacamas Lake	5248100	1	UJ	1	UJ	1	U	5	U	4	U	1	U
Lone Lake	5248108	0.98	UJ	0.98	UJ	0.98	U	0.98	U	3.9	U	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	UJ	0.97	UJ	0.97	U	4.8	U	3.9	U	0.97	U
Molson Lake	5248101	0.98	UJ	0.98	UJ	0.98	U	4.9	U	3.9	U	0.98	U
North Lake	5248106	0.97	UJ	0.97	UJ	0.97	U	4.9	U	3.9	U	0.97	U
South Lewis Co. Park Pond	5248105	0.98	UJ	0.96	UJ	0.96	U	2.4	U	0.96	U	0.96	UJ
Summit Lake	5248109	0.96	UJ	0.96	UJ	0.96	U	4.8	U	3.8	U	0.96	U
Summit Lake-Dup	5248109-Dup	1.0	UJ	1.0	UJ	1.0	U	5.0	U	4.0	U	1.0	U
Warden Lake	5248107	0.97	UJ	0.97	UJ	0.97	U	4.9	U	3.9	U	0.97	U

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	cis-Nonachlor		Dacthal (DCPA)		DDMU		Delta-BHC		Dieldrin	
Hatchery Feed											
Arlington	5144102	0.49	U	2.5	UJ	0.69	NJ	0.49	UJ	2.5	UJ
Chelan	5144096	0.5	U	2.5	U	1.5	NJ	0.5	UJ	2.5	U
Columbia Basin	5144098	0.49	U	2.4	UJ	0.73	NJ	0.49	UJ	2.4	UJ
Eells Spring	5144103	0.48	U	2.4	UJ	0.58	NJ	0.48	UJ	2.4	UJ
Ford	5144099	0.5	U	2.5	UJ	0.4	NJ	0.5	UJ	2.5	UJ
Ford-Dup	5144099-Dup	0.50	U	2.5	UJ	0.50	U	0.50	UJ	2.5	UJ
Mossyrock	5144097	0.5	U	2.5	U	1.2	NJ	0.5	UJ	3.8	NJ
Puyallup	5144104	0.5	U	10	UJ	1.1	NJ	0.5	UJ	10	UJ
Puyallup-Dup	5144104-Dup	0.49	U	0.49	UJ	1.0	NJ	0.49	UJ	9.9	UJ
Spokane	5144100	0.5	U	2.5	UJ	0.85	NJ	0.5	UJ	2.5	UJ
Tucannon	5144101	0.5	U	2.5	UJ	3.9	NJ	0.5	UJ	2.5	UJ
Vancouver	5144095	0.5	U	2.5	U	0.6	NJ	0.5	UJ	2.5	U
Hatchery Rainbows											
Arlington	5144087	0.49	U	2.5	U	0.9	NJ	0.49	UJ	0.77	J
Chelan	5144081	0.49	U	2.4	U	0.52	NJ	0.49	UJ	0.58	NJ
Columbia Basin	5144083	0.5	U	2.5	U	0.63	NJ	0.5	UJ	0.5	J
Eells Spring	5144088	0.5	U	2.5	U	0.5	U	0.5	UJ	0.75	J
Eells Spring-Dup	5144088-Dup	0.49	U	2.4	U	0.49	U	0.49	UJ	0.63	NJ
Ford	5144084	0.49	U	2.5	U	0.49	U	0.49	UJ	0.49	UJ
Mossyrock	5144082	0.48	U	2.4	U	0.48	U	0.48	UJ	0.88	NJ
Puyallup	5144089	0.47	U	2.3	U	0.47	U	0.47	UJ	0.47	UJ
Spokane	5144085	0.49	U	2.5	U	0.49	U	0.49	UJ	0.78	J
Troutlodge	5144090	0.49	U	2.4	U	0.49	NJ	0.49	UJ	0.75	J
Tucannon	5144086	0.49	U	2.4	U	0.62		0.49	UJ	0.49	UJ
Vancouver	5144080	0.5	U	2.5	U	0.5	U	0.5	UJ	0.33	NJ
Vancouver-Dup	5144080-Dup	0.50	U	2.5	U	0.50	U	0.50	UJ	0.30	J
Planted Rainbows											
Chapman Lake	5248102	1.0	U	4.0	U	1.0	U	1.0	UJ	0.79	UJ
Donnie Lake	5248103	1.0	U	4.0	U	1.0	U	1.0	UJ	0.79	UJ
Fan Lake	5248104	1.0	U	4.0	U	4.4		1.0	UJ	0.80	UJ
Lacamas Lake	5248100	1.0	U	4.0	U	1.0	U	1.0	UJ	0.80	UJ
Lone Lake	5248108	0.98	U	3.9	U	0.98	U	0.98	UJ	0.78	UJ
Lone Lake-Dup	5248108-Dup	0.97	U	3.9	U	0.97	U	0.97	UJ	0.78	UJ
Molson Lake	5248101	0.98	U	3.9	U	0.98	U	0.98	UJ	0.78	UJ
North Lake	5248106	0.97	U	3.9	U	0.97	U	0.97	UJ	0.55	NJ
South Lewis Co. Park Pond	5248105	0.96	U	0.96	U	0.98	U	0.96	U	0.96	U
Summit Lake	5248109	0.96	U	3.8	U	0.96	U	0.96	UJ	0.77	UJ
Summit Lake-Dup	5248109-Dup	1.0	U	4.0	U	1.0	U	1.0	UJ	0.80	UJ
Warden Lake	5248107	0.97	U	3.9	U	0.97	U	0.97	UJ	0.76	NJ

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Endo-sulfan I		Endo-sulfan II		Endo-sulfan Sulfate		Endrin		Endrin Aldehyde		Endrin Ketone	
Hatchery Feed													
Arlington	5144102	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Chelan	5144096	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Columbia Basin	5144098	2.4	UJ	2.4	UJ	REJ		2.4	UJ	REJ		REJ	
Eells Spring	5144103	2.4	UJ	2.4	UJ	REJ		2.4	UJ	REJ		REJ	
Ford	5144099	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Ford-Dup	5144099-Dup	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Mossyrock	5144097	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Puyallup	5144104	10	UJ	10	UJ	10	UJ	10	UJ	10	UJ	10	UJ
Puyallup-Dup	5144104-Dup	9.9	UJ	9.9	UJ	9.9	UJ	9.9	UJ	9.9	UJ	9.9	UJ
Spokane	5144100	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Tucannon	5144101	2.5	UJ	2.5	UJ	REJ		2.5	UJ	REJ		REJ	
Vancouver	5144095	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Hatchery Rainbows													
Arlington	5144087	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Chelan	5144081	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Columbia Basin	5144083	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Eells Spring	5144088	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Eells Spring-Dup	5144088-Dup	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Ford	5144084	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Mossyrock	5144082	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Puyallup	5144089	2.3	U	2.3	UJ	REJ		2.3	U	REJ		REJ	
Spokane	5144085	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Troutlodge	5144090	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Tucannon	5144086	2.4	U	2.4	UJ	REJ		2.4	U	REJ		REJ	
Vancouver	5144080	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Vancouver-Dup	5144080-Dup	2.5	U	2.5	UJ	REJ		2.5	U	REJ		REJ	
Planted Rainbows													
Chapman Lake	5248102	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Donnie Lake	5248103	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Fan Lake	5248104	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Lacamas Lake	5248100	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Lone Lake	5248108	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
Lone Lake-Dup	5248108-Dup	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
Molson Lake	5248101	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
North Lake	5248106	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U
South Lewis Co. Park Pond	5248105	0.96	U	0.96	U	0.96	UJ	0.96	U	0.96	UJ	0.96	U
Summit Lake	5248109	3.8	U	3.8	U	3.8	UJ	3.8	U	3.8	UJ	3.8	U
Summit Lake-Dup	5248109-Dup	4.0	U	4.0	U	4.0	UJ	4.0	U	4.0	UJ	4.0	U
Warden Lake	5248107	3.9	U	3.9	U	3.9	UJ	3.9	U	3.9	UJ	3.9	U

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Heptachlor		Heptachlor Epoxide		Hexachloro -benzene		Lindane		Methoxy-chlor		Mirex	
Hatchery Feed													
Arlington	5144102	0.49	U	2.5	UJ	0.16	J	0.49	U	2.5	UJ	0.49	UJ
Chelan	5144096	0.5	U	2.5	U	0.31	J	0.5	U	2.5	UJ	0.5	UJ
Columbia Basin	5144098	0.49	U	2.4	UJ	0.49	UJ	0.49	U	2.4	UJ	0.49	UJ
Eells Spring	5144103	0.48	U	2.4	UJ	0.15	J	0.48	U	2.4	UJ	0.48	UJ
Ford	5144099	0.5	U	2.5	UJ	0.16	J	0.5	U	2.5	UJ	0.5	UJ
Ford-Dup	5144099-Dup	0.50	U	2.5	UJ	0.19	J	0.50	U	2.5	UJ	0.50	UJ
Mossyrock	5144097	0.5	U	2.5	U	0.3	J	0.5	U	2.2	J	0.5	UJ
Puyallup	5144104	0.5	U	10	UJ	0.5	UJ	0.5	U	4.9	J	0.5	UJ
Puyallup-Dup	5144104-Dup	0.49	U	9.9	UJ	0.10	J	0.49	U	4.0	J	0.49	UJ
Spokane	5144100	0.5	U	2.5	UJ	0.12	J	0.5	U	2.5	UJ	0.5	UJ
Tucannon	5144101	0.5	U	2.5	UJ	0.16	J	0.5	U	2.5	UJ	0.5	UJ
Vancouver	5144095	0.5	U	2.5	U	0.17	J	0.5	U	2.5	UJ	0.5	UJ
Hatchery Rainbows													
Arlington	5144087	0.49	U	0.49	U	0.23	J	0.49	U	2.5	U	0.49	U
Chelan	5144081	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Columbia Basin	5144083	0.5	U	0.5	U	0.5	U	0.5	U	2.5	U	0.5	U
Eells Spring	5144088	0.5	U	0.5	U	0.5	U	0.5	U	2.5	U	0.5	U
Eells Spring-Dup	5144088-Dup	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Ford	5144084	0.49	U	0.49	U	0.49	U	0.49	U	2.5	U	0.49	U
Mossyrock	5144082	0.48	U	0.48	U	0.48	U	0.48	U	2.4	U	0.48	U
Puyallup	5144089	0.47	U	0.47	U	0.47	U	0.47	U	2.3	U	0.47	U
Spokane	5144085	0.49	U	0.49	U	0.1	J	0.49	U	2.5	U	0.49	U
Troutlodge	5144090	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Tucannon	5144086	0.49	U	0.49	U	0.49	U	0.49	U	2.4	U	0.49	U
Vancouver	5144080	0.5	U	0.5	U	0.3	NJ	0.5	U	2.5	U	0.5	U
Vancouver-Dup	5144080-Dup	0.50	U	0.50	U	0.50	U	0.50	U	2.5	U	0.50	U
Planted Rainbows													
Chapman Lake	5248102	1	U	0.79	UJ	1	U	1	U	4	U	1	U
Donnie Lake	5248103	1	U	0.79	UJ	1	U	1	U	4	U	1	U
Fan Lake	5248104	1	U	0.8	UJ	1	U	1	U	4	U	1	U
Lacamas Lake	5248100	1	U	0.8	UJ	1	U	1	U	4	U	1	U
Lone Lake	5248108	0.98	U	0.78	UJ	0.98	U	0.98	U	3.9	U	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	U	0.78	UJ	0.97	U	0.97	U	3.9	U	0.97	U
Molson Lake	5248101	0.98	U	0.78	UJ	0.98	U	0.98	U	3.9	U	0.98	U
North Lake	5248106	0.97	U	0.78	UJ	0.97	U	0.97	U	3.9	U	0.97	U
South Lewis Co. Park Pond	5248105	0.98	U	0.96	U	0.98	U	0.96	U	0.96	U	0.98	U
Summit Lake	5248109	0.96	U	0.77	UJ	0.69	J	0.96	U	3.8	U	0.96	U
Summit Lake-Dup	5248109-Dup	1.0	U	0.80	UJ	0.76	J	1.0	U	4.0	U	1.0	U
Warden Lake	5248107	0.97	U	0.78	UJ	0.97	U	0.97	U	3.9	U	0.97	U

Table C-5 (cont'd). Complete Results of Chlorinated Pesticide (Excluding DDT Compounds) Analysis of Feed and Fish Tissue Samples (ng/g ww)

	Sample Number	Oxychlordane		Pentachloro-anisole		Toxaphene		trans-Chlordane		trans-Nonachlor	
Hatchery Feed											
Arlington	5144102	0.49	U	0.49	UJ	4.9	U	0.49	U	0.68	
Chelan	5144096	0.5	U	0.5	UJ	5	U	1.1	NJ	1.1	NJ
Columbia Basin	5144098	0.49	U	0.49	UJ	3.9	NJ	0.2	J	0.7	
Eells Spring	5144103	0.48	U	0.48	UJ	4.8	U	0.19	J	0.44	J
Ford	5144099	0.5	U	0.5	UJ	5	U	0.5	U	0.15	J
Ford-Dup	5144099-Dup	0.50	U	0.50	UJ	5.0	U	0.50	U	0.16	J
Mossyrock	5144097	0.5	U	0.15	J	5	U	0.2	NJ	1.2	
Puyallup	5144104	0.5	U	0.5	UJ	3.6	J	0.5	U	0.5	U
Puyallup-Dup	5144104-Dup	0.49	U	0.49	UJ	4.9	U	0.49	U	0.49	U
Spokane	5144100	0.5	U	0.5	UJ	2.6	J	0.5	U	0.8	
Tucannon	5144101	0.5	U	0.11	J	5	U	0.5	U	0.3	J
Vancouver	5144095	0.5	U	0.5	UJ	5	U	0.5	U	0.77	J
Hatchery Rainbows											
Arlington	5144087	0.49	U	0.49	U	4.9	U	0.49	U	0.27	J
Chelan	5144081	0.49	U	0.49	U	4.9	U	0.49	U	0.42	J
Columbia Basin	5144083	0.5	U	0.5	U	5	U	0.5	U	0.45	J
Eells Spring	5144088	0.5	U	0.5	U	5	U	0.5	U	0.2	J
Eells Spring-Dup	5144088-Dup	0.49	U	0.49	U	4.9	U	0.49	U	0.17	J
Ford	5144084	0.49	U	0.49	U	4.9	U	0.49	U	0.49	U
Mossyrock	5144082	0.48	U	0.48	U	4.8	U	0.48	U	0.3	NJ
Puyallup	5144089	0.47	U	0.47	U	4.7	U	0.47	U	0.094	J
Spokane	5144085	0.49	U	0.49	U	4.9	U	0.49	U	0.49	U
Troutlodge	5144090	0.49	U	0.49	U	4.9	U	0.49	U	0.57	J
Tucannon	5144086	0.49	U	0.18	J	4.9	U	0.49	U	0.12	NJ
Vancouver	5144080	0.5	U	0.21	J	5	U	0.5	U	0.3	J
Vancouver-Dup	5144080-Dup	0.50	U	0.50	U	5.0	U	0.50	U	0.20	J
Planted Rainbows											
Chapman Lake	5248102	1	U	1	U	9.9	U	1	U	1	U
Donnie Lake	5248103	1	U	1	U	9.9	U	1	U	1	U
Fan Lake	5248104	1	U	1	U	10	U	1	U	1	U
Lacamas Lake	5248100	1	U	0.47	J	10	U	1	U	1	U
Lone Lake	5248108	0.98	U	0.98	U	0.98	U	0.98	U	0.98	U
Lone Lake-Dup	5248108-Dup	0.97	U	0.97	U	9.7	U	0.97	U	0.97	U
Molson Lake	5248101	0.98	U	0.98	U	9.8	U	0.98	U	0.98	U
North Lake	5248106	0.97	U	0.97	U	9.7	U	0.97	U	0.97	U
South Lewis Co. Park Pond	5248105	0.96	U	0.96	U	9.6	U	0.96	U	0.98	U
Summit Lake	5248109	0.96	U	0.96	U	9.6	U	0.96	U	0.96	U
Summit Lake-Dup	5248109-Dup	1.0	U	1.0	U	10	U	1.0	U	1.0	U
Warden Lake	5248107	0.97	U	0.97	U	9.7	U	0.97	U	0.97	U

Dup – Duplicate
U - Analyte was not detected at or above the reported result
UJ - Analyte was not detected at or above the reported estimated result
J - Analyte was positively identified. The associated numerical result is an estimate
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate
REJ - Data are unusable for all purposes

JANET T. MILLS
ATTORNEY GENERAL

TEL: (207) 626-8800
TTY USERS CALL MAINE RELAY 711

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March 17, 2015

By certified mail

Gina McCarthy, Administrator
U.S. Environmental Protection Agency
Office of the Administrator, Mail Code 1101A
1200 Pennsylvania Avenue, NW
Washington DC 20460

Eric Holder, Attorney General
U.S. Department of Justice
950 Pennsylvania Avenue, NW
Washington DC 20530

Re: **60-Day Notice of Maine's Intent to Sue EPA Over EPA's Action Dated February 2, 2015**

Dear Administrator McCarthy and Attorney General Holder:

By this letter, the State of Maine ("Maine") hereby provides notice of its intent to sue the United States Environmental Protection Agency ("EPA") and/or the United States over EPA's recent action dated February 2, 2015, which, among other things, unlawfully disapproves many of Maine's water quality standards. EPA's action also unlawfully usurps Maine's role in promulgating such standards under the Clean Water Act, and creates a two-tiered water quality regulatory system in violation of the *Maine Indian Land Claims Settlement Act*, 25 U.S.C. § 1721 *et seq.* ("MICSA") and the *Act to Implement the Maine Indian Land Claims Settlement Act,* set forth in Maine law at 30 M.R.S. §§ 6201 *et seq.* ("MIA") (collectively the "Settlement Acts").

In 1980 the Federal Government, Maine, and several Maine Indian Tribes negotiated a comprehensive settlement of Indian land claims to an area consisting of approximately two-thirds of Maine's land mass. Congress approved that settlement in MICSA, which also ratified and confirmed MIA. Together, these Settlement Acts create and define a nationally unique state-tribal relationship, and unambiguously confirm Maine's regulatory authority over Indian lands and natural resources. 30 M.R.S. § 6204; 25 U.S.C. § 1725(b)(1). Under the Settlement Acts, Maine's authority to regulate environmental matters applies uniformly throughout the State, without distinction as to tribal and non-tribal lands and natural resources, and this premise is foundational to the Settlement Acts. When the First Circuit Court of Appeals was called upon to interpret and apply these provisions in a case involving EPA's refusal to recognize Maine's authority to implement the Clean Water Act in Indian territory, the Court held that the Settlement

Acts are "about as explicit ... as is possible" in conferring environmental regulatory authority on the State over Indian lands and natural resources. *Maine v. Johnson*, 498 F.3d 37, 43 (1st Cir. 2007).

Under the Clean Water Act, Maine also has the responsibility to set water quality standards for all of its intrastate waters, including all waters in Maine's Indian lands. In order to ensure that these standards are consistent with the Clean Water Act, Maine periodically submits its new and revised water quality standards to EPA for review and approval. 33 U.S.C. § 1313. For many years, EPA approved Maine's standards without distinction as to Indian lands and waters, as the Clean Water Act and the Settlement Acts each require. However, beginning around 2004, EPA for the first time began inserting limiting language into its approval letters stating that those decisions did "not extend to waters that are within Indian territories or lands." Despite the First Circuit's emphatic ruling against EPA in the *Johnson* case, and despite Maine's repeated requests that EPA approve Maine's water quality standards throughout the State, EPA continued to refuse to approve these standards for waters in Indian lands based on EPA's unfounded jurisdictional concerns. At roughly the same time, and without Maine's knowledge, EPA also provided ongoing assistance to Maine's tribes in pursuit of separate tribal water quality goals – in some cases pursuant to the terms of a confidentiality agreement obligating EPA to use its best efforts to avoid freedom of access disclosures, which ensured that Maine was kept in the dark.

As a consequence, and in order to force EPA to fulfill its mandatory duties under the Clean Water Act, Maine filed a lawsuit against EPA in July 2014 asking for, among other things, a court order requiring EPA to 1) honor Maine's environmental regulatory jurisdiction to set water quality standards for all intrastate waters, including waters in Indian lands, and 2) act on all of Maine's outstanding standards for such Indian waters. During the briefing on Maine's lawsuit, and perhaps in recognition of the weaknesses of EPA's historical jurisdictional position, EPA finally conceded what *Johnson* had already decided years earlier – that Maine does indeed have the environmental regulatory authority under the Settlement Acts to set water quality standards for all Maine waters, including those in Indian lands. Also during briefing, and presumably in order to avoid the embarrassment of a court ordering the relief formally requested by Maine, EPA committed to finally acting on Maine's outstanding water quality standards by the end of January 2015. Based on these developments, and in light of the Settlement Acts and the *Johnson* decision, Maine expected that EPA would finally end its decade-long delay and approve all of Maine's outstanding water quality standards for waters in Indian lands, as they had already been approved for non-tribal waters. As we now know, this was never EPA's intention.

EPA's action, which was by letter dated February 2, 2015, consists of various EPA approvals, disapprovals, and ongoing inaction with respect to Maine's water quality standards. As telegraphed by EPA during its briefing of Maine's July 2014 lawsuit, EPA's action correctly concludes that Maine has statewide environmental regulatory jurisdiction under the Settlement Acts to set water quality standards for all Maine waters, including Maine's waters in Indian lands. However, EPA's action then takes a surprisingly convoluted and unlawful approach in order to reach what appears to be a pre-determined result. This portion of EPA's February 2, 2015 action is carefully built upon a series of unlawful determinations designed to get around Maine's statewide environmental regulatory authority under the Settlement Acts. These unlawful determinations collectively form the shaky underpinnings of the result that EPA appears to have sought all along – the disapproval of all of Maine's human health criteria for Indian waters, even though those same standards were previously approved by EPA for the same waters immediately outside of Maine's tribal areas. The unlawful aspects of EPA's February 2, 2015 action that contribute to EPA's ultimate decision to unlawfully disapprove Maine's human health criteria standards for Indian waters include, without limitation, the following:

1. EPA unlawfully asserts that, prior to its February 2, 2015 action, none of Maine's water quality standards were ever approved for waters in Indian lands, including those standards that were fully approved by EPA before 2004 without any qualification as to their effect on waters in Indian lands;

2. EPA unlawfully asserts that it must make a formal finding of Maine's environmental regulatory jurisdiction over waters in Indian lands before EPA can approve any of Maine's water quality standards for such waters;

3. EPA unlawfully asserts that the Settlement Acts must be construed in favor of the tribes and against Maine on jurisdictional issues;

4. EPA unlawfully asserts that its duties under the Clean Water Act must be informed by EPA's interpretation of the purpose, as opposed to the actual terms, of the Settlement Acts;

5. EPA unlawfully interprets the narrow portions of MIA that permit certain Maine Indian tribes to take fish without restriction within their reservations provided that such fish takings are for individual sustenance only, as more broadly constituting a designated use of "tribal sustenance fishing" with respect to waters in Indian lands;

6. EPA unlawfully interprets Maine's existing designated use of "fishing," as used throughout Maine's water classification system, as meaning "tribal sustenance fishing" with respect to waters in Indian lands;

7. EPA unlawfully usurps Maine's role as a "State" under the Clean Water Act by establishing its own newly-created designated use of "tribal sustenance fishing" in Maine without the benefit of any public input or other required process;

8. EPA unlawfully interprets its newly-created designated use of "tribal sustenance fishing" as requiring heightened human health water quality criteria for Maine waters in Indian lands, which EPA claims will also affect discharges into other surrounding Maine waters;

9. EPA unlawfully analyzes its newly-created designated use of "tribal sustenance fishing" in the context of tribal-only population data as opposed to general Maine population data, which EPA uses for all other Maine waters; and

10. EPA unlawfully disapproves Maine's human health water quality criteria with respect to waters in Indian lands.

In effect, EPA's February 2, 2015 action, by disapproving Maine's otherwise approved human health criteria for only those waters in Maine's Indian lands, creates a two-tiered water regulatory system that elevates the water regulatory goals of Maine's Indian tribes over the rest of Maine in violation of the Clean Water Act, the Settlement Acts, and the *Johnson* decision. To add insult to injury, EPA's February 2, 2015 action also indicates that any heightened standards ultimately implemented in Indian waters will have a regulatory reach beyond Maine's Indian waters to non-tribal waters within the same watersheds. To make matters still worse, EPA does not define the scope of what it considers to be the affected Maine waters in Indian lands. In this way, EPA's February 2, 2015 action, in addition to being unlawful, irresponsibly disrupts settled regulatory expectations and causes uncertainty with respect to Maine's long-established water classification system.

As a consequence, Maine intends to sue EPA in order to challenge EPA's disapproval of Maine's human health water quality criteria with respect to the unspecified waters in Indian lands, as well as other aspects of EPA's February 2, 2015 action, including, without limitation, the unlawful EPA determinations described above. Maine believes that all of its forthcoming legal challenge to EPA's February 2, 2015 action may properly be brought as an appeal of EPA's final February 2, 2015 action pursuant to the Administrative Procedures Act, 5 U.S.C. § 701 *et seq.* ("APA").

However, as an alternative to proceeding with an appeal under the APA, and in an abundance of caution, Maine also intends to assert as part of its forthcoming lawsuit against EPA, mandatory duty claims pursuant to 33 U.S.C. § 1365(a)(2). Pursuant to 33 U.S.C. §§ 1313(a) and 1313(c)(3), EPA has the non-discretionary duty to approve Maine's human health water quality criteria for all of Maine's intrastate waters, including Maine's Indian waters, when, like here, those standards were determined by EPA to meet the requirements of the Clean Water Act 1) without qualification as to their effect in Indian waters, as was the case with all of Maine's standards before 2004; and 2) for the same waters immediately outside of tribal areas. EPA violated this non-discretionary duty by, among other things, 1) attempting to revisit its pre-2004 unqualified approvals of Maine's water quality standards in order to retroactively reconsider their effect in Indian waters; and 2) disapproving Maine's human health water quality criteria with respect to waters in Indian lands after having approved those same standards for waters immediately outside of tribal areas in violation of the Settlement Acts.

With respect to these and any other mandatory duties alleged or determined to be at issue in EPA's February 2, 2015 action, Maine hereby provides this notice of its intent to sue EPA pursuant to 33 U.S.C. § 1365(b)(2). The entities giving this notice are the State of Maine, which is a sovereign state, and the Maine Department of Environmental Protection, which is an agency of the State of Maine, both of which are represented in this matter by Maine's Attorney General, Janet T. Mills. The address and contact information of the Maine Attorney General and the Commissioner of the Maine Department of Environmental Protection are as follows:

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Attorney General
State of Maine
6 State House Station
Augusta, ME 04333-0006
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Fax: (207)287-3145

Patricia W. Aho
Commissioner
Maine Department of Environmental Protection
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Counsel of record in this matter include the following:

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Sincerely,

Janet Mills

Janet T. Mills
Maine Attorney General

Sincerely,

Patricia W Aho

Patricia W. Aho
Maine Department of
Environmental Protection

cc: The Honorable Paul LePage
The Honorable Susan Collins
The Honorable Angus King
The Honorable Bruce Poliquin
The Honorable Chellie Pingree
Kirk Francis, Chief
Frederick Moore, III, Chief
William Nicholas, Sr., Chief
Brenda Commander, Chief
Edward Peter-Paul, Chief
H. Curtis Spalding, EPA Region I Administrator

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF THE
REGIONAL
ADMINISTRATOR

APR 08 2014

Maia Bellon, Director
Department of Ecology
P.O. Box 47600
Olympia, Washington 98504-7600

Dear Director Bellon:

I am writing in regards to your February 14, 2014 letter to Michael Grayum, Executive Director of the Northwest Indian Fisheries Commission and more recent conversations we have had with you and your staff. The U.S. Environmental Protection Agency was strongly encouraged by the Department of Ecology's timeline to adopt human health criteria with a draft rule by the end of March 2014 and a final rule submitted to the EPA by December 31, 2014. Although the EPA was disappointed to hear that Ecology will no longer be able to meet the commitment to issue a draft rule in March, we understand that Ecology remains committed to adopting a final rule by the end of 2014.

The EPA supports Ecology's use of the scientifically sound regional and local fish consumption data available in Washington as it develops its human health criteria. As I have previously stated, the best available science includes evidence of fish consumption rates well above 6.5 grams per day among high fish consumers in Washington, which raises concerns that the human health criteria currently in effect for Clean Water Act purposes in Washington are not sufficiently protective. In addition, as we have also discussed, another important element of a final rule is choosing a cancer risk level that provides risk protection for all Washington citizens, including communities that eat higher amounts of fish. The EPA remains committed to supporting Ecology as it moves forward with a rulemaking based on sound scientific data. This will help facilitate the EPA's review of Ecology's new or revised water quality standards, which requires EPA to ensure that criteria are protective of applicable designated uses and based on a sound scientific rationale, consistent with 40 CFR § 131.11(a).

If Ecology does not follow through with its stated timeframe for final rule adoption, the EPA intends to take the steps necessary to allow for a proposal of federally revised human health criteria for Washington, via amendment of the National Toxics Rule human health criteria for Washington, by May 31, 2015. For the sake of clarity, I note that this letter does not constitute, and is not intended as, an Administrator determination under CWA § 303(c)(4)(B).

The EPA is very appreciative of the challenging work that Ecology has undertaken thus far to adopt human health water quality criteria. I look forward to continuing our partnership to support state adoption of human health criteria to better ensure health protection for all Washington citizens. If you would like to discuss these topics further, please contact me directly or Dan Opalski, our Director for the Office of Water and Watersheds, at (206) 553-1855.

Sincerely,

Dennis J. McLerran
Regional Administrator

cc: Michael Grayum, Executive Director
Northwest Indian Fisheries Commission

Brian Cladoosby, Tribal Chairman
Swinomish Tribe

From:	Opalski, Dan
Sent:	Monday, March 17, 2014 10:35 AM
To:	ksus461@ecy.wa.gov
Subject:	FW: Listing and EJ Discussion

Kelly –

A slight addendum…

Consistent with our previous discussions, I wanted to confirm that Oregon DEQ has relatively recently proposed 303d listings for mercury based upon fish tissue concentrations (not relying on an OHA advisory).

I am understanding that some communication is now out on the end of March date slipping. I'd appreciate a chance to check in soon on this.

Thx. DanO.

From: Opalski, Dan
Sent: Saturday, March 15, 2014 12:26 AM
To: 'Susewind, Kelly (ECY)'
Subject: RE: Listing and EJ Discussion

Kelly –
Sorry I didn't get more back to you on the listing sooner. Here is what was reported to me:

DEQ has only listed impaired waters for fish tissue contamination when the Oregon Health Authority (OHA, formerly DoH) has issued fish advisories, i.e., DEQ has not done any independent review of fish tissue data for listing purposes, even for mercury, which is shown as a fish tissue criterion in their WQS.

OHA calculates their fish consumption advisories for a maximum of four, eight-ounce, meals per month which translates into 30.25 grams of fish per day, much lower than the 175 grams per day upon which the Oregon toxics criteria for human health are based**.**

So best I can tell this tracks pretty well with your understanding. However, I would say that because OHA's advisories, which trigger 303d listings, are based on fish tissue data, it is accurate to say that these listings are based upon tissue data. But it remains notable that DEQ does not independently review the tissue data for these purposes, nor does there appear to be any explicit translation of the tissue concentrations to their water column standards, and, finally, the fish consumption rate used by OHA is quite a ways off from the rate underlying their standards.

DanO.

From: Susewind, Kelly (ECY) [mailto:KSUS461@ECY.WA.GOV]
Sent: Tuesday, March 11, 2014 1:41 PM
To: Opalski, Dan
Cc: Bellon, Maia (ECY)
Subject: Listing and EJ Discussion

Hey Dan

Did a little looking on my own following today's discussion.

Listing:

The 2012 Oregon assessment states that:

- New and revised human health criteria apply to pollutants in the water column except for methyl mercury…..
- Category 5 listings require two or more samples not meeting the most stringent applicable criterion of a specific substance in the water, or
- A fish consumption advisory issued for a specific water body based on pollutants in fish tissue

We acknowledged that Oregon lists based on fish advisories, but that is far different than saying they do listing based on tissue. A quick perusal of Oregon's fish advisories only shows a few advisories generally based on mercury and PCBs.

We've also been contacted by DEQ staff regarding our listing policy because they are getting pressure to list based on tissue "like Washington."

Is there more information that I am missing?

EJ

I have a copy of the document: "EPA Policy on Environmental Justice for Tribes and Indigenous Peoples." It's a pre-decisional working draft dated November 14,2012.

Is that the document Dennis referred to?

The only real pertinent language I could find in that document was:

4. THE EPA ASSESSES THE POTENTIAL FOR DISPROPORTIONATELY HIGH AND ADVERSE HUMAN HEALTH OR ENVIRONMENTAL EFFECTS ON TRIBES OR INDIGENOUS COMMUNITIES.
a. The EPA considers both quantitative and qualitative information about the potential disproportionately high and adverse human health or environmental effects pertaining to, and/or provided by, tribes or indigenous stakeholders.
b. The EPA works to understand Traditional Ecological Knowledge and its role in protecting public health and the environment, and to understand community definitions of health and the environment.

As we discussed, tribal members, and anyone eating high amounts of fish, are at higher risk. They are at a risk exactly proportionate to the consumption rate and will be at the same ratio (proportion) regardless of where the rule lands. Interpreting this section of the policy to mean that they can't be at a higher risk would frustrate the entire system the HHC equations are based on and make it impossible to comply.

Is there a statement somewhere that one in a million risk rate is the baseline to establish environmental justice? Or that a higher risk rate is inherent in the approach, but establishes some criteria to define "disproportionately high and adverse effects?

I’m not trying to be argumentative, but we are getting to the end of a very contentious process, and I really need to understand these concepts in order to advise decision makers.

Thanks

Kelly

NACWA
A Clear Commitment to America's Waters

May 13, 2015

Dennis McLerran
Administrator
U.S. Environmental Protection Agency (EPA) Region 10
1200 Sixth Avenue; Mail Code: RA-210
Seattle, WA 98101
Via Electronic Mail: mclerran.dennis@epa.gov

Dear Administrator McLerran,

The National Association of Clean Water Agencies (NACWA) is writing to express its concerns with recent actions by the U.S. Environmental Protection Agency's (EPA) Region 10 office to influence the outcome of the Washington Department of Ecology's proposed human health criteria and implementation provisions, issued on January 12, 2015. NACWA represents the interests of more than 280 public wastewater treatment agencies across the country, including 10 in Washington.

The outcome of Washington's rulemaking process will have significant and long-term impacts for the clean water community and other dischargers across Washington and throughout Region 10. In addition, the Region's actions reflect a broader, nationally relevant concern for NACWA and its members over the increasingly coercive approach EPA uses during the state water quality standards development process.

At issue in Washington is the state's ability, as authorized under the Clean Water Act (CWA), to develop what it believes is a sound and balanced approach, which has been carefully evaluated and vetted with the state's stakeholders, to dealing with toxic pollutants. In response to Washington's January proposed rule, your office issued a strongly worded letter, dated March 23, 2015, outlining how the state's package does not "fully reflect" EPA policies, guidance and legal requirements. While we understand that it is standard practice for EPA to comment on proposed state water quality standards rules, the tone of this letter suggests that Washington has no other choice but to make their rule consistent not only with existing federal criteria and guidance, but also with EPA's policy preferences, as well as draft documents still undergoing revision at the federal level. EPA also does not indicate where the state failed to use the best scientific data to defend its proposal, choosing instead to roundly condemn the entire approach.

Section 303 of the Clean Water Act (CWA) outlines the authority and responsibility of the states to develop and regularly review and revise water quality standards. The responsibility of EPA is to review those standards once they are submitted to the Agency. EPA's regulations at 40 CFR 131.4 set forth the state requirements for standards development and 40 CFR 131.5 outlines EPA's authority to review those standards to determine whether the state has adopted uses "consistent with the requirements" of the CWA and criteria that "protect the designated water uses". However, the language in the CWA and the implementing regulations was not intended to give EPA authority to disapprove standards because the state's science and policy decisions are not identical to the Agency's preference, policies and guidance. Furthermore, the regulations provide no direction on how the Agency engages with the state during draft rule development prior to state final rule submittal. Instead, 40 CFR 131.21 outlines the process for EPA review once the state makes its formal submittal to the Agency and 131.22 lays out the process for EPA to develop standards for the state if the state fails to do so.

In practice, however, EPA routinely engages with the states before the formal submittal and significantly influences the content of state proposals, seeking to ensure full approval and obviate the need for formal EPA disapproval or promulgation of federal standards. Whether due to a lack of resources or political will, states often succumb to this "informal" pressure from EPA and make revisions to their rules to address EPA's preferences to ensure approval even if these changes may be counter to the state's policy, science, and risk choice position.

Even more concerning to NACWA is that, by coercing the state to promulgate standards that conform to EPA's approach, EPA is essentially eliminating judicial review. NACWA is concerned that this behavior by EPA violates the spirit and letter of the Administrative Procedures Act, and is contrary to the Agency's stated commitment to work more cooperatively and transparently with states and the regulated community.

This process of influence by EPA has reached concerning new levels with the development, review, and approval of Oregon's human health criteria and EPA's March 23, 2015 comments on the Washington proposal. In both cases EPA Region 10 has employed coercive pressure to ensure that the states only submit approvable programs that are effectively identical to federal preferences, guidelines, and policies. In the case of Washington's proposed rule, which in fact was consistent with the range of values and approaches included in existing federal guidance, EPA appears to ignore the flexibility afforded to states in its own guidance by insisting that the state's program conform to EPA's preferred approach. These tactics are inconsistent with the CWA's cooperative federalism foundation and history that provides the states the responsibility for developing and approving water quality standards. EPA has long used these strategies at the permitting stage – issuing 'interim objections' to signal to the state that changes must be made – to avoid EPA overfilling on permits and facing direct legal challenge to its policies. EPA's decision to use such tactics in its role in helping states develop state water quality standards is cause for great concern among NACWA's members.

It is reasonable to expect EPA to engage with the state during its standards development process and to provide input and guidance to assist the state in developing robust science, policy and risk decisions at the state level that satisfy the requirements of the CWA. But your office's March 23 letter to Washington is framed as a formal objection, rather than a discussion of the policy and science options and choices available to the state. State standards must, by law and regulation, reflect the best available science, but the standards development process also incorporates numerous state policy, science, and risk decisions including determining the level of acceptable risk. In performing its CWA-required review function – whether during the rule development process or during its official standards review – EPA must not overstep its authority and substitute its policy preferences over legitimate state policy, science, and risk decisions that are "consistent with the applicable requirements" of the CWA. The structure established by the CWA – where EPA provides criteria recommendations and guidance and the states develop water quality standards based on that information as well as state policy and risk decisions (where a range of acceptable CWA options exist) – must be preserved to ensure that federal preference and the criteria recommendations do not become de facto regulations.

In developing water quality criteria recommendations at the federal level EPA consistently points to its duty to develop scientifically-sound criteria that, by CWA mandate, are based solely on scientific and risk policy factors and do not account for cost impacts on the regulated community or other state-specific factors. In its interactions with the regulated community EPA asserts that its criteria recommendations are not directly enforceable and therefore have no cost impact. EPA's actions in Region 10 and elsewhere across the country – essentially requiring that state standards be identical to federal preference, criteria, and guidance – have the effect of applying those federal criteria recommendations, preference, and guidance as the law of the land.

In the case of Washington, the state must be allowed to exercise its CWA-delegated responsibilities in standards development without undue influence from EPA. If the state chooses to submit a package that EPA believes it cannot approve it must be allowed to do so. If EPA dislikes the standards submitted by the state the Agency can follow the appropriate procedures to disapprove the state standards and/or promulgate federal standards and then be prepared to defend either of those actions in federal court if any party chooses to challenge them.

Thank you for considering NACWA's concerns.

Sincerely,

Ken Kirk
Executive Director

cc:
Gina McCarthy, EPA
Ken Kopocis, EPA
Maia Bellon, Washington Department of Ecology
Robert Duff, Senior Policy Advisor, Governor Inslee's Office
Daniel Opalski, Director, Office of Water and Watersheds, EPA Region 10

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF
WATER AND WATERSHEDS

May 29, 2015

Don Essig
Idaho Department of Environmental Quality
1410 N. Hilton
Boise, Idaho 83706

RE: EPA comments on Idaho's Proposed Policy Decisions Related to Human Health Criteria for Toxics

Dear Don:

The EPA appreciates the opportunity to provide comments to the Idaho Department of Environmental Quality (DEQ) on the policy recommendations that DEQ will use to inform revisions to Idaho's human health ambient water quality criteria. In particular, the EPA appreciated DEQ's presentation at the April 21, 2015 negotiated rulemaking meeting, where you discussed these proposed policy decisions as well as several options DEQ is still contemplating. The EPA supports DEQ's ongoing efforts and recognizes the challenging work that DEQ has undertaken thus far in consideration of revisions to Idaho's human health criteria.

The enclosed detailed comments reflect many of the issues the EPA identified in our previous letters on each of the policy discussion papers developed by DEQ over the past year. Given that DEQ has further considered these important policy decisions and is now providing a recommended position, or in some cases consideration of several options, the EPA is providing more specific comments for your consideration. Please note that, in some instances, the EPA is providing more general comments at this time and is requesting additional information to better understand DEQ's proposal before providing more detailed comments.

In general, the EPA is encouraged that several of DEQ's proposed policy decisions reflect recommendations consistent with EPA's 2000 Human Health Methodology and more recent EPA policy documents. At the same time, the EPA is concerned about some of DEQ's proposed policy decisions and we have described those concerns and provide suggestions for addressing them in the enclosed comments. In addition, it is important to note some overarching themes that the EPA will consider when evaluating protective human health criteria:

- Tribal Reserved Rights: In addition to complying with the CWA and EPA's regulations, when setting criteria to adequately protect Idaho's designated uses, it is necessary to consider tribal reserved rights, including tribal treaty-reserved fishing rights (executive orders and federal statutes could also apply).

- Best available science: The EPA commends DEQ for its collaborative work to develop state-specific fish consumption survey data and tribal fish consumption survey data for

Idaho. The EPA is encouraged that Idaho is considering the tribal survey data along with the state-wide survey data, and appreciates Idaho's efforts to coordinate and collaborate with EPA and the tribes. Along with using local and regional FCR data, DEQ should use the best available science to select all the input parameters needed to derive its human health criteria. In many instances, the EPA's 2014 draft 304(a) recommended criteria represents the best available science. If the EPA's criteria recommendations become final before Idaho adopts a final human health criteria rule, the EPA recommends that the state use that information instead of the 2014 draft criteria information.

- Protection of Downstream Waters: It is important for Idaho to demonstrate how its revised human health water quality criteria will provide for the attainment and maintenance of the water quality of downstream waters, consistent with EPA's regulations at 40 CFR 131.10(b).

The EPA appreciates DEQ's efforts to revise Idaho's human health criteria for toxic pollutants and looks forward to continued conversations regarding these important decisions. In addition, EPA remains committed to supporting DEQ's work and is available to provide technical assistance as you develop a proposed rule. If you have any questions or would like to discuss these comments further, please contact me at (206) 553-1834 or Lon Kissinger at (206) 553-2115.

Sincerely,

Lisa Macchio
Water Quality Standards Coordinator

Enclosure

EPA's Comments on Idaho Department of Environmental Quality's (DEQ) Policy Recommendations Related to Revisions to Idaho's Human Health Criteria for Toxics
May 29, 2015

Derivation of FCR using consumers only

EPA supports DEQ's proposed policy decision to base its fish consumption rate (FCR) on consumers only and to exclude non-consumers in the derivation of a FCR for Idaho. This is consistent with EPA's recommendation to use consumer only data when available. In particular, EPA supports DEQ deriving FCRs from 24-hour recall survey results using a statistical modeling approach developed by the National Cancer Institute, the NCI method, to develop defensible consumer only FCRs for Idaho. This is consistent with EPA's approach to develop the FCR used to compute national human health ambient water quality criteria. If such modeling approaches are not used to derive FCRs from short term dietary recall data, biased FCRs would result.

Evaluate range of exposure/risk in both general and higher consuming subpopulations

EPA supports DEQ's proposed policy decision to evaluate the range of exposure/risk in both the general population and higher consuming populations. Human health criteria are designed to minimize the risk of adverse cancer and non-cancer effects occurring from lifetime exposure to pollutants through the ingestion of drinking water and consumption of fish/shellfish. When choosing exposure factor values to include in the derivation of a criterion for a given pollutant, EPA recommends considering values that are relevant to populations that are most susceptible to that pollutant. For example, highly exposed populations should be considered when setting criteria. To that end, EPA's methodology notes a preference for the use of local data to calculate human health criteria (e.g., locally derived FCRs, drinking water intake rates and body weights, and waterbody-specific bioaccumulation rates), over national default values, to better represent local conditions.[1]

Deterministic or Probabilistic

EPA needs additional detailed information to evaluate whether DEQ's proposal to employ probabilistic risk assessment (PRA) to develop human health criteria is scientifically defensible and protective. EPA recommends that DEQ present a draft proposal at the next rulemaking meeting that clearly defines desired outcomes for the PRA approach and how they will be met. For example, the EPA generally recommends that variables describing toxicity should not be distributed, as insufficient data generally exist to develop distributions for toxicity variables, and toxicity metrics are developed by consensus at the national level. Therefore, it is important for DEQ to clearly explain why it is choosing the PRA approach and how it will address the

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[1] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA-822-B-00-004. http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.

following types of issues, as these would be considerations in EPA's assessment of a PRA approach. EPA is available to provide more detailed comments once DEQ provides additional information on its proposal.

(1) The purpose and scope of the analysis should be clearly articulated. This should include derivation of human health criteria that are protective of higher fish consuming populations. The risk management decisions related to interpretation of output exposure or risk distributions should be specified (e.g., human health criteria shall be derived such that the 95th percentile of the risk distribution will equal 1 in 1,000,000).

(2) The methods used for the analysis (including all models and/or software used, all data upon which the assessment is based, and all assumptions that have a significant impact upon the results, for example correlation of variables) should be well documented, easily located, and reproducible. This documentation should include a discussion of the degree to which the data used are representative of the population under study, and possible sources of bias and uncertainty in both the input and output distributions. In particular, variability (the range of values a variable might assume) should be distinguished from uncertainty (lack of knowledge about a variable).

(3) DEQ also should calculate human health criteria using deterministic (e.g., point estimate) methods. Providing these values will allow comparisons between the probabilistic and deterministic approaches for developing human health criteria. When comparisons are made, it is important to explain the similarities and differences in the underlying data, assumptions, and models as well as the strengths and weaknesses of differing assumptions.

Exclusion of market fish

EPA is concerned with DEQ's proposed policy decision to exclude market fish from the FCR that it will use to derive revised human health criteria. As EPA stated in our June 2014 comment letter on this topic, a FCR that reflects the amount of fish Idahoans consume should not just include fish consumed from local waters. Therefore, EPA recommends that DEQ include market fish in the FCR used to derive human health criteria. This approach is consistent with a national water quality program principle that every state does its share to protect people who consume fish and shellfish that originate from multiple jurisdictions. In addition, the goal of water quality criteria for human health is to protect people from exposure to pollutants through fish and water over a lifetime, and the goal of a state's designated use should be that the waters are safe to fish in the context of the total consumption pattern of its residents.

Exclusion of anadromous fish

EPA is concerned with DEQ's proposed policy decision to exclude anadromous fish from the FCR, and recommends that DEQ include anadromous fish in the FCR used to derive HHC.

While EPA's 304(a) recommended criteria account for exposures to non-carcinogens and nonlinear carcinogens in anadromous fish using the RSC, EPA supports and recommends that states include anadromous fish in the FCR when there are available, scientifically sound regional and/or local data that suggest high consumption of anadromous fish. For example, because of the uncertainties in the sources of salmon contaminant body burdens (discussed in more detail below), the large amounts of salmon consumed by Native Americans, and the fact that market basket preferences of individuals may vary,[2] Oregon and Washington chose to include salmon in the FCR used to derive human health criteria. EPA approved Oregon's human health criteria in 2011. Similarly, EPA supported Washington's decision to derive human health criteria using a FCR that included anadromous fish consumption.[3] In light of this and the fact that Washington and Oregon are downstream from Idaho, implementation of human health water quality criteria throughout the Pacific Northwest would be facilitated by uniformly including salmon in the FCR for Idaho.

EPA also is concerned with DEQ's proposed policy decision to account for anadromous fish exposures using the RSC instead of the FCR because adjusting the RSC to reflect exposures to contaminants in anadromous fish is difficult to accomplish in a data driven way.

Because of uncertainty regarding where and how marine species acquire the bulk of their contaminant body burden, EPA also recommends that DEQ consider scientific studies in addition to the Hope 2012 study. For example, EPA believes that further characterization of salmon ocean habitat is warranted and some adult salmon may feed in, and acquire contaminants from, near coastal waters that are under the jurisdiction of the CWA. Also, the Hope paper's conclusions are limited by its focus on PCBs and not other toxics. Central to the modeling, is the assumption that contaminant uptake occurs largely through diet. While this is true for PCBs, depending on a chemical's lipophilicity, direct uptake from water may be a significant contributor to an organism's contaminant body burden (Qiao et al. 2001). In the case of adult salmon, direct uptake of chemicals from water is a possibility during their return migration through inland waters. The Hope paper also does not discuss different patterns of contaminant uptake associated with the complex life histories of other salmonids. In addition, the Hope paper

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[2] For example, a study on fish consumption habits of Asian Pacific Islanders demonstrated FCRs similar to Puget Sound Tribes but indicated that certain ethnic groups preferred to consume non-anadromous species.
Sechena R, Nakano C, Shiquan L, Polissar N, Lorenzana R, Truong S, Fenske R. 1999. Asian and Pacific Islander Seafood Consumption Study (EPA 910/R-99-003)
http://www.epa.gov/r10earth/pdf/asian_pacific_islander_seafood_consumption_1999.pdf

[3] Washington proposed draft HHC in January 2015 for public comment. The comment period closed on March 23, 2015, and Washington has not yet adopted final HHC and submitted them to EPA for CWA action. Therefore, EPA has not yet reviewed or acted upon Washington's HHC.

references EPA's policy of excluding salmon from the FCR used to assess site-specific health risks at Superfund sites in Puget Sound. However, it is important to note that EPA's Superfund policy generally applies to risk assessments for bioaccumulative pollutants in discrete geographic areas where cleanup is to occur, which does not raise the same scope of considerations or potential impacts as the development of state-wide water quality criteria. In summary, EPA recommends that DEQ consider that returning adult salmon may acquire contaminants directly from fresh water (Qiao et al. 2001).[4] DEQ may wish to consult with established experts (such as Weitkamp)[5] who have documented that certain adult salmon species from Idaho waters may reside in coastal waters of the U.S. (i.e., fall run chinook and coho salmon).

Risk Level

EPA supports DEQ's proposed policy decision to retain its 10^{-6} risk level to protect the populations in Idaho. However, EPA is concerned with DEQ's decision to protect high consuming populations, including tribes, at a 10^{-6} cancer risk level using the mean consumption rate of consumer only data. Instead, EPA recommends that DEQ consider the approach used by Oregon to protect high consuming populations at a 10^{-6} cancer risk level using the 95th percentile of consumer only data. This approach is more consistent with EPA's general recommendation that states and authorized tribes select a FCR that reflects consumption that is not suppressed when sufficient data are available.[6] Deriving criteria using an unsuppressed FCR furthers the restoration goals of the CWA, and ensures protection of human health as pollutant levels decrease, fish habitats are restored, and fish availability increases. Further, in cases where tribal treaty or other reserved fishing rights apply, selecting a FCR that reflects unsuppressed fish consumption may be necessary in order to satisfy such rights. Government-to-government consultation with affected tribes is important in deciding which fish consumption data should be used.

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[4] Qiao P, Gobas FAPC, Farrell AP. Relative Contributions of Aqueous and Dietary Uptake of Hydrophobic Chemicals to the Body Burden in Juvenile Rainbow Trout http://www.researchgate.net/profile/Frank_Gobas2/publication/12373146_Relative_contributions_of_aqueous_and_dietary_uptake_of_hydrophobic_chemicals_to_the_body_burden_in_juvenile_rainbow_trout/links/0fcfd5112a3b20b012000000.pdf

[5] http://www.nwfsc.noaa.gov/contact/display_staffprofile.cfm?staffid=189

[6] EPA. January 2013. *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions*. http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/upload/hhfaqs.pdf.

Relative Source Contribution (RSC)

EPA recommends that DEQ provide additional detailed information regarding its proposal to adjust the RSC based on changes in FCR, bioaccumulation, and water-plus-organism vs. organism only human health criteria. As previously noted, EPA is concerned because adjusting the RSC is difficult to accomplish in a data driven way. It is true that the relative dose fractions contributed by fish and water exposures relative to all other routes of exposure would be affected by consideration of the above factors. However, exposures not associated with fish and water ingestion are also chemical-specific and have not been presented in such a way as to support data driven modification of the RSC. To support this approach, DEQ would need to provide chemical-specific alternate route exposure to modify the RSC in a data driven way that is scientifically sound. DEQ also should consider the recommended adjusted RSCs that will be described in EPA's final updated 304(a) human health water quality criteria recommendations.

Bioaccumulation Factors (BAFs)

The EPA supports DEQ's proposed policy decision to use BAFs. This approach is consistent with the EPA's 2000 Human Health Methodology, which recommends use of BAFs when available, and reflects the latest scientific information on bioaccumulation. Unlike bioconcentration factors that only account for uptake from the water column, BAF's account for other exposure pathways. As DEQ is aware, the EPA is in the process of updating its national 304(a) recommended water quality criteria for the protection of human health and the proposed criteria updates include the use of BAFs specific to different trophic levels. During DEQ's presentation on April 21, 2015, DEQ recommended consideration of trophic level BAFs; more specifically, a trophic weighted BAF value based on information from DEQ's fish consumption survey. There are a number of issues DEQ may need to consider when weighting trophic level BAFs. For example, the data from a general population survey should be sufficiently robust to determine fish consumption by trophic level, and also representative of higher consumers, who may be consuming greater amounts of higher trophic level fish. For example, Columbia River Intertribal Fish Commission (CRITFC) survey respondents consume a much higher fraction of trophic level 4 fish than the general U.S. population (CRITFC 1994).[7] EPA is encouraged by DEQ's recommendation to derive criteria using BAFs and looks forward to reviewing additional details in order to evaluate DEQ's selected approach.

Body Weight and Drinking Water Intake Assumptions

EPA supports DEQ's proposed policy decision to apply a three step preference to estimate body weight assumptions consistent with EPA's guidance [i.e., 1) data from Idaho's fish consumption surveys, 2) data from the Idaho Department of Health and Welfare BRF State Survey, 3) EPA's 2011 Exposure Factors Handbook/NHANES]. If the approach to use local or regional data is not

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[7] Columbia River Intertribal Fish Commission. 1994. A Fish Consumption Survey Of The Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin. Technical Report 94-3 https://www.deq.idaho.gov/media/895853-fish-consumption-survey-1994.pdf

sufficiently reliable, EPA encourages DEQ to consider the new information used to update EPA's national criteria recommendations including EPA's 2011 Exposure Factors Handbook. For example, EPA derived its 2014 draft 304(a) recommendations using an updated body weight assumption of 80 kg, the national mean based on a survey of the U.S. population and described in EPA's 2011 Exposure Factors Handbook.

EPA supports DEQ's proposed policy decision to use a drinking water intake assumption of 2.4 L/day. EPA derived its 2014 draft 304(a) recommendations using a drinking water intake rate of 3 L/day. This rate represented a consumer-only estimate of combined direct and indirect water ingestion for all sources of water at the 90th percentile for adults ages 21 and older. In response to public comments that focused on the most current national drinking water data, EPA intends to finalize the updated 304(a) criteria using a drinking water intake rate of 2.4 L/day, which represents the per capita estimate of combined direct and indirect community water ingestion at the 90th percentile for adults ages 21 and older.

80	Plain Text 6	**State Primacy for Adoption of WQ Standards**	08	0054	0054.12	08	0054	As you are aware, the EPA has initiated a federal rulemaking process to amend Washington's existing human health criteria in the National Toxics Rule, which were last updated in 1992. The EPA is encouraged that Ecology proposed its own rule and we hope that Ecology will finalize a scientifically defensible rule that protects the health of Washington's citizens. As stated in Regional Administrator Dennis McLerran's December 18, 2014 letter to Director Maia Bellon, despite our having initiated a federal rulemaking, if Washington submits a final rule to the EPA for Clean Water Act review and action prior to our completion of a federal proposal, the EPA will fulfill its Clean Water Act duty to review and act on the state's submittal.	Comment noted.
81	0024-3	**State Primacy for Adoption of WQ Standards**	08	0024-3	0024.23	08	0024	In some instances where Ecology rejects EPA's EFH recommendations, Ecology asserts that states make the first effort at developing water quality standards. See, e.g., Overview at 15-17, 23, 31 ("risk management decision made by states"). While this is true, it does not give a state a free hand to disregard the requirements of the Clean Water Act and best science nor disregard the needs of the community. Further, Ecology's explanations in its Overview document are often garbled and unclear regarding what precisely Ecology is doing and why. See, e.g., Overview at 30-32 (presenting legally and scientifically flawed analysis of bioaccumulation vs. bioconcentration).	Ecology disagrees with the contention that the discussion of BCF and BAF are flawed.
82	0029c	**State Primacy for Adoption of WQ Standards**	08	0029c	0029c.16	08	0029	Comment No. 10: There is no scientific or public health policy basis for criteria based on a FCR of 175 g/day and risk policy of one in one million. Ecology is required to develop criteria that are scientifically defensible and based on the agency determinations for risk management – decisions under the Clean Water Act that are the prerogative of the state, not EPA. There has been a persistent misunderstanding or misrepresentation that a one in one million risk policy is a threshold or baseline for the protection of human health. This is exemplified by the statements from the EPA Region 10 Administrator that "everyone should be protected to the same level."[101] This statement ignores the fact there is no reasonable basis to protect everyone to same level – across any population there will always be a range of exposures and therefore a range of risk. There is also no basis in the long history of the regulatory management of cancer risk by EPA and the FDA that supports the contention that all fish consumers in Washington must be protected to a risk level of one in one million. The real question posed by demands to regulate the highest Tribal consumption rates at one in one million is whether Ecology should adopt a more stringent risk policy than required under the Clean Water Act and EPA guidance. If Ecology considered this demand, the effective risk policy would be in the range from one in one hundred million or one in ten million to one in one million. On this critical issue – whether Washington needs to adopt a more conservative range for its risk policy than EPA guidance – the Northwest Tribes and EPA Region 10 have been silent. Ecology presented the risk policy issue to EPA Region 10 on numerous occasions over the past two years. The origins and basis for the one in one million risk policy were the	Ecology has stated on numerous occasions that the FCR and the RL are risk management decisions. This is clear in EPA 2000. Ecology has not found a specific public health or scientific basis for the mandatory use of a risk level of one in one million or for a FCR of 175 g/day, although the state's decision to use 175 for the final criteria was based on consideration of many factors, with a main goal of protection of the public health of all people who consume fish and/or shellfish from Washington waters.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
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OFFICE OF
WATER AND WATERSHEDS

November 6, 2015

Don Essig
Idaho Department of Environmental Quality
1410 N. Hilton
Boise, Idaho 83706

RE: EPA Comments on Idaho's Revised Human Health Toxic Criteria, Proposed Rule, Docket No. 58-0102-1201

Dear Don:

The EPA appreciates the opportunity to provide comments to the Idaho Department of Environmental Quality (DEQ) on its proposed updated human health ambient water quality criteria, which were published for public comment on October 7, 2015. The enclosed comments reflect many of the issues the EPA identified in our previous comment letters to DEQ and, in some instances, provide additional clarification. The EPA continues to recognize the challenging work undertaken thus far in revising Idaho's human health criteria.

The EPA commends Idaho for using state of the art survey methodology to characterize current fish consumption rates for the general population and anglers in Idaho. Given the regulatory importance of these survey results, EPA strongly recommended that DEQ have the results peer reviewed by individuals with the necessary expertise, and address peer review concerns prior to fully incorporating this work into a regulatory context. EPA understands that DEQ has decided to conduct a peer review and is supportive of that effort.

The EPA also supports DEQ's decision to incorporate many of the EPA's latest scientific and policy recommendations consistent with the EPA's 2015 updates to its 304(a) national human health criteria recommendations. At the same time, the EPA remains concerned about some of DEQ's proposed decisions in deriving human health criteria. In particular, the EPA is concerned with DEQ's approach to calculating its fish consumption rate because DEQ has not adequately demonstrated how criteria derived using the proposed fish consumption rate would be scientifically defensible, would be protective of designated uses in Idaho (as informed by reserved rights of tribal consumers), and would ensure the attainment and maintenance of water quality standards in downstream waters in Oregon and Washington.

The EPA is available to further discuss our comments and we remain committed to providing assistance as DEQ develops the final rule. If you have any questions, please feel free to contact me or Lisa Macchio at (206) 553-1834.

Sincerely,

Angela Chung

Angela Chung, Manager
Water Quality Standards Unit

Enclosures

EPA Comments on Idaho Department of Environmental Quality's (DEQ) October 7, 2015 Proposed Rule Revisions to Idaho's Human Health Criteria for Toxics
Docket No. 58-0102-1201
November 6, 2015

The Idaho Department of Environmental Quality (DEQ) provided proposed new and revised surface water quality standards (WQS) found at IDAPA 58-0102-1201 to the public for review and comment on October 7, 2015.[1] The EPA reviewed the state's proposed rule and associated documents and provides the following comments for DEQ's consideration. The comments are organized as follows:

A. Fish Consumption Rate (FCR)
    1. DEQ's Fish Consumption Survey Analysis and Results
    2. Exclusion of Market Fish (Other than Rainbow Trout)
    3. Exclusion of Anadromous Fish
    4. Tribal Reserved Fishing Rights
B. Other Input Variables
    1. Cancer Risk Level
    2. Relative Source Contribution (RSC)
    3. Bioaccumulation Factor (BAF)
    4. Body Weight and Drinking Water Intake
    5. Toxicity Factors: Reference Doses (RfDs) and Cancer Slope Factors (CSFs)
C. Pollutant Scope
D. Use of Probabilistic Risk Assessment
E. Downstream Waters Protection
F. Specific Comments on DEQ's Proposed Rule Language

Please note that the EPA's positions described in the comments below, regarding the state's proposed WQS, are preliminary in nature and do not constitute an approval or disapproval by the EPA under the Clean Water Act (CWA) Section 303(c). Approval and/or disapproval decisions will be made by the EPA following adoption of the new and revised standards by the state of Idaho and submittal of revisions to the EPA. In addition, the EPA's comments do not constitute, and are not intended to be, an Administrator determination under CWA Section 303(c)(4)(B).

A. <u>Fish Consumption Rate (FCR)</u>

As the EPA has long acknowledged, it remains our practice to encourage states and authorized tribes to make appropriate adjustments to reflect local conditions affecting fish consumption.[2] Thus far, Idaho has not yet presented the EPA with a rationale that is adequate to establish that Idaho's proposed FCR is appropriate and will lead to criteria sufficient to protect Idaho's CWA Section 101(a)(2) uses (e.g., Primary and Secondary Contact Recreation, IDAPA 58.01.02.100.02(a)&(b)), as required under 40 CFR 131.11. While reserving final judgment on

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[1] DEQ, *Water Quality Docket No. 58-0102-1201 - Proposed Rule*, http://www.deq.idaho.gov/58-0102-1201.

[2] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA-822-B-00-004. http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.

this issue until we receive Idaho's final submission and supporting rationale, we emphasize that Idaho's approach currently appears to be inconsistent with the CWA and its implementing regulations. We outline our concerns in more detail below, and recommend that Idaho modify its approach consistent with the comments below.

1. DEQ's Fish Consumption Survey Analysis and Results

The EPA contracted with Westat, a well-known statistical consulting firm, to review DEQ's fish consumption survey results as reported in the Fish Consumption Survey report prepared by Northwest Research Group.[3] Westat identified a number of issues that DEQ should review (see attached memoranda from Westat), and EPA is available to discuss this information further. For example, Westat determined that the frequency of fish consumption declined over the seven day recall period. DEQ did not account for this trend, which could result in an underestimation of fish consumption. As previously noted, it is important for DEQ's fish consumption survey results to be peer reviewed by individuals with the necessary expertise. The Westat review provides information that DEQ should consider along with the results of its peer review. In particular, it is important that the National Cancer Institute (NCI) analysis, which involves many assumptions and employs statistical methodology not generally accessible to the lay person, be adequately reviewed. In addition, it is important that DEQ's final peer review findings be readily available and distributed to support the credibility of DEQ's survey results.

2. Market Fish (Other than Rainbow Trout)

CWA Section 303(c)(2)(A) requires that WQS protect "public health or welfare, enhance the quality of water and serve the purposes of [the Act]." CWA Section 101(a)(2) establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water [wherever attainable]." The EPA has previously interpreted the "fishable" language in Section 101(a)(2) to refer not only to protecting water quality so the fish and shellfish thrive, but also so that when caught they can be safely eaten by humans. Thus, in order to be consistent with Section 101(a)(2), the applicable criteria for such "fishable" designated uses must not only protect the aquatic organisms themselves but also protect human health through consumption of fish and shellfish.[4]

The EPA's recommended 304(a) water quality criteria to protect human health (and the EPA's accompanying risk assessment methodologies) reflect this longstanding conclusion about the CWA: consumers of fish and shellfish are to be assured that if criteria are met in a waterbody designated with the uses specified in Section 101(a) of the CWA, then that means they can safely eat fish and shellfish drawn from that waterbody.[5] Thus, the EPA has consistently implemented the CWA to ensure that the total rate of consumption of fish and shellfish from inland, estuarine, and near-coastal waters reflects the consumption rates that are characteristic of the population of concern. In other words, the EPA expects that the standards will be set such that residents can safely consume from local waters the amount of fish they would normally consume from all

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[3] Northwest Research Group, Idaho Fish Consumption Survey. August 25, 2015.

[4] EPA's interpretation of the CWA is consistent with years of past practice. As evidence, see memorandum from Geoffrey H. Grubbs and Robert H. Wayland (October 2000) posted at http://water.epa.gov/scitech/swguidance/standards/upload/2000_10_31_standards_shellfish.pdf

[5] See discussion in *Revisions to the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health*, 65 Fed. Reg. 66465 (2000).

inland and near shore waters. The EPA recognizes that consumers of fish and shellfish might not be limiting their consumption of fish and shellfish to those that were sourced from their own state's fishable waters. However, the relevant objective is to assure that they can do so without concern for their health.

Idaho's approach is to exclude from the FCR the fraction of the consumption of freshwater and estuarine fish and shellfish that is currently associated with fish originating from waters outside of Idaho.[6] Idaho justifies its approach on the grounds that Idaho lacks regulatory authority over fish caught outside of its borders. Based on the information and rationale EPA has received from Idaho to date, we note the following reasons why Idaho's justification for this approach is not scientifically sound:

- The purpose of including consumption from waters outside of Idaho's borders in the FCR is not to support any purported regulation of such waters by Idaho. Rather, the purpose of including this fish consumption in the FCR is so that a determination that a particular Idaho water body is "fishable" will result in adequate health protection for Idahoans should they consume, from local waters, the amount of fish they would normally consume from all inland and near shore waters.
- The approach of excluding "market fish" appears to assume that there is no exposure to pollutants from fish that were sourced outside of Idaho. This is because the full allowance for acceptable pollutant levels is given exclusively to local state waters. Consider if every state took this approach. For a non-carcinogenic pollutant with a specified Reference Dose, the criteria development equation would allocate this full dose to fish originating from the individual state. If a person then consumes overall 25 grams/day (g/day) of fish, comprised of 5 g/day each from 5 different states (and each state set a state-specific consumption rate of 5 g/day), then the consumer could potentially receive five times the acceptable pollutant dose.

3. Anadromous Fish

The EPA recognizes that Idaho has included steelhead, an anadromous species, in the calculation of its FCR. However, the EPA continues to have concerns with DEQ's proposed policy decision to exclude all other anadromous fish from the FCR, and recommends that DEQ either include all other anadromous fish in the FCR or provide additional demonstration of how criteria derived using a lower FCR that excludes anadromous fish will protect downstream shared waters in the Columbia River basin and protect the tribal populations exercising their treaty-reserved rights (see comments below regarding consideration of tribal reserved fishing rights).[7]

While the EPA's 304(a) recommended criteria account for exposures to non-carcinogens and nonlinear carcinogens in anadromous fish using the relative source contribution (RSC), the EPA supports and recommends that states include anadromous fish in the FCR when there is credible and compelling evidence of significant consumption of anadromous fish. For example, Oregon and Washington chose to include salmon in the FCR used to derive human health criteria due to,

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[6] Idaho makes one exception to this rule, with rainbow trout, on the grounds that the majority of the rainbow trout in the market comes from Idaho aquaculture facilities.

[7] EPA reference to anadromous fish in this letter refers to all other anadromous fish except steelhead.

amongst other reasons, the large amounts of salmon consumed by tribes, the variation in individual market basket preferences (i.e., the types of fish that people purchase and consume), and uncertainties in the sources of salmon contaminant body burdens from inland and near shore waters (e.g., salmon residing in Puget Sound). The EPA approved Oregon's human health criteria in 2011. Similarly, the EPA supports Washington's decision to develop human health criteria using a FCR that includes anadromous fish consumption.

The EPA also has reviewed recent work related to salmon contaminant acquisition from near coastal waters of the Pacific Northwest and recommends that DEQ also consider this available information. For example, the research conducted by Sandra O'Neill, James West, David Herman, and Gina Yitalo provides evidence that certain Pacific Northwest salmon species, most notably chinook and coho, acquire organic pollutants from near coastal marine waters. [8] O'Neill et al. assayed salmon and herring for several classes of persistent organic pollutants (POPs). The POPs of interest included polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), and the insecticide DDT. An analysis of these POPs in herring populations identified unique regionally-specific patterns of these chemicals or "fingerprints," thus showing herring are acquiring contaminants from waters under CWA jurisdiction. Chinook salmon harvested from specific locations were found to have the same contaminant "fingerprints" as those exhibited by co-located herring samples, suggesting that they are feeding on herring in near coastal waters. This work provides evidence that certain chinook salmon species are acquiring contaminants from near coastal waters of Washington and Oregon, as well as California and British Columbia. Similar but more limited data by O'Neill et al. indicate that coho salmon, which reside in coastal waters and have feeding preferences similar to chinook salmon, are also acquiring contaminants from waters under CWA jurisdiction.

In addition, EPA has communicated with Laurie Weitkamp and Peter Lawson from NOAA,[9] who have stated that chinook (and likely coho) salmon from Idaho reside in near coastal waters off the Oregon coast. Myers at al. 1998, analyzing coated wire tag recovery, has concluded that Snake River Chinook salmon have a coastal residence pattern.[10] O'Neill et al.'s work shows that resident chinook salmon from these waters have regional contaminant fingerprints specific to this area. Given the contaminant fingerprint correlation between herring and coastal resident salmon at all locations where both species were analyzed, it is very likely that coastal salmon originating in Idaho waters are acquiring contaminants from coastal waters under CWA jurisdiction.

EPA recognizes that salmon acquire most of their body weight and, therefore, most of their body burden of highly bioaccumulative contaminants during open-ocean feeding. However, it is

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[8] Ms. O'Neill and Mr. West are both with the Washington Department of Fish and Wildlife.

[9] L. Weitkamp,personal communication 5/19/2015. P. Lawson personal communication via phone, May, 2015.Dr. Laurie Weitkamp has extensively examined recovery of coated wire tags (CWTs) from adult salmon harvested in marine waters. CWTs, inserted into juvenile salmon in hatcheries, allow researchers to determine the relationship between spawning locations and ocean ranges of various salmon species. Dr. Peter Lawson has done genetic testing of adult salmon in marine waters. By matching unique DNA patterns of juvenile and adult salmonids, researchers can determine where adult salmon came from.

[10] Myers K.W., K.Y. Aydin, R.V. Walker, S. Fowler, M.L. Dahlberg. 1996. Known Ocean Ranges of Stocks of Pacific Salmon and Steelhead, as Shown by Tagging Experiments, 1956-1995. Submitted to the North Pacific Anadromous Fish Commission. Fisheries Research Institute. University of Washington School of Fisheries.

possible that salmon may acquire less bioaccumulative contaminants directly from water during their return spawning migration as adults.[11] EPA consulted with Frank Gobas, a well-known expert in bioaccumulation and bioconcentration in aquatic food webs, to evaluate this issue and prepare an analysis.[12] The analysis first involved the development of contaminant concentrations in salmon tissue that were associated with either a cancer risk of 1 in 1,000,000 or a non-cancer hazard quotient of 1. These risk-based concentrations assumed a fish consumption rate of 175 grams per day by an 80 kilogram person. Next, bioconcentration modeling was performed to determine the water concentration that results in a salmon tissue concentration associated with the aforementioned risk-levels.[13] The model includes quantitative structure activity relationship biotransformation of chemicals and the impacts of changing lipid content associated with migration energy expenditure.[14,15] The model also accounts for the time dependent nature of chemical uptake. This modeling utilized a range of migration times for spawning Idaho chinook and sockeye salmon associated with several harvest locations within Idaho. The longer the migration time, the greater the opportunity for contaminants to bioconcentrate. Finally, ratios of Idaho's proposed water quality criteria to modeled water concentrations were computed. The results showed, for example, toxicity ratios of 10 or greater for 13 chemicals with non-carcinogenic toxicity. In other words, for 13 non-carcinogenic chemicals, Idaho's proposed criteria could result in hazard quotients of 10 or more for populations consuming Idaho returning salmon at a rate of 175 grams per day or more. This far exceeds EPA's recommendation of limiting risks to non-carcinogens to a hazard quotient of 1 or less. Therefore, DEQ should consider these results. EPA has enclosed the analysis for your review and consideration (see attached spreadsheets).

Idaho cites work by Hope 2012, suggesting that salmon do not acquire contaminants from waters under CWA jurisdiction, to justify excluding anadromous species from the FCR used to develop DEQ's proposed criteria.[16] The Hope study's conclusions are limited by its focus on PCBs and not on other toxics, and the study does not consider salmon acquisition of contaminants from near coastal waters as demonstrated by O'Neill et al. Central to the modeling is the assumption that contaminant uptake occurs largely through diet. While this is true for PCBs, depending on a chemical's lipophilicity, direct uptake from water may be a significant contributor to an organism's contaminant body burden.[17] The Gobas work on contaminant bioconcentration in migrating adult Idaho salmon, described above, provides evidence that adult Idaho salmon may acquire contaminants directly from the water column through their gills, in addition to dietary

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[11] Less bioaccumulative contaminants refer to contaminants with log octanol-water partition coefficients (log Kow) between two and four.

[12] Dr. Gobas is with Simon Fraser University in Vancouver BC.

[13] Lo et a. 2015, Environ Toxicol Chem. 2015 Oct;34(10):2282-94

[14] US EPA EPI SUITE v. 4.11

[15] Debruyn et al. 2004, Environ Sci Technol. 2004 Dec 1;38(23):6217-24

[16] Hope, B.K. 2012. "Acquisition of Polychlorinated Biphenyls (PCBs) by Pacific Chinook Salmon: An Exploration of Various Exposure Scenarios." Integrated Environmental Assessment and Management 8:553–562. Cited by DEQ in: Considerations in Deciding Which Fish to Include in Idaho's Fish Consumption Rate Policy Summary, State of Idaho Department of Environmental Quality.

[17] Qiao, P., A.P.C. Gobas, and A.P. Farell. 2000. "Relative Contributions of Aqueous and Dietary Uptake of Hydrophobic Chemicals to the Body Burden in Juvenile Rainbow Trout." Archives of Environmental Contamination and Toxicology 39:369–377.

uptake. Finally, the Hope study also does not discuss different patterns of contaminant uptake associated with the complex life histories of other salmonids, such as steelhead.

In conclusion, DEQ should consider the above-referenced scientific information when making its final decision on whether to include anadromous salmonids, other than steelhead, in calculating the FCR. The EPA remains concerned that Idaho's decision to exclude most anadromous salmonids results in human health criteria that are not adequate to protect Idaho's primary and secondary contact recreation uses.[18]

4. Tribal Reserved Fishing Rights

Per EPA's regulations at § 131.11(a), water quality criteria must contain sufficient parameters or constituents to protect the designated use, and for waters with multiple use designations, the criteria must support the most sensitive use. In determining whether WQS comply with the CWA and EPA's regulations, when setting criteria to support the most sensitive fishing designated use in Idaho, it is necessary to consider other applicable laws, including federal treaties. In Idaho, certain tribes hold reserved rights to take fish for subsistence purposes, including treaty-reserved rights to fish at all usual and accustomed fishing grounds and stations and in unoccupied lands of the United States, which in combination appear to cover the majority of waters under state jurisdiction.

Many areas where reserved rights are exercised cannot be directly protected or regulated by the tribal governments and, therefore, the responsibility falls to the state and federal governments to ensure their protection.[19] In order to effectuate and harmonize these reserved rights with the CWA, such rights appropriately must be considered when determining which criteria are necessary to adequately protect Idaho's waters used for consumption of fish (designated as Primary or Secondary Contact Recreation, IDAPA 58.01.02.100.02(a)&(b)).

Protecting Idaho's fishing designated uses necessitates protecting the population exercising those uses. Where a population exercising such uses has a legally protected right to do so under federal law such as a treaty, the criteria protecting such uses must be consistent with such right. Thus, in order to protect the applicable fishing designated uses in areas where such rights apply, as informed by the treaty-reserved right to continue legally protected culturally important subsistence fishing practices, the state must consider the tribal population exercising their reserved fishing rights in Idaho as the target general population for the purposes of deriving criteria that will protect the subsistence fishing use and allow the tribes to harvest and consume fish consistent with their reserved rights.

The data used to determine the FCR are critical to deriving criteria that will protect the subsistence fishing use. The data used to determine a FCR must reasonably represent tribal subsistence consumers' practices that reflect consumption unsuppressed by fish availability or

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[18] As DEQ has acknowledged, "if anadromous species data are omitted from the data set, it is possible that the resulting criteria may not be adequately protective of Idahoans who eat salmon, steelhead, or other anadromous fish." *Idaho Fish Consumption Rate and Human Health Water Quality Criteria; Discussion Paper #5: Anadromous Fish*, pg. 4, available at http://www.deq.idaho.gov/media/1117748/58-0102-1201-discussion-paper5.pdf.

[19] Note that for formal and informal reservation lands, eligible tribes can obtain treatment in a similar manner as a state (TAS) status and set their own WQS under the CWA, including human health criteria.

concerns about the safety of available fish. Deriving criteria using an unsuppressed FCR furthers the restoration goals of the CWA, and ensures protection of human health as pollutant levels decrease, fish habitats are restored, and fish availability increases. If sufficient data regarding unsuppressed fish consumption levels are unavailable, consultation with tribes is important in deciding which fish consumption data should be used.

With these principles in mind, the EPA has concerns with whether DEQ's decision to calculate the FCR based only on current consumption of Idaho fish, and to use a mean FCR for high consuming populations, will adequately protect the treaty-reserved subsistence fishing use. First, in calculating the FCR, DEQ has not considered suppression, specifically suppressed consumption amongst tribal populations in Idaho with reserved rights to fish for their subsistence. Current average FCRs for the Nez Perce and Shoshone Bannock tribes are below heritage rates documented for both of these tribes, as well as heritage rates for the Kootenai and Coeur d'Alene tribes, suggesting that current tribal consumption rates could be suppressed.[20] Second, given that tribal consumption rates are likely suppressed, DEQ has not provided adequate justification for how a rate based on the mean FCR for the tribal target general population will adequately protect tribal fish consumers exercising their treaty-reserved rights, including those whose consumption is not suppressed. Finally, as discussed in greater detail above, the omission of anadromous species from the FCR may result in criteria that are not adequately protective of Idaho's designated uses as informed by the reserved fishing rights of tribal consumers.[21] Based on local conditions in Idaho, it is particularly appropriate to include anadromous species in the FCR, because it is well documented that a large proportion of fish consumption for the tribal target population to be protected consists of anadromous species, such as salmon.[22]

Accordingly, EPA recommends that DEQ select a FCR that reflects the tribal subsistence consumers' unsuppressed fish consumption, including consumption of anadromous fish. If such data are unavailable at this time, the EPA recommends using an upper percentile of consumer-only data to account for uncertainty in the unsuppressed consumption rates of tribal consumers within the state and to help ensure that the resulting criteria protect the tribal target general

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[20] Polissar, N.L, Al Salisbury, C. Ridolfi, K. Callahan, M. Neradilek, D.S. Hippe, *A Fish Consumption Survey of the Nez Perce Tribe Volumes I-III.* Seattle, WA: The Mountain-Whisper-Light Statistics (2015); Polissar, N.L, Al Salisbury, C. Ridolfi, K. Callahan, M. Neradilek, D.S. Hippe, *A Fish Consumption Survey of the Shoshone-Bannock Tribes Volumes I-III.* Seattle, WA: The Mountain-Whisper-Light Statistics (2015); Ridolfi Inc., *Heritage Fish Consumption Rates of the Kootenai Tribe* (November 17, 2014); Ridolfi Inc., *Heritage Fish Consumption Rates of the Coeur d'Alene Tribe* (July 19, 2015).

[21] As DEQ has acknowledged, "if anadromous species data are omitted from the data set, it is possible that the resulting criteria may not be adequately protective of Idahoans who eat salmon, steelhead, or other anadromous fish" and "the complexity of Pacific Northwest fish consumption and its high inclusion of these fish species in the diets of all means that ignoring anadromous fish would be less protective of those within Idaho who enjoy consuming these types of fish." *Idaho Fish Consumption Rate and Human Health Water Quality Criteria; Discussion Paper #5: Anadromous Fish*, pg. 4 & 5, available at http://www.deq.idaho.gov/media/1117748/58-0102-1201-discussion-paper5.pdf.

[22] "Including marine fish in the fish consumption rate may be particularly appropriate if a large proportion of fish consumption for the population to be protected consists of marine fish (such as salmon) and this exposure is clearly documented." USEPA, *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions*, pg 5, *available at* http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/upload/hhfaqs.pdf.

population exercising their treaty-reserved rights. Additionally, government-to-government communications with affected tribes could inform, among other things, which fish consumption data should be used by DEQ.

B. Idaho's Other Proposed Human Health Criteria Inputs

1. Cancer Risk Level

The EPA supports DEQ's proposed policy decision to retain its 10^{-6} cancer risk level to derive human health criteria.

2. Relative Source Contribution (RSC)

In June 2015, the EPA published final updated ambient water quality criteria recommendations for the protection of human health for 94 chemical pollutants.[23] These updated recommendations reflect the latest scientific information and EPA policies, including updated body weight, drinking water consumption rate, FCR, bioaccumulation factors, health toxicity values, and relative source contributions (RSCs). The EPA supports DEQ's proposed approach to use RSC values specified in EPA's 2015 final 304(a) human health criteria recommendations.

3. Bioaccumulation Factors (BAFs)

As stated in DEQ's Technical Support Document (TSD) for the human health criteria, DEQ created an Idaho-specific BAF weighting equation using Idaho fish consumption survey data and stated that the approach they used was similar to the framework that EPA used to derive the BAF weighting in the EPA's 2015 final human health criteria recommendations.[24] According to the TSD, DEQ used food frequency data collected for the Idaho general population and dietary recall data for the tribal population. From these data, DEQ developed a trophic level weighted BAF using the following equation: $(FCR_{TL2} \text{ x } BAF_{TL2} + FCR_{TL3} \text{ x } BAF_{TL3} + FCR_{TL4} \text{ x } BAF_{TL4}) / (FCR_{TL2} + FCR_{TL3} + FCR_{TL4})$. This approach is appropriate and addresses the EPA's previous concern that Idaho tribal populations consume larger amounts of high trophic level fish relative to the U.S. general population. However, the EPA recommends that DEQ provide more information on the derivation of the trophic level specific FCRs used to compute weighted BAFs.

4. Body Weight and Drinking Water Intake

As discussed in the TSD, body weight estimates used in the calculation of Idaho's proposed human health criteria are based on use of a body weight distribution DEQ developed from the general population data from DEQ's fish consumption survey. Using this data, a logarithmic distribution was developed for body weight for calculation of Probabilistic Risk Assessment (PRA)-based proposed human health criteria.[25] EPA is supportive of DEQ's approach to using

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[23] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA, 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.

[24] Idaho Department of Environmental Quality. *Idaho Human Health Criteria, Technical Support Document.* October 2015.

[25] Ibid

the Idaho local data for estimating body weight and concurs that the body weight distribution was appropriately derived.

As discussed in the TSD, DEQ developed drinking water intake estimates for the PRA-based calculation of the proposed human health criteria based on the National Health and Nutrition Examination Survey (NHANES) 2003-2006 data as presented in the EPA's Exposure Factors Handbook. A distribution was fit to the body-weight normalized drinking water intake values to ensure an appropriate correlation with body weight. This distribution was then used in the PRA approach and applied to both Idaho general and tribal populations.[26] The EPA selected the 90th percentile of this distribution (2.4 liters/day) to derive the EPA's 2015 final 304(a) human health criteria recommendations. Although DEQ's approach to estimating drinking water intake differs from the EPA's, DEQ's drinking water rate distribution has been appropriately derived.

In addition, the correlation between drinking water ingestion rate and body weight was adequately addressed in DEQ's PRA analysis. However, DEQ should re-evaluate the correlation between body weight and fish consumption rate using regression on log transformed fish consumption and body weight distributions (See enclosed Westat memoranda).

5. Toxicity Factors (Reference Doses (RfDs) and Cancer Slope Factors (CSFs))

The EPA supports DEQ's proposal to use RfDs and CSFs consistent with the EPA's 2015 final 304(a) human health criteria recommendations or, in some cases, toxicity factors based on the latest science.

C. Idaho's Proposed Pollutant Scope

The EPA is supportive of DEQ taking this opportunity to revise most of its currently applicable human health criteria and to include additional human health criteria for pollutants with EPA 304(a) criteria recommendations that Idaho had not previously adopted. DEQ is proposing to update or add criteria for 104 chemicals. As previously noted, the EPA published updated final 304(a) recommended human health criteria for 94 pollutants in June 2015.

D. Idaho's Use of Probabilistic Risk Assessment (PRA) to Derive Human Health Criteria

The EPA continues to question the fish consumption distribution that DEQ used in its PRA analysis (see the EPA's comments above regarding inclusion of market and anadromous fish in developing a FCR). Use of a FCR distribution that does not include consumption of market and anadromous fish will result in PRA-based criteria that will produce fish- and water-based contaminant exposures that exceed acceptable levels.

Additionally, DEQ's PRA for high fish consuming populations are derived using the assumption that, at the selected criteria, the mean of the hazard quotient distribution will equal one, and the mean of the risk distribution will equal 1×10^{-6}. EPA remains concerned with this approach. This approach will allow for a large fraction of high fish consumers, including tribes with reserved fishing rights (see above discussion on tribal reserved fishing rights), to have exposures

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[26] Ibid

that either exceed an acceptable dose (i.e., the reference dose) for noncarcinogens or exceed a dose associated with a risk of 1×10^{-6} for carcinogens.

Another concern is development of an appropriate tribal fish consumption distribution for PRA. The National Cancer Institute (NCI) method cannot be used to characterize consumption of a particular grouping of fish (e.g., fish caught in Idaho waters) if the data necessary for the method are not available. Idaho has used tribal Food Frequency Questionnaire (FFQ) and NCI data in an attempt to develop "NCI-like" estimates of average tribal consumption of fish caught in Idaho waters. As previously noted, DEQ should include market fish, including anadromous species, in the FCR used to set Idaho's AWQC. The EPA also has methodological concerns about using FFQ and NCI data to derive "NCI-like" FCR statistics based on Westat's review of the PRA approach (see attached Westat memoranda). Thus, the EPA recommends that the NCI group 2 (i.e., anadromous, near coastal and inland fish and shellfish) FCR data for the Nez Perce Tribe be used to develop statistics representing current fish consumption.

E. Idaho's Proposed Approach to Downstream Protection

The EPA is encouraged by DEQ's inclusion of a downstream protection narrative criterion in the proposed rule, following the language in EPA's "*Templates for Narrative Downstream Protection Criteria in State Water Quality Standards*" (EPA publication No. 820-F-14-002). However, the EPA's *Protection of Downstream Waters in Water Quality Standards: Frequently Asked Questions* suggests that states consider a more tailored and specific narrative criterion and/or a numeric criterion in certain situations, such as when more stringent numeric criteria are in place downstream and/or environmental justice issues are relevant.[27] As mentioned above, most of Idaho's waters are in the Columbia River basin and are, therefore, upstream of Washington's and Oregon's portion of the Columbia River. The EPA strongly encourages DEQ to adopt numeric human health criteria (either in addition to or instead of a narrative criterion) that ensure the attainment and maintenance of downstream human health water quality criteria, or to provide additional rationale detailing how use of a narrative downstream protection criterion in combination with Idaho's numeric human health criteria will ensure the attainment and maintenance of downstream human health criteria, consistent with the EPA's regulations at 40 CFR 131.10(b).

F. Other Specific Comments on Idaho's Preliminary Rule Language

Section 010. Definitions.

46. Harmonic Mean. EPA supports DEQ's proposed revisions to this definition. However, EPA continues to suggest DEQ consider including the following equation in the definition for harmonic mean, as it provides additional clarity:

$$Q(harmonic) = n / \sum_{i=1}^{n} \frac{1}{Qi}$$

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[27] EPA. June 2014. *Protection of Downstream Waters in Water Quality Standards: Frequently Asked Questions.* http://water.epa.gov/scitech/swguidance/standards/library/upload/downstream-faqs.pdf

Section 210. Numeric Criteria for Toxic Substances for Waters Designated for Aquatic Life, Recreation, or Domestic Water Supply Use.

210.01.a. Criteria for Toxic Substances. EPA supports DEQ's proposed revisions to the application of the human health criteria for toxics for the protection of consumption of water and organisms such that these criteria apply only to primary and secondary contact recreation uses and no longer apply to aquatic life uses. Given that the provision in Idaho's water quality standards at Section 100.02 a. and b. states in part that secondary contact recreation may include activities such as fishing, the application of the water and organisms human health toxic criteria to only recreation uses and not aquatic life is appropriate.

With respect to DEQ's proposed revision to the headings in the toxics criteria table, specifically for the human health criteria, EPA recommends DEQ retain the word "organisms" and not replace it with the word "fish." "Organisms" more closely represents the concept that consumption is meant to encompass more than just fish but rather fish, shellfish, and other aquatic life.

210.03. Applicability. DEQ has proposed clarifying language regarding mixing zones as well as revising the low flow design conditions applicable to human health criteria. Consistent with the 2000 Human Health Methodology, DEQ has proposed to revise its regulations to require the harmonic mean flow be used to implement both carcinogen and noncarcinogen human health criteria.[28] EPA supports this proposed revision.

210.03.d.ii. This provision provides a frequency and duration for human health criteria that are not to be exceeded based on an annual harmonic mean. EPA understands DEQ is attempting to clarify the frequency and duration for the state's human health criteria and is supportive of that effort. EPA's 304(a) recommendations for human health criteria are based on long-term average exposure over a lifetime (70 years). Idaho's proposed duration of one year is protective because it represents long-term or chronic exposure but within a reasonable timescale for the purposes of regularly assessing attainment of the criteria. However, the harmonic mean is an inappropriate measure of central tendency in this context, because it is likely to under-represent the presence of pollutants in ambient water. Harmonic means are an appropriate measure of central tendency when evaluating rates with varying denominators, such as flows or speeds. However, for measures of varying mass per volume, such as concentrations of contaminants in ambient water, the arithmetic (for skewed datasets) or the geometric mean is the more appropriate measure of central tendency. EPA recommends that DEQ delete reference to the harmonic mean and, instead, insert arithmetic mean.

210.05.a.iii. The proposed revisions update the reference from EPA's ACQUIRE database to ECOTOX database. EPA supports this revision.

210.05.b.ii. The EPA is concerned that this provision lacks specificity with regard to a fish consumption rate and the target population to be protected that will be used to derive numeric human health criteria in the future, when numeric criteria are not identified in the toxics table. It

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[28] FR Vol 65 No. 214. Pg. 66450. Revisions to the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000).

would seem reasonable to specify an appropriate fish consumption rate as well as the target population and percentile of the target population that would be used to estimate a fish consumption rate consistent with how Idaho's numeric criteria in the table at Section 210 were derived. For example, the language in b.ii. refers to using a fish consumption rate that is representative of the population to be protected. The EPA suggests DEQ include specific language identifying the population to be protected consistent with EPA's previous comments.

284.04.b and c. DEQ combined the wording in 04.b. and c. and deleted any redundant language. These revisions are not substantive as they do not change where the criteria apply. The EPA supports the proposed revisions regarding the application of the site-specific criteria for the South Fork Coeur d'Alene River subbasin.

400.06 Intake Credits for Water Quality Based Effluent Limitations. This provision refers to the Idaho Pollutant Discharge Elimination System Program (IPDES) rules and is not a water quality standard. However, in EPA's October 2, 2015 letter from Michael Lidgard to Paula Wilson, EPA provided comments on IDAPA 58.01.25 regarding the proposed intake credit rule language as proposed in the IPDES rules. The EPA is continuing to coordinate with DEQ's IPDES program and has recommended that, if DEQ intends to adopt an intake credit provision into the IPDES rules, it be consistent with the Great Lakes Initiative (GLI). Another option is for DEQ to consider Oregon's intake credit provision rule language, as that language is most similar to the GLI and was approved by EPA.

Westat | An Employee-Owned Research Corporation

Memo

Date: October 19, 2015

To: Greg Frey, SRA

From: John Rogers, Rebecca Birch, and David Marker

Subject: Review of Idaho Fish Survey

Westat was requested by SRA and EPA to review three documents and a translation procedure, all related to the findings from the Idaho Fish Survey. Our comments are as follows.

1. Overall comments:

In our comments, "fish" refers to fish and shellfish.

It is not very unclear how many days of dietary recall data were collected. First, the daily dietary recall questions were only answered if question FFQ3 [did you eat fish in the last 7 days] is Yes. So someone who ate fish only on day 8 would be excluded from the dietary recall questions. It appears that 8 days of daily recall were reported for those who ate fish yesterday but only 7 days for those who did not eat fish yesterday. If FCR24_1 [did you eat fish yesterday] is Yes, the questionnaire collects data about yesterday's fish consumption. Then the instructions for questions FCR7D_1_A through FCR7D_3_B distinguish between "excluding yesterday how many meals did you eat … that included fish or seafood in the past 7 days" [looks like 8 days total] if fish was eaten yesterday versus "… in the past 7 days how many meals did you eat …" and "Not including today, what was the most recent day of the week when you consumed …" if fish was not eaten yesterday [looks like 7 days total].

Given that the dietary recall data were collected only if the respondent said they ate fish in the past seven days, we think the fish consumption in the seven days prior to the call should be used when aggregating dietary recall data across multiple days, not 8 days.

The definition of consumption events is unclear. If two different types of fish are consumed at a meal, the FFQ seems to count this as one consumption event. Is this one or two consumption events in the dietary recall? Is every snack a consumption event regardless of size or how many types of fish were consumed?

Frequency of fish consumption was assessed using the FFQ and the multiple days of dietary recall data. The report says "the total number of consumption events estimated using the dietary recall questions is significantly lower than the total number of consumption events estimated using the food frequency questions" (page 81) but provides no data for comparison to quantify what "significantly lower" means. At the same time the report notes that the reported frequency of fish consumption drops as the days between the consumption event and the survey contact increases (page 75). Might this indication of recall bias explain some of the difference?

The report notes that there are differences between the portion size estimates from the FFQ and the average portion size estimates from the dietary recall. Interpretation of that difference is complicated by: 1) the skewed distribution of the amounts from the daily recalls; 2) how the respondent estimates long-term portion size; and 3) differences in what a portion means between the FFQ and dietary recall. If the respondent provides an estimate of the median portion size (as opposed to the mean), the difference between the log-transformed portion sizes may be less significant, and more normally distributed.

It is not clear how a "complete" survey was defined. Also the survey report gives weighted sample sizes (is this weighted population estimate scaled down to the sample size?). We would like to see unweighted sample sizes. Table 1 (page 10) in the IMS analysis report provides unweighted sample sizes. However, it is still unclear concerning the number of subjects that were consumers versus non-consumers.

In theory, usual fish intake can be estimated from 24-hour recalls or multiple-day recalls (in this case 7 or 8 day recalls). However, if the best estimate of usual fish intake is based on 24-hour recalls, then the decrease in the reported frequency of fish consumption with increasing length of the recall period (days between the consumption event and the survey contact) indicates that the estimate based on multiple-day recalls will be biased low. Correcting this bias requires making some assumptions (such as logit(probability of fish consumption) and log(amount consumed per day) changes linearly with the length of the recall period). With a reasonable assumption, this bias can be corrected by

1) fitting a more complicated version of the NCI model that includes an adjustment;
2) scaling the estimated usual fish consumption from the NCI model up to adjust for the bias (applying a multiplicative factor, perhaps (probability of fish consumption on Day 1)/(Probability of fish consumption on any day in the recall period)); or,
3) using only the first (yesterday) day of dietary recall to estimate usual fish consumption.

Using just the 24-hour recall, if separate models are fit for anglers and non-anglers, the NCI model may not converge due to few respondents with two recalls, both with fish consumption. Scaling the output when predicting data from several days may be the easiest option.

The NCI macro uses the NLMIXED procedure. The weights in the NLMIXED procedure are defined using the REPLICATE statement. The documentation for the REPLICATE statement states that "Only the last observation of the REPLICATE variable for each subject is used". Thus, the same weight is used for each recall within a person. The best weight to use is the weight for the respondent (used for the first recall). As a result, 1) the analysis file for the NI method should have the weight for the first recall on both the records for the first and second recall; and 2) the weight for the second recall defined by NRG is not used in the analysis.

In the IMS report, Table 1 (page 10) shows the sample sizes for anglers and non-anglers and the number of respondents used in the NCI model. It is not completely clear why some cases were not included in the NCI model. Does the line labeled "Annual Fish Consumption Unavailable" correspond to those that did not eat fish in the last year (non-consumers)? There are 243 cases labeled “Recall Data Unavailable (i.e. Missing)”. What does this mean? There were 660 respondents that were dropped because various covariates were missing. Without knowing specifics about the missing values, perhaps imputed values could be used or missing values can be treated as a separate category of the categorical variables? How does the distribution of the demographic variables for those in the NCI model compare to the distribution for all fish consumers?

2. Idaho Fish Consumption Survey

SUBMITTED TO: Idaho Department of Environmental Quality
SUBMITTED BY: Northwest Research Group, LLC www.nwresearchgroup.com
DATE SUBMITTED: Final: August 25, 2015

We are interested in identifying any survey design factors that might introduce any uncertainty or bias/loss of accuracy in results of the fish consumption survey. In addition to whatever the reviewers identify as a potential issue, we would specifically like comments on the topics listed below.

2.1 Representativeness of sample using a telephone interview.

The methodology to collect data using a telephone interview using two frames (cell and landline) seems appropriate. According to the 2012 National Health Interview Survey only 2.7 percent of adults in Idaho are without a cell or land line phone. Those people will not be represented. While there may be some reason to think they have different fish consumption levels than others with otherwise similar demographics (since they are by definition living somewhat removed from society lives), there impact on overall estimates are likely to be small.

2.2 Methodology used to select land line and cell phone numbers and representativeness of sample

The methodology to select land line and cell numbers appears to be appropriate. The resulting samples of telephone numbers should be representative of the cell phone or landline populations. See item 2.11.

2.3 Stratification of sample based on Idaho health districts.

The stratification approach looks appropriate, trying to enforce geographic and gender representativeness in the sample minimizes variation in the weights.

2.4 Representation of anglers and non-anglers and weighting

They decided to use only the telephone landline and cell lists for sampling and classifying the anglers based on reported possession of a fishing license. This approach appears to be reasonable. The number of anglers estimated from the survey (33%) differs somewhat from the number estimated by IDFW (26%). It is possible that anglers were more likely to respond to a survey on fish consumption then non-anglers. At the same time, the list from IDFW has some uncertainty in that two lists of different sizes were provided.

2.5 Quotas for age, gender, and income and relation to representativeness of the sample

In general, enforcing the quotas helps to reduce the required effects of weighting. However, quota sampling has been discouraged for decades in government surveys because it can introduce biases that are not necessarily accounted for through the weighting process. In particular, it results in over-representing those who are easier to reach by telephone. Of particular interest in a fish consumption survey, those who spend a greater amount of time away from home (including fishing) are harder to reach, and thus are underrepresented in a quota sample. If they are reachable by cell phone this form of bias may be reduced, but it is hard to know for sure.

2.6 Consideration of race and representativeness of the survey sample

The racial breakdown of the population is only reported as White Alone versus Non-White (roughly 5%). Race was not used for weighting. Since quotas were not used for race, the sample may not be representative of the population racial distribution. A weighting adjustment based on race would improve the representativeness of the weighted sample with respect to race. See item 2.11.

The proportion of whites in the sample is higher than in the State of Idaho. Nationally, whites consume less fish than non-whites (EPA, 2014). If the weighting were to include race it might improve the accuracy of the estimates.

2.7 Impact of not being able to interview 5% of contacted households because of language issues.

Obviously, this subpopulation will not be represented in the survey results. To the extent that this subpopulation is similar to others with similar demographics, a weighting adjustment based on demographics might make the weighted sample more representative.

They report that early analysis indicated no significant differences in consumption rates between English speaking Hispanic and non-Hispanic respondents. However, this does not mean that there will be no difference between English speaking and non-English speaking respondents. They are assuming that English speaking Hispanics are more similar to non-English speaking Hispanics than they are to non-Hispanics in dietary behavior, which may or may not be true.

In particular, if the non-English speakers are Native Americans, their lack of English could be hypothesized to be correlated with following more traditional lifestyles, ones that involve consumption of much greater amounts of fish. In such a case their exclusion will underestimate the true fish consumption in Idaho.

2.8 Quantifying portion size:

2.8.1 Use of common objects to describe portion size

If the common object is familiar to the study population, it is likely easier for respondents to report their portion size in relation to the object than to estimate weight (grams or ounces) or volume (cups or tablespoons), unless they cooked it themselves. They did qualitative research among the population of interest to assist them in selecting common objects to be used as portion size references.

2.8.2 Asking respondents to quantify portion size in ounces

It is likely difficult for respondents to provide the amount of fish they consumed in ounces, unless they prepared the fish. However, they tested the use of portion size estimation aids (PSEA) to assess if using PSEAs would improve reporting of fish consumed in ounces. They report that the results showed saying the PSEA was equivalent to a specific number of ounces and asking respondents to then provide their consumption in ounces provided accurate estimates. This is the methodology they used. It seems reasonable and best available without pre-mailing (or directing to a website) portion size pictures like what are used in the ASA24.

2.8.3 Use of a deck of cards as the portion size estimation model

According to their research, most people thought about a deck of cards or palm of hand when estimating portion sizes and there was no difference in accuracy between these two PSEAs. They chose to go with a deck of cards. This choice seems reasonable given the research findings and that hand sizes vary by age and gender and other factors.

2.9 Use of an 8 day recall period, (SEE: p 24, item 6 describing recall issues for longer periods from qualitative research).

The use of a single versus multiple-day dietary recall for assessing usual fish consumption depends on a combination of bias and precision. The decrease in the reported frequency of fish consumption with increasing length of the recall period (page 75) will contribute to increased bias as the number of recall days increases. The bias can be corrected in various ways (an adjustment factor, modifying the NCI model, or using only the first day of dietary recall). The increasing imprecision of the respondent recall as the length of the recall period increases affects the precision of the estimates; but the NCI method can still be used to calculate those estimates if proper adjustments are made. As a result, increasing the recall period has diminishing benefit. We recommend either adjusting the estimates for bias associated with the longer recall period or calculating the usual fish consumption from only the first recall day. Disregarding this length bias, as was apparently done, can produce inaccurate estimates.

Assuming that respondents had a difficult time recalling fish consumption events beyond a few days (like they report), an 8 day recall period probably underestimates usual fish consumption due to the likely lowered estimated probability of consumption (for those that were reported no consumption and may have forgotten a fish consumption event).

2.10 Impact of response rate on survey results

Non-response contributes to possible bias and decreased precision of the survey estimates. NRG appeared to make reasonable efforts to increase or maintain response rates while collecting the data. Without independent estimates of fish consumption for the non-respondents it is not possible to truly assess the bias. A non-response adjustment to the weights can help to minimize the bias. An analysis of frequency and amount of fish consumption as a function of the effort used to collect the data (such as number of contacts to get a completed survey response) can be used to approximate the possible bias due to non-response. The non-response adjustment (post stratification) provides minimal adjustment for non-response. We recommend additional adjustments of the weights to account for different non-response rates for different demographic groups. NRG provided some adjustment of the weights for health region and gender; however did not provide more extensive adjustments for non-response (particularly with respect to an apparent imbalance in income) citing concerns for possible large weights in some health districts. While it is true that such adjustments may increase the variance, they will reduce the bias. In general this trade-off is worthwhile when the response rates are not high. We recommend additional non-response weight adjustments.

2.11 Weighting of results based on land vs. cell phones

The general approach to weighting the combined cell and landline samples, as represented by BW_1, is reasonable. However some details of the implementation are unclear or appear incorrect, in particular:

1) On page 35 they define CP as the number of cell phones but it appears to really be whether or not they have a cell phone used for making or receiving phone calls (this is ok, but should be corrected in the documentation)
2) On page 35, the numbers for the universe counts (ULL and UCP) seem very implausible....they must be larger. If these are in error, then obviously the weights are wrong.
3) On page 35, the formula for BW_1 is wrong (we assume it is just a typo, since the -1 should be an exponent)
4) They did not collect the number of adults in the household and therefore made a "fix" based on the number in the household; that is a potential source of bias
5) The question they used to determine phone service (TEL on page 104) is not a standard one and might lead to some errors. For example, the cell phone is based on personal use and the landline is household availability and the two are confused in this question.
6) The purpose and implementation of the adjustment in BW_2 on page 36 is unclear. Is the adjustment (BW_2) applied to all respondents in a health district or only the cell-phone-only respondents? It is not clear what some of the numbers in Table 12 are or where they came from. They appear to be household numbers; however the adjustment should be for adults; this may be a potential source of bias. Based on the numbers in the last three columns of Table 12, it looks like the purpose of BW_2 is to get the percentage of cell-only households in the sample to equal the corresponding percentage in the population; however, it is not clear how the equations for BW_2 and BWFinal achieve that for the "Non Wire-less Only" respondents.

2.12 Implementation of post stratification weighting

The post stratification provides some adjustment for non-response. However, it excluded adjustments by income level, household composition, and education.

2.13 Weighting for re-contact interviews

The weighting for the re-contact interviews provides a simple adjustment for non-response. If these weights were important, we would recommend a more complicated adjustment. However, since the NCI model only uses one weight per respondent (preferably the weight for the first recall, not a separate weight for each recall), the calculation of an adjusted weight for each recall is not required when using the NCI method for analysis.

2.14 Imputation used to populate missing values

The imputation used to populate missing values is not explained in detail. The discussion on page 42 says the values were imputed based on characteristics of their neighbors but provides no description of how "neighbors" are defined. It is not clear what values were or were not imputed. It is also not clear how the imputed values were used. Were they used to create Table 15? Were they used for weighting? The second bullet on page 42 seems to imply the imputed values were not used in the analysis file.

2.15 Data processing and calculations

We found no problems with what was presented. However, the description does not say how the 7 or 8 day fish consumption (average or sum?) was calculated from the daily values (only the calculation for daily values for yesterday is presented, we assume the other days consumption was calculated in a similar manner). We recommend the fish consumption be calculated for 7 and not 8 days, as noted in the overall comments.

2.16 Bootstrapping approach used to develop confidence limits

The Bootstrapping approach apparently does not incorporate the weights. As a result, for evaluating population differences, the confidence intervals may be smaller than appropriate. It is not clear how the confidence intervals were used. The word "significant" is used in several places. It is not clear if it refers to statistical significance.

2.17 Discussion Section

2.17.1 Addressing non-response bias

They say 25 percent is "significantly higher than the average response rate." Twenty-five percent is not unreasonable for a telephone survey these days, but it still leaves room for significant nonresponse bias if the respondents are not like the nonrespondents. It is difficult to know if the 75 percent that did not respond are systematically different in their fish consumption behaviors. This is of particular concern given that they used a quota sample rather than a traditional random sample. This might contribute to the over-representation of higher income individuals and anglers

– these groups may be more interested in the survey topic thus more likely to respond. Could non-response be adjusted for with weighting factors?

2.17.2 Impact of over-representation of higher income individuals and anglers

They mention that more complicated weights could be applied to adjust for these differences, but that could result in large weights within individual health districts. They could assess the impact of the over-representation by applying the weights, running the analysis, and comparing the results.

In general it is always true that weighting adjustments will reduce precision (larger standard errors for sampling), but the trade-off is that it will hopefully reduce bias. This is important because the confidence intervals, or tests of hypotheses, will only have the claimed level of accuracy (e.g. 95 percent) if the bias is trivial. If there are large biases all of these intervals will be incorrect. That is why we do typically adjust for known under-represented groups. In some cases it may be worthwhile to trim a few excessively large weights. This process is expected to produce smaller overall mean squared errors, and more appropriately-sized confidence intervals.

2.18 Review of the questionnaire and identification of any issues in accurately recording fish consumption. Of particular interest is review of the methodology for inquiry into consumption over the past 7 days.

As noted in the general comments above, clarification of when there is data for 7 days versus 8 days is needed. Also, given the decrease in the proportion of respondents reporting fish consumption with increasing length of the recall period, estimates based on multiple-day recalls are likely to be biased low without an appropriate adjustment.

3. NCI Method Estimates of Usual Intake Distributions for Fish Consumption in Idaho

This report was prepared under DEQ Contract K079 with Information Management Services, Inc.: Dennis W. Buckman, PhD, Ruth Parsons, BA, Lisa Kahle, BA, September 9, 2015.

We are interested in any NCI data analysis factors that might introduce uncertainty or bias/loss of accuracy in NCI results. We are particularly interested in whether or not the data analysis approach is sufficiently described. In addition to whatever the reviewers identify as potential issues, we would like comments on the topics listed below:

3.1 How well are the selection and impact of covariate choices documented?

The covariates used in the NCI model are listed in the report (page 11). No justification for using these covariates is provided. In addition to these covariates, three other variables that are apparently available are: gender, household composition (single versus multi-person, see page 40 of the survey report), and amount consumed from the FFQ. An easy approach to selecting covariates is to include all available covariates. Alternatively a combination of a weighted logistic regression (using the SAS SURVEYLOGISTIC procedure with the BRR weights created for calculating confidence intervals for usual fish consumption) predicting the probability of fish consumption in a recall, and a weighted linear regression predicting log-transformed (or Box-Cox transformed) amount of fish consumed (using the SAS SURVEYREG procedure), can be used to assess which predictors or interactions of predictors are statistically significant when predicting the outcome. For the NCI model, we recommend including the same predictors for both the probability and amount models, including predictors that are significant when predicting either probability of consumption or transformed amount. In general it is important to include predictors that are clearly significant (p<.01). Predictors that are believed to be related to fish consumption but not significant should also be included. We believe the amount consumed from the FFQ should be an important predictor of amount consumed in the NCI model. For continuous predictors (body weight, age, and amount consumed from the FFQ) the weighted regression models can be used to assess how the variables might be transformed and whether the relationships are linear.

3.2 Are there any issues associated with use of 8 days of dietary recall information rather than the last 24 hours?

Yes. At a minimum, compared to using only the last 24 hours, the estimates are biased without an adjustment for the decreasing frequency of reported fish consumption as the length of the recall period increases. See the general comments above.

3.3 Is the combination and weighting of general and angler populations done appropriately?

The details of how the NCI macros were applied to the data files are not completely clear. For each type of fish consumption, we suspect the NCI method was applied to the data from the angler and non-angler subpopulations in separate runs, that all runs used the survey weights, and the summary statistics calculated from the simulated usual intake values for each respondent (from the DISTRIB macro) were calculated using the survey weight associated with the first recall for each respondent. The summary statistics can be calculated after combining the output files from the runs of the DISTRIB macro. If these procedures were used, we believe the calculations were done appropriately.

3.4 How, and how well, is it documented that the results meet assumptions of the NCI model (e.g. transformed positive fish consumption rates are normally distributed)?

The report provides no information on the values of Box-Cox transformation parameter (lambda), whether the transformed consumption amounts are normally distributed (a normal quantile plot of the transformed consumption amounts (not the plot from the NCI Box-Cox macro that was used) would help), whether there are any outliers, and the estimates of the variance components from the NCI model fit (between person for the probability model and the within and between person components for the amount model). This information would help assess the model fit and why the NCI macro had problems estimating lambda and the correlation parameter. In our experience, setting lambda instead of fitting lambda in the model and ignoring the correlation parameter has little effect on the results when calculating usual intake of fish. Given the relatively large number of respondents with two recalls with reported fish consumption we are surprised that lambda and the correlation parameter could not be fit using the MIXTRAN macro; at the same time, we have no reason to question this result.

4. Development of Human Health Water Quality Criteria for the State of Idaho (Draft), Windward Environmental, September 15, 2015

We are interested in whether or not the probabilistic analysis is adequately described. Further, we are interested in any methodological issues that were inappropriately or incompletely addressed in the PRA. In addition to anything that the reviewers might provide, we are interested in the following topics:

4.1 Selection of input distributions, in particular development of a Nez Perce fish consumption rate distribution.

The distribution fit to the percentiles of body weight appears to provide a good fit to the data. The distribution fit to the percentiles of drinking water intake per body weight appears to provide a reasonable fit to the data. Given the limited data for fish consumption for the Nez Pierce tribe, interpolating while setting the lower 5 percent to the 5th percentile and setting a maximum value and interpolation for percentiles above the 95th percentile appears reasonable.

One might question how the maximum value was obtained. Based on the footnote on page 12 of the Windward report, the maximum was based on what might be the maximum simulated value from the NCI DRISTRIB macro for the Idaho general population (1,261 g/day) multiplied by 0.242. If we have understood the calculations, this approach appears somewhat arbitrary because 1) the maximum value depends on how many simulated values DISTRIB creates, and 2) the adjustment factor of 0.242 seems to be based on calculations that are unrelated to the relationship between the maximum of the two distributions. A possible alternative is to calculate the 95th and 99.9th percentile for the general Idaho population and assume the ratio of those percentiles is the same for the general Idaho populations and the Nez Pierce population.

4.2 Correlation

4.2.1 Between body weight and drinking water ingestion rate

Assuming the drinking water ingestion rate per body weight is independent of the body weight appears to be a reasonable assumption. If needed, analysis of NHANES data could be used to test the assumptions. Thus simulating body weight and independently simulating drinking ingestion rate per body weight appears to be reasonable.

4.2.2 Between body weight and fish consumption rate

We expect the fish consumption rate to increase with increasing body weight. The assumed distribution for the body weight appears to be a lognormal distribution. The distribution of fish consumption rate can often be reasonably approximated by a lognormal distribution. Thus, when assessing correlation, we strongly recommend plotting and calculating the correlation between the log-transformed body weight and the log-transformed FCR. The statistical assessment of correlation (here using regression) assumes the prediction errors are normally distributed with roughly constant variance. That assumption is clearly not true for the data plotted in Figure 2-3 of the Windward report. We expect a plot using the log-transformed values will have an approximate bivariate normal distribution.

5. Translation of NPT consumption of 'Group 2' fish to equivalent consumption of 'Idaho Fish'

> We are interested in whether or not the approach is adequately documented and whether or not there are any issues with this analytical approach. In particular, we are interested in how IDEQ has processed weighting factors in deriving consumption rates of fish caught in Idaho.

In general the re-grouping of fish seems appropriate given the available data. We have three concerns:

1. The explanation of how the prorating was done is hard to follow. The prorating of event salmon (salmon + steelhead): If a participant reported 10 oz. of salmon at events and 6 oz. of chinook and 4 oz. of steelhead at nonevents, then they were assigned 4 oz. for event steelhead. Is this how it was done?

2. Why was Coho left out of the prorating? Is it sometimes confused with steelhead?

3. The fraction of salmon + steelhead that is chinook is apparently calculated separately for each respondent. Where does the 81.3% come from? This is apparently the weighted mean percent of chinook (out of salmon+chinook+ coho+steelhead) across all participants that reported nonevent salmon, chinook, coho, and steelhead, is that correct? Although the fraction you are interested in can be calculated for each respondent, the resulting fractions can be imprecise, resulting in biased overall estimates. As an alternative, we recommend calculating the ratio of the weighted mean chinook non-event consumption to the weighted mean salmon+chinook+ coho+steelhead non-event consumption and using one ratio for all respondents. If there is concern that the ratio may differ among respondents, the ratio can be calculated separately for different demographic groups.

The application of the weights seems appropriate. The resulting fraction of the Group 2 that was assigned as Idaho fish (0.242) was then multiplied by the results that were obtained from the NCI Method for the original Group 2.

Westat

An Employee-Owned
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Memo

Date: October 26, 2015

To: Greg Frey, SRA, and Lon Kissinger, EPA

From: John Rogers

Subject: To-do list for improving the estimates of Idaho fish consumption

At the request of SRA, Westat provides the following recommended to-do list for predicting fish consumption from the ID survey. Note that these recommendations are based on our understanding of the data and the calculations used previously. The recommendations may need to be adjusted for unanticipated characteristics of the data. The to-do list refers to comments in our October 19, 2015 memo.

The to-do list:

Revise the survey weights:

- Recalculate the base weights, noting the comments in item 2.11.
- Review the imputation of the missing demographic variables. This needs to be described better.
- Adjust the base weights for non-response using raking. The variables used for raking would include those in Table 15 in the NRG report. This will create respondent weights adjusted for imbalance due to the sampling process and non-response, W_i. If a few weights are particularly large relative to most weights, those weights might be trimmed. The weights for other cases would be increased so that the sum of the weights is unchanged.
- Set the weight for the second recall to equal the weight for the first recall.

Revise the calculations to calculate fish consumption over 7 days.

- For each respondent and recall, calculate the quantity of fish consumed in each day of the recall ("yesterday" and the prior 7 days) as documented on page 116 of the NRG report, call this A_{ird}, i references the respondent (1 to N), r references the recall (1 or 2), and d references the day (1 to 8). Then calculate the average daily consumption over the first 7 days for each respondent and recall: $A_{ir(7)} = \frac{\sum_{d=1}^{7} A_{ird}}{7}$.

- Using only the first recall for each subject ($r = 1$), calculate the weighted mean of the fish consumption on the first day and the fish consumption across the first 7 days (the sums are over all completed recalls):
$$\bar{A}_1 = \frac{\sum_{i=1}^{N} A_{i11} W_i}{\sum_{i=1}^{N} W_i}$$
$$\bar{A}_{(7)} = \frac{\sum_{i=1}^{N} A_{i1(7)} W_i}{\sum_{i=1}^{N} W_i}$$
Note: this is a slightly different formula than outlined in the comments.

- Calculate the ratio for adjusting the NCI estimate of usual fish consumption to estimate usual fish consumption adjusted for decreased recall over time.
$$R = \frac{\bar{A}_1}{\bar{A}_{(7)}}$$

Fitting the NCI model

- Decide what cases to include in the NCI model. Is there a reasonable way to include cases with missing demographic variables, such as treating the missing values as a separate category or using imputed demographic variables?

- Create BRR replicate weights for calculating variances.

- Decide what predictors to use:

    - Use the SAS SURVEYLOGISTIC procedure to identify significant predictors of reported fish consumption (Yes versus No) using the BRR weights. First identify significant main effects. Second identify significant two-way interactions of the significant main effects. Candidate predictors would be demographic variables (including body weight) and FFQ variables (frequency of fist consumption, amount consumed). It is worth considering transforming or categorizing the FFQ variables to handle non-linear relationships. Although it can be done different ways, we suggest 1) including main effects that are significant at the 5% level; 2) including interactions of the main effects that are significant at the 1% level; and 3) including any other main effects believed to be associated with fish consumption.

    - Use the SAS SURVEYREG procedure to identify significant predictors of log-transformed (or Box-Cox transformed) reported amount of fish consumed using the BRR weights, using the steps above.

- In the NCI model, we suggest using the same covariates for the probability and amount models.

- Fit the NCI model to $A_{ir(7)}$. If necessary, determine the Box-Cox transformation parameter (Lambda) before fitting the NCI model. If the correlated model cannot be fit, using the uncorrelated model is OK. Report the Lambda and the magnitude of the variance components from the NCI model when using the full sample weight.

- Multiply the usual fish consumption from the NCI DISTRIB macro by the ratio R from above to provide an unbiased estimate of usual fish consumption.

Do the calculations for the PRA:

- Revise the adjustment for estimating the top 5% of the Nez Pierce distribution, see comment 4.1.
- Consider a correlation between log-transformed body weight and log-transformed usual fish consumption. Alternatively, if the body weight is a significant predictor of usual fish consumption (in the probability and particularly the amount model), the distribution of fish consumption should be a function of body weight.
- Calculate the weighted fraction of chinook across all respondents when adjusting for different fish species categories (Group 2 versus ID fish). See comment 5, item 3.

Clarify various items, see comments, in particular:

- The process for developing imputed values when data were missing
- Weighting of angler and general populations in developing overall results
- Discussion in the NCI analysis report as to how well model assumptions are met

Review of DEQ Approach for Developing an NCI-Like Distribution of Idaho Caught Fish, 11/5/15

EPA requested Westat review DEQ's approach for developing an "NCI-like" fish consumption rate (FCR) distribution for fish from Idaho waters. This memo summarizes conversations between Lon Kissinger EPA Region 10 and Westat statistician Dr. John Rogers.

DEQ developed a Nez Perce distribution of consumption of Idaho caught fish by scaling the NCI-derived distribution for consumption of Category 2 fish, multiplying the percentiles by 0.242 to calculate the percentiles of the distribution of Nez Perce Idaho fish consumption. The scaling factor, 0.242, was the ratio of the average consumption of Idaho caught fish to the average consumption of Category 2 fish. Both of these averages were obtained from the Nez Perce FFQ survey. The resulting scaled or transformed NCI-distribution is referred to here as the "NCI-like" distribution.

After discussions with Westat regarding the relationship between the NCI-derived distributions for different types of fish, we suggest that further analysis be done on the approach used to develop a Nez Perce "NCI-like" distribution of Idaho caught fish. It appears that the current procedure is likely to underestimate the upper percentiles of the Idaho fish consumption distribution.

Given that FCR distributions are reasonably log normally distributed, there is likely a linear relationship between log transformed percentiles of the distribution of Idaho caught fish consumption and the distribution of Group 2 fish consumption (for which we have the NCI estimate of the distribution).

Let P_I represent percentiles of the distribution of Idaho caught fish consumption that are to be estimated. Let $P_{G2,NCI}$ represent percentiles of the distribution of Group 2 fish consumption estimated using the NCI method. Then assume:

$$\mathrm{Ln}(P_i) = \ln(S) + F*\mathrm{Ln}(P_{G2,NCI}), \text{ or equivalently } P_i = S * (P_{G2,NCI})^F.$$

The problem is how to estimate S, a scaling factor, and F, a slope roughly equal to the ratio of the standard deviation of $\mathrm{Ln}(P_i)$ to the standard deviation of $(\ln P_{G2,NCI})$.

Using results from NHANES data previously analyzed for EPA Headquarters, Westat did a quick analysis comparing the NCI-derived distributions of fish consumption for different types of fish. Let R equal the ratio of the mean fish consumption for the fish type used as the dependent distribution to the mean fish consumption for the fish type used as an independent distribution. When predicting the distribution of a less consumed fish type from the distribution of a more consumed fish type (i.e., $R < 1$), it appears the F should be greater than 1.0 with higher slopes as R decreases.

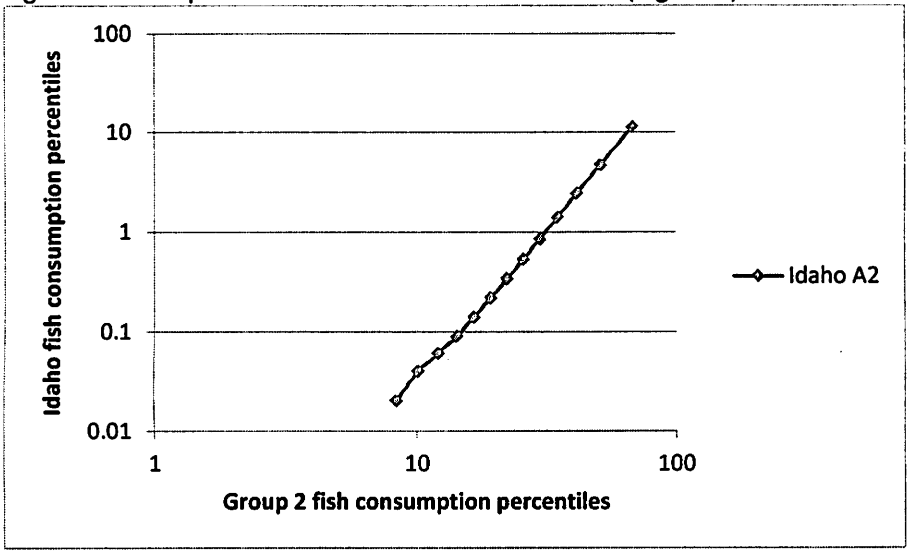
As an example of the calculations, Table 1 has the 35th through 95th percentiles of the consumption distributions for all fish and for Idaho caught fish from the Idaho state survey (see: NCI Method Estimates of Usual Intake Distributions for Fish Consumption in Idaho, Tables A1 and A2, using All Subjects). Lower percentiles were not included because the estimates were reported as "<.01" or were particularly imprecise.

Table 1 Percentiles of fish consumption for all subjects

Percentile	All Fish Table A1	Idaho fish Table A2
35	8.31	0.02
40	10.09	0.04
45	12.06	0.06
50	14.25	0.09
55	16.61	0.14
60	19.27	0.22
65	22.29	0.34
70	25.71	0.53
75	29.74	0.84
80	34.85	1.38
85	41.44	2.42
90	51.11	4.66
95	67.66	11.24

Figure 1 shows a plot of the percentiles of Idaho fish consumption as a function of the percentiles of all fish consumption, using log scales. As can be seen, the log-transformed percentiles fall on a roughly straight line.

Figure 1. Plot of percentiles for Idaho fish versus all fish (log scale)



Fitting a linear regression to predict the log-transformed percentiles for Idaho fish consumption from the log-transformed percentiles of all fish consumption gives a slope of F = 3.00. Although this analysis used selected percentiles, using all percentiles between the 1st and 99th percentiles and using more precision is recommended.

Different slopes will be obtained using different data or different subsets of the data (such as anglers only). For all subjects in the Idaho state survey the ratio of the means (R) is .106, smaller than the ratio of 0.242 estimated for the Nez Perce from the FFQ. Although one could use F = 3.00 for the Nez Perce, since F appears to increase as R decreases and R for the Idaho state data is less than for the Nez Perce, an appropriate slope for predicting Nez Perce Idaho fish consumption from Group 2 fish consumption may be less than 3.00. Some judgment is required to set the value of F. Considerations might include:

- calculations using Idaho data (as above),
- calculations using NHANES data, or possibly
- calculations using FFQ data (note that the precision and bias of FFQ data are uncertain and lower percentiles of FFQ estimated Idaho fish consumption are zero; it is not possible to calculate the log of zero).

Once F is set, calculate R, in the case of the Nez Perce based on the FFQ data. R is the ratio of the reported means of Idaho fish consumption and Group 2 fish consumption:

$$R = \mathrm{Mean}(I_{FFQ}) / \mathrm{Mean}(G2_{FFQ}) = 0.242$$

Also calculate the mean of $P_{G2,NCI}$ and $(P_{G2,NCI})^F$ across all percentiles (excluding the 0th and 100th percentile). These means are calculated using the percentiles from the DISTRIB macro because those are the data that are available.

The calculations assume the ratio of the mean Idaho fish consumption to the mean Group 2 fish consumption is the same for the FFQ data as for the NCI or "NCI-like" data, i.e.,:

$$\mathrm{Mean}(I_{FFQ})/\mathrm{Mean}(G2_{FFQ})=\mathrm{Mean}(P_i)/\mathrm{Mean}(P_{G2,NCI})$$

Since $\mathrm{Mean}(P_i) = S^* \mathrm{Mean}((P_{G2,NCI})^F)$, solving for S gives:

$$S = R * \mathrm{Mean}(P_{G2,NCI}) / \mathrm{Mean}((P_{G2,NCI})^F)$$

Finally, calculate the "NCI-like" distribution:

$$P_i = S * (P_{G2,NCI})^F$$

The mean of P_i across all percentiles (excluding the 0th and 100th percentile) should be equal to $\mathrm{Mean}(I_{FFQ})$. Note that if F = 1.0, then S = R and the scaled NCI distribution is the same as calculated previously by Idaho DEQ. Using a slope (F) greater than 1.0 spreads out the distribution, particularly the upper tail, compared to using F = 1.

We expect the approach outlined above, using an estimated value of the slope F, will provide a better estimate of Nez Perce Idaho caught fish consumption distribution than assuming F equals 1.0.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF THE
REGIONAL
ADMINISTRATOR

DEC 18 2014

Maia Bellon, Director
Department of Ecology
P.O. Box 47600
Olympia, Washington 98504-7600

Dear Director Bellon:

I am writing in follow up to my letter dated April 8, 2014, in which I described the U.S. Environmental Protection Agency's intention to amend the National Toxics Rule for the State of Washington's human health water quality criteria should the Washington Department of Ecology not finalize its human health water quality criteria by the end of 2014. Consistent with that letter, I am informing you that the EPA has initiated its internal federal rulemaking process to amend the NTR for Washington's human health water quality criteria and plans to publicly announce the initiation of the process on the EPA's Website in mid-January 2015 via a monthly notice that summarizes upcoming EPA regulatory actions (known as the Action Initiation List).

At the same time, as you know, the EPA remains interested and committed to supporting the State's process to complete a water quality standards submission for the EPA to review. I am encouraged by Ecology's timeline to issue a draft rule for public comment in January 2015, and appreciate the Governor's personal investment in moving the State's efforts forward. I continue to strongly encourage the State to fully consider the issues that the EPA has raised during the State's rulemaking process, particularly regarding the need for the State to base its decision on sound science and the best available data, which provide evidence of fish consumption rates well above 6.5 grams per day in Washington, and to explain why a change in the State's long-standing cancer risk protection level is necessary and how it is consistent with its strategy for protecting higher fish consumers in Washington. I am hopeful that Washington's submission to the EPA fully addresses these issues, protects human health and the environment, and is consistent with the Clean Water Act.

The EPA recognizes that its federal rulemaking activities, specifically the timeframe for developing draft federal water quality criteria for Washington, would overlap with Washington's potential timeline for finalizing its rule. Therefore, it is important to note that, if Washington were to submit a final rule to the EPA for Clean Water Act review and action, the EPA would likely pause its federal rulemaking activities to fulfill its required duty to review and act on the submittal under the Clean Water Act (to either approve the submittal within 60 days or disapprove within 90 days). However, initiating the EPA's internal rulemaking process now, preserves the EPA's ability to propose a rule in a timely manner should action on our part become necessary.

Consistent with the input we have provided the State, the EPA will ensure that its federal rulemaking process fully considers the best available science, including local and regional information, and applicable EPA policies, guidance, and legal requirements. These policy and legal considerations would include an assessment of downstream waters protection, environmental justice, federal trust responsibility, and tribal treaty rights and how those issues should inform the EPA's analysis of the protectiveness of the water quality criteria. At this time, the EPA believes it would be able to complete a proposed federal rule within approximately 9-12 months unless, as previously noted, it pauses its process to review a final State submittal. The EPA acknowledges that this would mean the earliest timeline for a federal proposal would likely be August 2015, which is later than the May 2015 timeframe I noted in my April 2014 letter. I believe the August timeframe strikes a balance by providing time for Washington to potentially complete its rulemaking process and submit a final rule to the EPA for Clean Water Act review while at the same time allowing the EPA to prepare to move forward with updating the federal rule should that action become necessary.

Finally, the EPA recognizes that industry and local governments have raised concerns about implementation flexibility and being provided time to meet new, more stringent water quality standards. The EPA supports Ecology's efforts to regularly engage a broad range of stakeholders about these concerns during its rulemaking process, and several of those concerns have been addressed in the State's analysis on the potential economic costs and benefits of the preliminary draft rule. The EPA intends to continue working with the State on its development and use of appropriate implementation mechanisms that are consistent with the Clean Water Act, including variances and compliance schedules.

We are keenly aware of the need to implement water quality standards in ways that make reasonable progress in improving water quality while protecting the economic viability of state industries and communities. To that end, the EPA is available to meet jointly with Ecology and key stakeholders to discuss how implementation mechanisms can and should work to make progress toward improved water quality while accounting for the needs of the regulated community. We look forward to continuing to work with the State on a successful path forward.

The EPA remains very appreciative of the challenging work that Ecology has undertaken thus far to adopt human health water quality criteria and we look forward to reviewing a rule proposal in January. Developing water quality standards that protect public health remains a high priority issue for the EPA, especially in Region 10. Please note that, as with my April 8, 2014 letter, this letter does not constitute and is not intended as an Administrator determination under CWA section 303(c)(4(B). If you would like to discuss these topics further, please contact me directly or have your staff contact Dan Opalski, our Director for the Office of Water and Watersheds, at (206) 553-1855.

Sincerely,

Dennis J. McLerran
Regional Administrator

cc: Michael Grayum, Executive Director
Northwest Indian Fisheries Commission

Brian Cladoosby, Tribal Chairman
Swinomish Tribe

Matt Steuerwalt, Policy Advisor
Washington State Governor's Office

Considerations in Deciding Which Fish to Include in Idaho's Fish Consumption Rate

Policy Summary

State of Idaho
Department of Environmental Quality

August 2015

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Introduction

Water quality criteria are established, in part, to protect human health. For strongly bioaccumulative environmental contaminants, the major route of exposure is through consuming contaminated fish tissue. Therefore, water quality criteria for toxic chemicals are derived based on the usual fish consumption rate (FCR) for a targeted population. This paper summarizes the factors considered in recommending which fish to include in Idaho's regulatory FCR.

Idaho Regulatory Jurisdiction

Idaho does not have regulatory authority over discharges to either estuarine or marine waters. As such, Idaho water quality criteria have very little effect on the contaminant body burden (i.e., total amount of contaminant) of estuarine or marine fishes. Similarly, Idahoans' exposure to estuarine or marine fishes is mostly limited to what they purchase in the market.

In addition, the Clean Water Act only applies to US waters. The US Environmental Protection Agency (EPA) acknowledges this regulatory reality by excluding marine fish from its estimated national FCR. Furthermore, EPA suggests that "an inland state may only be interested in freshwater fish UFCRs [usual fish consumption rates]," acknowledging the lack of regulatory authority inland states have over the quality of both marine and estuarine fishes (EPA 2014).

Moreover, inclusion of fish in Idaho's regulatory FCR implies that Idaho water quality standards can be used to improve the quality of those included fish. Therefore, the Idaho Department of Environmental Quality (DEQ) limited the FCR to only those fish that are likely to pick up their contaminant body burden in Idaho waters and that can subsequently be expected to have reduced contaminant body burdens as a result of criteria implementation.

Market Fish versus Idaho Fish

The proposed rule excludes most market fish from the FCR used to calculate ambient water quality criteria largely because Idaho does not regulate the contaminant load of market fish. Although Idaho does have an active aquaculture industry, Idaho does not support a commercial fishing industry.[1] Therefore, it is reasonable to assume that nearly all fish purchased in the market are from outside of Idaho and that Idaho water quality standards will have little or no effect on their contaminant burden. The one exception is Rainbow Trout, as discussed below.

Importation of Market Fish

Approximately 90% of seafood consumed in the US is imported from foreign countries (i.e., not regulated under the Clean Water Act).[2] The top 10 seafood species consumed in the United States are largely imported from Asia (Table 1, Figure 1).

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[1] *www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings*

[2] *www.fishwatch.gov/wild_seafood/outside_the_us*

Table 1. US per capita consumption (in 2011) and likely origin of the 10 most popular species of market seafood.[a]

Species	Per Capita Consumption (pounds)	Origin
Shrimp	4.2	>90% foreign farmed
Canned tuna	2.6	Imported from Thailand, Philippines, Vietnam, Ecuador
Salmon	1.952	Two-thirds is farmed, mainly imported from Norway, Chile, and Canada, with a small amount grown domestically
Pollock	1.12	Most is wild-caught in Alaska
Tilapia	1.287	Aquaculture. China supplies most of the tilapia in our markets, followed by Ecuador, Indonesia, and Honduras
Pangasius	0.628	Aquaculture, primarily Vietnam, with production increasing in China, Cambodia, Laos, and Thailand
Catfish	0.559	Farm-raised in the US
Crab	0.518	Wild-caught in US waters
Cod	0.501	Wild-caught in US waters. Our Alaska fisheries for Pacific cod account for more than two-thirds of the world's Pacific cod supply
Clams	0.331	Wild-caught and farm-raised in the US

[a] *Source*: *www.fishwatch.gov/features/top10seafoods_and_sources_10_10_12*

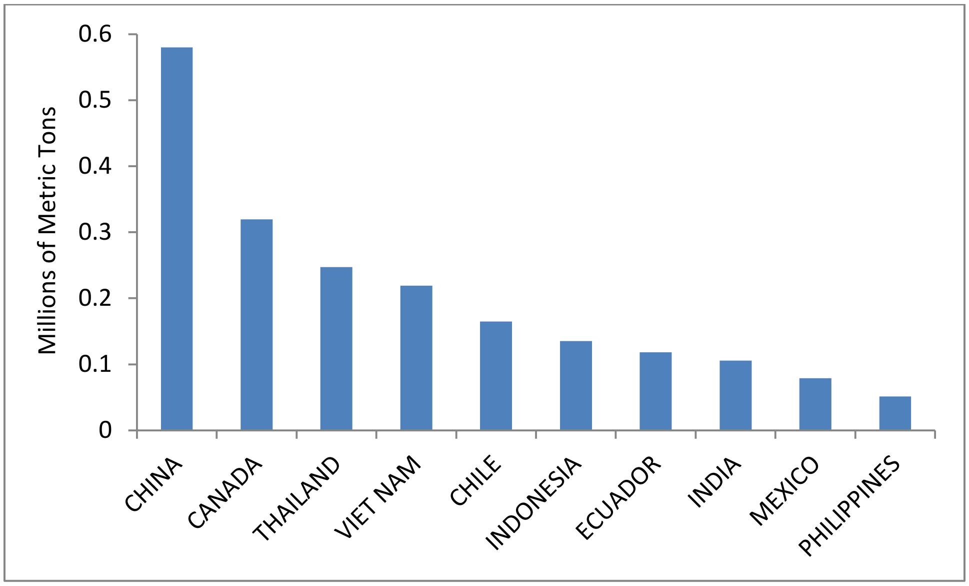

Figure 1. Top ten countries of origin for imported US seafood. Data available from *www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/applications/monthly-product-by-countryassociation*.

Rainbow Trout

Idaho does have an active aquaculture industry and is a national leader in trout production, accounting for 52% of the total value of fish sold by trout growers in the US.[3] Because of the high likelihood that a trout purchased in the market originated in Idaho waters, we chose to include market trout in our regulatory FCR.

Anadromous Fish

As articulated in DEQ discussion paper #5—dated July 2014—the issue when considering anadromous fish for inclusion in an FCR is where they acquire their burden of contaminants and how that should be handled in developing water quality criteria that are applied to Idaho.

DEQ proposed excluding anadromous salmon from our regulatory FCR for reasons related to their life history and the limits of our regulatory authority. Although anadromous salmon spend key parts of their lifecycle in Idaho waters, the majority of their growth, and subsequent body burden of environmental contaminants, is derived from the marine environment.

Relative Time in Marine versus Idaho Waters

Idaho salmon spend more of their life outside than within Idaho waters. The majority of Idaho Chinook Salmon emigrate as subyearling smolts, with the remainder emigrating as yearlings. Copeland et al. (2013) found that subyearling smolts accounted for up to 60% of all Chinook emigrants (and an even larger proportion of wild Chinook emigrants) moving downstream at Lower Granite Dam (Figure 2).

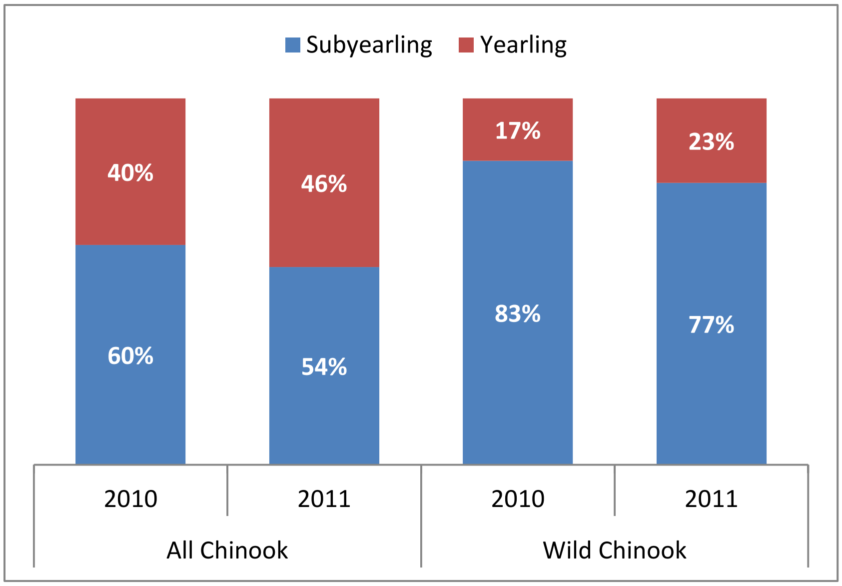

Figure 2. Percent of juvenile Chinook emigrants that were subyearling and yearling for all Chinook and wild Chinook at Lower Granite Dam, 2010 and 2011. The majority emigrate as subyearlings.

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[3] *http://usda.mannlib.cornell.edu/usda/current/TrouProd/TrouProd-03-06-2015.pdf*

Most of these fish spend 2 or 3 years at sea before returning to Idaho waters to spawn. According to data from the Fish Passage Center (*www.fpc.org*), from 2000 to 2012 more than 90% of Chinook Salmon returning over Lower Granite Dam had spent at least 2 years at sea (Table 2).

Table 2. Percent of Chinook Salmon spending 1, 2, 3, or 4 years at sea before returning over Lower Granite Dam on the Snake River.

Migration Year	1 Year at Sea (%)	2 Years at Sea (%)	3 Years at Sea (%)	4 Years at Sea (%)
2000	1.5	44.6	53.7	0.2
2001	4.3	63.8	31.9	0.0
2002	10.0	75.5	14.6	0.0
2003	3.4	69.3	27.3	0.0
2004	2.3	64.8	32.0	0.8
2005	6.1	57.6	36.4	0.0
2006	7.0	72.1	20.9	0.0
2007	9.6	78.1	12.3	0.0
2008	13.1	66.6	20.2	0.0
2009	9.1	64.7	26.3	0.0
2010	18.1	59.2	22.7	0.0
2011	10.9	78.7	10.5	0.0
2012	23.1	76.9	0.0	0.0
Total, 2000–2012	9.1	67.1	23.8	0.5

Relative Growth in Marine versus Idaho Waters

Salmon growth is largely achieved in the open ocean, with more than 98% of the final weight of a salmon being achieved at sea (Quinn 2005). In fact, for the average Chinook, Sockeye, and Coho Salmon, more than 99% of the total weight of adult fish is achieved at sea (Table 3)

Table 3. Generalized weights of salmon as they enter the ocean (smolts) and adult weights, as well as the percent of total adult weight achieved at sea. Summarized from Quinn (2005).

Species	Smolt Weight (grams)	Adult Weight (grams)	Percent Weight Achieved at Sea
Chinook	18	7,220	99.75
Sockeye	10	2,690	99.63
Coho	18	3,020	99.41

Relative Source of Body Burden of Contaminants

Although salmon are known to acquire contaminants in freshwaters during early life and spawning (Qiao et al. 2000; Johnson et al. 2007), the vast majority of their body burden of contaminants is acquired in the marine environment since the vast majority of their body mass is acquired at sea.

O'Neill and West (2009) found that while Chinook smolts from a highly contaminated stream acquired organic contaminants from their natal stream, this accounted for only 3.8% of their final body burden of these contaminants.

Hope (2012) modeled 16 scenarios for Chinook Salmon exposure to polychlorinated biphenyls (PCBs), a common and typical contaminant of Chinook Salmon and their prey. He found that exposure scenarios that only included exposure in the freshwater environment (instream or through contaminated hatchery food) could not approximate observed body burden of PCBs in Chinook Salmon. Moreover, scenarios that only included exposures in estuarine and marine environments did approximate actual, observed contaminant body burdens. These results suggest that current, observed levels of PCBs in anadromous fish are almost entirely acquired outside of freshwater; removing all PCBs from the freshwater environment will have virtually no effect on the concentration of contaminants in Idaho salmon.

EPA (2014) acknowledges the insignificant role that freshwater water quality has on the contaminant body burden of anadromous fish, classifying salmon as 96% marine, 0.5% freshwater, and 3.5% estuarine. The freshwater component accounts for kokanee, a landlocked form of Sockeye Salmon. EPA states that "the freshwater percent is landlocked Sockeye Salmon (kokanee) found natively in Alaska, Washington, and Oregon, but they have also been introduced to many other states for recreational fishing." Kokanee are an important and popular freshwater species harvested in Idaho. We did not include kokanee as part of our salmon grouping, but accounted for them separately and included them in our FCR.

Steelhead Trout

Compared to other anadromous salmonids, steelhead trout life histories are highly complex. It is difficult or impossible to generalize what fraction of their time is spent in saltwater as opposed to freshwater. The anadromous and resident forms often inhabit the same waters, where they often interbreed. Furthermore, offspring may develop either migratory life history strategy, regardless of the life history strategy of their parents.

Because of the complexity of life history strategies exhibited by steelhead, and because we are not able to accurately distinguish between anadromous steelhead and resident Rainbow Trout, steelhead are included as Idaho fish in our regulatory FCR.

Further Rationale for Excluding Anadromous Salmon

Idahoans who depend largely on anadromous salmon for subsistence are particularly susceptible to high levels of fish-borne contaminants. These individuals may be looking toward this rule-making effort as a way to reduce their exposure to these contaminants. If Idaho included anadromous salmon in the FCR, we would be implying that these criteria will reduce exposure from anadromous salmon, which is not the case.

By excluding the majority of anadromous salmon and using the relative source contribution (RSC) to account for the contribution from salmon (and market fish), we are being explicit about what Idaho's water quality criteria can affect and about Idaho's jurisdictional reach.

This approach is consistent with EPA's approach, as outlined in its FCR estimate used to develop the 2015 national recommended human health criteria (EPA 2014). In its FCR, EPA limited consumption to only inland and near-shore fish, since marine fish are exposed to contaminants outside the jurisdiction of the CWA. Furthermore, EPA (2014) assigned salmon as being 96% marine (excluded from FCR used for criteria recommendation), 3.5% estuarine, and 0.5% freshwater. Since Idaho does not have jurisdiction over any near-shore marine or estuarine waters, we are proposing to exclude the estuarine proportion of salmon as well.

Popularity of Idaho Gamefish Species

The Idaho Department of Fish and Game (IDFG) conducted an angler opinion survey in 2011 to inform their *Fisheries Management Plan* (IDFG 2012). Among other information, the survey identified the most popular gamefish in Idaho (Figure 3).

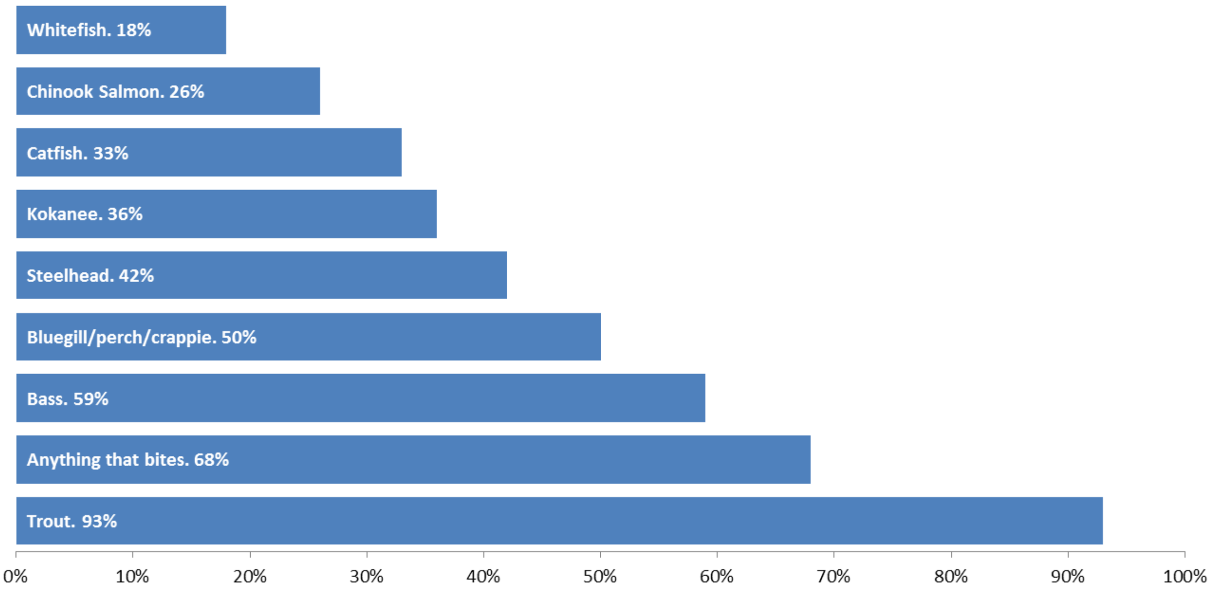

Figure 3. Gamefish most often targeted by Idaho anglers.

While the survey does not specifically address harvesting versus catch and release, it is reasonable to assume that anglers prefer to harvest fish in roughly the same proportions, making trout the most popular fish for Idaho anglers.

Suppression

Suppression of fish consumption can affect the rates reported in a survey of usual fish consumption rates. Fish consumption can be suppressed due to contamination of fishes, which in turn causes a decreased consumption of fish due to health concerns. Consumption of fish could also result from decreased availability of fish from historical levels.

From a regulatory perspective, human health water quality standards can only affect the first instance of suppression: when consumption is suppressed due to health concerns associated with contaminated fish. While there are certainly individuals in Idaho who may be limiting their fish consumption due to health concerns, this represents a very small percentage of the population: only 3% of respondents to Idaho's fish consumption survey (NWRG 2015) reported that they didn't consume seafood due to concerns about pollution or contamination. Conversely, nearly half (48%) of respondents indicated that they consumed fish at least in part for its health benefits.

Human-health based water quality standards cannot affect the second instance of suppression: when fish consumption is suppressed due to lack of availability or access to fish. Water quality standards are set to protect human health based on current conditions. Using contemporary rates is our best tool for protecting human health at current conditions. While heritage rates can be estimated, they do not reflect current reality. We believe requiring dischargers to meet criteria based on historical or future availability is unreasonable.

Fish Consumption has Increased

The concerns about suppression of fish consumption are real, and certain individuals have certainly reduced their consumption of certain fish due to both health concerns and lack of availability. Nonetheless, the broader view is that fish consumption has increased and the trend has been toward higher consumption. According to data provided by the US Department of Agriculture, since 1980, the per capita consumption of fish for the United States has increased from 12.4 pounds per year to over 15 pounds per year (US Census Bureau 2012). EPA's recommended FCR has similarly increased over the years (Figure 4). So, while localized suppression is occurring, overall fish consumption has been rising, and so has the level of consumption accounted for in the water quality criteria. Thus, concerns that suppressed fish consumption is causing a downward spiral in fish quality is not evident.

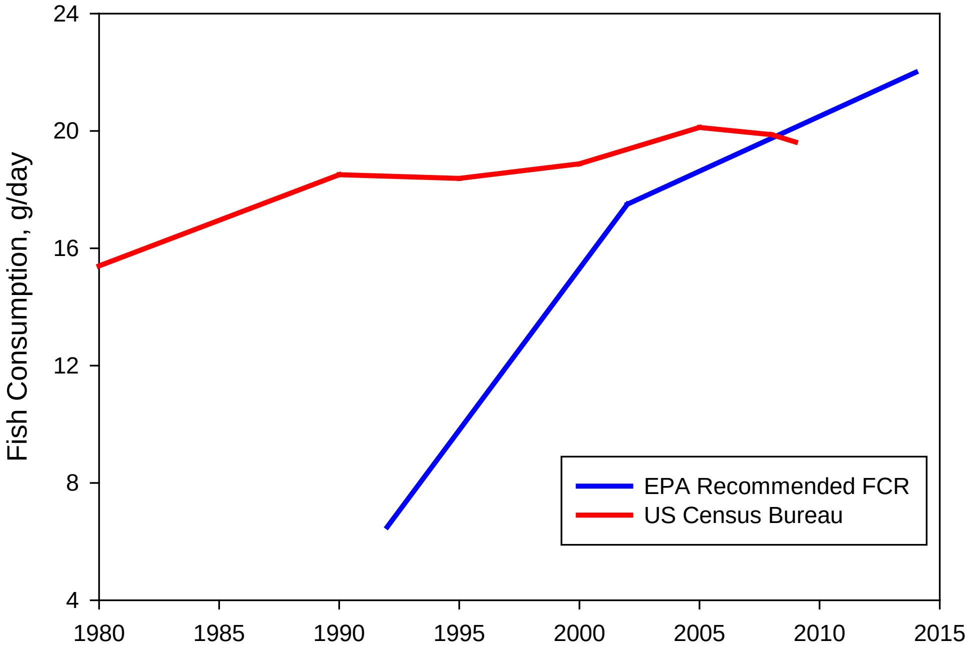

Figure 4. Per capita consumption of fish in the United States and EPA-recommended fish consumption rate (FCR), 1980–2014.

If fish become more readily available, and fish consumption increases, it is highly likely that Idaho will revise its standards and associated FCR. In fact, Idaho water quality standards have been moving toward more stringent criteria. In Idaho's 2005 update of human health criteria, our FCR increased from 6.5 to 17.5 grams/day. In 2015, we are again looking at more stringent criteria, or at least keeping them the same. Based on EPA's 2014 proposed national 304(a) criteria, we would have an increased FCR of 22 grams/day and a drinking water intake increased from 2 liters/day to 2.4 liters/day. These trends are likely to continue in the future.

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from other aircraft operating in visual weather conditions. The area would be depicted on appropriate aeronautical charts thereby enabling pilots to circumnavigate the area or otherwise comply with IFR procedures. Class E airspace designations for airspace areas extending upward from 700 feet or more above the surface of the earth are published in paragraph 6005 of FAA order 7400.9D dated September 4, 1996, and effective September 16, 1996, which is incorporated by reference in 14 CFR 71.1. The Class E airspace designation listed in this document would be published subsequently in the Order.

The FAA has determined that this proposed regulation only involves an established body of technical regulations for which frequent and routine amendments are necessary to keep them operationally current. Therefore this proposed regulation—(1) Is not a ''significant regulatory action'' under Executive Order 12866; (2) is not a ''significant rule'' under DOT Regulatory Policies and Procedures (44 FR 11034; February 26, 1979); and (3) does not warrant preparation of a Regulatory Evaluation as the anticipated impact is so minimal. Since this is a routine matter that will only affect air traffic procedures and air navigation, it is certified that this proposed rule will not have a significant economic impact on a substantial number of small entities under the criteria of the Regulatory Flexibility Act.

List of Subjects in 14 CFR Part 71

Airspace, Incorporation by reference, Navigation (air).

The Proposed Amendment

Accordingly, pursuant to the authority delegated to me, the Federal Aviation Administration proposes to amend part 71 of the Federal Aviation Regulations (14 CFR part 71) as follows:

PART 71—[AMENDED]

1. The authority citation for part 71 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40103, 40113, 40120; E.O. 10854, 24 FR 9565, 3 CFR 1959–1963 Comp., p. 389; 14 CFR 11.69.

§ 71.1 [Amended]

2. The incorporation by reference in 14 CFR 71.1 of the Federal Aviation Administration Order 7400.9D, Airspace Designations and Reporting Points, dated September 4, 1996, and effective September 16, 1996, is amended as follows:

Paragraph 6005 Class E airspace areas extending upward from 700 feet or more above the surface of the earth.

* * * * *

AGL SD E5 South Dakota, SD [New]

That airspace extending upward from 1,200 feet above the surface within an area bounded on the north by latitude 43°40′00″ N, on the east by longitude 100°05′00″ W, on the south by the South Dakota, Nebraska border, an on the west by longitude 102°00′00″ W.

* * * * *

Issued in Des Plaines, Illinois on May 7, 1997.

Maureen Woods,

Manager, Air Traffic Division.

[FR Doc. 97–13261 Filed 5–20–97; 8:45 am]

BILLING CODE 4910–13–M

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 63

[AD–FRL–5828–4]

National Emission Standards for Hazardous Air Pollutants, Proposed Rule for Pharmaceuticals Production

AGENCY: U.S. Environmental Protection Agency (U.S. EPA).

ACTION: Extension of public comment period.

SUMMARY: The EPA is announcing the extension of the public comment period on the proposed national emission standards for hazardous air pollutants (NESHAP) for pharmaceuticals production (62 FR 15754), which was published on April 2, 1997.

DATES: Written comments must be received on or before July 2, 1997.

ADDRESSES: Submit comments in duplicate if possible to: Air Docket Section (LE–131), Attention: Docket No. A–96–03, U.S. Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460. The EPA requests that separate copies be sent to the appropriate contact person listed below. The docket may be inspected at the above address between 8:00 a.m. and 5:30 p.m. on weekdays, and a reasonable fee may be charged for copying.

FOR FURTHER INFORMATION CONTACT: For information concerning the NESHAP, contact Mr. Randy McDonald at (919)541–5402, Organic Chemicals Group, Emission Standards Division (MD–13), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. For information concerning the effluent limitation guideline pretreatment standards or new source performance standards, contact Dr. Frank Hund at (202) 260–7786, Engineering and Analysis Division (4303), U.S. Environmental Protection Agency, 401 M Street SW., Washington, DC 20406.

SUPPLEMENTARY INFORMATION: In response to a request from the Pharmaceutical Research and Manufacturers of America (PhRMA), EPA is extending the public comment period on the proposed standards from June 2, 1997 to July 2, 1997. The EPA agrees with PhRMA that an extension of the comment period will provide for more meaningful, constructive comments on the proposed rule. Having extended the comment period, EPA nonetheless encourages commenters to submit their comments (or as many of their comments as possible) before July 2; this would assist EPA in its considerations of the issues raised. Because the EPA has continued during the comment period to examine the issues outlined in the solicitation of comments section in the preamble of the proposed rule, EPA does not believe the extension of the comment period will disrupt the Agency's schedule for promulgating this regulation.

List of Subjects in 40 CFR Part 63

Environmental protection, Air pollution control, Hazardous substances, Reporting and recordkeeping requirements.

Dated: May 14, 1997.

Richard Wilson,

Acting Assistant Administrator for Air and Radiation.

[FR Doc. 97–13322 Filed 5–20–97; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 131

[FRL–5827–8]

Withdrawal From Federal Regulations of the Applicability to Alaska of Arsenic Human Health Criteria

AGENCY: Environmental Protection Agency.

ACTION: Proposed rule and request for comments.

SUMMARY: In 1992, EPA promulgated federal regulations establishing water quality criteria for toxic pollutants for several states, including Alaska (40 CFR 131.36). In this action, EPA is proposing to withdraw the applicability to Alaska of the federal human health criteria for arsenic. EPA is providing an

opportunity for public comment on withdrawal of the federal criteria because the state's arsenic criteria differ from the federal criteria.

DATES: EPA will accept public comments on its proposed withdrawal of the human health criteria for arsenic applicable to Alaska until July 7, 1997. Comments postmarked after this date may not be considered.

ADDRESSES: An original plus 2 copies, and if possible an electronic version of comments either in WordPerfect or ASCII format, should be addressed to Sally Brough, U.S. EPA Region 10, Office of Water, 1200 Sixth Avenue, Seattle, Washington, 98101.

The official administrative record for the consideration of this proposal for arsenic is available for public inspection at EPA Region 10, Office of Water, 1200 Sixth Avenue, Seattle, Washington, 98101, between 8:00 a.m. and 4:30 p.m. Copies of the record are also available for public inspection at EPA's Alaska Operations Offices: 222 West 7th Avenue, Anchorage, AK and 410 Willoughby Avenue, Janeau, AK.

FOR FURTHER INFORMATION CONTACT: Fred Leutner at EPA Headquarters, Office of Water (4305), 401 M Street, SW, Washington, DC, 20460 (telephone: 202–260–1542), or Sally Brough in EPA's Region 10 (telephone: 206–553–1295).

SUPPLEMENTARY INFORMATION:

Potentially Affected Entities

Citizens concerned with water quality in Alaska, and with pollution from arsenic in particular, may be interested in this proposed rulemaking. Since criteria are used in determining NPDES permit limits, entities discharging arsenic to waters of the United States in Alaska could be affected by this proposed rulemaking. Potentially affected entities include:

Category	Examples of affected entities
Industry	Industries discharging arsenic to surface waters in Alaska.
Municipalities	Publicly-owned treatment works discharging arsenic to surface waters in Alaska.

This table is not intended to be exhaustive, but rather provides a guide for readers regarding entities likely to be affected by this action. This table lists the types of entities that EPA is now aware could potentially be affected by this action. Other types of entities not listed in the table could also be affected. To determine whether your facility could be affected by this action, you should carefully examine the applicability criteria in § 131.36 of title 40 of the Code of Federal Regulations. If you have any questions regarding the applicability of this action to a particular entity, consult the person listed in the preceding **FOR FURTHER INFORMATION CONTACT** section.

Background

On December 22, 1992, the Environmental Protection Agency (EPA or Agency) promulgated a rule to establish federal water quality criteria for priority toxic pollutants applicable in 14 states. That rule, which is commonly called the National Toxics Rule (NTR), is codified at 40 CFR 131.36. The specific requirements for Alaska are codified at § 131.36(d)(12) and among other criteria, include water quality criteria for the protection of human health from arsenic. EPA promulgated a human health criterion for Alaska of 0.18 µg/L to protect waters designated for water consumption (i.e., sources of drinking water) plus the consumption of aquatic life which includes fish and shellfish such as shrimp, clams, oysters and mussels. This criterion is located in column D1 in the criteria matrix at section 131.36(b)(1). EPA also promulgated a criterion of 1.4 µg/L for waters designated for the human consumption of aquatic life without considering water consumption. This criterion is located in column D2 in the criteria matrix. These concentrations are designed to not exceed an excess lifetime cancer risk of 1 in 100,000 (or 10^{-5}) and reflects Alaska's preference in recent rule adoptions and in correspondence with EPA's Region 10. See 57 FR 60848, 60867.

EPA's criteria for human health protection from arsenic toxicity used in the NTR were based on carcinogenic effects. Alaska had adopted by reference EPA's published Clean Water Act (CWA) section 304(a) criteria for human health into the state's water quality standards. However, EPA's criteria guidance for carcinogens was presented at 3 different cancer risk levels, and the state had never officially adopted a specific cancer risk level. Accordingly, since Alaska did not have human health criteria for arsenic in place, EPA promulgated such criteria for the state in the NTR.

Subsequent to the promulgation of the NTR, a number of issues and uncertainties arose concerning the health effects of arsenic. EPA determined that these issues and uncertainties were sufficiently significant to necessitate a careful evaluation of the risks of arsenic exposure. Accordingly EPA has undertaken a number of activities aimed at reassessing the risks to human health from arsenic. [See Basis and Purpose section below.]

In light of EPA's review of the health effects of arsenic, the State of Alaska has proposed that the Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) for arsenic of 50 µg/L currently in the state's water quality standards be used as meeting the requirements of the Clean Water Act in lieu of the current human health criteria in the NTR. As adopted by Alaska, the MCL for arsenic applies to all fresh waters that have the public water supply designated use. (According to the state, this includes all but 20 fresh-water segments.) For the reasons discussed subsequently, EPA finds that the MCL for arsenic in freshwaters designated for public water supply, in conjunction with Alaska's aquatic life criteria for arsenic, meets the requirements of the CWA, and accordingly proposes to withdraw the applicability to Alaska of the human health criteria for arsenic promulgated in the NTR.

If EPA removes the applicability of the NTR arsenic human health criteria to Alaska, the state has in place a chronic marine aquatic life criterion of 36 µg/L, a chronic freshwater aquatic life criterion of 190 µg/L, and the freshwater criterion of the MCL of 50 µg/L for waters designated for public water supply discussed above. The aquatic life criteria are in place for all of the state's marine and estuarine waters, and in those few cases where the MCL is not applicable in freshwaters.

Basis and Purpose

There are a number of ongoing national activities that may affect and/or necessitate a future change in the arsenic criteria for both ambient and drinking water in Alaska. The National Academy of Sciences (NAS) has initiated a study of the health risks posed by arsenic in water. Results of the study are expected in the Spring of 1998. Moreover, EPA is in the process of re-evaluating the risk assessments for arsenic as part of a pilot program for reconfiguring the Integrated Risk Information System (IRIS). EPA originally planned this re-evaluation to cover aspects of both cancer and non-cancer risks and to include examination of data not previously reviewed. With the initiation of the NAS study, EPA redirected the focus of the IRIS re-evaluation to the application of the proposed revisions to EPA's Guidelines for Cancer Risk Assessment. The IRIS re-evaluation of arsenic is expected in

1997. EPA encourages the state to review its water quality criteria for arsenic as this new information becomes available.

EPA has recognized the use of appropriate MCLs in establishing water quality standards under the CWA. Agency guidance notes the differences between the statutory factors for developing SDWA MCLs and CWA section 304(a) criteria, but provides that where human consumption of drinking water is the principal exposure to a toxic chemical, then an existing MCL may be an appropriate concentration limit. See guidance noticed in 54 FR 346, January 5, 1989. Similarly, the CWA section 304(a) human health guidelines are consistent with this position. See 45 FR 79318, November 28, 1980.

To determine whether the MCL could appropriately be used in lieu of the NTR's human health criteria for arsenic, EPA has prepared an exposure analysis to estimate the significance of human consumption of fish and shellfish containing the amounts of inorganic arsenic indicated as present in representative samples of fish and shellfish, in conjunction with the consumption of water containing concentrations of arsenic currently existing in the Nation's waters. See EPA's ''Arsenic and Fish Consumption Concerns'' in the administrative record for this rulemaking. This analysis first recognizes that the most important toxic form of arsenic is inorganic arsenic. Inorganic arsenic is the principal form in surface waters and almost the exclusive form in ground waters. However, the arsenic in fish and most shellfish is largely present as organic arsenic (mostly arsenobetaine). Available information indicates that arsenobetaine passes through these organisms with minimal retention in the fish and shellfish tissues.

In the NTR, EPA based the promulgated criteria on the human health criteria methodology contained in the 1980 human health guidelines. To estimate the ambient water concentration of a pollutant that does not represent a significant risk to the public (i.e., the criteria levels), the methodology makes certain assumptions about human exposure to pollutants. The methodology assumes that for most people, drinking water intake is 2 liters per day, and that fish consumption is 6.5 grams per day (a little less than one-half pound per month). The methodology incorporates a bioconcentration factor (BCF) to account for a pollutant's concentration in fish and shellfish tissue versus its concentration in the water. The methodology also assumes that all of the water and fish consumed is contaminated at the criteria levels (the ''safe'' levels).

Using these same exposure factors from the methodology, EPA has assessed the effect of using the arsenic MCL. Assuming that the concentration of arsenic in water is at the MCL of 50 μg/L, most people would be exposed to 100 μg of arsenic from their drinking water intake (i.e., 2 L/day × 50 μg/L = 100 μg/day), and 0.6 μg/day of inorganic arsenic from consuming 6.5 grams of fish and shellfish collected from water at the arsenic MCL concentration and assuming the BCF used in the NTR. (See derivation in EPA's ''Arsenic and Fish Consumption Concerns'' in the record.) The total estimated exposure would be 100.6 μg/day which could consist entirely of inorganic arsenic. EPA considers the small increment of exposure from fish consumption to be insignificant. EPA therefore concludes that when applied to fresh waters in Alaska, use of 50 μg/L generally provides a level of protection equivalent to that provided by the MCL. A full characterization of other exposure scenarios is contained in EPA's exposure analysis described above. This analysis is in the administrative record for this proposal and is currently undergoing external peer review. The results of the peer review will be considered before final action is taken on this rule.

For regions in Alaska where high levels of arsenic in the potable water are accompanied by high levels of fish and shellfish consumption, the State of Alaska should develop site-specific criteria for the surface waters involved considering the arsenic content of the drinking water and fish consumed. In developing site-specific criteria the state should characterize the size and location of the population of concern and determine their fish/shellfish and water intake rates. The fish and shellfish consumption should consider the species and dietary intake on a per species basis. Actual total arsenic and inorganic arsenic values for the species consumed and actual concentrations in drinking water should be used in the exposure calculations whenever possible.

The Agency solicits comment on whether there are any locations in Alaska where the arsenic criteria in the NTR should not be removed. For such locations, EPA solicits data documenting such existing conditions which indicate that fish consumers may be at an unacceptable risk of arsenic toxicity, and whether some other site-specific arsenic human health criteria may be appropriate. EPA solicits any information such as that described above concerning possible site-specific criteria to be developed by the State of Alaska.

Regulatory Procedural Information

This proposed withdrawal of human health criteria for arsenic in Alaska is deregulatory in nature and would impose no additional regulatory requirements or costs. Therefore, it has been determined that this proposed action is not a ''significant regulatory action'' under the terms of Executive Order 12866 and is therefore not subject to OMB review.

Based on the fact that this action is deregulatory in nature and would impose no regulatory requirements or costs, pursuant to section 605(b) of the Regulatory Flexibility Act, the Administrator certifies that this action will not have a significant economic impact on a substantial number of small entities. EPA has determined that this action does not contain a Federal mandate that may result in expenditures of $100 million or more for state, local and tribal governments, in the aggregate, or to the private sector in any one year. EPA has also determined that this action contains no regulatory requirements that might significantly or uniquely affect small governments. Thus, today's action is not subject to the requirements of sections 202, 203 and 205 of the UMRA.

This proposed rule does not impose any requirement subject to the Paperwork Reduction Act.

List of Subjects in 40 CFR Part 131

Environmental protection, Water pollution control, Water quality standards.

Dated: May 14, 1997.

Carol M. Browner,

Administrator.

For the reasons set out in the preamble, title 40, chapter I, part 131 of the Code of Federal Regulations is proposed to be amended as follows:

PART 131—WATER QUALITY STANDARDS

1. The authority citation for part 131 continues to read as follows:

Authority: 33 U.S.C. 1251 *et seq.*

§ 131.36 [Amended]

2. In § 131.36(d)(12)(ii) the table is amended under the heading ''Applicable Criteria'', in the entry for ''Column D1'' and three entries for

''Column D2'' by removing the number ''2'' from the list of numbers.

[FR Doc. 97–13325 Filed 5–20–97; 8:45 am]

BILLING CODE 6560–50–P

FEDERAL COMMUNICATIONS COMMISSION

47 CFR Part 1

[MD Docket No. 96–186]

Assessment and Collection of Regulatory Fees For Fiscal Year 1997

May 16, 1997.

AGENCY: Federal Communications Commission.

ACTION: Notice of proposed rulemaking; availability of documents.

SUMMARY: The Commission has placed several documents in the docket file associated with this proceeding which provide background information used in developing its regulatory fee proposals for FY 1997.

FOR FURTHER INFORMATION CONTACT: Peter W. Herrick, Office of Managing Director at (202) 418–0443, or Terry D. Johnson, Office of Managing Director at (202) 418–0445.

SUPPLEMENTARY INFORMATION:

Additional Cost of Service Information Related to Establishing Regulatory Fees for Fiscal Year 1997 Available in MD Docket No. 96–186

The Office of the Managing Director, in response to a request by Comsat International Communications, has provided to Comsat additional documents related to the Commission's distribution of costs among services and other information utilized in the development of its annual regulatory fees. *See letter* to Robert A. Mansbach, Esquire from Andrew S. Fishel, Managing Director, dated April 4, 1997. Relevant information provided to Comsat and other information related to the development of the Commission's regulatory fees, including actual FY 1996 payment information, has been placed in the docket file for the Commission's proceeding to establish its regulatory fees for Fiscal Year 1997. These materials are available for public inspection during regular business hours in the Commission's Public Reference Room (Room 239) at its headquarters, 1919 M Street, N.W., Washington, D.C. *See* notice of proposed rulemaking re assessment and collection of regulatory fees for Fiscal Year 1997, MD Docket No. 96–186, 62 FR 10793, March 10, 1997. Copies of materials contained in the docket file may be purchased from the Commission's copy contractor, International Transcription Services (ITS), in Room 246 or by calling 202–857–3800.

Federal Communications Commission.

LaVera F. Marshall,

Acting Secretary.

[FR Doc. 97–13368 Filed 5–20–97; 8:45 am]

BILLING CODE 6712–01–P

FEDERAL COMMUNICATIONS COMMISSION

47 CFR Part 73

[MM Docket No. 97–131, RM–9078]

Radio Broadcasting Services; Twin Falls, ID

AGENCY: Federal Communications Commission.

ACTION: Proposed rule.

SUMMARY: This document requests comments on a petition for rule making filed on behalf of JTL Communications Corporation requesting the allotment of Channel 294A to Twin Falls, Idaho, as an additional local FM broadcast service at that community. Coordinates used for Channel 294A at Twin Falls are 42–33–42 and 114–28–12.

DATES: Comments must be filed on or before July 7, 1997, and reply comments on or before July 22, 1997.

ADDRESSES: Secretary, Federal Communications Commission, Washington, DC 20554. In addition to filing comments with the FCC, interested parties should serve the petitioner's counsel, as follows: J. Frederick Mack and Bradley J. Wiskirchen, Esqs., Holland & Hart, Suite 1400, U.S. Bank Plaza, 101 South Capitol Boulevard, PO Box 2527, Boise, ID 83701.

FOR FURTHER INFORMATION CONTACT: Nancy Joyner, Mass Media Bureau, (202) 418–2180.

SUPPLEMENTARY INFORMATION: This is a synopsis of the Commission's Notice of Proposed Rule Making, MM Docket No. 97–131, adopted May 7, 1997, and released May 16, 1997. The full text of this Commission decision is available for inspection and copying during normal business hours in the FCC's Reference Center (Room 239), 1919 M Street, NW., Washington, DC. The complete text of this decision may also be purchased from the Commission's copy contractors, International Transcription Service, Inc., (202) 857–3800, 2100 M Street, NW., Suite 140, Washington, DC 20037.

Provisions of the Regulatory Flexibility Act of 1980 do not apply to this proceeding.

Members of the public should note that from the time a Notice of Proposed Rule Making is issued until the matter is no longer subject to Commission consideration or court review, all *ex parte* contacts are prohibited in Commission proceedings, such as this one, which involve channel allotments. See 47 CFR 1.1204(b) for rules governing permissible *ex parte* contacts.

For information regarding proper filing procedures for comments, See 47 CFR 1.415 and 1.420.

List of Subjects in 47 CFR Part 73

Radio broadcasting.

Federal Communications Commission.

John A. Karousos,

Chief, Allocations Branch, Policy and Rules Division, Mass Media Bureau.

[FR Doc. 97–13285 Filed 5–20–97; 8:45 am]

BILLING CODE 6712–01–P

FEDERAL COMMUNICATIONS COMMISSION

47 CFR Part 73

[MM Docket No. 97–130; RM–8751]

Radio Broadcasting Services; Galesburg, IL and Ottumwa, IA

AGENCY: Federal Communications Commission.

ACTION: Proposed rule.

SUMMARY: The Commission requests comments on a petition filed by Northern Broadcast Group proposing the substitution of Channel 224B1 for Channel 224A at Galesburg, Illinois, and the modification of Station WGBQ(FM)'s license accordingly. To accommodate the upgrade, petitioner also requests that the allotment reference coordinates for now vacant and unapplied-for Channel 224C3 at Ottumwa, Iowa, be modified. Channel 224B1 can be allotted to Galesburg, in compliance with the Commission's minimum distance separation requirements with a site restriction of 13.4 kilometers (8.3 miles) northwest at petitioner's requested site. The coordinates for Channel 224B1 at Galesburg are North Latitude 41–02–50 and West Longitude 90–27–30. *See* Supplementary Information, *infra.*

DATES: Comments must be filed on or before July 7, 1997 and reply comments on or before July 22, 1997.

ADDRESSES: Federal Communications Commission, Washington, D.C. 20554. In addition to filing comments with the

ENVIRONMENTAL PROTECTION AGENCY

[EPA–HQ–OECA–2014–0064; FRL–9929–77–OEI]

Information Collection Request Submitted to OMB for Review and Approval; Comment Request; NESHAP for Steel Pickling, HCl Process Facilities and Hydrochloric Acid Regeneration Plants (Renewal)

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice.

SUMMARY: The Environmental Protection Agency has submitted an information collection request (ICR), ''NESHAP for Steel Pickling, HCl Process Facilities and Hydrochloric Acid Regeneration Plants (40 CFR part 63, subpart CCC) (Renewal)'' (EPA ICR No. 1821.08, OMB Control No. 2060–0419) to the Office of Management and Budget (OMB) for review and approval in accordance with the Paperwork Reduction Act (44 U.S.C. 3501 *et seq.*). This is a proposed extension of the ICR, which is currently approved through June 30, 2015. Public comments were previously requested via the **Federal Register** (79 FR 30117) on May 27, 2014 during a 60-day comment period. This notice allows for an additional 30 days for public comments. A fuller description of the ICR is given below, including its estimated burden and cost to the public. An Agency may not conduct or sponsor and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number.

DATES: Additional comments may be submitted on or before July 29, 2015.

ADDRESSES: Submit your comments, referencing Docket ID Number EPA–HQ–OECA–2014–0064, to (1) EPA online using *www.regulations.gov* (our preferred method), by email to *docket.oeca@epa.gov,* or by mail to: EPA Docket Center, Environmental Protection Agency, Mail Code 28221T, 1200 Pennsylvania Ave. NW., Washington, DC 20460, and (2) OMB via email to *oira_submission@omb.eop.gov.* Address comments to OMB Desk Officer for EPA.

EPA's policy is that all comments received will be included in the public docket without change including any personal information provided, unless the comment includes profanity, threats, information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute.

FOR FURTHER INFORMATION CONTACT: Patrick Yellin, Monitoring, Assistance, and Media Programs Division, Office of Compliance, Mail Code 2227A, Environmental Protection Agency, 1200 Pennsylvania Ave. NW., Washington, DC 20460; telephone number: (202) 564–2970; fax number: (202) 564–0050; email address: *yellin.patrick@epa.gov.*

SUPPLEMENTARY INFORMATION:

Supporting documents which explain in detail the information that the EPA will be collecting are available in the public docket for this ICR. The docket can be viewed online at *www.regulations.gov* or in person at the EPA Docket Center, EPA West, Room 3334, 1301 Constitution Ave. NW., Washington, DC. The telephone number for the Docket Center is 202–566–1744. For additional information about EPA's public docket, visit *http://www.epa.gov/dockets.*

Abstract: This rule applies to all facilities that pickle steel using hydrochloric acid or regenerate hydrochloric acid, and are major sources or are part of a facility that is a major source.

In general, all NESHAP standards require initial notifications, performance tests, and periodic reports by the owners/operators of the affected facilities. They are also required to maintain records of the occurrence and duration of any startup, shutdown, or malfunction in the operation of an affected facility, or any period during which the monitoring system is inoperative. These notifications, reports, and records are essential in determining compliance, and are required of all affected facilities subject to NESHAP.

Any owner/operator subject to the provisions of this part shall maintain a file of these measurements, and retain the file for at least five years following the date of such measurements, maintenance reports, and records. All reports are sent to the delegated state or local authority. In the event that there is no such delegated authority, the reports are sent directly to the United States Environmental Protection Agency (EPA) regional office.

Form Numbers: None.

Respondents/affected entities: Steel pickling, hydrochloric acid process and regeneration facilities.

Respondent's obligation to respond: Mandatory.

Estimated number of respondents: 100 (total).

Frequency of response: Initially, occasionally and semiannually.

Total estimated burden: 35,100 hours (per year). Burden is defined at 5 CFR 1320.3(b).

Total estimated cost: $3,530,000 (per year), includes $10,600 annualized capital or operation & maintenance costs.

Changes in the Estimates: The increase in burden and cost from the most recently approved ICR is due to an adjustment. It is not due to any program changes. During the 2012 RTR, EPA did not add additional requirements, other than reporting performance test results through the WebFIRE interface if the test methods used are those supported by the Electronic Reporting Tool (ERT). However, we updated the estimated number of average number of respondents subject to Subpart CCC from 72 to 100. The increase in the number of facilities results in an overall increase in the respondent and Agency burden and in O&M costs.

Courtney Kerwin,

Acting Director, Collection Strategies Division.

[FR Doc. 2015–15796 Filed 6–26–15; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

[EPA–HQ–OW–2014–0135; FRL–9929–85–OW]

Final Updated Ambient Water Quality Criteria for the Protection of Human Health

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of availability.

SUMMARY: The Environmental Protection Agency (EPA) announces the final updated recommended ambient water quality criteria for the protection of human health for ninety-four chemical pollutants to reflect the latest scientific information and implementation of existing EPA policies found in *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000).* The EPA issued the draft updated human health criteria on May 13, 2014 and accepted written views from the public until August 13, 2014. The EPA prepared responses to those public comments. The EPA's recommended ambient water quality criteria for the protection of human health provide technical information for states and authorized tribes to establish water quality standards (*i.e.,* criteria) to protect human health under the Clean Water Act. These final 2015 updated section 304(a) human health criteria recommendations supersede EPA's previous recommendations.

FOR FURTHER INFORMATION CONTACT: Jamie Strong, Office of Water, Health and Ecological Criteria Division (4304T), Environmental Protection Agency, 1200 Pennsylvania Avenue NW., Washington, DC 20460; telephone number: (202) 566–0056; email address: *strong.jamie@epa.gov.*

SUPPLEMENTARY INFORMATION:

I. General Information

A. How can I get copies of this document and other related information?

1. *Docket.* EPA has established a docket for this action under Docket ID No. EPA–HQ–OW–2014–0135; FRL–9929–85–OW. Publicly available docket materials are available either electronically through *www.regulations.gov* or in hard copy at the EPA Water Docket in the EPA Docket Center, (EPA/DC) EPA West, Room 3334, 1301 Constitution Ave. NW., Washington, DC. The EPA Docket Center Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566–1744, and the telephone number for the Water Docket is (202) 566–2426.

2. *Electronic Access.* You may access this **Federal Register** document electronically from the Government Publishing Office under the ''**Federal Register**'' listings at FDSys (*http://www.gpo.gov/fdsys/browse/collection.action?collectionCode=FR).* EPA's final criteria documents for the ninety-four chemical pollutants, the response to views from the public on the draft criteria, and supporting information are also available on EPA's Web site *http://water.epa.gov/scitech/swguidance/standards/criteria/health/.*

II. What are EPA's recommended water quality criteria?

EPA's recommended water quality criteria are scientifically derived numeric values that EPA determines will generally protect aquatic life or human health from the adverse effects of pollutants in ambient water.

Section 304(a)(1) of the Clean Water Act (CWA) requires EPA to develop and publish and, from time to time, revise criteria for protection of water quality and human health that accurately reflect the latest scientific knowledge. Water quality criteria developed under section 304(a) are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects. Section 304(a) criteria do not reflect consideration of economic impacts or the technological feasibility of meeting pollutant concentrations in ambient water.

EPA's recommended Section 304(a) criteria provide technical information for states and authorized tribes to consider and use in adopting water quality standards that ultimately provide the basis for assessing water body health and controlling discharges of pollutants into waters of the United States. Under the CWA and its implementing regulations, states and authorized tribes are required to adopt water quality criteria to protect designated uses (*e.g.,* public water supply, aquatic life, recreational use, or industrial use) and that are based on sound scientific rationale. EPA's recommended criteria do not substitute for the CWA or regulations, nor are they regulations themselves. Thus, EPA's recommended criteria do not impose legally binding requirements. States and authorized tribes have the discretion to adopt, where appropriate, other scientifically defensible water quality criteria that differ from these recommendations. Ultimately, however, such criteria must protect the designated use and be based on sound scientific rationale.

III. Information on EPA's 2015 final updated human health criteria

EPA announces the availability of final updated national recommended water quality criteria for the protection of human health for ninety-four chemical pollutants. These revisions are based on EPA's existing methodology for deriving human health criteria in *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (2000) (EPA–822–B–00–004, October 2000). The methodology describes EPA's approach for deriving national recommended water quality criteria for the protection of human health. Table 1 presents the updated human health criteria for ninety-four chemical pollutants.

TABLE 1—REVISED HUMAN HEALTH WATER QUALITY CRITERIA

Pollutant	CAS No.	Human health water quality criteria for the consumption of	
		Water + organism (µg/L)	Organism only (µg/L)
1,1,1-Trichloroethane	71–55–6	10,000	200,000
1,1,2,2-Tetrachloroethane	79–34–5	0.2	3
1,1,2-Trichloroethane	79–00–5	0.55	8.9
1,1-Dichloroethylene	75–35–4	300	20,000
1,2,4,5-Tetrachlorobenzene	95–94–3	0.03	0.03
1,2,4-Trichlorobenzene	120–82–1	0.071	0.076
1,2-Dichlorobenzene	95–50–1	1,000	3,000
1,2-Dichloroethane	107–06–2	9.9	650
1,2-Dichloropropane	78–87–5	0.90	31
1,2-Diphenylhydrazine	122–66–7	0.03	0.2
1,3-Dichlorobenzene	541–73–1	7	10
1,3-Dichloropropene	542–75–6	0.27	12
1,4-Dichlorobenzene	106–46–7	300	900
2,4,5-Trichlorophenol	95–95–4	300	600
2,4,6-Trichlorophenol	88–06–2	1.5	2.8
2,4-Dichlorophenol	120–83–2	10	60
2,4-Dimethylphenol	105–67–9	100	3,000
2,4-Dinitrophenol	51–28–5	10	300
2,4-Dinitrotoluene	121–14–2	0.049	1.7
2-Chloronaphthalene	91–58–7	800	1,000
2-Chlorophenol	95–57–8	30	800
2-Methyl-4,6-Dinitrophenol	534–52–1	2	30

TABLE 1—REVISED HUMAN HEALTH WATER QUALITY CRITERIA—Continued

Pollutant	CAS No.	Human health water quality criteria for the consumption of	
		Water + organism (µg/L)	Organism only (µg/L)
3,3′-Dichlorobenzidine	91–94–1	0.049	0.15
3-Methyl-4-Chlorophenol	59–50–7	500	2,000
Acenaphthene	83–32–9	70	90
Acrolein	107–02–8	3	400
Acrylonitrile	107–13–1	0.061	7.0
Aldrin	309–00–2	0.00000077	0.00000077
alpha-Hexachlorocyclohexane (HCH)	319–84–6	0.00036	0.00039
alpha-Endosulfan	959–98–8	20	30
Anthracene	120–12–7	300	400
Benzene	71–43–2	0.58–2.1	16–58
Benzidine	92–87–5	0.00014	0.011
Benzo(a)anthracene	56–55–3	0.0012	0.0013
Benzo(a)pyrene	50–32–8	0.00012	0.00013
Benzo(b)fluoranthene	205–99–2	0.0012	0.0013
Benzo(k)fluoranthene	207–08–9	0.012	0.013
beta-Hexachlorocyclohexane (HCH)	319–85–7	0.0080	0.014
beta-Endosulfan	33213–65–9	20	40
Bis(2-Chloro-1-Methylethyl) Ether	108–60–1	200	4,000
Bis(2-Chloroethyl) Ether	111–44–4	0.030	2.2
Bis(2-Ethylhexyl) Phthalate	117–81–7	0.32	0.37
Bis(Chloromethyl) Ether	542–88–1	0.00015	0.017
Bromoform	75–25–2	7.0	120
Butylbenzyl Phthalate	85–68–7	0.10	0.10
Carbon Tetrachloride	56–23–5	0.4	5
Chlordane	57–74–9	0.00031	0.00032
Chlorobenzene	108–90–7	100	800
Chlorodibromomethane	124–48–1	0.80	21
Chloroform	67–66–3	60	2,000
Chlorophenoxy Herbicide (2,4–D)	94–75–7	1,300	12,000
Chlorophenoxy Herbicide (2,4,5–TP) [Silvex]	93–72–1	100	400
Chrysene	218–01–9	0.12	0.13
Cyanide	57–12–5	4	400
Dibenzo(a,h)anthracene	53–70–3	0.00012	0.00013
Dichlorobromomethane	75–27–4	0.95	27
Dieldrin	60–57–1	0.0000012	0.0000012
Diethyl Phthalate	84–66–2	600	600
Dimethyl Phthalate	131–11–3	2,000	2,000
Di-n-Butyl Phthalate	84–74–2	20	30
Dinitrophenols	25550–58–7	10	1,000
Endosulfan Sulfate	1031–07–8	20	40
Endrin	72–20–8	0.03	0.03
Endrin Aldehyde	7421–93–4	1	1
Ethylbenzene	100–41–4	68	130
Fluoranthene	206–44–0	20	20
Fluorene	86–73–7	50	70
gamma-Hexachlorocyclohexane (HCH)	58–89–9	4.2	4.4
Heptachlor	76–44–8	0.0000059	0.0000059
Heptachlor Epoxide	1024–57–3	0.000032	0.000032
Hexachlorobenzene	118–74–1	0.000079	0.000079
Hexachlorobutadiene	87–68–3	0.01	0.01
Hexachlorocyclohexane (HCH)-Technical	608–73–1	0.0066	0.010
Hexachlorocyclopentadiene	77–47–4	4	4
Hexachloroethane	67–72–1	0.1	0.1
Indeno(1,2,3-cd)pyrene	193–39–5	0.0012	0.0013
Isophorone	78–59–1	34	1,800
Methoxychlor	72–43–5	0.02	0.02
Methyl Bromide	74–83–9	100	10,000
Methylene Chloride	75–09–2	20	1,000
Nitrobenzene	98–95–3	10	600
Pentachlorobenzene	608–93–5	0.1	0.1
Pentachlorophenol	87–86–5	0.03	0.04
Phenol	108–95–2	4,000	300,000
p,p′-Dichlorodiphenyldichloroethane (DDD)	72–54–8	0.00012	0.00012
p,p′-Dichlorodiphenyldichloroethylene (DDE)	72–55–9	0.000018	0.000018
p,p′-Dichlorodiphenyltrichloroethane (DDT)	50–29–3	0.000030	0.000030
Pyrene	129–00–0	20	30
Tetrachloroethylene (Perchloroethylene)	127–18–4	10	29
Toluene	108–88–3	57	520

TABLE 1—REVISED HUMAN HEALTH WATER QUALITY CRITERIA—Continued

Pollutant	CAS No.	Human health water quality criteria for the consumption of	
		Water + organism (µg/L)	Organism only (µg/L)
Toxaphene	8001–35–2	0.00070	0.00071
trans-1,2-Dichloroethylene (DCE)	156–60–5	100	4,000
Trichloroethylene (TCE)	79–01–6	0.6	7
Vinyl Chloride	75–01–4	0.022	1.6

The revision of these criteria is a systematic update of EPA's national recommended human health criteria. EPA previously described its process for publishing revised criteria [see National Recommended Water Quality Criteria—Correction (64 FR 19781; or EPA–822–Z–99–001) or the **Federal Register** Notice for EPA's 2000 Methodology (65 FR 66444)]. EPA updated the human health criteria using externally peer-reviewed information sources.

On May 13, 2014, EPA announced the availability of the draft updated human health criteria in the **Federal Register** notice ''Updated National Recommended Water Quality Criteria for the Protection of Human Health'' (79 FR 27303) and announced that written views would be accepted from the public until July 14, 2014. In response to stakeholder requests, on June 23, 2014, EPA announced in the **Federal Register** (79 FR 35545) an extension of the public comment period for an additional 30 days, until August 13, 2014. EPA reviewed and considered all public comments received and prepared responses to those comments.

EPA developed chemical-specific science documents for each of the ninety-four chemical pollutants. These documents detail the latest scientific information supporting the final human health criteria, particularly the updated toxicity and exposure input values. A fact sheet and a summary of updated input parameters (*e.g.,* health toxicity values, bioaccumulation factors) used to derive the final updated criteria are provided. All these documents, including EPA's responses to views received during the comment period, are available on EPA's Web site at *http://water.epa.gov/scitech/swguidance/standards/criteria/health/.*

IV. What is the relationship between EPA's 2015 final updated human health criteria and state or tribal water quality standards?

Section 303(a)–(c) of the CWA requires states and authorized tribes to adopt water quality standards for their waters. As part of the water quality standards triennial review process set forth in section 303(c) of the CWA, states and authorized tribes are required to review and revise, if appropriate, their water quality standards at least once every three years.

States and authorized tribes must adopt water quality criteria that protect designated uses. 40 CFR 131.11(a)(1). Criteria must be based on a sound scientific rationale and contain sufficient parameters or constituents to protect the designated uses. Id. Criteria may be expressed in either narrative or numeric form. EPA's regulations provide that states and authorized tribes should adopt numeric water quality criteria based on:

(1) EPA's recommended section 304(a) criteria; or

(2) EPA's recommended section 304(a) criteria modified to reflect site-specific conditions; or

(3) Other scientifically defensible methods. (40 CFR 131.11(b)).

It is important for states and authorized tribes to consider any new or updated section 304(a) recommended criteria as part of their triennial review process to ensure that state or tribal water quality criteria reflect sound science and protect applicable designated uses. EPA recently proposed revisions to its water quality standards regulations that would, if finalized without substantive change, require states during their triennial reviews to consider new or updated section 304(a) recommended criteria and, if they do not adopt new or revised criteria for such pollutants, provide an explanation to EPA and the public as to why the state did not do so. These final updated section 304(a) human health criteria recommendations supersede EPA's previous recommendations.

Dated: June 22, 2015.

Kenneth J. Kopocis,

Deputy Assistant Administrator, Office of Water.

[FR Doc. 2015–15912 Filed 6–26–15; 8:45 am]

BILLING CODE 6560–50–P

FEDERAL MINE SAFETY AND HEALTH REVIEW COMMISSION

Sunshine Act Notice

June 25, 2015.

TIME AND DATE: 10:00 a.m., Thursday, July 9, 2015.

PLACE: The Richard V. Backley Hearing Room, Room 511N, 1331 Pennsylvania Avenue NW., Washington, DC 20004 (enter from F Street entrance).

STATUS: Open.

MATTERS TO BE CONSIDERED: The Commission will consider and act upon the following in open session: *Secretary of Labor* v. *Newtown Energy, Inc.,* Docket No. WEVA 2011–283 (Issues include whether the Administrative Law Judge erred by concluding that the violation in question was not significant and substantial and was not the result of an unwarrantable failure to comply.).

Any person attending this meeting who requires special accessibility features and/or auxiliary aids, such as sign language interpreters, must inform the Commission in advance of those needs. Subject to 29 CFR 2706.150(a)(3) and § 2706.160(d).

CONTACT PERSON FOR MORE INFO: Emogene Johnson (202) 434–9935/(202) 708–9300 for TDD Relay/1–800–877–8339 for toll free.

Sarah Stewart,

Deputy General Counsel.

[FR Doc. 2015–16049 Filed 6–25–15; 4:15 pm]

BILLING CODE 6735–01–P

FEDERAL RESERVE SYSTEM

Change in Bank Control Notices; Acquisitions of Shares of a Bank or Bank Holding Company

The notificants listed below have applied under the Change in Bank Control Act (12 U.S.C. 1817(j)) and § 225.41 of the Board's Regulation Y (12 CFR 225.41) to acquire shares of a bank or bank holding company. The factors that are considered in acting on the

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HON. ROBERT S. LASNIK

UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON
AT SEATTLE

SIERRA CLUB; and CENTER FOR
ENVIRONMENTAL LAW AND POLICY,

Plaintiffs,

and

THE SPOKANE TRIBE OF INDIANS,

Plaintiff-Intervenor

v.

DENNIS McLERRAN; GINA MCCARTHY
and U.S. ENVIRONMENTAL PROTECTION
AGENCY,

Defendants.

and

SPOKANE COUNTY; KAISER ALUMINUM
OF WASHINGTON LLC; and STATE OF
WASHINGTON DEPARTMENT OF ECOLOGY,

Defendant-Intervenors.

No. 2:11-cv-01759-RSL

EPA'S CONSOLIDATED BRIEF (A) IN SUPPORT OF ITS CROSS-MOTION FOR SUMMARY JUDGMENT AND (B) IN OPPOSITION TO PLAINTIFFS' AND INTERVENOR-PLAINTIFF TRIBE OF SPOKANE INDIANS' RESPECTIVE MOTIONS FOR SUMMARY JUDGMENT

Filed pursuant to order on briefing schedule

Oral Argument Requested

TABLE OF CONTENTS

INTRODUCTION AND SUMMARY

Defendants United States Environmental Protection Agency, et al., (collectively "EPA"), oppose Plaintiffs' and Intervenor Spokane Tribe of Indians' motions for summary judgment and cross-move for summary judgment in EPA's favor.

The Washington State Department of Ecology ("Ecology") has a robust program establishing total maximum daily loads ("TMDLs") throughout Washington State. Over the past fifteen years, Ecology has established hundreds of TMDLs, and it is continuing to develop others for waterbody segments that do not meet water quality standards, including many within the Spokane River Basin. Notwithstanding such ongoing TMDL work, because many TMDLs remain to be completed, Ecology has had to make necessarily difficult choices regarding the priority and timing of which TMDLs will be developed before others, how to allocate limited resources among competing environmental demands, and the establishment of interim, supplemental steps to reduce pollution until required TMDLs are completed. Among its many prioritization decisions, Ecology determined that a TMDL for polychlorinated biphenyls ("PCBs") for the Spokane River should be a lower priority, primarily due to the lack of critical information and analysis, and that Ecology will devote its efforts and resources in the interim to reduce PCBs in the River through a Task Force created for this purpose comprised of State and local agencies, dischargers of pollutants, and environmental groups created for this purpose. If these or other supplemental measures are not enough for the Spokane River to attain applicable PCB standards, Ecology has committed to develop a Spokane River PCB TMDL. Based upon EPA's review of Ecology's plans and the rest of the record in this case, EPA reasonably concluded that Ecology has not renounced its obligation to develop and establish a Spokane River PCB TMDL and that the absence of such a State-submitted TMDL at this time does not constitute Ecology having constructively submitted "no" PCB TMDL (i.e., a State determination that none will be needed). Accordingly, the Clean Water Act ("CWA") does not require that EPA approve or disapprove such a constructive submission.

Plaintiffs and the Spokane Tribe invoke the constructive submission theory in an effort to circumvent and undermine this and other ongoing State decisions as to how best to protect the environment. By demanding a PCB TMDL for the Spokane River, which Plaintiffs and the Tribe believe should be prioritized before all other TMDLs and other State efforts to reduce pollution, and by seeking a court order that EPA establish that particular TMDL, Plaintiffs and the Tribe ask the Court to usurp Ecology's role and substitute their own priorities for the State's reasonable pollution prevention and remediation plans. Plaintiffs and Intervenor are understandably focused on concerns posed by PCBs in the Spokane River. There are, however, other, ongoing efforts to reduce PCBs and other pollutants in the Spokane River and in numerous other impaired water-bodies throughout the State that also require the attention of limited State and federal resources.

Section I.A below demonstrates that as a matter of law the constructive submission theory is not applicable where, as here, parties seek to compel the establishment of one particular TMDL above all others, and that such claims must therefore be dismissed and summary judgment entered for EPA. Section I.B explains that Plaintiffs have waived their right to challenge EPA's administrative finding that there has been no constructive submission, because they elected not to brief that Administrative Procedure Act challenge in their summary judgment motion. Section I.C demonstrates that EPA reasonably concluded that Ecology has not disavowed establishing a PCB TMDL for the Spokane River, that Ecology has a reasonable plan for reducing PCBs in the Spokane River and obtaining needed information, and that Ecology remains committed to developing a TMDL if necessary. Ecology, therefore, has not made a constructive submission, and thus EPA has no duty to approve or disapprove such a submission. Section II responds to the arguments proffered by Intervenor Spokane Tribe. Finally, Section III demonstrates that even if there is a constructive submission, Plaintiffs and the Tribe are not entitled to the relief they seek.

BACKGROUND

I. STATUTORY AND REGULATORY BACKGROUND

The Clean Water Act establishes a comprehensive program "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" through the reduction and eventual elimination of the discharge of pollutants into those waters. 33 U.S.C. § 1251(a). States are primarily responsible for achieving these goals. *Id.* § 1251(b); *Chevron U.S.A. v. Hammond*, 726 F.2d 483, 489 (9th Cir. 1984) ("[T]he states maintain primary responsibility for abating pollution in their jurisdictions."); *District of Columbia v. Schramm*, 631 F.2d 854, 860 (D.C. Cir. 1980) (the CWA "scheme . . . impose[s] major responsibility for control of pollution on the states"). State lists of water quality limited segments ("WQLS") within their boundaries ("Section 303(d) lists") and Total Maximum Daily Loads ("TMDLs") are but one part of the complex water pollution control regime created by the CWA.

A. The NPDES Permit Program

The CWA's central regulatory features are established by the National Pollutant Discharge Elimination System ("NPDES") permit program. 33 U.S.C. § 1342(a)(1); 40 C.F.R. §122.44(a), (d)(1). Pollutant discharges from point sources[1]/ into waters of the United States are prohibited unless in compliance with specified sections of the CWA. 33 U.S.C. § 1311(a). If the conditions of a permit are violated, they may be enforced by the United States, or any interested person, including a State. *Id.* § 1319. Forty-six States, including Washington, are authorized to administer NPDES permit programs under their State laws and regulations, though EPA retains an oversight role. *Id.* § 1342(b). In the remaining States, EPA issues the permits. *Id.* § 1342(a). EPA first approved Washington's NPDES permitting program in 1973. 54 Fed. Reg. 40517 (Oct. 2, 1989).

NPDES permits control water pollution from point sources by means of two different overarching strategies. The first approach, the "technology-based" approach, reduces pollution by requiring dischargers to achieve specified restrictions on the quantities, rates, and concentrations (known as "effluent limitations") based on specific process-based controls. 33 U.S.C. §§ 1311, 1314, 1316-17, 1363(11). The CWA requires EPA to develop and promulgate national technology-based regulations establishing minimum levels of wastewater treatment for categories of industrial sources. *Rybachek v. EPA*, 904 F.2d 1276, 1283 (9th Cir. 1990). During the 1970s

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[1]/ A "point source" is defined as "any discernible, confined and discrete conveyance ... from which pollutants are or may be discharged." *Id.* § 1362(14) (*e.g.*, industrial, commercial and municipal discharges). This statutory definition excludes "agricultural stormwater discharges and return flows from irrigated agriculture." *Id.* § 1362(14). The term "nonpoint source" commonly refers to any source of water pollution that is not a point source and is typically associated with diffuse sources and rural areas.

and 1980s, EPA gave priority to developing the new technology-based regulations, which EPA and the states implemented through the new NPDES permit program. Because of the magnitude and scope of the national water pollution control task, and consistent with stated Congressional intent, EPA and the States dedicated implementation resources to developing these technology-based controls and basic programs, deferring action on the next level of controls based on water quality standards. *See* 1A *Leg. History of the Water Pollution Control Act Amendments of 1972* (Comm. Print 1973), at 171. Accordingly, EPA has issued technology-based regulations for more than 50 major categories of industrial dischargers. 40 C.F.R. Pts. 405-471. After establishment of NPDES permitting programs, including technology-based controls, regulatory efforts focused on the difficult task of determining the desired water quality for each waterbody and establishing effluent limits based upon such standards.

B. Water-Quality-Based Controls

The CWA is designed to ensure that water quality standards would be attained even if technology-based controls were insufficient to do so. CWA § 303 directs the States, with federal approval and oversight, to adopt water quality standards for each particular waterbody or waterbody segment within their boundaries. 33 U.S.C. § 1313(a), (b) & (c)(1). Water quality standards identify (1) the "designated uses" for each waterbody (e.g., public water supply, propagation of fish, and/or recreational uses) and (2) the "water quality criteria" expressed as levels (e.g., concentrations and/or conditions) that must not be exceeded in order for the waterbody to support those uses (e.g., oxygen concentrations necessary for healthy fish). *Id.* § 1313(c)(2). EPA either approves a State's proposed water quality standards or, if it disapproves, proposes and promulgates standards for the State. *Id.* § 1313(c)(3).

After adoption and approval of water quality standards, CWA section 303(d) directs the States to identify and prioritize the impaired or threatened waters within their borders, known as water-quality-limited segments ("WQLSs"). *Id.* § 1313(d)(1)(A) & (B); 40 C.F.R. § 130.7(b)(1). States are then to develop plans, known as total maximum daily loads ("TMDLs") for pollutants in those WQLSs. 33 U.S.C. § 1313(d).

CWA § 303(d)(2) requires that each State submit "from time to time" its list of WQLSs. *Id.* § 1313(d)(2). EPA's regulations specify that the States submit their lists of WQLSs (the "Section 303(d) list") to EPA on a biennial basis. 40 C.F.R. § 130.7(d). EPA must approve or disapprove Section 303(d) lists within 30 days after submission. 33 U.S.C. § 1313(d)(2). If EPA disapproves, it must identify the WQLSs to be added within 30 days from the date of disapproval. *Id*. Although States submit their priority rankings of WQLSs for TMDL development with their Section 303(d) lists, EPA does not approve or disapprove the substance of these rankings. *Id.* Moreover, if a WQLS on a 303(d) list subsequently achieves the water quality standard for which it is impaired, it may be removed from the next Section 303(d) list and thus a TMDL is no longer required. 40 C.F.R. §§ 131.7(b)(1) & 130.2(j).

States are required to establish a priority ranking for TMDL development for WQLSs included on the Section 303(d) list. 33 U.S.C. § 1313(d)(1)(A). In establishing priority ranking, States must consider the severity of the pollution and the uses of the listed waterbody. *Id.* § 1313(d)(1)(A). Beyond these two statutory factors, States retain considerable discretion and may consider other factors, including: vulnerability of particular waters; recreational, economic, and aesthetic importance of particular waters; restoration potential; degree of public interest and support; State or national policies and priorities; technical considerations, such as the complexity of the impairment; availability of adequate data and models; and implementation of watershed-based permitting programs or basin planning cycles. *See* V.1, T.47 at 971-72; V.1, T.19 at 242.[2]/

States identify those WQLSs targeted for TMDL development in the next two years. 40 C.F.R § 130.7(b)(4) & (d)(1). States have discretion in selecting higher and lower ranked waters for TMDL development based on the numerous factors described above.

TMDL development requires States to identify the maximum amount of pollutant

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[2]/ The administrative record for judicial review in this case was filed on April 22, 2013, in paper form, in five binders (or volumes), as well on a compact disc. Dkt. No. 60. References in this brief to that record are to the volume and document number (or tab), cited as "V._, T._, at __." Page numbers are to the bate-stamped number, except as indicated. Documents supplementing the Court's review were filed September 17, 2013, Dkt. 79, and are bate-stamped beginning with "Supp." Some exhibits to Plaintiffs' brief attach only selected pages from the record, with Plaintiffs' underlining that is not in the record.

"loading", *i.e.*, quantity of a particular pollutant that the WQLS can receive from all combined sources and still meet the relevant water quality standard for a pollutant. 33 U.S.C. § 1313(d)(1)(C); 40 C.F.R. § 130.2(e). Each TMDL must, among other things: (1) be designed to meet water quality standards; (2) include, as appropriate, both wasteload allocations from point sources and load allocations from non-point sources; (3) consider the impacts of background pollutant contributions; (4) consider seasonal variations; (5) include a margin of safety; and (6) be subject to public participation. *Id.* §§ 130.7, 130.7(c)(1), 130.2(g)-(i). Developing a TMDL often requires a significant amount of work, and may take years once initiated depending, among other things, upon the information and studies required. Once a State submits a TMDL to EPA, the CWA requires that EPA approve or disapprove that TMDL within 30 days of its submittal by the State, and if EPA disapproves a particular TMDL, EPA must establish a federal TMDL for the WQLS within 30 days of the Agency's disapproval. 33 U.S.C. § 1313(d)(2).

The CWA does not requires States to develop and submit TMDLs to EPA on any particular schedule, requiring instead that States submit TMDLs to EPA "from time to time." *Id.* § 1313(d)(2). In 1997 Guidance, EPA recommended that States normally plan to establish TMDLs for all WQLSs on their 1998 Section 303(d) lists and subsequent lists within eight to thirteen years of initial listing, but recognized that shorter or longer times may be needed depending on State-specific factors.[3]/ These factors may include: number of impaired segments; length of river miles, lakes or other bodies for which TMDLs are needed; proximity of list waters to each other within a watershed; number and relative complexity of TMDLs; number and similarities or differences among the source categories to be allocated; availability of monitoring data or models; and relative significance of the environmental harm or threat. *Id.*

Importantly, TMDLs function primarily as planning devices and are not self-executing. *Pronsolino v. Nastri*, 291 F.3d 1123, 1129 (9th Cir. 2002). A TMDL does not, by itself, prohibit any conduct or require any actions. Instead, each TMDL represents a goal that may be

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[3]/ *See* http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/2003_10_21_tmdl_ratepace 1997guid.pdf (at p.3). Though not part of the administrative record in this case, the Court may take judicial notice of this document for the purpose for which it is introduced.

implemented by adjusting pollutant discharge requirements in individual NPDES permits and/or by establishing nonpoint source controls. *Sierra Club v. Meiburg*, 296 F.3d 1021, 1025 (11th Cir. 2002). Thus, TMDLs form the basis for further State actions that may require or prohibit conduct with respect to particularized pollutant discharges. Regardless of whether a TMDL has been established, States must include effluent limits as stringent as necessary to meet water quality standards in NPDES permits. 33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.44(d)(1)(vii)(A).

Where a TMDL has been established for a WQLS, the TMDL may provide allocation information for individual NPDES permits for point sources and/or establish goals for non-point source controls. The absence of TMDLs does not prevent NPDES permitting authorities from otherwise assuring that point source discharges do not cause or contribute to exceedances of water quality standards. *See* 43 Fed. Reg. 60,662, 60,665 (Dec. 28, 1978). EPA guidance to permitting agencies explains how to derive water-quality-based permit limits, both prior to establishment of a TMDL and consistent with any applicable TMDL once established.[4]/ Where a TMDL has not been established, EPA's guidance recommends that the permit writer establish as part of the process to develop a specific NPDES permit, a facility-specific allocation, sometimes referred to in this context as a discharge-specific concentration allowance. Manual at 6-31--6-35. In this process, the more current and reliable the underlying information, the more effective and defensible the allocation. *See id.* at 6-30--6-31. Where numeric effluent limitations are infeasible to calculate, NPDES permits may include best management practices. 40 C.F.R. § 122.44(k)(3).

C. The Constructive Submission Theory

The CWA requires that EPA approve or disapprove a TMDL within 30 days of its submittal by the State, and if EPA disapproves, EPA must establish a federal TMDL for the WQLS at issue within 30 days of disapproval. 33 U.S.C. § 1313(d)(2). On its face, however, the CWA imposes no duty for EPA to establish TMDLs if a State fails to establish and submit them to

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[4]/ [NPDES] Permit Writers' Manual, EPA-833-K-10-001 (2010) ("Manual"), Ch. 6, 6-30–6-35 (available at: http://cfpub.epa.gov/npdes/writermanual.cfm?program_id=45). Though not part of the administrative record in this case, the Court may take judicial notice of this document for the purpose for which it is introduced.

EPA. In the past, many States were not able to develop any TMDLs while implementing technology-based approaches to address water pollution. Because a State's refusal to submit any TMDLs over a prolonged period of time could frustrate the TMDL program, some courts adopted what came to be known as the "constructive submission" theory. The theory holds that the prolonged failure by a State to submit *any* TMDLs may constitute the "constructive" submission of no TMDLs (*i.e.*, that none are necessary), which submission EPA must approve or disapprove. *San Francisco Baykeeper v. Whitman*, 297 F.3d 877, 881 (9th Cir. 2002). If EPA disapproves such a constructive submission, this triggers the requirement that EPA establish TMDLs for the State.

D. Judicial Review Under the Clean Water Act

The CWA jurisdictional scheme restricts the types of claims that can be brought against EPA. The citizen suit provision allows suits to be brought in district court against the "the Administrator [of EPA] where there is alleged a failure of the Administrator to perform any act or duty under this chapter which is not discretionary with the Administrator." 33 U.S.C. § 1365(a)(2). Such citizen suit claims are available only where Congress has imposed a clear-cut, mandatory duty for EPA to act in the statute. *Infra* at 26, n.12. The reasonableness of the content of EPA's action or prospective action, however, cannot be dictated or reviewed by the Court under the citizen suit provision. *Scott v. City of Hammond, Ind.*, 741 F.2d 992, 995 (7th Cir. 1984).

In contrast, content-based review of certain EPA final actions, not at issue here, is available under the CWA exclusively in the U.S. Courts of Appeal. 33 U.S.C. § 1259(b)(1). Review of other "final agency actions" not covered by that Section is based upon the Administrative Procedure Act, in federal district court, under the APA's arbitrary, capricious or not in accordance with law standard of review. 5 U.S.C. § 706(2)(A).

NPDES permit decisions by Ecology are reviewed in the appropriate State tribunals.

II. FACTUAL BACKGROUND

A. The Development of Washington's Section 303(d) Program

Ecology's first Section 303(d) list was prepared in 1992. The 1996 Section 303(d) list had

666 WQLS listed. Ecology subsequently submitted, and EPA approved, 303(d) lists in 1998, 2004, 2008, and 2010. See V.1, T.16 & 21; V.2, D.40. As Ecology has continued to monitor the numerous waterbody segments throughout Washington, it has added additional WQLS to its 303(d) lists. Ecology's 2010 303(d) list, which EPA approved on December 21 2012, contains 4009 WQLSs for TMDL development. V.2, D.40 at 672..

In 1998, after two environmental groups filed a lawsuit in this Court, EPA entered into an out-of-court settlement agreement by which Ecology would complete a large number of TMDLs by December 31, 2013. The agreement provides that EPA would complete the TMDLs, if Ecology failed to do so. V.1, D.32 at 446-447. Ecology has since devoted significant resources to TMDL development. Since 1999, Ecology has completed 1372 TMDLs. V.1, T.A, at 1 n.1; V.1, D.16 at 220. Ecology is currently working on the development of TMDLs in 23 sub-watersheds throughout the State for numerous pollutants, including temperature, dissolved oxygen, bacteria, and pH. The Administrative Record in this case amply documents Ecology's TMDL output and its continued commitment to develop TMDLs. *E.g.*, V.1, T.A, 3, 5, 6, 8-14, 16-17 & 19-29.

Four segments of the Spokane River and one tributary (called the Little Spokane River) were first listed for PCBs on its 1996 Section 303(d) list. Dkt. 79, at Supp. 2710 & 2732. Over the years, as Ecology continued to gather information, the numbers of segments and parameters for the Spokane watershed continued to increase. There are currently 15 waterbody segments of the Spokane exceeding standards for PCBs. V.1, D.15 at 80. Ecology spent over 12 years completing work on dissolved oxygen TMDLs that addressed elevated levels of phosphorus, ammonia and CBOD (carbonaceous biochemical oxygen demand) in the Spokane River. V.1, D.4 at 503. EPA approved these nine Spokane River and Lake Spokane Dissolved Oxygen TMDLs in May 2010. V.1, D.17 at 000224. Ecology also developed 23 TMDLs for waters impaired by temperature, bacteria and turbidity in a major tributary to the Spokane River, Hangman (Latah) Creek. EPA approved these TMDLs in September 2009. *Id.* at 222-23. Ecology also developed 36 TMDLs for waters impaired by temperature, bacteria and turbidity in the Little Spokane River. EPA approved these TMDLs in April, 2012.[5]/ In 1999, Ecology developed, and EPA approved, five TMDLs for cadmium, lead, and zinc in the Spokane watershed. *See* V.1, T.15 at 82. Ecology is currently working on an additional TMDL to address the dissolved oxygen and pH impairments on the Little Spokane River. Even with these TMDLs, the Spokane watershed remains impaired for temperature, fecal coliform, and dioxin, as well as PCBs.

B. Ecology's Preliminary Work on a PCB TMDL for the Spokane River

1. The Nature of PCB Pollution

PCBs were first produced for commercial use in 1929 and have been used for hundreds of purposes. Production continued until a 1979 ban on all PCB manufacturing, processing, and distribution due to evidence that PCBs build up in the environment and concerns about possible human carcinogenicity. V.1, T.15 at 91. PCBs are released into the environment through improper disposal or leakage. *Id.* Even after their release, PCBs do not break down readily in the environment and can bioaccumulate. *Id.* at 92. Many of the same properties that made PCBs commercially desirable - their stability and resistance to degradation - make them extremely persistent in the environment. *Id.* at 92. Thus, in important respects, PCBs are a legacy pollutant.

Washington State’s water quality standards include a human health criterion for PCBs at 170 picograms per liter (“pg/l”). V.1, T.15 at 83-84. When this lawsuit was filed, the Spokane Tribe water quality standard included a PCB human health criterion set at 3.37 pg/l. *Id.* at 83.[6]/ Based on elevated levels of PCBs and other pollutants in Spokane River fish, the Washington Department of Health and the Spokane Regional Health District issued an advisory in 2003, updated in 2008, to avoid or limit consumption of fish in parts of the Spokane River. *Id.* at 97.

Though PCBs can pose significant environmental concerns, they are one of many pollutants that demand attention within Washington’s waterways. As discussed above, numerous

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[5]/ *See* http://www.ecy.wa.gov/programs/wq/tmdl/littlespokane/ (EPA’s April 2012 approval is available by clicking the link in next to last paragraph of this page). Though not part of the record in this case, the Court may take judicial notice of this document for the purpose for which it is introduced.

[6]/ EPA recently approved, on December 19, 2013, a revised Tribal criterion set at 1.3 pg/l.

WQLSs continue to require attention, and Ecology continues to prioritize this task consistent with its assessment of the environmental benefits that would be realized and the resources available.

2. Ecology's Efforts to Obtain Information Necessary for a Spokane River PCB TMDL

While devoting significant resources to investigations supporting TMDL development for numerous WQLSs on its 303(d) lists, Ecology also conducted preliminary investigations into PCBs and the Spokane River. For example, Ecology's environmental assessment program identified numerous ongoing projects to which it intended to commit resources in Fiscal Year 2003, including TMDL development. V.5, T.105. Among many TMDL projects, Ecology explained that it was initiating certain preliminary work for potential use in developing a PCB TMDL in the Spokane River, pertaining to the "numerous variables [that] present sampling and analytical difficulties in developing predictive models of PCB behavior in the environment." *Id.* at 002426. This would "develop a sampling and monitoring strategy for gathering information to understand PCB dynamics in wastewaters, sediment, surface waters, and fish tissue from the Spokane River." *Id.*

By June of 2006, Ecology had prepared a document titled "Spokane River PCBs Total Maximum Daily Load[:] Water Quality Improvement Plan." V.3, T.90, at 1319-1645. This document includes the header "Draft – 6-19-06 – Do not cite or quote," *id.* at 1319, and was submitted for inclusion in the administrative record in this case by Plaintiffs. *See* V.1, T.B & C. Although this draft document focused on portions of the Spokane River administered by Washington, Ecology used the more stringent PCB water quality standard adopted by the Spokane Tribe as the basis for any such potential TMDL. V.3, D.90 at 1331. Although this document included, in preliminary draft form, some elements of a proposed TMDL, it failed to include critical information in numerous areas, primarily because more investigation remained necessary. For example, in a section titled "What Needs to be Done?," *id.* at 1419, the draft document explains that "PCB Source Identification" must occur in numerous significant areas. *Id.* The draft document states that stormwater discharges contribute significantly to PCBs in the Spokane River

(55 percent of known source categories). The draft explained, however, that particular sources of PCBs in stormwater are not generally known and thus could not be targeted for reduction, *id.* at 1419-21, and that the stormwater data available was not reliable.[7]/ The draft document stated that "more thorough sampling needs to be conducted in this first step in this process," *id.* at 1419, explaining that "PCB source identification begins with determining how the PCBs have entered the storm drains and if ongoing sources exist." *Id.* at 1420. The draft explained the similar need to identify PCB sources within the sanitary sewer system. *Id.* at 1421.

Another example of critical, missing information involves the fact that "[t]he Spokane River at Stateline [the Idaho/Washington border] contributes about 25 percent of the PCB load to the system." *Id.* The draft document explains that "data needs to be gathered on the potential sources of PCBs (e.g, point sources, stormwater, contaminated and/or potential contaminated sites) in the Idaho portion of the Spokane River." *Id.* A similar need exists to identify PCB sources from watersheds draining to the Little Spokane River, which enters the Spokane River. *Id.*

Finally, the 2006 draft document identified the total daily loading of PCBs into the relevant reach of the Spokane River (3,664 mg/d), V.3, D.90 at 1401, but failed to identify PCB sources or otherwise account for nearly half (46.3%) of that daily loading. *Id.*[8]/ Thus the 2006 draft document does not account for 46.3% of the PCB loading, in addition to the lack of information described above regarding PCB loading from the Spokane stormwater, the Spokane sanitary sewer, the Stateline border, and the Little Spokane River source categories. Because of the limited information available and inability to assign reductions to unknown sources, the draft document suggested that for the known categories of PCB sources very aggressive reductions could be necessary for the known catagories of PCB sources, in some cases exceeding 99%. *Id.* at 1402-03.

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[7]/ *See id.; also id.* at 1413 ("Stormwater from Spokane has the potential to deliver large PCB loads to the river (1,100 mg/d) and may account for a significant portion of loading from exogenous sources. However, stormwater sampling was limited and since data had not been previously collected from this source in the Spokane River basin, the representativeness of those data is uncertain.")

[8]/ The chart at 1401 (V.3, T.90) shows a total daily PCB load of 3,664 mg/d, but identifies sources totaling only 1968.9 mg/d, which includes the loading of 477 mg/d at the Idaho border. Thus the 2006 draft document fails to identify sources or categories of sources or otherwise account for 46.3% of the PCB loading.

The draft document contemplated that some of the missing information and analysis may be included in a separate, future document to be developed by Ecology that would be called a "Water Quality Implementation Plan." *Id.* at 1417-21. The draft did not suggest a strategy to identify the sources or otherwise account for the very high percentage of unidentified PCB loading to the River.

Ultimately, given the significant information gaps about PCB occurrences and sources in the Spokane River, Ecology recognized that considerable new studies and analyses would be necessary before a PCB TMDL for the Spokane River could be completed. *See, e.g.*, V.1, T.14A at 503; *infra* at 16-17 (Ecology's decision not to prioritize the completion of the PCB TMDL). Thus the State did not issue the 2006 draft document for the public notice and comment that would be required for any proposed TMDL prior to deeming it complete for submission to EPA.[9]/ Rather, Ecology initiated additional investigations regarding PCBs in the Spokane River. For example, to better understand the role of stormwater and obtain more reliable data, the State conducted a study "to refine PCB loading estimates to the Spokane River from the City of Spokane's stormwater drainage system" and, as "[a] secondary goal . . . to begin PCB source identification for future mitigation efforts," and issued a report in 2007 based on its findings.[10]/

Thereafter, the State further sought to identify other information gaps and the means to close those gaps. One 2009 draft document, entitled "Draft Spokane River PCBs TMDL: Volume 1. Water Quality Study Findings," which also includes the header "DRAFT – 7-09 – Do not cite or quote," V.3, T.69 at 1102, was submitted to EPA by Plaintiffs for inclusion in the administrative record in this case. V.1, T.B &C. This draft document is not a draft TMDL – it does not, for

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[9]/ Although some Ecology reports suggest that Ecology submitted a proposed Spokane River PCB TMDL for the public notice and comment required before it could be finalized, V.2, T.42 at 705; V.1, T.14 at 503, EPA believes that this statement is in error. The administrative record in this case does not contain any such proposal, public notice, public comments nor Ecology responses to comments from such a process, and EPA has no record that it ever occurred.

[10]/ *See* Spokane River PCB TMDL Stormwater Loading Analysis Final Technical Report, at v. (abstract) (December 2007). Although not included in the administrative record in this case, this report is available on the State's web site, https://fortress.wa.gov/ecy/publications/publications/0703055.pdf, and the Court may take judicial notice of it for the purpose for which it is introduced.

example, contain proposed load allocations for sources. Rather, as its subtitle indicates, it is a draft technical study that could be used in developing a future draft TMDL V.2, T.68 at 1217 ("This project constitutes a technical water quality study to support TMDL development for PCB contaminants in the Spokane River."); *also id.* at 1121-21.

In part to better reflect this draft document's contents, and the fact that it was not itself a draft TMDL, in 2011 Ecology issued this report, in modified and final form, titled "Spokane River PCB Source Assessment 2003-2007." V.1, T.15 at 63-216. Although this 2011 report indicates progress in addressing some information gaps and data reliability issues in some areas, *see* V.5, T132 at 2675, it did not, among other things, identify or otherwise account for the large unknown sources of PCB loadings into the relevant reach of the Spokane River. For example, of the total daily PCB loading of 3,664 mg into the River, only a total loading of 1571 mg/day from seven categories of sources were identified, including 477 mg/day at the Stateline. V.1, T.15 at 163. Based upon its updated data, this 2011 report could not account for 57% of the PCB loading in the relevant reach of the River. The 2009 precursor draft also lacks this information. V.3, T.69 at 1205.

C. Ongoing State Efforts to Reduce PCBs and Other Toxics in the Spokane River

Ecology has worked to reduce PCBs in the Spokane River while investigating PCBs and their sources for a potential PCB TMDL. Ecology has utilized available information and taken significant steps to reduce and cleanup toxics in or that may enter the River, including PCBs. For example, as detailed in Ecology's 2012 Spokane River Toxics Reduction Strategy, V.2, T.42, Ecology in 2007 provided oversight as contractors removed PCB-contaminated soil from Donkey Island in the Spokane River. *Id.* at 701. Prior to that, Ecology directed contractors in 2006 to cap over PCB-contaminated sediments on the river bottom near the Upriver Dam. *Id.* PCBs at several other sites have either been cleaned up or are undergoing required investigation of appropriate remedial options pursuant to the State's cleanup laws to address past pollution. *Id.* at 701-2; V.2, T.68, at 1091-93. In addition to these cleanup efforts focused on PCBs, the 2012 Spokane River Toxics Reduction Strategy details the State's ongoing efforts to reduce other toxics in the Spokane

River, such as dioxins and furans, metals such as arsenic, cadmium, lead and zinc, and pharmaceuticals and personal care products. *Id.* at 692-95 & 697-712.

Ecology has also worked closely with the City of Spokane, which in 2011 entered into a settlement agreement with the Spokane Riverkeeper to develop an adaptive management plan for reducing PCB discharges from Spokane's stormwater as much as possible, by:

> 1. Analyzing, organizing, and interpreting existing PCB sampling data as it relates to the City's stormwater NPDES permit.
> 2. Identifying likely sources of PCBs and prioritizing appropriate remedial actions to be accomplished and best management practices to be followed.
> 3. Developing and designing an adaptive approach for additional data collection and additional remedial actions that further reduce PCBs within the City and in the Spokane River for the long term.

Id. at 707-708.

In addition, in 2011, the Department of Ecology, together with PCB dischargers in the Spokane River Basin, conservation and environmental groups, local and regional government agencies, EPA, and other interested parties created the Spokane River Regional Toxics Task Force ("Task Force"). V.1, T.4, at 14. The final January 23, 2012, Memorandum of Agreement establishing the Task Force explains that its "goal . . . will be to develop a comprehensive plan to bring the Spokane River into compliance with applicable quality standards for PCBs." *Id.* This includes the more stringent PCB water quality standard adopted by the Spokane Tribe. *Id.* at 15. To accomplish that goal, the Task Force's functions include:

> – Identify data gaps and collect necessary data on PCBs and other toxics . . . for the Spokane River
>
> – Further analyze the existing and future data to better characterize the amounts, sources and locations of PCBs and other toxics as defined above entering the Spokane River.
>
> – Prepare recommendations for controlling and reducing the sources of listed toxics in the Spokane River.
>
> – Review Toxic Management Plans, Source Management Plans, and BMPs [Best Management Practices].
>
> – Monitor and assess the effectiveness of toxic reduction measures. . . .

Id. at 14.

Members of the Task Force include the Washington Departments of Ecology and Health, the City of Spokane, Spokane County, and the Spokane Regional Health District, the Lake Spokane Association, the Spokane Riverkeeper, the Lands Council, Kaiser Aluminum Washington, LLC, and the Inland Empire Paper Co. *Id.* at 30-40. EPA has also committed its support for and participation in the Task Force. V.1, T.7. All holders of Washington NPDES permits that may discharge PCBs into the Spokane River are required, as a condition of their permit, to participate in the Task Force. *See, e.g.*, V.2, T.45, at 845. The Spokane Tribe was invited to join the Task Force. Although it initially supported the Task Force and its efforts, V.3, T.89 at 1317, it ultimately elected not to participate in it. Plaintiffs in this case also elected not to participate in the Task Force.

The first draft work plan of the Task Force, adopted October 24, 2012, explains in detail specific work plan elements for the years 2012 through 2016, which include "Work Plan Element 1 – Data review, data gap evaluation, analysis, and implementation plan," V.2, T.41 at 679-81 (emphasis in orig.), and "Work Plan Element 5 – Develop strategy for reduction of point sources and non-point sources of PCBs," *id.* at 683-84 (emphasis in org.). The Task Force's documents its monthly activities and other information regarding its operation on its web site (www.srrttf.org). Thus, the Task Force works to identify PCB sources and to develop strategies for reducing PCBs.

Current PCB concentrations in fish tissue are lower than they have been historically. Between 1996 and 2005 there has been a significant decrease in the PCB levels in Mountain Whitefish and Rainbow Trout in the Spokane River. V.1, D.15 at 152-53.

D. Ecology's Decision to Defer Continued Development of a Spokane River PCB TMDL for Submission to EPA at This Time

Ecology has determined not to continue to devote its limited resources for the development and completion of a PCB TMDL for the Spokane River at this time. Ecology's reasons for deferring completion of the TMDL are documented in the administrative record in this case. As an initial matter, Ecology has a robust TMDL program, and Ecology is continuing to devote its limited resources to the development of other TMDLs, both within the Spokane Basin Watershed and in other water-quality-limited segments throughout the State. *See supra* at 9-10. Against this backdrop, Ecology explained several specific reasons for deferring a PCB TMDL at this time. First, there are significant data gaps that precluded it from completing a TMDL at this time, with much work remaining. *See, e.g.*, V.1, T.A at pp 3-4*;* V.2, T.42 at 705; V.1, T.15 at 173 & V.1, T.35 at 481-83 (data to be obtained). In this regard, Ecology employee Jim Bellatty, testifying on behalf of Ecology in 2013 before the Washington State Pollution Control Hearings Board, explained that Ecology's draft PCB TMDL could not be finalized because sources for 57% of the PCB loading in the relevant reach of the Spokane River have not been identified. V.5, T.132, at 2671-72 & 2683. In light of key gaps in information, Ecology is concerned that any TMDL at this time would be highly uncertain, inequitable, and impracticable. *Id.* at 7671 & 2683. In addition, Ecology had recently devoted a great deal of its resources, spanning 12-years, in a difficult process to complete in 2010 a dissolved oxygen TMDL for the Spokane River. V.1, D.4 at 503; V.5, T132 at 2671-72. In light of that experience, Ecology was concerned that, given the significant information gaps for PCBs, and absent a cooperative approach, the continued development to finalization of a PCB TMDL at this time would suffer lengthy delays and expend considerable resources, without resulting in timely environmental benefits. *Id.; also* V.1, T.A at p.4. At the same time, Ecology was aware that community support exists for it to make as much direct progress as possible to reduce PCBs through its Task Force (described *supra*), rather than to delay such potential progress until after a TMDL is completed. V.2, T.42 at 706; V.1, T.1.

Ecology has also made clear that the Task Force's work is not in lieu of development of a Spokane River PCB TMDL. V.1, T.1, at 2. The Task Force serves as a measure designed to obtain critical information about PCBs and their sources in the Spokane River and to implement strategies that can obtain near-term PCB reductions where possible. *Supra* at 15-16; V.1, T.35. Ecology expressly recognized that it would still be obliged to complete a PCB TMDL for the Spokane River if the Task Force or other measures fail to achieve applicable water quality standards. V.2, T.44 at 706 ("a PCB TMDL still remains a tool and will be necessary if ongoing toxics reduction strategies do not result in compliance with water quality standards.").

E. EPA's April 12, 2013, Letter Determining That Ecology Has Not Renounced Establishing a Spokane River PCB TMDL If One Is Required and That EPA Is Therefore Not Required to Establish Such a TMDL Under Plaintiffs' Constructive Submission Theory

Plaintiffs' original, one-count Complaint in this action (Dkt. No. 1, ¶¶ 23-26) alleged that Ecology's failure to finalize a PCB TMDL for the Spokane River constitutes its intent to never complete such a TMDL and thus the constructive submission of no PCB TMDL, the disapproval of which by EPA would create a mandatory duty under the CWA citizen suit provision for EPA to establish a PCB TMDL for the Spokane River. On November 6, 2012, this Court held that review in this case is limited to the administrative record. Dkt. No. 49. Thereafter, in December 2012, Plaintiffs submitted two letters to EPA, attaching numerous documents not in EPA's administrative record, for EPA to review administratively. V.1, T.B & C. These documents included several internal Ecology draft documents, many of which are described above. Based on these documents, Plaintiffs contend that Ecology has disavowed submitting an actual PCB TMDL for the Spokane River, thereby constructively submitting no TMDL; Plaintiffs thus requested that EPA approve or disapprove that constructive submission, and if disapproved, to establish a PCB TMDL. *Id.*

EPA reviewed the full administrative record in this case, including the new documents submitted by Plaintiffs, and on April 12, 2013, issued its administrative determination, concluding that "Ecology's decision to delay completion of a PCB TMDL for the Spokane River is within the discretion of the State of Washington" and that "Ecology has not renounced completion of a PCB TMDL for the Spokane River if one is required." V.1, T.A, at 1 (internal citation). EPA thus concluded that there has not been a constructive submission by Ecology of a PCB TMDL and that EPA is not "required to issue such a TMDL in lieu of Ecology." EPA also detailed the bases for its findings. EPA first noted that Ecology has "demonstrated its commitment to develop and implement" a robust TMDL program under Section 303(d) of the Act over the past fifteen years, and that "Ecology is continuing to establish large numbers of TMDLs each year in accordance with its judgment of how best to protect the environment and allocate its limited resources." *Id.*

Ecology established and EPA approved 1372 TMDLs since 1999 using EPA's national counting system. *Id. & n.1*. EPA further explained Ecology's priority-setting process, and noted that in December 2012 EPA approved Ecology's 303(d) list and found "that the state's process for targeting waters for TMDL development in this period is appropriate." *Id.* at 2 (internal citation).

In its administrative determination, EPA expressed support for Ecology's use of interim, supplemental approaches to achieve water quality standards, especially for those WQLSs for which a TMDL will not be issued in the near term, in an effort to reduce pollution and achieve water quality standards. This approach is reasonable because "[i]f water quality standards are attained through implementation of such interim, supplemental approaches, development of a TMDL [for that WQLS] would not be necessary." *Id.* EPA explained that Ecology's use of the Task Force to make progress achieving the applicable PCB standards represents such a measure, and that EPA supports the Task Force's work. *Id.* at 3.

EPA also explained its support for the Task Force's reasonable goal of completing the work outlined in its work plan by 2016 to reduce PCBs, *id.*, Ecology's commitment in its May 2012 letter (V.1, T.1 at 1-2) that it will in five years "evaluate progress in reducing PCB contamination in the Spokane River," and Ecology's acknowledgment that "[i]f Ecology determines that the [Task Force] is failing to make measurable progress toward meeting applicable water quality criteria for PCBs, Ecology . . . will proceed with development of a TMDL in the Spokane River for PCBs if necessary." V.1, T.A at 3. EPA further reviewed Ecology's acknowledged commitment to proceed with development of a TMDL for PCBs in the Spokane River if necessary, and explained that this "leads EPA to conclude that Ecology has not repudiated its legal obligation to develop a PCB TMDL if needed." *Id.* at 4.

EPA noted that a "straight to implementation" ("STI") project is a type of interim approach used by Ecology, *id.* at 2-3 (describing such approaches), and that Ecology may have once intended to develop an STI project for the Spokane River, but that as Ecology further developed its STI program, it appeared that the Task Force was not an STI. *Id.* at 2-3. EPA noted, however, that the name given to a particular project or project type is not important, so long as it remains "an interim, supplemental tool that does not displace ultimate TMDL development if needed." *Id.* at 3 n.10.

EPA also reviewed Ecology's decision to defer the continued development and completion of a PCB TMDL for the Spokane River at this time, and found them reasonable. In particular, EPA highlighted the significant information gaps that led Ecology not to finalize its draft PCB TMDL, and Ecology's experience of lengthy delays and large resource expenditures establishing the dissolved oxygen TMDL for the Spokane River. *Id.* at 4. "These factors support Ecology's decision not to finalize a PCB TMDL for the Spokane River prematurely, e.g., before adequate information and resources are available." *Id.* Further, the Task Force has "the potential to fill the existing data gaps and to achieve PCB reductions until such time that a needed PCB TMDL is issued." *Id.*

Finally, EPA explained that Ecology's approach reflects its priorities to "balance[] its available resources for issuing TMDLs with other effective tools to reduce pollution within its borders where TMDLs have not yet been issued." *Id.* at 4. EPA thus concluded that it would not be appropriate "in these circumstances for it to usurp Ecology's authority by issuing a PCB TMDL for the Spokane River at this time." *Id.* EPA therefore concluded that "Ecology has not constructively submitted to EPA a PCB TMDL for the Spokane River, and to the extent that such a constructive submission could be considered to have occurred, EPA declines to disapprove such a constructive submission." *Id.* EPA explained that it will monitor Ecology's efforts to reduce PCB pollution in the Spokane River, including "its ongoing progress in issuing TMDLs for other water bodies," and that it "may reconsider this decision if significant relevant circumstances change." *Id.*

After EPA issued this determination, Plaintiffs filed an amended complaint on April 22, 2013, which retained Plaintiffs' original constructive submission claim under the Clean Water Act citizen suit provision, Dkt. No. 61 ¶¶ 36-39, and added a new, second claim challenging EPA's April 12, 2012, determination under the Administrative Procedure Act. *Id.* ¶¶ 41-42.

F. The Pollution Control Hearing Board's July 2013 Decision

In 2011, Ecology issued the Spokane County Regional Water Reclamation Facility an NPDES permit for discharges into a water-body segment that is not listed as impaired for PCBs under Washington's 303(d) lists. Plaintiffs in this case challenged that permit before the Washington Pollution Control Hearing Board (the "Board"), alleging that it unlawfully authorized PCB discharges. Board Decision pg.1 (attached hereto as Exhibit A). The Board agreed with Ecology that the available data was not adequate for preparation of a numeric effluent limit for PCBs in the permit, *id.* pg.22, that the permit therefore required best management practices, or narrative effluent limits, *id.*, and that any narrative limits used in such a circumstance must "require defined steps towards compliance with standards." *Id.* at p.24. Therefore, the Board remanded the matter to Ecology with instructions, among other things, that Ecology (a) include deadlines and mandatory requirements for identification and implementation of measures to reduce PCBs coming into the treatment facility, (b) identify the expected reductions in toxicant loadings and the schedule for initiating such reductions; and (c) requiring the use of ongoing monitoring data to set a numeric effluent limitation at the earliest possible time. *Id. at* p.27. In so ruling, the Board reviewed the important role of the Task Force and stated that it "finds that the creation of the Task Force is a positive step toward bringing the Spokane River into compliance with water quality standards for PCBs" and that "the actions undertaken by the Task Force are necessary to address the water quality problems in the Spokane River . . . ." *Id.*

STANDARD OF REVIEW

I. EPA'S DECISION MUST BE UPHELD UNLESS PLAINTIFFS ESTABLISH THAT EPA'S ACTION WAS ARBITRARY AND CAPRICIOUS.

Under the Administrative Procedure Act, EPA's final agency actions under the Clean Water Act must be upheld unless they are "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." 5 U.S.C. § 706(2)(A). The scope of review under this standard is narrow, and a court may not substitute its judgment for that of the agency. *See Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto Ins. Co.*, 463 U.S. 29, 43 (1983); *Citizens to Preserve*

Overton Park v. Volpe, 401 U.S. 402, 416 (1971). Rather, “Congress has assigned the courts perform ‘only the limited, albeit important, task of reviewing agency action to determine whether the agency conformed with controlling statutes,' and whether the agency has committed ‘a clear error of judgment.’” *Maryland Dep't of Human Resources v. U.S. Dep't of Agric.*, 976 F.2d 1462, 1475 (4th Cir. 1992) (quoting *Baltimore Gas & Elec. Co. v. NRDC*, 462 U.S. 87, 97 (1983), and *Overton Park*, 401 U.S. at 416).

The party asserting an APA challenge bears the burden of demonstrating that the agency's actions were arbitrary or capricious. *Nw. Ecosystem Alliance v. U.S. Fish & Wildlife Serv.*, 475 F.3d 1136, 1140 (9th Cir. 2007). This standard is a “highly deferential, presuming the agency action to be valid.” *Id.* “The court may not set aside agency action as arbitrary or capricious unless there is no rational basis for the action.” *Friends of the Earth v. Hintz*, 800 F.2d 823, 831 (9th Cir. 1986).

Under this deferential standard the agency’s factual determinations are entitled to substantial deference. *Arkansas v. Oklahoma*, 503 U.S. 91, 112 (1992); *Central Arizona Water Cons. Dist. v. EPA*, 990 F.2d 1531, 1539-40 (9th Cir. 1993). As long as the agency’s factual determinations are supported by the administrative record they should be upheld, even if there are alternative findings that could also be supported by the record. *Arkansas*, 503 U.S. at 112. Even an agency decision “of less than ideal clarity" may be upheld by the court “if the agency's path may reasonably be discerned.” *Dioxin/Organochlorine Center v. Clarke*, 57 F.3d 1517, 1525 (9th Cir. 1995) (quoting *Motor Vehicle Mfrs. Ass'n v. State Farm Mutual Ins.*, 463 U.S. 29, 43 (1983)). Further, when examining agency scientific findings made within an area of an agency's technical expertise, a reviewing court must generally be at its most deferential. *Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 376-77 (1989).

II. JUDICIAL REVIEW IS LIMITED TO THE ADMINISTRATIVE RECORD AND IS CONDUCTED THROUGH A SUMMARY JUDGMENT PROCEEDING.

In a case such as this, judicial review is limited to the administrative record prepared by the agency for its decision. *Overton Park*, 401 U.S. at 419-20; *Vermont Yankee Nuclear Power Corp.*

v. NRDC, 435 U.S. 519, 549 (1978). This rule implements the well-settled principle that judicial review of agency action is confined to review of the record that was before the agency when it made its decision, and not extra-record material that was not considered by the agency at the time that it took final action. *Federal Power Comm'n v. Transcontinental Gas Pipe Line Corp.*, 423 U.S. 326, 331 (1976). Extra-record declarations, however, may be submitted by the Agency to clarify or explain information contained in the record. *See Camp v. Pitts*, 411 U.S. 138, 142-43 (1973). This Court has held that review in this case is limited to the administrative record. Dkt. No. 49.

Finally, because review is limited to the administrative record, resolution of this case is proper through summary judgment. *Adams v. United States*, 318 F.2d 861, 865 (9th Cir. 1963). In such a proceeding, the district court "is not required to resolve any facts in a review of an administrative proceeding. Certainly, there may be issues of fact before the administrative agency. However, the function of the district court is to determine whether or not as a matter of law the evidence in the administrative record permitted the agency to make the decision it did." *Occidental Eng'g Co. v. INS*, 753 F.2d 766, 769 (9th Cir. 1985). The Parties to this matter have stipulated that all claims for relief in this case will be resolved through the instant summary judgment proceedings. *Infra* at 30 n.15.

ARGUMENT

I. ECOLOGY HAS NOT MADE A CONSTRUCTIVE SUBMISSION FOR A SPOKANE RIVER PCB TMDL, AND THEREFORE PLAINTIFFS' COMPLAINT SHOULD BE DISMISSED WITH PREJUDICE AND SUMMARY JUDGMENT ENTERED FOR EPA.

A. The Constructive Submission Theory May Not, As a Matter of Law, Apply Where, As Here, the State Has a Robust Program for Establishing TMDLs.

Plaintiffs invoke the nondiscretionary duty prong of the CWA citizen suit provision, 33 U.S.C. § 1365(a)(2), alleging that Ecology has constructively submitted no PCB TMDL for the Spokane River, and that this triggers EPA's nondiscretionary duty under CWA § 303(d)(2), *id.* § 1313(d)(2), to approve or disapprove that submission. Plaintiffs and the Spokane Tribe thus invoke the constructive submission doctrine in an effort to circumvent and undermine Ecology's decisions as to how best to protect the environment, by targeting a particular TMDL that they believe should be established before all others. As discussed below, the constructive submission theory is inapplicable where, as here, the State has a robust program for establishing TMDLs.

1. The Constructive Submission Caselaw Supports EPA's Interpretation.

Plaintiffs' claim depends on a novel, and untenable, reading of the CWA and the applicable caselaw that would expand the constructive submission theory well beyond the limited circumstances in which it applies. The Ninth Circuit explained in San Francisco Baykeeper v. Whitman, 297 F.3d 877, 881 (9th Cir. 2002), that the doctrine was created by the courts to address the narrow situation in which a State has submitted no TMDLs at all for a prolonged period of time, *id.* at 881 (i.e.,"a complete failure by a state to submit TMDLs"), and this State inaction is "construed as a constructive submission of no TMDLs, which in turn triggers the EPA's nondiscretionary duty to act." *Id.* If EPA disapproves the constructive submission of no TMDLs, EPA then becomes obliged to establish the TMDLs pursuant to section 303(d)(2). If EPA approves the constructive submission of no TMDLs, that decision is reviewable under the Administrative Procedure Act. *Hayes v. Whitman*, 264 F.3d 1017, 1023 (10th Cir. 2001) (citing *Scott*, 741 F.2d at 995 & 997). In *Baykeeper*, the Ninth Circuit concluded that California's actions, having submitted at least eighteen TMDLs, "preclude any finding that the state has 'clearly and unambiguously' decided not to submit any TMDLs." *Id.* at 883 (citing *Hayes*, 264 F.3d at 1024).

In its decision adopting the constructive submission theory, the Ninth Circuit carefully reviewed the caselaw, and explained that since its first formulation in *Scott v. City of Hammond*, 741 F.2d 992 (7th Cir. 1984), the theory has been narrowly interpreted and applied "only when 'the state fails to submit any TMDLs and has no plans to remedy this situation.'" *Baykeeper*, 297 F.3d at 882 (explaining and quoting the district court's interpretation of *Scott*); *id.* (concluding that "the district court's ruling is consistent with how other circuits have interpreted and applied *Scott*"). Thus the Ninth Circuit concluded that the doctrine may apply only where no TMDLs have been submitted by the State over a prolonged period of time and the State has no plan to remedy this situation. *Baykeeper*, 297 F.3d at 881-883.

In this case, there is no dispute that Ecology has an ongoing, robust program for establishing TMDLs, having submitted 1372 TMDLS to EPA since 1999. *Supra* at 9-10. Even where States have submitted far fewer TMDLs, the courts have declined to find a constructive submission. *See Baykeeper*, 297 F.3d at 882-83) (citing cases). Moreover, where the doctrine has been found to apply, the State has submitted no, or only very few, TMDLs over a prolonged period of time and had no intention of remedying that situation.[11]/

The theory is not available here, as a means to alter Ecology's priorities regarding the order or timing in which particular TMDLs should be established or how limited State resources should be allocated. Although Plaintiffs prefer that Ecology establish a PCB TMDL for the Spokane River immediately, a claim for such relief is simply not available. The Tenth Circuit stated in *Hayes,* 264 F.3d at 1024, the "constructive-submission theory is not designed to challenge the timeliness or adequacy of the state's TMDL submissions . . . ." *See also Sierra Club v. Browner*, 843 F.Supp. 1304, 1314 (D.Minn.,1993) ("the Act does not set deadlines for the development of a certain number of TMDLs."). And in the Ninth Circuit the law is clear that the theory may apply only where the State has submitted no TMDLs. *Baykeeper*, 297 F.3d at 882.

Plaintiffs' contend that the *Baykeeper* case is inapposite, because it involved what Plaintiffs call a "programmatic" challenge where the "plaintiffs complained of a state's overall failure to submit any or an adequate number of TMDL," Pl Br. at 24-25, whereas Plaintiffs here are concerned with one particular TMDL. Such a distinction cannot evade the rule in *Baykeeper*. A necessary corollary to the *Baykeeper* holding, *i.e.*, that an ongoing State TMDL program that has already established 18 TMDLs precludes finding a constructive submission, is the Ninth Circuit's acknowledgment that there are many more TMDLs in that State (California) to be established. For these remaining TMDLs, whether taken as a group or individually, the constructive submission doctrine cannot be used to upset the State's priorities and resource allocations. As explained in

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[11]/ *E.g., Kingman Park Civic Ass'n v. EPA*, 84 F. Supp. 2d 1, 6 (D.D.C. 1999) ("An eighteen-year failure to calculate and submit any TMDLs constitutes constructive – if not outright – determination that no TMDLs are necessary."); *Alaska Center for the Environment v. Reilly*, 762 F. Supp. 1422, 1426-27 (W.D. Wa. 1991) (holding that failure by state to submit to EPA any TMDL for over ten years was constructive submission).

section B below, the reason for so limiting the theory is clear. Courts quite properly are not willing to invoke the constructive submission theory, and the necessarily narrow nondiscretionary duty prong of the CWA citizen suit provision,[12]/ in order to second-guess and supersede discretionary policy choices Congress reserved to States to prioritize waters under their 303(d) programs and to allocate limited State resources as the State believes appropriate to protect the environment. That is why *Hayes* concluded that a constructive submission theory cannot challenge "the timeliness" of a State's TMDL submissions or their content, and the Ninth Circuit concluded that the doctrine may apply only where no TMDLs have been submitted.

Plaintiffs' reliance (at 25) on three other cases for their overly expansive view of the constructive submission theory is unavailing. Although the claim in *Scott* concerned TMDLs for only Lake Michigan, it arose in a context in which the State had submitted no TMDLs at all over a prolonged period, 741 F.2d at 996-97, and it is that circumstance that the Court explained that the theory may apply. *Id.* Here, Ecology has already submitted and EPA has approved 1372 TMDLs statewide and, for the Spokane River watershed alone, Ecology has already submitted and EPA has approved 73 TMDLS. *Supra* at 9-10. Moreover, as explained in *Baykeeper,* 297 F.3d at 882, the *Scott* court remanded the case to the district court instructing it "to proceed as if the states had submitted proposals of no TMDL's" and still left open the possibility that a constructive submission may not be found. *Scott*, 741 F.2d at 997 n.11.

Plaintiffs' reliance on *Hayes* is also misplaced. While the Court in one part of its opinion describes the constructive submission theory in the singular, referring to the clear intent to submit no TMDL for a particular waterbody, in others places it speaks in the plural, referring to the submission of no TMDLs needed to trigger the theory. 264 F.3d at 1023 (the theory applies "[o]nly upon this determination that the states' inaction was so clear as to constitute a 'constructive submission' of no TMDLs"). Moreover, as the Ninth Circuit in *Baykeeper*

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[12]/ Claims against EPA under citizen suit provisions are limited to "'clear-cut' nondicretionary dut[ies]." *Farmers Union Cent. Exchange, Inc. v. Thomas*, 881 F.2d 757, 760 (9th Cir. 1989) (reviewing the similar citizen suit provision under the Clean Air Act). Thus, the CWA citizen suit provision "cannot be employed to challenge the substance or content of an agency action." *Scott*, 741 F.2d at 996; *see also Sierra Club v. Thomas*, 828 F.2d 783, 791 (D.C. Cir. 1987).

explained, the key fact in *Hayes* for why no constructive submission was found was not the focus on a particular TMDL, but the fact that Oklahoma had submitted between three and twenty-nine TMDLs with a commitment for more. *Baykeeper*, 297 F.3d at 882. Accordingly, the Ninth Circuit explained that *Hayes* should be construed to mean the constructive submission theory may apply only when no TMDLs are submitted. *Id.* Finally, in *City of Arcadia v. EPA*, 411 F.3d 1103, 1105 (9th Cir. 2005), also relied upon by Plaintiffs, the court described the constructive submission theory using the singular, but it did so only in passing, in a background section, and the holding of the case did not involve application of the theory at all. This passing reference carries no weight whatsoever. In sum, Plaintiffs have not cited a single case in which the constructive submission theory has been applied to compel establishment of a single, particular TMDL from among the many that may ultimately be required, and EPA is not aware of such a case.

2. EPA's Reasonable Interpretation is Fully Supported by the CWA

EPA's interpretation is also fully supported by the CWA § 303(d) provisions regarding State TMDL prioritization and the cases interpreting it. The CWA vests States with authority to exercise their own judgment as to when particular TMDLs should be established and how their limited resources should be allocated, without the threat of judicial intervention requiring that EPA usurp that State discretion and decisionmaking. For example, while the CWA requires that States establish a priority ranking for TMDLs, EPA is not required to pass judgment on that prioritization or approve or disapprove the State's order. Although CWA § 303(d)(1)(A) requires that "[e]ach State shall identify those waters within its boundaries . . . * * * [and] establish a priority ranking for such waters," 33 U.S.C. § 1313(d)(1)(A), the CWA only requires each State "from time to time" to submit to EPA for approval "the <u>waters identified</u> and the <u>loads established</u>." *Id.* § 1313(d)(2) (emphasis added). Thus, the CWA is specific and clear: EPA must review only the 303(d) list (the "waters identified") and the TMDLs (the "loads") once they are submitted to EPA. Conspicuously absent from Section 303(d)(2) is any mention of EPA approval of priority rankings set by the States under Section 303(d)(1)(A). "Where Congress includes particular language in one section of a statute but omits it in another section of the same Act, it is generally-presumed that Congress acts intentionally and purposely in the disparate inclusion or exclusion." *Russello v. U.S.*, 464 U.S. 16, 23 (1983).

Accordingly, the courts that have reviewed this question have agreed that EPA is not required to review and approve the particular priority ranking States establish for TMDL development. The Court in *Potomac Riverkeeper, Inc. v. EPA*, 2006 WL 890755, at 10 (D. Md. 2006), explained as follows:

> While a state's § 303(d) list must list waters 'targeted' for TMDL development within the next two years, this requirement is a form of goal setting. This requirement does not, however, require EPA, prior to approval, to ascertain, based on the state's historic average number of impairments resolved per year, whether the state can actually complete the 'targeted' TMDLs in the next two years. In addition, there is no provision that requires EPA to approve or disapprove a state's priority rankings.

Id. at 10 (footnote omitted).[13]

Plaintiffs' theory in this lawsuit, therefore, contradicts the CWA's clear text and structure and is not supported by applicable caselaw. The constructive submission theory may not, as a matter of law, be used, as Plaintiffs' intend here, to supersede and reorder the State's priorities and decisions.

This limitation on the constructive submission theory is a corollary to the prohibition on its use to challenge the timing or content of State TMDLs, *Scott*, 741 F.3d at 995, and the Ninth Circuit's holding that the theory may apply only if no TMDLs have been submitted and the State

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[13] EPA also notes that, in *Sierra Club, Inc. v. Leavitt*, 393 F.Supp.2d 1263, 1273 (N.D. Fla. 2005) (N. D. Fla. 2005), *aff'd and rev'd in part; judgment vacated in relevant part*, 488 F.3d 904 (11th Cir. 2007), the district court declined to second-guess the State's particular priority ranking for completing TMDLs in a case challenging EPA's approval of a 303(d) list, explaining:

> No requirement is present that EPA approve the [States'] rankings. Importantly, in its Decision Document, while the EPA specifically approves or disapproves [the State's] decision to list, not list, or delist waters, the section discussing prioritization does not "approve" or "disapprove" [the State's] ranking; it merely concludes that Florida did, in fact, rank its waters and set a TMDL schedule accordingly. Because there is no requirement that the EPA actually approve or disapprove of a state's priority rankings, . . . summary judgment is granted in favor Defendants

On appeal, the Eleventh Circuit concluded that plaintiffs did not actually challenge the particular ranking of listed waters, and thus it did not address that issue and vacated district court's summary judgment on that claim and remanded. 488 F.3d at 917-918. Nevertheless, the district court properly addressed this issue.

has no plan to remedy that situation. *Baykeeper*, 297 F.3d at 882. This limitation also follows from the discretion CWA § 303(d) preserves for the States. A contrary ruling would open the floodgates to numerous lawsuits against EPA by groups dissatisfied with how limited State or federal resources were allocated, in an effort to redirect development to their preferred TMDL in lieu of other environmental projects or TMDLs in other communities. Such "special pleading" lawsuits on behalf of those groups' narrow priorities would ensnare the courts in disputes they are ill-suited and not authorized by statute to resolve, *i.e.*, second-guessing the States' judgments about how to best protect the environment in the face of limited resources. These are precisely the types of claims the CWA and caselaw foreclose.[14]/

EPA's interpretation is fully consistent with the plain meaning of Section 303(d) and the applicable caselaw. However, even were the statute ambiguous, EPA's construction is reasonable, and should be upheld. Accordingly, EPA has not failed to perform a nondiscretionary duty under the CWA citizen suit provision, and thus Plaintiffs' and the Tribe's complaints should be dismissed and summary judgment entered for EPA.

B. Plaintiffs Have Waived Their Right to Challenge EPA's Determinations That Ecology Has Not Renounced Establishing a PCB TMDL for the Spokane River If Necessary and That Ecology Has Thus Not Constructively Submitted Such a TMDL.

Even assuming, arguendo, that a constructive submission claim could be used to compel EPA to establish a particular TMDL, Plaintiffs have waived their right to raise such a claim here. As discussed *supra* at 18-20, on April 12, 2012, EPA reached its administrative determination that Ecology has not disavowed establishing a Spokane River PCB TMDL if needed and that Ecology has not therefore constructively submitted such a TMDL. In their amended complaint, Plaintiffs include an additional claim (claim two) against EPA under the Administrative Procedure Act challenging EPA's April 12, 2012, determination, alleging that EPA's "determination that Ecology has not submitted a Spokane River PCB TMDL is arbitrary, capricious, an abuse of discretion, and

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[14]/ EPA does not here opine on what recourse Plaintiffs may have on claims in State court directly against Ecology regarding its priorities under State law or regulations. That matter is not before the Court.

not in accordance with law, and their refusal to approve or disapprove the TMDL, and, if disapprove, to establish a TMDL as required by 33 U.S.C. § 1313(d)(2) constitutes agency action unlawfully withheld or unreasonably delayed." Dkt. No. 61¶ 41. Because Plaintiffs have elected not to argue their second claim to challenge EPA's determination in their motion for summary judgment, that claim is waived in accordance with the caselaw and the parties' stipulated agreement and the Court's Scheduling Orders that all claims in this case will be resolved by these summary judgment proceedings.[15]/

The rule in this Court is clear that such claims must be dismissed with prejudice. *See, e.g.,Wild Bainbridge v. Mainlander Services Corp.* 544 F. Supp. 2d 1159, 1167 (W.D. Wash. 2008) ("Pursuant to the parties' agreement that all claims against the federal defendants will be resolved by summary judgment, all claims not raised in Wild Bainbridge's summary judgment motion are dismissed as to the Corps."); *Thunderbird Trading v. U.S. Bureau of Alcohol, Tobacco and Firearms*, No. C92-5181, 2007 WL 1128810, at *10 (W.D. Wash. Ap. 16, 2007) (where all parties agreed that all issues are to be decided on summary judgment, on those issues in the Plaintiff's complaint not raised in the Plaintiff's brief "the Court presumes that Plaintiff has abandoned them. Therefore, to the extent that Plaintiff makes claims, if any, regarding these issues, Plaintiff's claims should be dismissed with prejudice and summary judgment for the Defendants should be granted.").[16]/

Accordingly, because Plaintiffs elected not to pursue its challenge to EPA's April 12, 2012, determination, the determination necessarily stands intact.

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[15]/ Order, dated April 8, 2013 (Dkt. No. 58) (entering the parties Stipulation and Proposed Order to Modify Scheduling Order at 2 & 4 ¶ 7); Order, dated September 12, 2013 (Dkt. No. 78) (entering the parties' Stipulation and [Proposed] Briefing Schedule, at 4 ¶ 5); *see also* Order, dated December 23, 2013 (Dkt. No. 88) (entering the parties Stipulation and [Proposed] Modified Briefing Schedule).

[16]/ *Also Mountain States Legal Found. v. Espy*, 833 F. Supp. 808, 813 nn.4-6 (D. Id. 1993) (where the plaintiff agreed that all claims in its complaint would be resolved through summary judgment, claims not raised in its summary judgment motion were waived and dismissed with prejudice); *City of Santa Clarita v. Dep't of Interior*, No. 02-00697, 2006 WL 4743970 at *11 (C.D. Cal. Jan. 30 2006) (same), *aff'd*, 249 Fed. Appx. 748 (9th Cir. 2007).

C. The Court Should Uphold EPA's Reasonable Determined That Ecology Has Not Renounced Submitting a PCB TMDL for the Spokane River if Needed and That Such a TMDL Has Not Been Constructively Submitted to EPA.

1. The Administrative Record Supports EPA's Finding That There Has Not Been a Constructive Submission.

Assuming, arguendo, that Plaintiffs can overcome the legal bars discussed above to either of their claims, the Court should uphold EPA's reasonable determination and reject those claims. As explained in detail, *supra* at 18-20, EPA in its April 12, 2013, determination concluded that "Ecology's decision to delay completion of a PCB TMDL for the Spokane River is within the discretion of the State of Washington" and that "Ecology has not renounced completion of a PCB TMDL for the Spokane River if one is required." V.1, T.A, at 1. EPA thus determined that there has not been a constructive submission by Ecology of a PCB TMDL. These determinations are amply supported by the record.

As detailed above, Ecology has a robust, ongoing TMDL program, having issued 1372 TMDLs since 1999, including 73 TMDLs in the Spokane River watershed, and Ecology is committed to continuing this progress. *Supra* at 9-10. Although Ecology initiated the process to develop a PCB TMDL for the Spokane River, those efforts disclosed significant information gaps and the need for additional study and analysis, which prevented Ecology from completing that TMDL. *Supra* at 11-14; V.1, T.A at p.4; V.5, D.132 at 2671, 2675, 2683. Ecology also recently completed a lengthy, technically complex and contentious twelve-year process to establish a dissolved oxygen TMDL for the Spokane River, V.1, T.A at p.4, V.1, D.4 at 503; V.5, T.132 at 2671-72, and based upon lessons it learned there, Ecology was concerned that pressing forward on a PCB TMDL for that same water-body, especially given the significant gaps in information and the importance of a cooperative approach, would result in further, lengthy delays in establishing such a TMDL. *Id.; supra* at 16-17. Ecology thus determined to devote its limited resources to other TMDLs at this time, and to supplemental measures, including the Task Force, to fill data gaps and to achieve near-term PCB reductions. *Id.* EPA supports the work of the Task Force and other interim measures until such time that a PCB TMDL can be completed if necessary. V.1, T.A at pp.2-3. Moreover, even if the Task Force or other measures fail to adequately reduce PCBs, the information gained by the Task Force would assist in the development of a TMDL. *Supra* at 15-16.

EPA also found reasonable Ecology's commitment to review the Task Force's progress in five years. V.1, T.A at 3. Ecology further committed to establish a PCB TMDL if the Task Force or other measures it may adopt fail to achieve applicable PCB water quality standards. V.2, T.44 at 706 ("a PCB TMDL still remains a tool and will be necessary if ongoing toxics reduction strategies do not result in compliance with water quality standards."); *also* V.1, T.1 at 2. If the applicable PCB water quality standards are met through supplemental measures, no TMDL would be required. EPA explained that this "leads EPA to conclude that Ecology has not repudiated its legal obligation to develop a PCB TMDL if needed." Id. at 4. EPA concluded that Ecology must retain discretion to manage and establish priorities for TMDL development, including how limited resources should be expended to reduce pollution where TMDLs have not yet been completed. *Id.*

In their effort to discredit Ecology's reasons for deferring a PCB TMDL, Plaintiffs argue that Ecology shared with EPA a "complete draft TMDL" to review, that this draft TMDL included all elements required in a TMDL for approval by EPA, and that Ecology's draft TMDL went through the public notice process required for TMDL development. This is incorrect. As an initial matter, the documents Plaintiffs contend are technically complete TMDLs are each marked "Draft . . . Do not cite or quote," V.3, T.90, at 1319; V.3, T.69 at 1102, which demonstrates that Ecology never believed them complete. Ecology also has not conducted the notice and comment proceedings required before a TMDL can be submitted to EPA. *Supra* at 13 n.9. Moreover, Ecology itself explained that significant gaps in information and need for additional new information prevented these preliminary drafts from being finalized. The background section of this brief details important areas where these draft documents are incomplete. *Supra* at 11-14, 17.

For example, the draft document that Plaintiffs and the Tribe contend is a complete and approvable PCB TMDL for the Spokane River could not identify the sources or categories of sources or otherwise account for 57% of the PCB loading in the relevant reach of the River. V.1, T.15 at 163 (figure 19); *supra* at 14. Further, in uncontested testimony in a proceeding before the

Pollution Control Hearing Board involving the same plaintiffs in this case, a spokesperson for Ecology explained as follows:

Q	And I believe you testified earlier that this draft TMDL failed to account or was unable to discover roughly 57 percent of the sources of PCB loading to the river?
A	Correct.
Q	Would Ecology develop a total maximum daily load for a pollutant if it didn't even know where 57 percent of the sources of that pollutant came from?
A	No.
Q	Why not?
A	It would leave too much uncertainty and I think it would require the dischargers to pay an inequitable amount of their resources to solve the rest of the PCB problem.

V.5, D.132 at 2683 (questions by counsel for Ecology; answers by Ecology employee Jim Bellatty); *id.* at 2671 (this large information gap "leaves a lot of unanswered questions and uncertainty with our ability to be able to do a TMDL"). This and the other record information readily rebuts Plaintiffs' conclusory assertions that political pressure prevented Ecology from finalizing the TMDL.

In sum, EPA fully explained the bases for its April 12, 2013, determination and the record amply supports EPA's findings. Plaintiffs' burden to demonstrate otherwise is particularly high in this case, where inherent in the State's decisions are judgments about how best to allocate limited resources to protect the environment.

2. Plaintiffs' Arguments Challenging EPA's Decision Are Without Merit.

Plaintiffs contend that a Memorandum of Agreement between EPA and Ecology in 1997 regarding Ecology's commitment to establish TMDLs, as well as Ecology's 303(d) lists from 1996 through 2010, required that Ecology have developed a PCB TMDL for the Spokane River by 2013. Pl. Br. at 26-27 & 34. This argument is flawed on several counts. First, neither that Memorandum of Agreement, V.1, T.34, nor the out-of-court settlement agreement that EPA entered in 1998 with two environmental groups regarding TMDL development, V.1, T.32, required Ecology to have established and submitted a Spokane River PCB TMDL to EPA by this time. Consistent with the CWA, those documents necessarily preserve Ecology's discretion to select which particular TMDLs to develop and when to do so. For example, Attachment A to the Memorandum of Agreement and settlement agreement describes Ecology's 303(d) prioritization process for initiating development of TMDLs in different management area watersheds throughout the State over five-year cycles, V.1, T.33, including the Spokane area. It does not require that the TMDL on which Ecology initiates development in the Spokane area be for PCBs. *Id.* at 457. Similarly, the settlement agreement preserves Ecology's discretion to substitute between TMDLs it intends to develop from the State's different 303(d) lists. V.1, T.32 at 47-48 (¶ 7).

Nor is there anything to Plaintiffs' claim that Ecology has departed from its prioritization process and ignored the Spokane River and its tributaries. As explained above, since 1999, Ecology submitted and EPA has approved 1372 TMDLs, many of which were for WQLSs in the Spokane River and its tributaries. Further, on April 12, 2012, EPA approved an additional 57 TMDLs submitted by Ecology for the Little Spokane River watershed, for fecal coliform bacteria, temperature and turbidity. [Is the 57 Included in the total?] Thus, Ecology has not, as Plaintiffs' claim, departed from its prioritization process and ignored the Spokane River. Rather, Ecology has exercised its discretion by prioritizing and completing the particular TMDLs that in its judgment will best protect water quality most efficiently with the State's finite resources.

Plaintiffs further argue that because Ecology initiated development of a PCB TMDL for the Spokane River, Ecology was required to have already completed and submitted that TMDL to EPA. However, as explained above, Ecology has adapted its priorities based upon the circumstances, deciding to defer establishing a PCB TMDL for the Spokane River and to establish other TMDLs at this time, and to adopt interim, supplemental measures to reduce PCBs in the Spokane River. Nothing in the CWA or EPA's regulations precludes Ecology from altering course in this manner. Moreover, while EPA's regulations direct States to submit 303(d) lists every two years, and to include a priority ranking of waters "targeted for TMDL development within the next two years," 40 C.F.R. § 130.7(d)(1), this language plainly does not require completion of such TMDLs within that two-year period. Nor could it, since, as discussed above, the CWA preserves the State's discretion in this regard, requiring only that States submit TMDLs to EPA "from time to time," 33 U.S.C. § 1331(d)(2). Rather than require TMDLs be submitted in two years, this language expressly preserves State discretion to determine when such TMDLs should be developed and submitted to EPA. Similar "time to time" language under a different Section 303 provision are construed precisely in this manner. *American Canoe*, 30 F. Supp. 2d at 923. Indeed, "courts have generally held that the use of the phrase 'time to time' does not create a nondiscretionary administrative duty." *Id.* [17]/

Plaintiffs argue that Ecology has decided to utilize a "straight-to-implementation project" ("STI") for reducing PCBs in the Spokane River, that STI projects necessarily preclude TMDLs, and that this demonstrates that Ecology has decided no PCB TMDL for the Spokane River will ever be established. Pl. Br. at 28. EPA reasonably addressed this in its April 2012 determination, explaining that STIs are a type of interim approach to identify PCB sources and practices to prevent contamination reaching the water body, and that Ecology's "definition and use of this term [i.e., STI] are changing over time." V.1, T.A at pp. 2-3. Further, while Ecology once appeared to refer to the Task Force or other measures to reduce PCBs in the Spokane as an STI, it no longer does so. *Id.* at p.3 n.10. The key point here, however, is that Ecology has committed to establish a PCB TMDL if it is ultimately needed, and that it therefore does not matter whether the Task Force, or any other interim, supplemental measures Ecology may adopt, may have once been or are called STIs. *Id.* Moreover, if Plaintiffs here intend to challenge STIs generally or in other contexts, that issue is not before the Court; neither the issues nor administrative record in this case provide the Court with the opportunity or ability to resolve whether STIs generally or in other contexts preclude TMDLs. And then, Plaintiffs depiction of STIs is incorrect, because an Ecology presentation in the record from 2011 states that an STI "does not preclude further TMDL

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[17]/ *See, e.g., NRDC v. Thomas*, 885 F.2d 1067, 1075 (2nd Cir. 1989) (Clean Air Act provision requiring revision of a list of air pollutants "from time to time" does not impose a nondiscretionary duty); *Oljato Chapter of the Navajo Tribe v. Train*, 515 F.2d 654, 661 (D.C. Cir. 1975) (Clean Air Act provision imposing a duty in which EPA may from "time to time" revise certain standards does not impose a nondiscretionary duty). Rather, a nondiscretionary duty is typically one in which the statute requires performance by a date certain. *Sierra Club*, 828 at 791 (absent a readily-ascertainable deadline, "it will be almost impossible to conclude that Congress accords a particular agency action such high priority as to impose upon the agency a 'categorical[] mandat[e]' that deprives it of all discretion over the timing of its work.").

pathway." V.3, T.86 at 1307.

Eventually, Plaintiffs frankly concede in their brief, as they must, that Ecology has not renounced its obligation to establish a PCB TMDL if one is ultimately necessary, but they then argue that Ecology has not adequately identified what "measurable progress," "activities," or "metrics" would make the TMDL "unnecessary." Pl. Br. at 28-29. Plaintiffs confuse the issue and distort Ecology's position; it is undisputed that the TMDL will ultimately not be needed if and when the Spokane River meets the applicable PCB water quality standards. *See supra* at 5. Moreover, Ecology's point is that, for now, it has chosen to pursue various interim measures, such as the Task Force, to reduce PCBs in the Spokane River, while development of the PCB TMDL is deferred for the reasons discussed above. At the same time, Ecology has clearly committed that it will evaluate the Task Force's progress in five years, V.1, T.1 at 1-2, and if "measurable progress" is not being made and other measures are not available, "Ecology would be obligated to proceed with development of a [Spokane River PCB] TMDL . . . ." *Id.* at 2. Thus Ecology explained that "it is committed to proceed with a TMDL should it be necessary." *Id.* Further, if such a TMDL is needed, Ecology will have the benefit of the additional needed information gathered (based on the work of the Task Force) for developing the TMDL. *Supra* at 15-16; V.1, T.35 at 481-84 (data to be gathered). Based upon this, EPA reasonably concluded that "Ecology has not repudiated its legal obligation to develop a PCB TMDL if needed," *V.1 T.A*, at 4.

Plaintiffs next complain that the Task Force is not adequate, alleging that it is "controlled by the NPDES dischargers." Pl. Br. at 29. Such an attack, however, is incorrect, given that several governmental entities and other environmental groups are members of the Task Force. *Supra* at 15. Indeed, Plaintiffs as well as the Spokane Tribe were invited to participate in the Task Force, but declined. Although Plaintiffs doubt that the Task Force will achieve its goal, this is no reason to fault Ecology for pursuing interim measures to reduce PCB pollution, much less to equate Plaintiffs' projections of the Task Force's failure to Ecology constructively renouncing ever establishing a TMDL. Nor is it a proper criticism that the Task Force did not, up-front, identify measures it will adopt to reduce PCB pollution, given that it was only recently established and part of its mission is to identify those measures. *Supra* at 15-16. Moreover, Plaintiffs inaccurately suggest that the Pollution Control Hearing Board was critical of the Task Force. To the contrary, while the Board merely concluded that participation in the Task Force is not a defense to NPDES permit compliance, Board Decision at p.27, a matter not at issue here, the Board stated that it "finds that the creation of the Task Force is a positive step toward bringing the Spokane River into compliance with water quality standards for PCBs" and that "the actions undertaken by the Task Force are necessary to address the water quality problems in the Spokane River . . . ." *Id.* at p.26.

Finally, Plaintiffs allege that absent a PCB TMDL for the Spokane River, NPDES permits issued by Ecology for PCB discharges into the Spokane River will be inadequate. Pl. Br. at 33. This argument is flawed for several reasons, and we address it in detail *infra* at 42-43 & 45. EPA highlights here that if Plaintiffs believe those State-issued permits are inadequate, the remedy is to challenge them through the State administrative process and court system, rather than improperly attempt to adjudicate their adequacy in this case. Plaintiffs' unsupported claims that NPDES permits will be inadequate thus provide no support for the claims in this case. Moreover, as explained *supra* at 7, even where a TMDL has not yet been established, States still must include effluent limits in NPDES permits as stringent as necessary to meet water quality standards, 33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.44(d)(1)(vii)(A). Indeed, as explained below, the presence of a PCB TMDL may not result in any change in the stringency of NPDES permits.

In sum, Plaintiffs have not met the high burden to upset EPA's April 12, 2013, determination nad have not established that a constructive submission has occurred.

II. THE INTERVENOR SPOKANE TRIBE'S CLAIMS SHOULD BE REJECTED.

The Tribe in its second amended complaint asserts two claims for relief. In its first claim, under the CWA citizen suit provision, the Tribe incorporates portions of Plaintiffs' claim and alleges that "EPA breached its trust responsibility and fiduciary duty to the Tribe by failing to perform its nondiscretionary duties under 33 U.S.C. § 1313(d)(2)," Dkt. No. 74, Attach. 1 ¶ 22. The Tribe's second claim, after incorporating Plaintiffs' description, alleges that "EPA Defendants' April 12, 2013 determination failed to protect the interests of the Spokane Tribe, and

EPA Defendants have breached and will continue to breach their trust responsibility and minimum fiduciary duty owed to the Spokane Tribe because the April 12, 2013 determination is not in accordance with 33 U.S.C. § 1313(d)(2) and federal common law, and is in violation of 5 U.S.C. § 706(2)(A)&(D) [*i.e.*, APA standards of review]." *Id.* ¶ 24. This language explicitly limits the claims in this case to arguments that EPA's alleged failure to comply with the CWA, the APA, and any applicable common law, also constitutes a breach of EPA's alleged trust responsibility and fiduciary duty owed the Tribe.

In its brief, the Tribe argues that, for the downstream PCB-impaired water-body segment it administers within its jurisdiction, the Tribe has established PCB water quality standards that are more stringent than those adopted by Ecology for the upstream segments Ecology administers, to account for risks posed by the greater fish consumption assumed for Tribal members. The Tribe argues that unless PCBs upstream are adequately reduced, the Tribe's more stringent water quality standard in the downstream segment within its jurisdiction cannot be met. According to the Tribe, only an EPA-established TMDL for the upstream segment administered by Ecology will ensure NPDES limits within that segment that can accomplish PCB reductions downstream on the reservation, and that the general fiduciary duty weighs in favor of finding a constructive submission under the CWA citizen suit (claim one). In the alternative, the Tribe contends that EPA's determinations that Ecology has not renounced its obligation to establish a TMDL and that no constructive submission has occurred should be set aside under the Administrative Procedure Act (claim two). The Tribe's arguments miscast the nature of EPA's general trust responsibility and provide no basis to find a constructive submission or upset EPA's determination. As discussed below, there is no specific fiduciary duty owed the Tribe in this case. Moreover, nothing in EPA's decision undermines the Tribe's ability to enforce its tribal PCB standard.

A. EPA's Compliance with the CWA and its Regulations Satisfies its General Trust Responsibility.

Although the relationship between the United States and Indian tribes has been described as a trust, the scope of the federal trust responsibility is not defined by common law fiduciary duties or those imposed on a private trustee. *United States v. Jicarilla Apache Nation*, 131 S. Ct. 2313, 2323 (2011). Rather, tribes must point to specific statues and regulations that "establish [the] fiduciary relationship and define the contours of the United States' fiduciary responsibilities." *Id.* at 2325 (citation omitted). Thus the only cognizable breach of trust claim is one founded upon a definite and express fiduciary duty imposed on the federal government by administrative regulation or Act of Congress. *United States v. Navajo Nation*, 537 U.S. 488, 511 (2003); *United States v. White Mountain Apache Tribe,* 537 U.S. 465, 477 (2003). Accordingly, the federal common law trust duties applicable to private beneficiaries, which the Tribe seeks to impute to the federal government, *see* Tribe Br. at 15, do not provide independent bases for the claims asserted by the Tribe. *See Pacific Coast Fed'n of Fisherman's Ass'ns v. United States BLM*, 2005 U.S. Dist. *LEXIS* 36035, *34 (N.D. Cal. Mar 8, 2005).

There is a "distinctive obligation of trust incumbent upon the Government in its dealings with [Indian tribes]." *Gros Ventre Tribe v. United States*, 469 F.3d 801, 810 (9th Cir. 2006) (quoting *United States v. Mitchell*, 463 U.S. 206, 225 (1983)). However, "[w]ithout an unambiguous provision by Congress that clearly outlines a federal trust responsibility, courts must appreciate that whatever fiduciary obligation otherwise exists, it is a limited one only." *Shoshone-Bannock Tribes v. Reno*, 56 F.3d 1476, 1482 (D.C. Cir. 1995). While that general trust relationship allows the federal government to consider and act in the tribes' interests in taking discretionary actions, it does not impose a duty on the federal government to take action beyond complying with generally applicable statutes and regulations. *Jicarilla*, 131 S. Ct. at 2325. Accordingly, in the absence of a specific duty that has been placed on the government with respect to the Tribe, the United States' general trust responsibility "is discharged by the agency's compliance with general regulations and statutes not specifically aimed at protecting Indian tribes." *Morongo Band of Mission Indians v. F.A.A.*, 161 F.3d 569, 574 (9th Cir. 1998); *Okanogan Highlands Alliance v. Williams*, 236 F.3d 468, 479 (9th Cir. 2000) (Bureau of Land Management's approval of gold mine satisfied trust obligations by the agency's compliance with NEPA); *Gros Ventre*, 469 F.3d at 814.

Here, the Tribe alleges in its CWA citizen suit claim that EPA breached fiduciary duties owed in the CWA by not establishing a TMDL. Second Amended Complaint ¶ 24 (Dkt. No. 73, Attach. 1). The Tribe does not identify where the CWA establishes a fiduciary duty mandating that EPA establish a PCB TMDL for the Spokane River, much less that a mandatory duty requires EPA do so at this time. Instead, the Tribe duplicates the arguments of Plaintiffs (which we refute above) based upon the government's general statutory and regulatory obligations under the CWA. Accordingly, EPA satisfied its general trust responsibility by its compliance with the CWA.

B. The Indian Law Canon of Construction Raise by the Tribe Does Not Apply, and Even if It Did, It Would Not Result in a Finding of a Constructive Submission.

The Tribe contends that an Indian law canon of construction requires that any statutory ambiguity be interpreted to benefit the Tribe, and that this canon is triggered in this matter because under CWA section 518(e), 33 U.S.C. § 1377(e), the Tribe has been granted the right "to be treated as a state," *id.*, for purposes of issuing water quality standards. Tribe Br. at 5-6. Even assuming arguendo this were accurate, this canon is inapplicable because, as demonstrated in Section 1.A above, the provision of the CWA at issue in this case is not ambiguous: the constructive submission theory does not, as a matter of law, apply in this case. And beyond that, the CWA calls for EPA to approve or disapprove TMDLs arises only if TMDL submissions (actual or constructive) have occurred, and there is no ambiguity in that statutory proposition. The canon of construction raised by the Tribe does not apply when the statue is clear. Thus the Court need not decide whether the canon cited by the Tribe applies here.

Even were the applicable law ambiguous, the referenced canon would not apply in this circumstance. This canon applies only to "'statutes passed for the benefit of dependant Indian tribes.'" *Hoonah Indian Ass'n v. Morrison*, 170 F.3d 1223. 1228 (9th Cir. 1999) (quoting *Bryan v. Itasca County, 426 U.S. 373, 392 (1976)).* Regardless of whether this canon may apply to ambiguous interpretations of the Tribe's authority under 33 U.S.C. § 1377(e), or the Tribe's administration of its own program, it certainly would not extend here to the Section 303(d) TMDL program administered by Ecology, *id.* § 1313(d), EPA's obligation to approve or disapprove a

TMDL once submitted, *id.* § 1313(d)(2), or the CWA provisions governing the Tribe's assertion that the Court must order EPA to establish a PCB TMDL and thereby usurp Ecology's role and substitute the Tribe's priorities for the State's reasonable pollution prevention and remediation plans. The latter generally applicable provisions of the CWA just discussed are the only provisions at issue in this case, and thus the referenced canon would not apply.

The Tribe also appears to rely upon the canon when recounting selected documents and information in the administrative record, which it construes in its favor, in an effort to establish that Ecology has renounced its obligation to issue a TMDL that may be necessary, and thus has constructively submitted a PCB TMDL to EPA. However, even if the canon somehow applied to the interpretation of the CWA, it does not apply to the judicial review of record information. Rather, the applicable arbitrary and capricious standard of the Administrative Procedure Act applies. The Tribe has not met its burden to demonstrate that EPA's determinations are arbitrary and capricious or contrary to law.

C. The Tribe's Arguments Based Upon Alleged Impacts to Its Fishing Rights Are Not Properly Before the Court, and Provide No Basis to Reject EPA's Determination.

In the context of its APA claim, the Tribe contends that EPA's April 12, 2013, decision is arbitrary, capricious or contrary to law because it "fails to preserve and protect the Tribe's fishing rights." Tribe Br. at 16. The Tribe appears to base its argument on its assertion that it has "a right to water quality that can sustain fish and other aquatic life." Tribe Br. at 6 (citing *United States v. Anderson*, 591 F. Supp. 1, 5 (E.D. Wash. 1982), *aff'd in part and rev'd in part*, 736 F.2d 1358 (9th Cir. 1984)). That case, however, involved an adjudication of the Tribe's water rights in the Chamokane Stream, and the Court addressed only "[t]he quantity of water needed to carry out the reserved fishing purposes" as it relates to "flow" and "water temperature." Moreover, this is far different than the circumstance here, where the issue is PCB contamination and the State's decision of how best to expend resources to reduce that pollutant. *See Hopi Tribe v. United States*, 113 Fed. Cl. 43, 49 (2013) (reserved water rights do not impose mandatory fiduciary duties on the United States to build drinking water infrastructure). This issue, however, is not properly before the Court, regardless of what the scope of the Tribe's fishing rights may be, and should be dismissed. Plaintiffs' second amended complaint does not include a claim based upon alleged violation of fishing rights. Stipulations entered by the Parties and filed in Court further demonstrate that the Intervenor Tribe's complaint was not to so expand the claims in this case.[18]/

Even if this issue were properly before the Court, the Tribe has not made the necessary showing to support its assertion that the lack of an EPA-issued TMDL adversely impacts the Tribe's fishing rights. TMDLs are not self-executing and thus do not themselves reduce pollution.

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[18]/ After this Court ruled that review in this case is limited to the administrative record, Dkt. No. 49, Plaintiffs requested that EPA review documents and approve or disapprove a constructive submission, V.1, T.B & C, which resulted in EPA's April 12, 2012, determination that no constructive submission had occurred, V.1, T.A, and the inclusion of additional documents in the record for judicial review. Dkt. No. 58 at 2, 4-5 (¶ 8) (Order dated April 8, 2013). Counsel for the Tribe did not, as part of that process, request that EPA consider or determine impacts to its fishing rights. *See id.* Moreover, Plaintiffs, and the Tribe, were to add an additional cause of action in their amended complaints only to secure their challenge to EPA's April 12, 2013, determination. That process, however, was not to enlarge the basic issues originally in this case. After the Tribe filed its First Amended Complaint, Dkt. No. 64, counsel for EPA contacted counsel for the Tribe and objected because the Tribe's new second and third causes of action added the claims that EPA failed to comply with certain specific alleged fiduciary duties, including primarily an alleged failure to consult with the Tribe as part of that process. *Id.* ¶¶ 19-23. Ultimately, to ensure no misunderstanding, through an exchange of emails and calls, the Parties' all agreed to the following:

> The Parties agree that in the Tribe's Second Amended Complaint, the Tribe is not raising a breach of trust/fiduciary duty claim based upon EPA's alleged failure to consult with the Tribe upon considering the additional documents and in issuing its April 12 letter. Thus, the Tribe, in the second claim of its second amended Complaint, may only challenge as a breach of trust/fiduciary duty the merits of EPA's decision that there has been no constructive submission.

Emails dated September 6 and 9, 2013, Attachment A hereto. Based on this agreement, the Parties' filed a joint stipulation, Dkt. No. 73, which the Court entered on September 12, 2013, Dkt. No. 74, thereby authorizing the filing of the Tribe's Second Amended Complaint, to ensure that the claims in this action were not expanded. The stipulation filed by the Parties explained as follows:

> To resolve disagreements regarding the scope of the amended complaint filed by the Tribe, the Parties hereby stipulate to the Intervenor-Plaintiff Spokane Tribe of Indians filing a second amended complaint, which is attached (Attachment 1). <u>This proposed second amended complaint is narrower than the Complaint previously filed by Intervenor-Plaintiff Spokane Tribe, and thus its filing will neither expand the claims in this lawsuit nor delay their resolution</u>, while also resolving disputes the Parties had regarding the scope of the first amended complaint previously filed by the Spokane Tribe of Indians.

Doc. Nos. 73 & 74, ¶ 3 (emphasis added). Accordingly, the Tribe's arguments in its motion for summary judgment alleging fishing rights have been violated are not properly before the Court and must be dismissed.

Even if EPA were required to establish a PCB TMDL, it may not result in any reduction in PCBs in the River or in fish located within the Tribe's fishing grounds. The Tribe contends that the lack of an EPA-issued PCB TMDL has resulted or will result in State-issued NPDES permits that lack adequate PCB limits or will not make adequate progress reducing PCBs in the Spokane River. They offer, however, only speculative and conclusory assertions in this regard, and neither the issues nor administrative record in this case provide the Court with the authority, or basis, to assess the adequacy of such future permits. As explained *supra* at 7, the lack of a TMDL does not preclude the inclusion of appropriate effluent limits in NPDES permits. Regardless of whether a TMDL has been established, NPDES permits still must include effluent limits as stringent as necessary to meet water quality standards. 33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.44(d)(1)(vii)(A). A PCB TMDL, therefore, would not necessarily make NPDES permits any more stringent. Moreover, the Tribe's theory of how of its fishing rights are impacted inappropriately assumes the Task Force will fail to reduce PCBs. Ecology, however, reasonably reached the contrary conclusion, and the Pollution Control Hearing Board concurred that the work of the Task Force is necessary to reducing PCBs and meeting water quality standards. *Supra* at 37.

The Tribe's argument also fails because the issuance of NPDES permits will also take into account the Tribe's PCB water quality standard. The Tribe's recourse for inadequate NPDES permits is to appeal them. Thus, the Tribe has not demonstrated that an EPA-issued TMDL is required to protect the Tribe's fishing rights.

The Tribe also appears to argue that EPA was under a mandatory fiduciary duty to take into consideration impacts to the Tribe's fishing rights in deciding that Ecology has not constructively submitted a Spokane River PCB TMDL. Tribe Br. at 15-16. As noted *supra* at 42 n.18, as part of EPA's consideration of Plaintiffs' administrative request, the Tribe did not request that EPA determine or consider any potential impact to its fishing rights, and that issue is not properly raised in this case. In any event, the Tribe does not point to a source of law containing a specific mandatory fiduciary duty that would require that EPA disrupt Ecology's priorities and efforts to reduce PCBs and establish a federal PCB TMDL for the Spokane River at this time.

In sum, the Tribe's fishing rights claim is not properly before the Court. Even if it were, the Tribe has not shown that its fishing rights have been adversely affected by EPA's determination that there has not been a constructive submission, or that there is a mandatory fiduciary duty for EPA to establish a PCB TMDL for the Spokane River.

III. PLAINTIFFS ARE NOT ENTITLED TO THE REMEDY SOUGHT.

Plaintiffs request that the Court order EPA to establish a Spokane River PCB TMDL "within 90 days." Pl. Br. at 32. Plaintiffs' requested relief is unfounded and impracticable. Thus, even assuming that Plaintiffs were entitled to some relief, the requested relief should be denied.

Injunctive relief may not be granted as a matter of course. *Weinberger v. Romero-Barcelo*, 456 U.S. 305, 311 (1982); *Amoco Prod. v. Gambell,* 480 U.S. 531, 546 n.12 (1982). The Supreme Court explained in a citizen suit case that "the court [must] 'balance[] the conveniences of the parties and possible injuries to them according[ly] as they may be affected by the granting or withholding of the injunction." *Weinberger*, 456 U.S. at 312; *Amoco*, 480 U.S. at 542. In formulating a remedy, "the court must be careful not to intrude upon the agency's realm of discretionary decision making." *Idaho Sportsmen v. Browner*, 951 F. Supp. 962, 968 (W.D. Wash. 1996).

To the extent that the Court determines that some injunctive relief is appropriate here, the CWA citizen suit provision provides that the remedy is limited to "order[ing] the Administrator to perform [the nondiscretionary] act or duty" 33 U.S.C. § 1365(a) (i.e., a remand to EPA to approve or disapprove the constructive submission). A constructive submission triggers a mandatory duty on the part of the EPA Administrator to either approve or disapprove the constructive submission. *Hayes*, 264 F.3d at 1023. Only if the Administrator disapproves the constructive submission is the EPA Administrator under a duty to establish a TMDL. *Id.; also Scott*, 741 F.2d 997. Accordingly, imposing a schedule on EPA to establish a PCB TMDL is not an appropriate remedy. *See also American Canoe Ass'n v. EPA,* 30 F. Supp.2d 908, 922 & n.17 (E.D. Va. 1998) ("the appropriate remedy for the plaintiffs' TMDL [complaint] would appear to be an order directing EPA to approve or disapprove Virginia's constructive submission within 30 days . . . .").

Furthermore, EPA's determination on remand could be challenged by Plaintiffs as final agency action; the Court's role would then be limited to reviewing EPA's approval or disapproval determination. *Hayes*, 264 F.3d at 1023; *American Canoe*, 30 F. Supp. 2d at 923 n.17 ("[i]f the EPA approved the [constructive] submission, this would appear to be a final agency action which could be challenged for abuse of discretion under the Administrative Procedure Act").

Even assuming the Court's authority extends to ordering EPA to establish a Spokane River PCB TMDL, Plaintiffs' have not shown that the injury to them if the relief is not granted outweighs the damage to EPA and the public interest if it is. For example, Plaintiffs contend that the lack of a PCB TMDL has resulted or will result in State-issued NPDES permits that lack PCB limits necessary to reduce PCB discharges and achieve water quality standards. As explained *supra* at 7, 37, 42-43, such assertions lack any foundation. As explained, NPDES permits must require effluent limits that ensure water quality standards will be met, regardless of whether a relevant TMDL has been established, 33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.44(d)(1)(vii)(A), and Plaintiffs' recourse if they believe State-issued permits are inadequate is to appeal such permits in the appropriate State administrative or judicial tribunal. Nor have Plaintiffs demonstrated that the Task Force will fail to reduce PCBs or that the relief they seek would result in any, let alone quicker, PCB reductions.

Plaintiffs also make no showing that the public interest will not be harmed by the Order they seek, due to the diversion of resources from equally or even more important State or federal TMDL development effort or other environmental projects. In this regard, it should be recognized that the entire docket of EPA involves issues affecting health and welfare. An increase in resources devoted to the PCB TMDL sought by Plaintiffs and Intervenor would result in a concomitant re-direction of resources devoted to other EPA programs designed to protect health and welfare.

If the Court were to conclude that an order requiring EPA to establish a PCB TMDL is appropriate, EPA should not be ordered to comply with Plaintiffs' proposed schedule to establish a PCB TMDL within 90 days. While Plaintiffs argue that this is reasonable "because the work has already been done to prepare a technically sound TMDL," Pl. Br. at 32, this is clearly not the case. As discussed above, there are significant gaps in the draft TMDL Ecology prepared that would require an extended period of time to address. In considering the time necessary for EPA to complete such a complex regulatory action, the Agency must have the time it reasonably determines necessary to investigate and develop the necessary information. Even once a complete proposal is prepared, for complex regulatory actions EPA must have the time to consider the "complex scientific, technological, and policy questions" raised, reach "considered results," and establish a defensible action that will protect the environment. *Sierra Club v. Thomas*, 828 F.2d at 798. "[B]y decreasing the risk of later judicial invalidation and remand to the agency, additional time spent reviewing a rulemaking proposal before it is adopted may well ensure earlier, not later, implementation of any eventual regulatory scheme." *Id*. at 798-99. Finally, EPA's consideration of what schedule might be possible would require the consideration of additional information well beyond that contained in the administrative record in this case.

In short, even if Plaintiffs prevailed under a constructive submission theory, they would not be entitled to any of the injunctive relief they seek.

CONCLUSION

For the reasons stated above, the Court should grant EPA's cross-motion for summary judgment and deny Plaintiffs' and Intervenor's motions for summary judgment.

Respectfully submitted,

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CERTIFICATE OF SERVICE

I hereby certify that the foregoing filing was electronically filed with the Clerk of the Court on January 29, 2014, PST, using the Court's electronic filing system, which will send notification of said filing to the attorneys of record that have, as required, registered with the Court's system.

/S/ David Kaplan

2015 Annual Toxics Management Report
Spokane County Regional Water Reclamation Facility
NPDES Permit WA-0093317

2015 Annual Toxics Management Report
Spokane County Regional Water Reclamation Facility
NPDES Permit WA-0093317

BC Project 142892

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List of Abbreviations

Anatek	Anatek Labs, Inc.
ATSDR	Agency for Toxic Substances and Disease Registry
AXYS	AXYS Analytical Services
BMP	best management practice
CAS	Chemical Abstracts Service
COC	chain of custody
Consultant	Brown and Caldwell
County	Spokane County
DeBDE	decabromodiphenyl ether homolog group
DeCB	decachlorobiphenyl homolog group
DiBDE	dibromodiphenyl ether homolog group
DiCB	dichlorobiphenyl homolog group
Dioxin	2,3,7,8-Tetra-Chlorodibenzo-P-Dioxin
DMI	Dishman-Mica Interceptor
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
Facility	Spokane County Regional Water Reclamation Facility
HpBDE	heptabromodiphenyl ether homolog group
HpCB	heptachlorobiphenyl homolog group
HxBDE	hexabromodiphenyl ether homolog group
HxCB	hexachlorobiphenyl homolog group
HDPE	high-density polyethylene
L	liter(s)
LOD	limits of detection
mgd	million gallon(s) per day
MH	manhole
mL	milliliter(s)
MoBDE	monobromodiphenyl ether homolog group
MoCB	monochlorobiphenyl homolog group
ng/L	nanogram(s) per liter
NoBDE	nonabromodiphenyl ether homolog group
NoCB	nonachlorobiphenyl homolog group
NPDES	National Pollutant Discharge Elimination System
NVI	North Valley Interceptor
NVIPS	North Valley Interceptor Pump Station
OcBDE	octabromodiphenyl ether homolog group
OcCB	octachlorobiphenyl homolog group
PCB	polychlorinated biphenyl
PBDE	polybrominated diphenyl ether
PeBDE	pentabromodiphenyl ether homolog group
PeCB	pentachlorobiphenyl homolog group
Permit	NPDES Permit WA-0093317
pg/L	picogram(s) per liter
PMF	Positive Matrix Factorization
ppm	part(s) per million
Q1	first quartile
Q3	third quartile
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
R^2	correlation coefficient
Report	Annual Toxics Management Report
ROW	right-of-way
RSD	relative standard deviation
SCC	Spokane County Code
SCRWRF	Spokane County Regional Water Reclamation Facility
SRRTTF	Spokane River Regional Toxics Task Force
SVI	Spokane Valley Interceptor
SVIPS	Spokane Valley Interceptor Pump Station
TeBDE	tetrabromodiphenyl ether homolog group
TeCB	tetrachlorobiphenyl homolog group
TiO_2	titanium dioxide
TriBDE	tribromodiphenyl ether homolog group
TriCB	trichlorobiphenyl homolog group
TSCA	Toxics Substance Control Act
TSS	total suspended solids

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Executive Summary

Background

Spokane County (County) owns the Spokane County Regional Water Reclamation Facility (Facility, or SCRWRF), which provides advanced treatment for wastewater before discharging reclaimed water to the Spokane River in accordance with National Pollutant Discharge Elimination System (NPDES) Permit WA-0093317 (Permit), effective December 1, 2011.

Special Condition S13 of the Permit requires that the County help create and participate in a regional toxics task force. Accordingly, the County took a leading role in the creation of the Spokane River Regional Toxics Task Force (SRRTTF). The goal of the task force is to develop a comprehensive plan to bring the Spokane River into compliance with applicable water quality standards for PCBs. The County plans to use the information gained from the Special Condition S12 Toxics Management Action Plan to further the efforts of the SRRTTF.

PCBs are everywhere (Ecology, 2012). Global background alone could put any water body on the planet, including the Spokane River, over the human health water quality objectives. Consequently, this Report must be read in context with the fact that sources outside of the control of the County currently and in the future will continue to contribute PCBs to the County's collection system. Additionally, because this Report is based on a small data set, the analyses and recommendations in this Report may be subject to change based on data that is collected in the future.

Measurable Progress

In 2014, the County continued to make substantial measurable progress toward PCB load reduction and in the characterization of PCBs in the Spokane River and their sources. Comparison of the 2014 influent and effluent data shows that the Facility provided very effective treatment, **removing more than 99% of the total PCBs and PBDEs measured in the influent.** Dioxin was not detected in the influent or effluent samples collected during 2014. Through its participation in the SRRTTF, and through independent investigative activities, the County has helped improve understanding of PCB sources and implemented a range of measures to address them.

The Permit requires sampling and analysis of Facility influent and effluent for polychlorinated biphenyls (PCBs), 2,3,7,8-Tetra-Chlorodibenzo-P-Dioxin (Dioxin), and polybrominated diphenyl ethers (PBDEs). The Permit also requires preparation of an Annual Toxics Management Report (Report) that describes the monitoring results, potential sources of the measured compounds, and County management actions to reduce the discharge of PCBs to the Spokane River.

Although not explicitly required by the Permit, the County voluntarily designed and implemented a systematic "track-down" sampling program to help identify potential PCB sources to the wastewater collection system. In 2013, the County collected samples near the outlets to the three main basins in the wastewater collection system upstream of the Facility. In 2014, the County collected track-down samples from seven locations within the Dishman-Mica Interceptor (DMI) basin, which had the highest PCB concentrations in the 2013 track-down sampling. Specific sampling sites were selected based on tributary area, land use, and approximate age of development. The 2014 track-down sampling results did not identify specific sources or geographic hot-spots for PCBs. The results reinforce the fact that PCBs are a ubiquitous contaminant and suggest a low level presence throughout the wastewater collection system, rather than few large sources.

The County evaluated PCB and PBDE homolog patterns to help identify potential sources, as required by the Permit. While, the evaluation indicated that higher molecular weight homolog groups comprised a larger proportion of the influent samples as compared to the effluent samples, the evaluation was not able to discern potential sources. While not required by the Permit, the County performed an additional evaluation using Positive Matrix Factorization (PMF), an advanced source apportionment tool that has been used to identify PCB sources in water, sediment, and air. This more advanced PMF analysis was conducted to provide more definitive information on potential PCB and PBDE sources,.

The PMF analysis did an excellent job of reproducing the PCB data and identified seven distinct source types or factors that account for 90 percent of the total PCB mass across all samples. Most of the factors are strongly correlated to Aroclors and Aroclor mixtures. However, one factor (factor 2) is mainly composed of PCB-11, which is not from Aroclors but is often found in yellow dyes and pigments. This factor was more prevalent at the North Valley Interceptor Pump Station (NVIPS) than at the Spokane Valley Interceptor Pump Station (SVIPS). Factor 1, consisting of dissolved-phase, low molecular weight Aroclors, comprised the majority of the effluent. Factor 6, which is similar to unweathered Aroclor 1254, was particularly abundant in the December 2014 track-down sample from a subbasin of the collection system with older (1950s era) residential development. Aroclor 1254 has been found in building materials such as caulk, and other applications. Factor 3, which resembles a mixture of the four most common Aroclors, was much more prevalent in the SVIPS samples versus the NVIPS samples. The PMF analysis also did an excellent job of reproducing the PBDE data, accounting for nearly 100 percent of the PBDE mass found in the samples. The PMF showed that the main source of PBDE is from commercial formulations, such as Bromkal. The 2014 PMF results are similar to those of 2013; therefore, continued monitoring for PBDEs is unlikely to significantly improve the understanding of PBDE sources or management measures.

The County used the track-down sampling and PMF results to help refine its toxic management activities proposed in this Report for upcoming work.

Spokane County's accomplishments during 2014 included public education, participation in the SRRTTF, and many other activities, as follows:

- Revised purchasing ordinance which allows for testing of products for PCBs, similar to the state of Washington and the city of Spokane
- Continued a multimedia public outreach program focused on residential and commercial/industrial sewer customers
- Hired a water resources communications specialist to implement outreach and education and to participate on the Spokane River Regional Toxics Task Force (SRRTTF)
- Updated County web presence to include PCB information
- Developed and mailed a PCB primer to all County wastewater treatment customers, both commercial/industrial and residential (about 40,000 customers)
- Developed a PCB informational poster for display in the Water Resource Center and other venues
- Coordinated an Open House event at the Water Resource Center, including PCB information
- Coordinated a meeting with other regional municipal wastewater treatment entities to discuss outreach to commercial and pretreatment customers regarding toxics
- Sent letters to County industrial pretreatment customers requesting individual meetings to provide PCB information
- Presented at several area conferences regarding track-down influent and effluent sampling results
- Provided input to the Washington Legislature regarding revising the Toxics Management Act to reduce inadvertent production of PCBs

- Provided in-kind and financial support to the local EnviroStars program, a local source control/waste minimization program aimed at businesses
- Played an active role in the SRRTTF including financial support for administrative and technical tasks
- Provided financial support for PCB monitoring and education by the SRRTTF.

In 2015, Spokane County plans to continue and expand its activities as follows:

- Hold spring and fall open houses at the Water Resource Center
- Increase collaboration with non-dischargers to disseminate toxics management information (e.g., Spokane Riverkeeper)
- Provide updates as warranted to wastewater treatment customers regarding new and useful PCB information that can provide consumer guidance
- Update PCB information on the County website
- Meet with industrial pretreatment customers to review latest information on PCBs
- Present at area conferences and to citizen groups
- Provide input to the Legislature regarding impending legislation related to PCBs
- Continue in-kind and financial support to the local EnviroStars program
- Support industry-wide reformulation of products that can contain elevated concentrations of PCB-11 as well as commercial products that contain elevated PBDE concentrations (e.g., Bromkal)
- Continue to remove and dispose of remaining County-owned, PCB-containing materials and equipment as they are encountered
- Continue to contribute data on PCB concentrations and sources to the SRRTTF's regional clearinghouse to help increase understanding of the potential sources and to help regional management efforts
- Continue to play an active role in the SRRTTF including financial support for administrative and technical tasks
- Support the SRRTTF in identifying commercial products that could contain inadvertently produced PCBs
- Review the County wastewater customer database in light of the ongoing chemical fingerprinting analysis, and perform follow-up actions as appropriate.

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Section 1

Introduction

The County owns the Spokane County Regional Water Reclamation Facility (Facility, or SCRWRF), which provides treatment for wastewater before discharging reclaimed water to the Spokane River. The Facility is operated by a third-party operator, CH2M Hill, under contract with the County. Also under contract to Spokane County, a consultant team led by Brown and Caldwell (Consultant) is providing services for activities related to sampling and analysis of toxic compounds associated with the Facility and collection system. In addition to Brown and Caldwell, the Consultant team includes Landau Associates, AXYS Analytical Services, Anatek Labs, Inc., and Dr. Lisa Rodenburg of Rutgers University.

The Washington State Department of Ecology (Ecology) issued the Facility's National Pollutant Discharge Elimination System (NPDES) Permit WA-0093317 (Permit), effective December 1, 2011. Section S2 of the Permit requires routine sampling and analysis of Facility influent and effluent for polychlorinated biphenyls (PCBs), 2,3,7,8-Tetra-Chlorodibenzo-P-Dioxin (Dioxin), and polybrominated diphenyl ethers (PBDEs).

Special Condition S12 of the Permit requires preparation of an Annual Toxics Management Report (Report) by April 15 of each year. The Report must include:

- analytical results for PCBs, Dioxin, and PBDEs
- detection limits
- quality assurance/quality control (QA/QC) procedures
- pattern analysis of homologs
- potential sources suggested by the data analysis

Special Condition S12 also requires preparation of a Toxics Management Action Plan that addresses:

- future source identification activities
- locations and frequencies of future toxics sampling in the wastewater collection system
- source control and elimination of PCBs from contaminated soils and sediments, stormwater entering the wastewater collection systems, and industrial or commercial sources
- eliminating active sources such as:
    - older mechanical machinery
    - older electrical equipment and components
    - construction material content such as paints and caulking
    - commercial materials such as inks and dyes

Special Condition S12 also requires that the County consider changes in procurement practices and ordinances to control and minimize toxics, including preferential use of PCB-free substitutes for those products containing PCBs below the regulated levels in sources such as:

- construction materials such as paints and caulking
- commercial materials such as inks and dyes
- soaps and cleaners

As stated in Special Condition S12, the goals of the Toxics Management Action Plan are to:

- reduce toxicant loadings, including PCBs, to the Spokane River to the maximum extent practicable, realizing statistically significant reductions in influent concentration of the toxicants to the Facility over the next 10 years
- reduce PCBs in the effluent to the maximum extent practicable so that in time the effluent does not contribute to PCBs in the Spokane River exceeding applicable water quality standards

Special Condition S13 of the Permit requires that the County help create and participate in a regional toxics task force. Accordingly, the County took a leading role in the creation of the Spokane River Regional Toxics Task Force (SRRTTF). The goal of the task force is to develop a comprehensive plan to bring the Spokane River into compliance with applicable water quality standards for PCBs. The County plans to use the information gained from the Special Condition S12 Toxics Management Action Plan to further the efforts of the SRRTTF.

PCBs are everywhere (Ecology, 2012). Global background alone could put any water body on the planet, including the Spokane River, over the human health water quality objectives. Consequently, this Report must be read in context with the fact that sources outside of the control of the County currently and in the future will continue to contribute PCBs to the County's collection system. Additionally, because this Report is based on a small data set, the analyses and recommendations in this Report may be subject to change based on data that is collected in the future.

1.1 Study Area Description

The Facility treats wastewater from portions of unincorporated Spokane County, the cities of Spokane Valley and Millwood, and portions of Liberty Lake. Two influent trunk lines, the North Valley Interceptor (NVI) and the Spokane Valley Interceptor (SVI), convey wastewater to the Facility via two pump stations (see Figure 1-1).

The NVI sewershed encompasses approximately 13,000 acres. The sewershed land use composition is approximately 46 percent residential, 35 percent commercial/industrial/right-of-way (ROW), and 19 percent open space. There are a total of 5,970 customers in the NVI sewershed, of which 5,580 are residential and 390 are commercial/industrial. The NVI wastewater collection system includes approximately 130 miles of gravity pipe, 11 miles of force main, and 2,650 manholes (MHs).

The SVI sewershed encompasses approximately 24,000 acres. The sewershed land use composition is approximately 66 percent residential, 30 percent commercial/industrial/ROW, and 4 percent open space. There are a total of 22,135 customers in the SVI sewershed, of which 21,109 are residential and 1,026 are commercial/industrial. The SVI wastewater collection system includes approximately 360 miles of gravity pipe, 11 miles of force main, and 7,200 manholes.

The two pump stations shown on Figure 1-1 convey wastewater from the NVI and SVI sewersheds to the Facility. Typically, all of the wastewater in the NVI Pump Station (NVIPS) and SVI Pump Station (SVIPS) is pumped to the Facility, but occasionally a small portion is conveyed to the City of Spokane Riverside Park Water Reclamation Facility.

Seven active dischargers are covered by the County's industrial pretreatment program. In addition, one industrial customer is permitted to haul wastewater to the Facility.

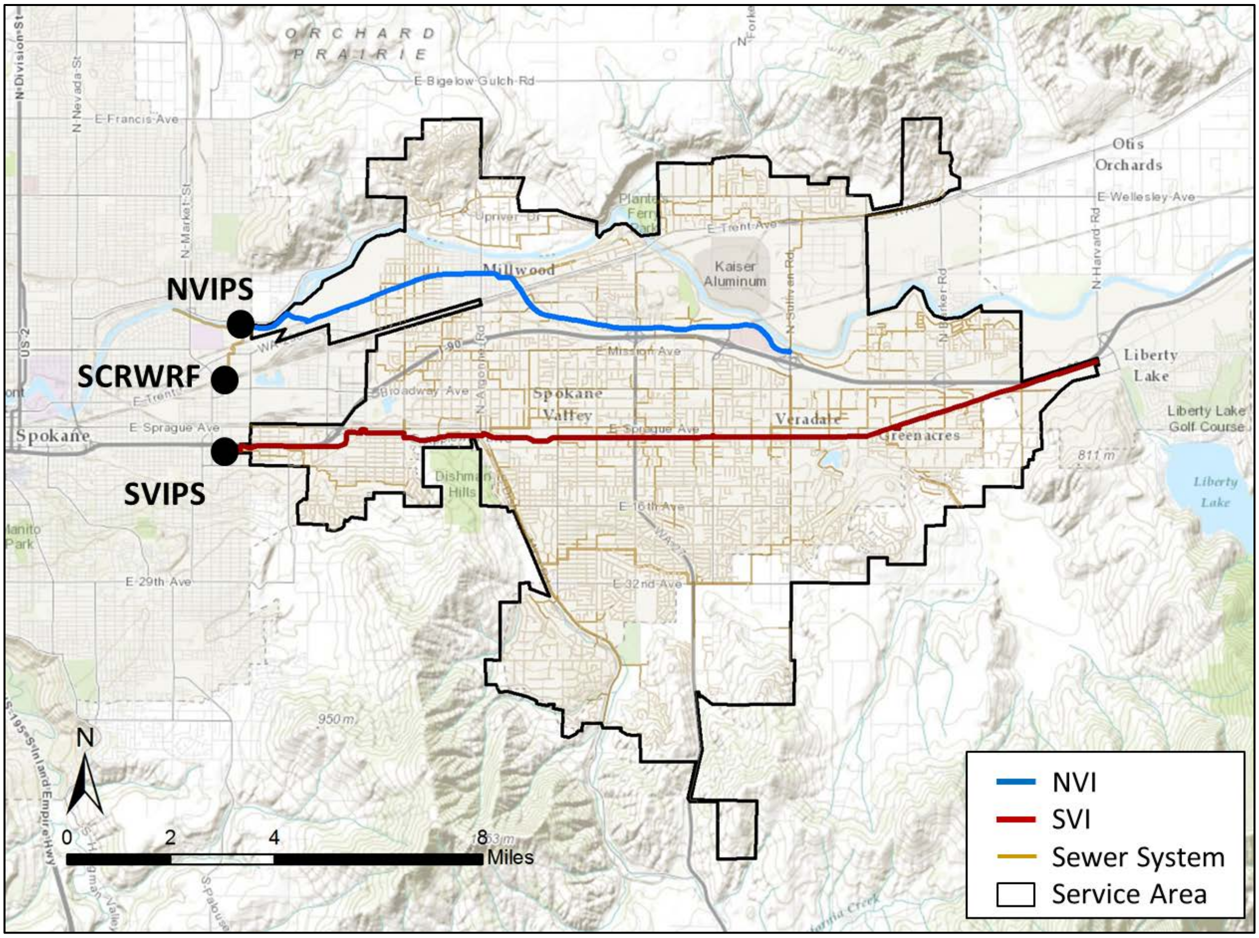

Figure 1-1. Study area

1.2 Organization of This Report

Section 2 of this document contains the Annual Report required for Special Condition S12 of the NPDES Permit. It describes the toxics monitoring and source identification activities performed by the County during the preceding year.

Section 3 of this document contains the Toxics Management Action Plan required for Special Condition S12. It describes the County's proposed source identification and source control measures for the subsequent year of operation.

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Section 2

Annual Toxics Management Report

This section summarizes the framework of the sampling program, including quality objectives, sampling methods, laboratory procedures, and quality control, as well as the sampling results and source assessment.

The Facility's NPDES Permit requires the following sampling program per Special Condition S2:

- total PCBs in each influent trunk line: bimonthly (once every 2 months)
- Dioxin in each influent trunk line: bimonthly (once every 2 months)
- PBDEs in each influent trunk line: quarterly (once every 3 months)
- total PCBs, Dioxin, and PBDEs in the Facility effluent: quarterly (once every 3 months)

The toxic compounds listed above have very limited solubility in water so they are often associated with particulate matter. Total suspended solids (TSS) data could help discern potential relationships between measured toxics concentrations and suspended solids. Therefore, the County is voluntarily analyzing samples for TSS (per Standard Method 2540D) even though this is not required by the Permit.

Sampling commenced in October 2012, and a total of 14 sampling events had been conducted as of December 31, 2014. The County's first Annual Toxics Management Report (April 2013) presented the results for the Permit-required sampling of influent and effluent. The April 2013 report also described the strategy for track-down sampling in the County's collection system to help identify potential sources of PCBs and PBDEs.

The County began track-down sampling at locations upstream of each trunk line in June 2013. Between June and December 2013, track-down samples were taken from three manholes during four sampling events (bimonthly samples), and were analyzed for PCBs and PBDEs. The April 2014 Annual Report recommended track-down sampling at seven manholes, and analysis of the samples for PCBs only. PBDES were not included in the proposed 2014 track-down sampling, based on the 2013 results. Track-down sampling began in June 2014 after Ecology approved the Annual Report. Section 2.1 describes the track-down sampling locations and methods in more detail…

The sampling was conducted by the Consultant. AXYS Analytical Services (AXYS), located in Sidney, B.C., Canada, performed the toxics analyses and Anatek Labs, Inc. (Anatek), located in Spokane, Washington, performed the TSS analyses.

2.1 Sampling Locations and Methods

Ecology approved the County's Quality Assurance Project Plan (QAPP) for toxics monitoring on October 1, 2012. The QAPP details the project schedule, quality objectives, sampling procedures, measurement procedures, analytical requirements, quality control, and data validation protocols for Section S2 monitoring. The QAPP was revised in 2013 and 2014 to reflect updates to the track-down sampling locations and methods. Ecology approved both QAPP revisions.

2.1.1 Influent Trunk Lines and Effluent

In accordance with the Permit, the County collects samples from the Facility's effluent line and its two influent trunk lines. The two influent trunk lines were sampled at the SVIPS and NVIPS. These pump stations direct flow from each interceptor to the Facility. Sampling was conducted at the influent channel of each pump station. Facility effluent was sampled at a manhole within the Facility property. The manhole is part of the Facility outfall and is located downstream of all treatment plant processes.

For the influent trunk lines and effluent sampling, an Isco 3700 automated composite sampler was used to collect 24 time-weighted samples at hourly intervals. The sampler used a peristaltic pump to draw samples from the liquid stream. Samples were collected into pre-cleaned, glass bottles. This composite sample was well mixed and aliquoted in the field into pre-cleaned amber glass bottles provided by AXYS for PCB, Dioxin, and PBDE analyses. For TSS analysis, a sample was taken from the composite sample and placed in high-density polyethylene (HDPE) bottles provided by Anatek.

2.1.2 Collection System Track-Down Samples

Based on the 2013 track-down sampling results for the NVIPS and SVIPS (as reported in the County's *2014 Annual Toxics Management Report*), the County focused its efforts in 2014 on sampling from manholes (MH) in the Dishman-Mica Interceptor (DMI) basin. In addition to sampling at two major branch points (DMI MHA and DMI MHB), five upstream subbasins were sampled to assess potential relationships between the year of home/commercial construction and PCB concentration in the sewage (DMI MHC through DMI MHG). Figure 2-1 and Table 2-1 summarize the seven locations sampled in 2014.

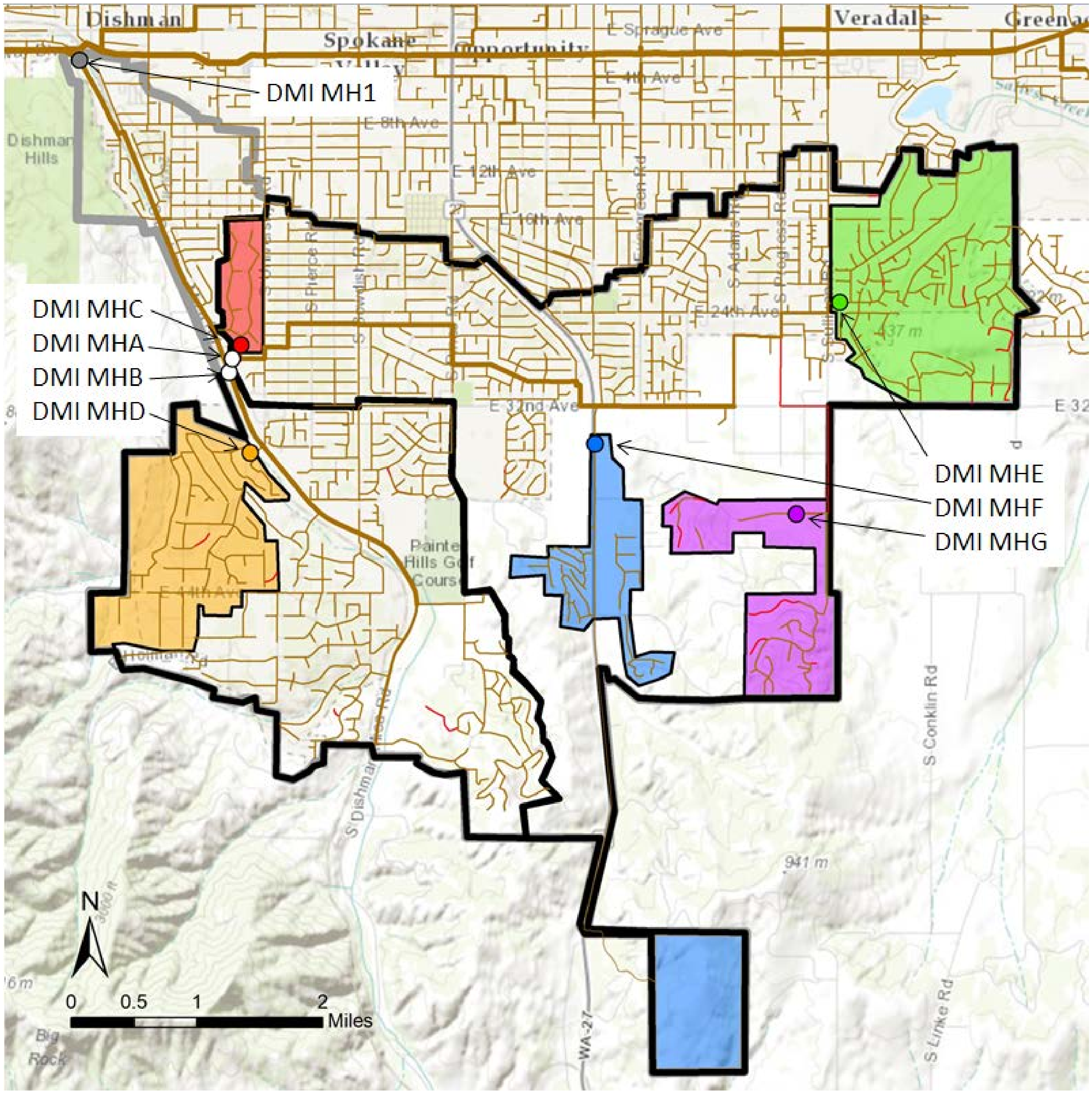

Figure 2-1. 2014 track-down sampling locations in five tributary sub basins

Table 2-1. Summary of 2014 Track-Down Sampling Locations

Site	Manhole ID	Parcels	Land use [a]				Year of construction [a,b]			
			Resid.	Comm.	Ind.	Other [c]	<1960	1960–79	1980–99	2000+
DMI MHA	104.8/28	6,315	98%	1%	0%	2%	11%	49%	27%	13%
DMI MHB	104/29	2,498	73%	6%	0%	21%	1%	57%	33%	9%
DMI MHC	105.3/26.8	148	94%	4%	0%	2%	73%	15%	11%	1%
DMI MHD	105.7/36	509	76%	1%	0%	23%	1%	63%	26%	10%
DMI MHE	156.8/23.2	936	75%	2%	0%	24%	1%	27%	37%	35%
DMI MHF	135.1/35.2	229	33%	33%	0%	34%	0%	4%	60%	36%
DMI MHG	Bella Vista PS	348	85%	0%	0%	15%	0%	17%	69%	13%

a. *Percentages refer to land area for land use, and number of parcels for year of construction.*

b. *Year of construction of primary structure on the parcel.*

c. *Other includes undeveloped land, parks, and utilities.*

DMI MHA and DMI MHB divide the DMI basin at 28th Avenue. DMI MHA receives flow from the eastern two-thirds of the basin. DMI MHB receives flow from the southern third of the basin. The DMI MHA basin is nearly all residential, while the DMI MHB basin has a small commercial component, and includes a number of large undeveloped parcels.

Most of the homes in the DMI MHC subbasin were built prior to 1960. The DMI MHD subbasin contains homes built in the 1960s and 1970s. DMI MHE, DMI MHF, and DMI MHG all contain newer homes. The newest of these is the DMI MHF subbasin, where only 4% of homes were built prior to 1980.

Collection of 24-hour composite samples from the track-down locations was impractical because of traffic control requirements and lack of power and security for automated equipment. Therefore, the track-down samples consisted of composite samples collected over a period of 40 minutes. Samples were collected on weekdays, and the sampling times were arranged to vary by event, so the same sites were sampled at different times during each event. However, all samples were collected between 8 a.m. and 3 p.m. Other than the short collection period, the sampling protocol was similar to the influent trunk line and effluent sampling locations.

2.2 Sampling and Laboratory Procedures

Procedures to maintain the custody and integrity of the samples began at the time of sampling and continued through transport, sample receipt, preparation, analysis and storage, data generation and reporting, and sample disposal. Records concerning the custody and condition of the samples are maintained in field and laboratory records.

Field personnel maintain chain-of-custody (COC) records for all field and field QC samples. A sample is defined as being under a person’s custody if any of the following conditions exist:

- it is in his/her possession
- it is in his/her view, after being in his/her possession
- it was in his/her possession and was subsequently locked
- it is in a designated secure area

The following information concerning the sample is documented on the contract laboratory COC form:

- sample identification
- date and time of sample collection
- source of sample (including name, location, and sample type)
- preservative used (if any)
- analyses required
- name of sample collector(s)
- custody transfer signatures and dates and times of sample transfer from the field to transporters and to the laboratory or laboratories

All samples are uniquely identified, labeled, and documented in the field at the time of collection. Samples collected in the field are transported to the laboratory via overnight shipping. Samples are packed in ice to keep them cool during collection and transportation.

2.2.1 Permit Requirements

Analytical methods are either specified or recommended for the constituents included in the NPDES Permit monitoring requirements. The Permit provisions related to the analytical portion of this monitoring effort are summarized below:

- Special Condition S2.A(7)(15): For PCBs use U.S. Environmental Protection Agency (EPA) Method 1668. Reporting limits are described in the QAPP.
- Special Condition S2.A(7)(17): For PBDEs use draft EPA Method 1614. Reporting limits are described in the QAPP.
- Special Condition S2 does not specify an analytical method for Dioxin. Appendix A of the Permit recommends EPA Method 1613 for analysis of Dioxin (Chemical Abstracts Service [CAS] No. 176-40-16).

Table 2-2 lists the methods used to analyze samples collected from the Facility influent and effluent, as per the approved QAPP.

Table 2-2. Analytical Methods

Constituent	Analytical protocol
PCB congeners	EPA 1668A
PBDEs	EPA 1614
Dioxin	EPA 1613B

2.2.2 Quality Objectives and Control

Quality objectives are established for this project to control the degree of total error in data results. These objectives are established to achieve an acceptable level of confidence in decisions made from the collected data. The established objectives include the following:

- implement procedures for field sampling, sample custody, equipment operation and calibration, laboratory sample analysis, data reduction, and data reporting that will provide for the consistency and thoroughness of data generation
- assess the quality of data generated to ensure that collected data are scientifically valid, of known and documented quality, and legally defensible, where appropriate
- ensure that the QAPP and associated project plans are properly implemented

- document field conditions, sampling, and other activities using appropriate field reports to sufficiently re-create each sampling, analytical, testing, and monitoring event

Data quality control is determined by the analysis of sample blanks and duplicates.

Three types of blanks are used in this study:

- Rinsate blanks, also called "equipment blanks," are collected by running a sample of ultrapure water prepared by AXYS through the sampling equipment after it has been cleaned but before it is used for sampling. The rinsate blank indicates the extent to which contaminants are introduced through the sampling procedure, equipment, or exposure to ambient air during the sample collection. Rinsate blanks were collected at the NVIPS, SVIPS, and effluent sampling locations during the October 2012 event, and at one sampling location for all subsequent events. An additional rinsate blank was collected at the DMI MH1 track-down sampling location for the June 2013 sampling event. Rinsate blanks were tested for the toxic pollutants subject to testing at a given site during a given event. Rigorous decontamination procedures were followed to minimize equipment contamination (e.g., sampler tubing was shipped to AXYS for cleaning prior to each sampling round).
- Travel blanks are bottles of ultrapure water, prepared by AXYS, that accompany the samples en route from the sampling locations to the laboratory. The travel blank remains unopened until analyzed and helps to distinguish between potential bias introduced by contamination of sample water during transfer, shipping, and handling as opposed to contamination from sampling equipment. Travel blank(s) are prepared and provided by AXYS for each sample event. Travel blanks were tested for all pollutants subject to testing at a given site during a given event.
- Laboratory blanks are samples of ultrapure water prepared by AXYS that never leave the laboratory. They are tested alongside the samples and are used to determine potential sources of contamination or bias in the laboratory itself.
- Field duplicates are used to assess repeatability of sampling and analysis, and to evaluate analytical precision. One field duplicate was collected during each sampling event, and analyzed by the laboratory as a blind, meaning that the lab was not informed where the sample was collected. Field duplicates were tested for a single pollutant (PCBs, Dioxin, or PBDE) during each event.

In addition to rinsate, travel, and laboratory blanks, matrix spikes are used to assess analytical interferences related to the sample matrix. The laboratory tests known quantities of specific analytes in samples of ultrapure water and in field samples, and determines the percent recovery of the analyte in the field sample. Matrix spikes were performed on every sample.

The Quality Control Comment/Action Records for each test event are included in Appendix A.

2.3 Sampling Results

This section summarizes the analytical results from the toxics sampling conducted from October 2012 through December 2014. NVIPS and SVIPS were sampled bimonthly and the effluent was sampled quarterly in compliance with the NPDES Permit requirements. Track-down samples from the collection system were taken from June 2013 through December 2014. Appendix B contains the complete laboratory results for the samples collected in 2014. In the County's previous Annual Reports, PCB totals were reported without adjusting for blank contamination. However, the City of Spokane, the largest wastewater discharger to the Spokane River, has been calculating total PCBs using a 10x all-blanks censoring approach. Ecology used a similar blank censoring method for its recent study of PCBs in the Palouse River watershed (Lubliner, 2009). To facilitate comparison with the City data, this Annual Report shows all total PCB data (influent, effluent, and trackdown samples) calculated using a 10x all-blanks censoring approach.

2.3.1 Influent/Effluent

Table 2-3 lists the total daily flows at the NVIPS and SVIPS on the sampling dates. On several dates the total amount pumped to the Facility was slightly less than the total flow in the interceptors because some flow was conveyed to the City of Spokane Riverside Park Water Reclamation Facility. On average, the NVIPS and SVIPS accounted for roughly 28 percent and 72 percent, respectively, of the total flow entering the Facility on the sampling dates.

Table 2-3. NVIPS and SVIPS Daily Flows

Year	Sampling dates	Flow pumped to Facility (mgd) [a]		
		NVIPS	SVIPS	Total
2012	October 10–11	1.82	4.87	6.69
	December 18–19	1.83	4.42	6.25
2013	February 6–7	1.84	5.06	6.90
	April 16–17	1.83	4.90	6.73
	June 25–26	1.99	4.48	6.47
	August 20–21	2.03	5.11	7.14
	October 22–23	1.73	4.98	6.71
	December 17–18	1.95	5.13	7.08
2014	February 10–11	1.94	5.21	7.15
	April 21–22	1.97	4.40	6.37
	June 23–24	2.03	4.43	6.45
	August 12–13	2.10	5.16	7.26
	October 20-21	2.00	5.21	7.20
	December 8–9	2.06	5.31	7.37

a. The interceptors can send flow to the Facility or to the City of Spokane Riverside Park Water Reclamation Facility. Listed flows do not include flows in the interceptor that were pumped to the City of Spokane Riverside Park Water Reclamation Facility.

PCBs have been sampled from the influent pump stations during 14 sampling events from October 2012–December 2014. The effluent was sampled during nine different events. The total PCB concentrations measured at influent trunk line and effluent sampling locations throughout the entire sampling period are plotted in Figure 2-2.

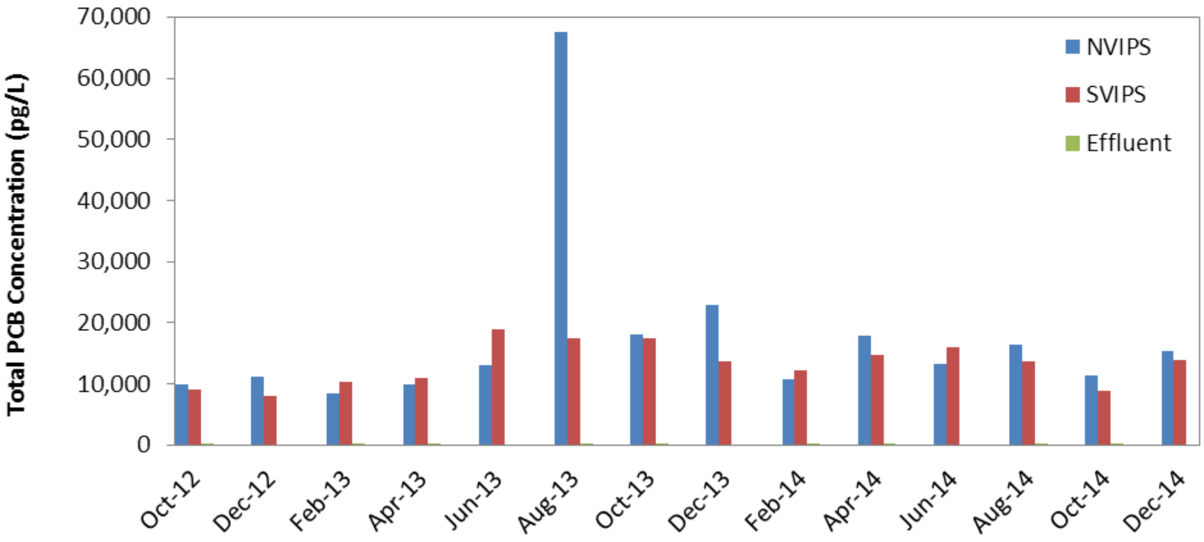

Figure 2-2. Total PCB concentrations in influent trunk line and effluent samples, Oct. 2012–Dec. 2014

Figure 2-3 presents the same effluent sampling data shown in Figure 2-2, zoomed in 100x on the y-axis to show the very low levels of PCBs in the effluent samples as compared to the influent samples.

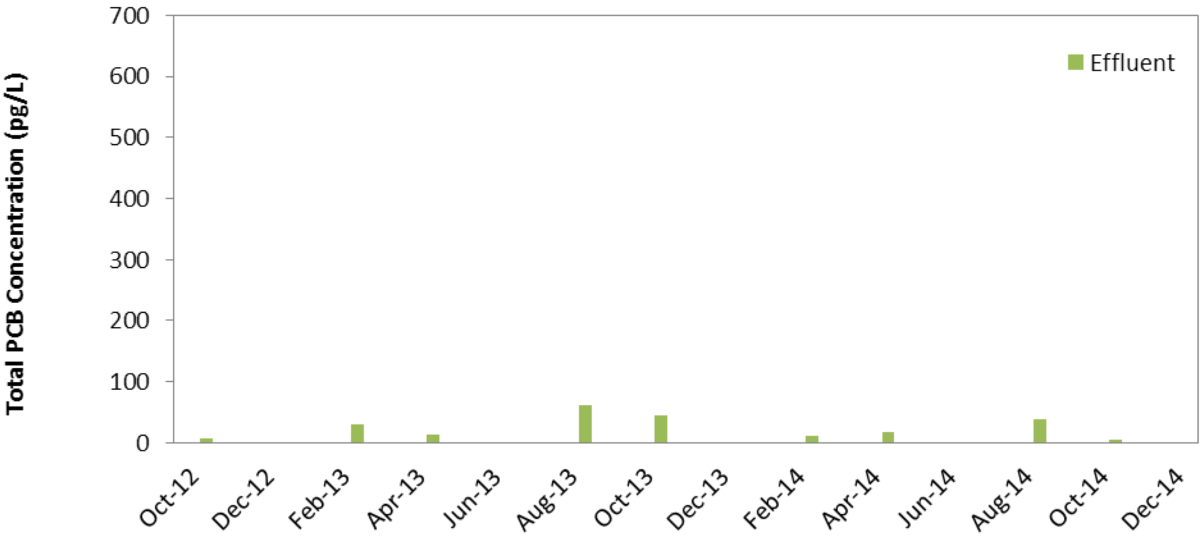

Figure 2-3. Total PCB concentrations in effluent samples, Oct. 2012–Dec. 2014

Table 2-4 summarizes the total PCB concentrations in influent trunk line and effluent samples measured during 2012-2014. Figure 2-3 shows the statistical variation in the data for each sample for the entire sampling period. PCB concentrations in the NVIPS and SVIPS samples ranged from 8,060 to 67,630 picograms per liter (pg/L). Effluent PCB concentrations ranged from 6 to 62 pg/L.

Table 2-4. Total PCB Concentrations (pg/L) and Statistics for 2012--2014 for Influent Trunk Line and Effluent Samples

Statistics	NVIPS	SVIPS	Effluent
Number of Samples	14	14	9
Mean	17,580	13,240	30
Standard Deviation	14,960	3,480	20
Minimum	8,370	8,060	6
Maximum	67,630	18,920	62

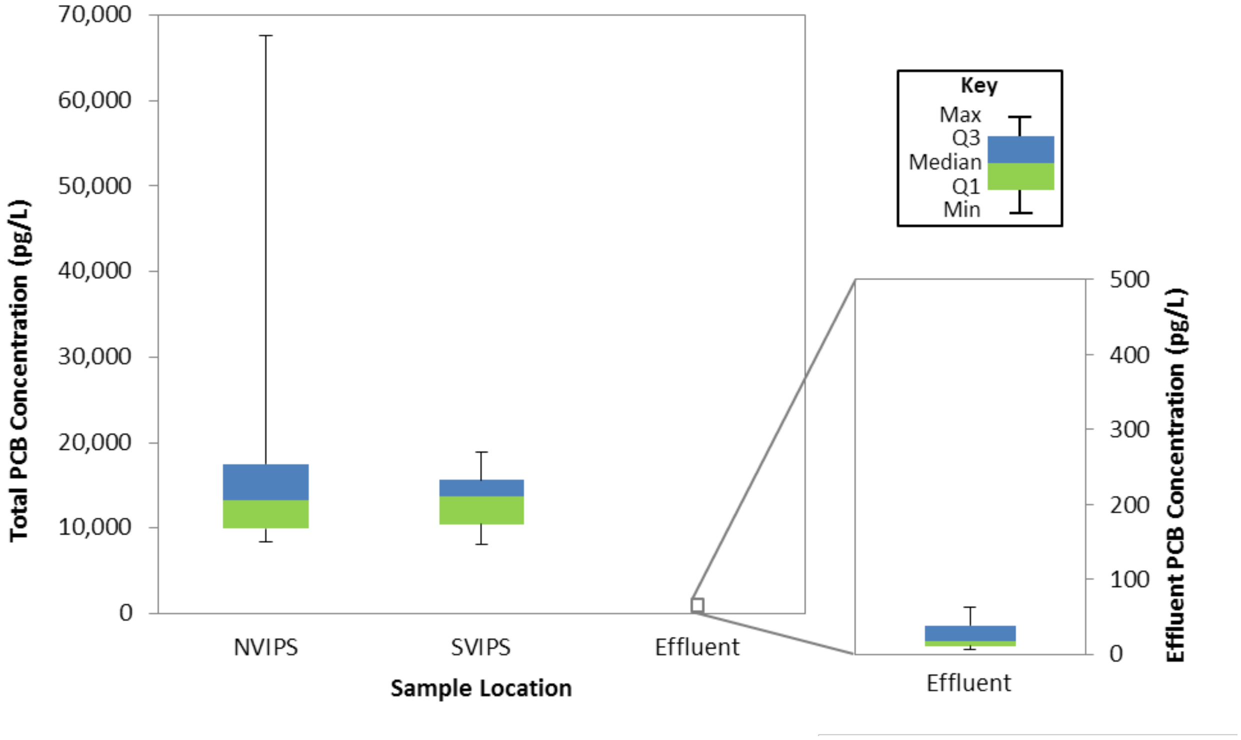

Figure 2-4. Box-whisker plot of total PCB concentrations in influent trunk line and effluent samples

For the majority of the sampling events, the total PCB concentration in the NVIPS and SVIPS samples were similar. If the August 2013 total PCB concentration at the NVIPS is excluded, the total PCB concentrations averaged 13,730 and 13,240 pg/L for the NVIPS and SVIPS, respectively. The August 2013 event is discussed in detail in the 2014 Annual Report.

PCB concentrations in effluent samples were much lower than the influent (NVIPS and SVIPS) samples. In Figure 2-4, the box-whisker plot shows the median, first and third quartile, and minimum and maximum values for the influent and effluent samples. The first quartile (Q1) represents the value where 25 percent of the data is less than this value. The third quartile value (Q3) represents the value where 75 percent of the data is less than this value. Based on the average concentrations of PCBs and flows measured at the NVIPS, SVIPS, and effluent locations, the Facility is removing greater than 99 percent of the total mass of PCBs entering the Facility.

Table 2-5 presents Dioxin results for 2012-2014. Only 1 of the 37 influent and effluent samples contained Dioxin at levels above the laboratory quantitation criteria. This sample (NVIPS, June 2013) had a reported concentration of 1.03 pg/L. Based on these results, continued Dioxin analysis is unlikely to improve the County's toxics management program.

Table 2-5. Summary of Dioxin Data (pg/L)

Statistics	NVIPS	SVIPS	Effluent
Total number of samples	14	14	9
Number of detected samples	1	0	0
Range of concentration detected	1.03	--	--
Range of detection limit	0.498–0.62	0.496–0.91	0.497-0.543

PBDEs were sampled from the influent pump stations and effluent during nine events during 2012–14. The total PBDE concentrations are summarized in Figures 2-5 and 2-6 and Table 2-6. The total PBDE concentrations presented in this section represent the sum of 46 compounds. The total PBDE concentrations do not include estimated concentrations of compounds that fell below laboratory quantitation criteria, or congeners that were not detected at the reporting level. Figure 2-5 shows the total PBDE concentrations measured at influent trunk line and effluent sampling locations throughout the entire sampling period.

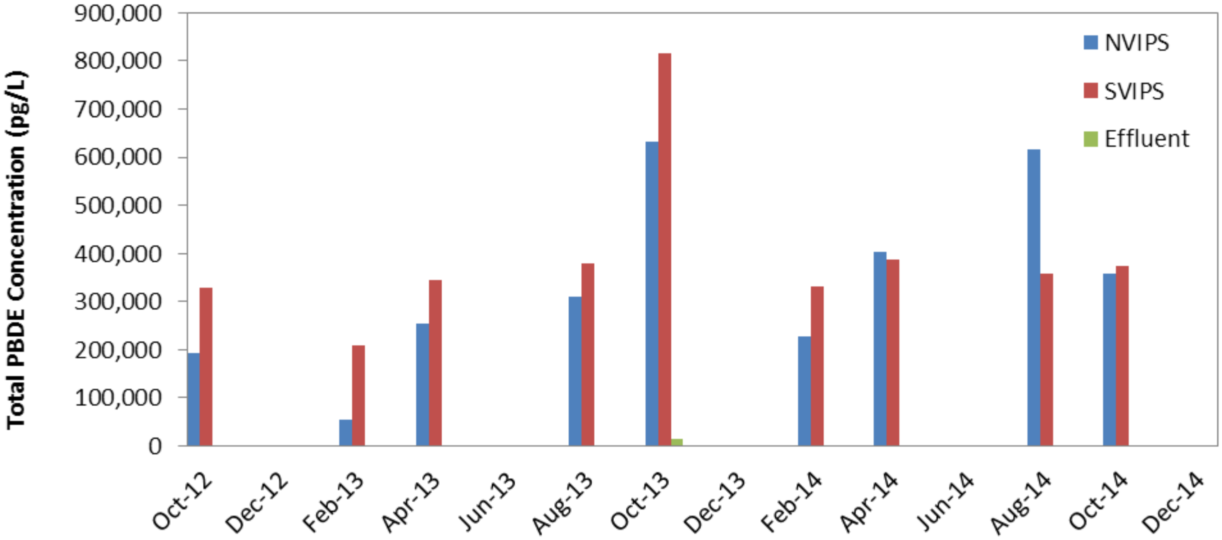

Figure 2-5. Total PBDE concentrations in influent trunk line and effluent samples, Oct. 2012–Dec. 2014

Figure 2-6 presents the same effluent sampling data shown in Figure 2-5, zoomed in on the y-axis to show the low levels of PBDEs in the effluent samples as compared to the influent samples.

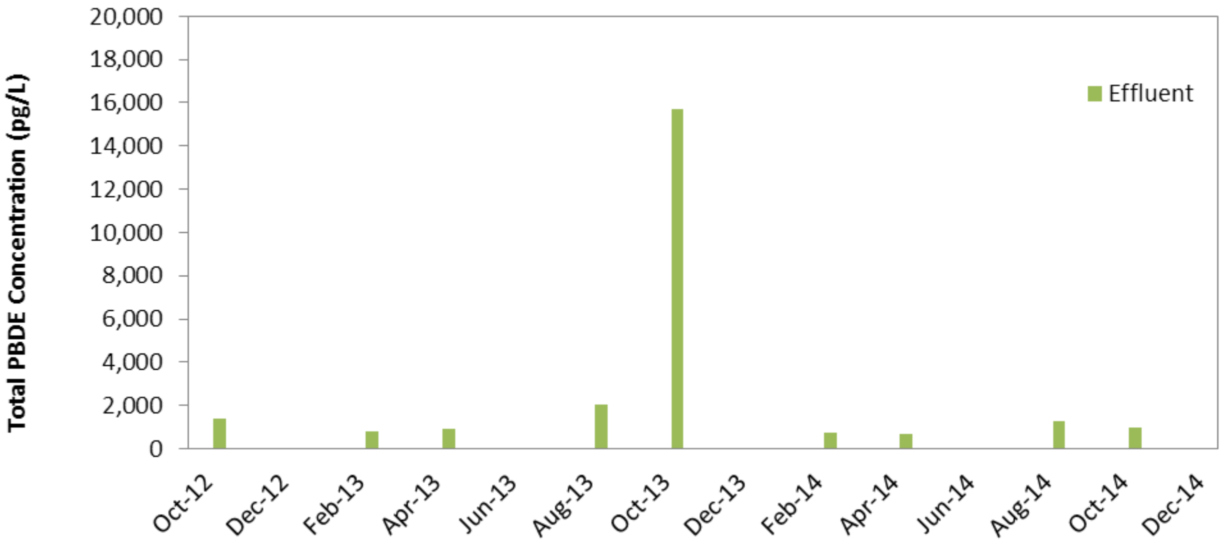

Figure 2-6. Total PBDE concentrations in effluent samples, Oct. 2012–Dec. 2014

Table 2-6. Total PBDE Concentrations (pg/L) and Statistics for 2012 – 2014

Statistics	NVIPS	SVIPS	Effluent
Number of Samples	9	9	9
Mean	338,300	392,200	2,730
Standard Deviation	190,900	167,300	4,900
Minimum	53,300	210,200	660
Maximum	631,600	815,600	15,700

The total PBDE concentration in the NVIPS and SVIPS samples ranged from 53,300 to 815,600 pg/L. Effluent PBDE concentrations ranged from 660 to 15,700 pg/L. In Figure 2-7, the box-whisker plot shows the median, first and third quartile, and minimum and maximum PBDE values for the influent and effluent samples. Based on the average flows and concentrations of PBDEs at the NVIPS, SVIPS, and effluent locations, the Facility removed greater than 99 percent of the PBDE mass entering the Facility.

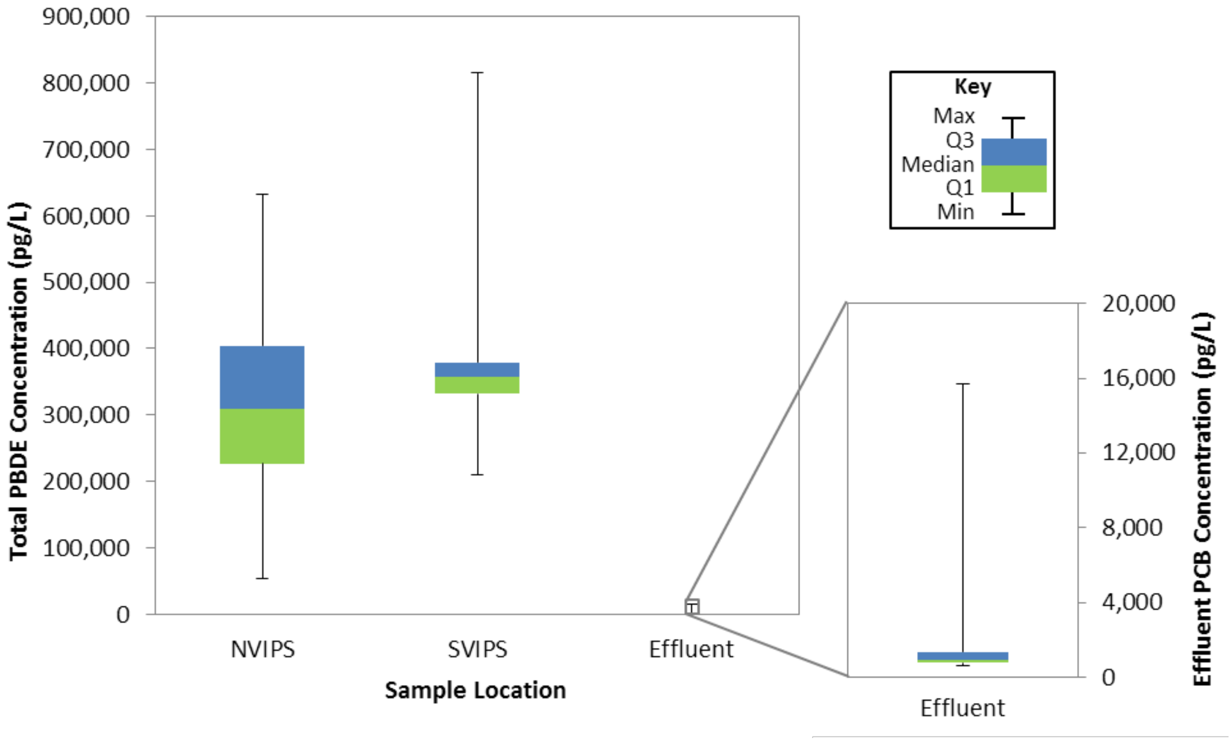

Figure 2-7. Box-whisker plot of total PBDE concentrations in influent trunk line and effluent samples

2.3.2 Collection System Track-Down Samples

The DMI basin was selected for further track-down based on the PCB concentrations measured in 2013–14 and reported in the 2014 Annual Report. As noted in section 2.1.2, there are multiple complicating factors in sampling subbasins including highly variable flows over a 24-hour period, traffic control requirements, and lack of power and security for automated equipment. Samples were taken as 40-minute composites at the approximate times listed in Table 2-7.

Table 2-7. Sampling Dates and Times for Track-Down Samples in 2014

Sampling Location	Date	Time	Date	Time
DMI MHA	6/23/2014	1:35 PM	12/8/2014	2:50 PM
DMI MHB	6/23/2014	12:32 PM	12/8/2014	1:30 PM
DMI MHC	6/24/2014	7:30 AM	12/9/2014	8:30 AM
DMI MHD	6/23/2014	3:15 PM	12/8/2014	11:48 AM
DMI MHE	8/12/2014	2:45 PM	10/20/2014	12:45 PM
DMI MHF	8/12/2014	1:00 PM	10/20/2014	8:40 AM
DMI MHG	8/13/2014	7:30 AM	10/20/2014	2:25 PM

DMI MH1, the manhole located at the outlet of the DMI basin, had an average PCB concentration of 20,090 pg/L in 2013. This was higher than the average concentrations measured at either influent pump station, or at the track-down locations upstream along the SVI and NVI.

The DMI basin splits near 28th Avenue, where one trunk line continues south along the Dishman-Mica Highway, and the other trunk line continues west. Sampling locations DMI MHA (west) and DMI MHB (south) cover each of these trunk lines.

Higher PCB concentrations were noted at DMI MHA on both sampling occasions. The average concentration at DMI MHA was approximately double that observed at DMI MHB. However, much of the difference is related to a high concentration in one sample collected at DMI MHA in June 2013 (33,000 pg/L).

Five more sampling locations were distributed throughout the DMI basin. These locations were intended to assess the importance of the year of housing construction to PCB observations. DMI MHC was located in a basin developed largely in the 1950s, DMI MHD was located in a basin developed largely in the 1970s, while the other three locations (DMI MHE, DMI MHF, and DMI MHG) were all located in basins developed in the past 10–20 years.

Data from the track-down sampling locations are summarized in Table 2-8 and Figure 2-8.

Table 2-8. Total PCB Concentrations (pg/L) and Statistics for Track-Down Samples in 2014

Statistics	DMI MHA	DMI MHB	DMI MHC	DMI MHD	DMI MHE	DMI MHF	DMI MHG
Sample 1	33,000	14,000	8,120	53,800	8,160	5,340	3,640
Sample 2	19,700	12,600	20,800	14,900	11,100	590	28,600
Average	26,300	13,300	14,500	34,400	9,600	2,970	16,100

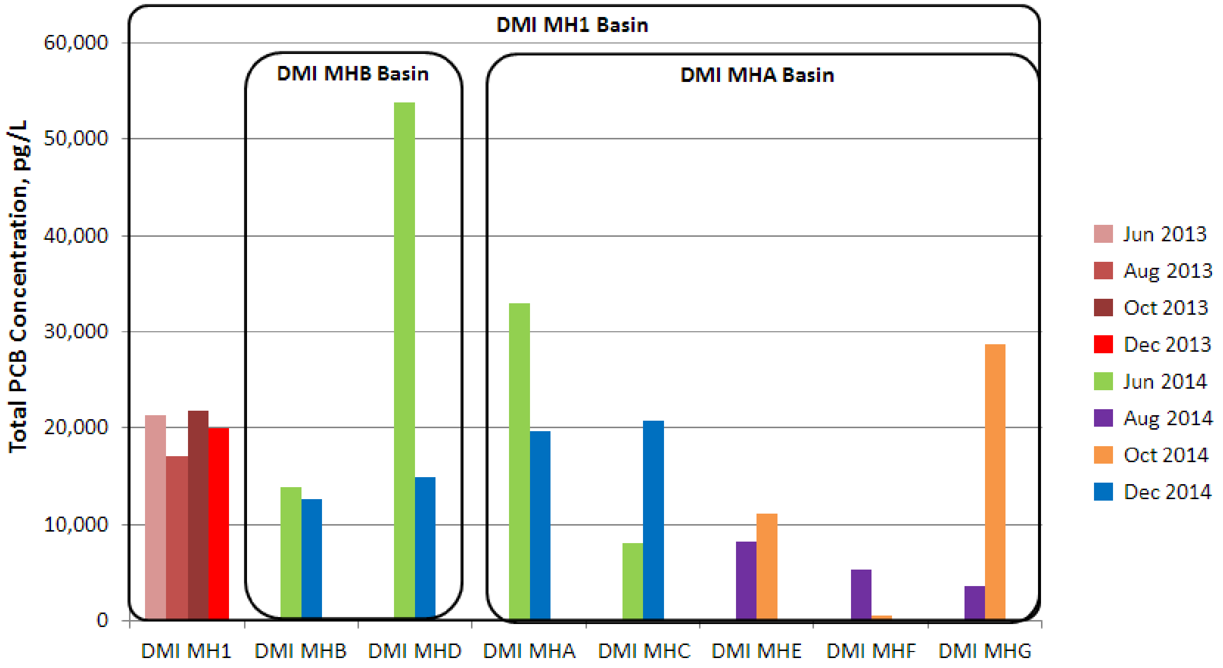

Figure 2-8. Total PCB concentrations at track-down locations within the DMI basin

The data at these locations (Figure 2-7) were difficult to compare, which may be related to the small number of observations (only two samples were taken at each location) at the time of this report's publication. DMI MHF, which covers a basin including new multifamily residential, as well as the trunk line to the Mica Landfill, had low PCB concentrations on both sampling events (5,340 and 590 pg/L). Relatively high PCB concentrations were noted during the June 2014 sampling event at DMI MHD (53,800 pg/L) and during the October 2014 sampling event at DMI MHG (28,600 pg/L).

The June 2014 loading at DMI MHD was not correlated with a high loading at downstream DMI MHA, which may indicate that the loading was of short duration. During the event, the wastewater sample at DMI MHD appeared unusually dark, with a relatively low pH and high solids (TSS) content (920 mg/L).There was low flow in the manhole during the event. The high solids loading may be associated with a flush of sediment because County maintenance crews have reported occasional grease plugging and subsequent flushing at that location. The relatively high PCB concentrations observed at DMI MHA, DMI MHD, and DMI MHG were noted only in one of the two samples taken at each site, limiting the conclusiveness of these data.

Given the limited number and duration of track-down samples, a correlation between the year of construction and the average PCB concentration in the downstream sewer could not be established. Aside from DMI MHF, which had consistently low PCB concentrations, none of the other subbasin sites demonstrated consistently noteworthy results. The DMI MHF subbasin has the highest proportion of new construction (only 4 percent homes built prior to 1980).

In summary, the track-down sampling conducted in Year 2 yielded the following results:

1. All sites were sampled two times during 2014, making it difficult to draw statistically relevant conclusions from the data. A third sampling event will be conducted at each of these sites, with results included in the 2016 Annual Report.
2. PCB concentrations at DMI MHA were consistently higher than those at DMI MHB.
3. PCB concentrations in the upstream basins demonstrated high variability compared to samples taken at the influent pump stations or the Year 1 track-down locations.
4. The site with the highest proportion of new construction had the lowest average PCB concentrations. Given the limited number and duration of track-down samples, a correlation between the year of construction and the average PCB concentration in the downstream sewer could not be established.

2.3.3 Pattern Analysis

PCBs and PBDEs are chemical groups comprising numerous individual congeners. Analyzing the pattern of congener concentrations within each sample can help identify relationships between samples and potential sources. This section presents pattern analysis for PCBs and PBDEs.

There are 209 PCB congeners, which can be sorted into homolog groups based on the number of chlorine atoms attached to the biphenyl ring. Congeners with a single chlorine atom are grouped into the monochlorobiphenyl homolog group (MoCB), congeners with two chlorine atoms are grouped into the dichlorobiphenyl homolog group (DiCB), and so on. The largest molecular weight congener is the decachlorobiphenyl homolog (DeCB) with ten chlorine atoms. Different PCB sources may comprise different levels of homolog groups. Analyzing the relative proportion of each homolog group within samples can demonstrate differences between the samples that may relate to potential different sources of PCBs.

Figure 2-9 presents the average proportion of each homolog group when compared to the average total PCB concentration for the influent trunk lines and effluent samples.

The homolog patterns for the NVIPS and SVIPS are similar to each other, while the Facility effluent appears to have a distinctly different homolog pattern compared to influent. NVIPS and SVIPS homolog patterns reflect a broad spectrum of all molecular weights of PCB congeners, and are mostly made up of tetra- through hexa-chlorinated biphenyl groups. The effluent contains primarily low-molecular weight PCB congeners (mono-chlorinated through tetra-chlorinated biphenyl groups), demonstrating the Facility's ability to filter out the higher molecular weight congeners that are present in the influent.

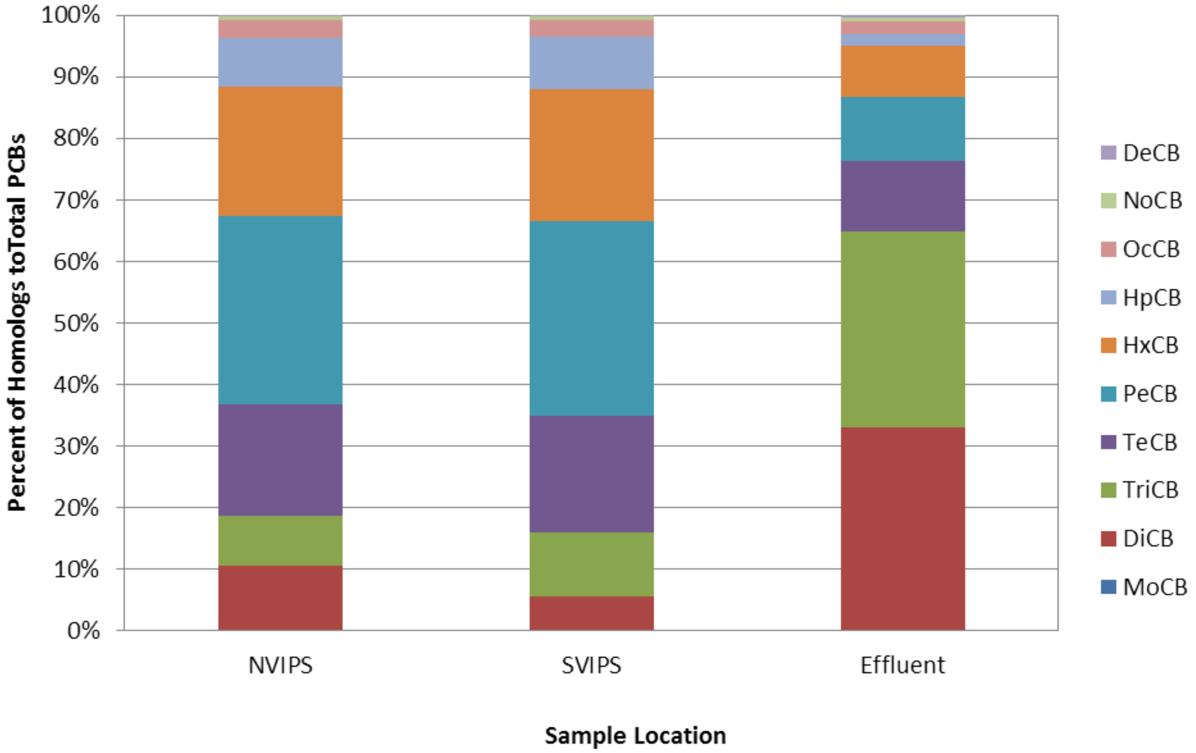

Figure 2-9. Comparison of PCB homolog composition for each sample type

The amount of each homolog was compared to the total PCB concentrations.

Figure 2-10 presents PCB homolog patterns for the track-down sampling locations. SVI MH1, NVI MH1 and DMI MH1 have very similar homolog proportions. The DMI MHB and DMI MHD, both in the DMI MHB subbasin, also have similar homolog proportions. More variability exists in the DMI MHA basin, which included five sampling locations. DMI MHE and DMI MHF have the highest proportion of low molecular weight congeners up to tetrachlorobiphenyls (TeCB) in that basin, much more than DMI MHA or DMI MHC. This variability in homolog pattern is evidence of different types of PCB sources in the sewershed.

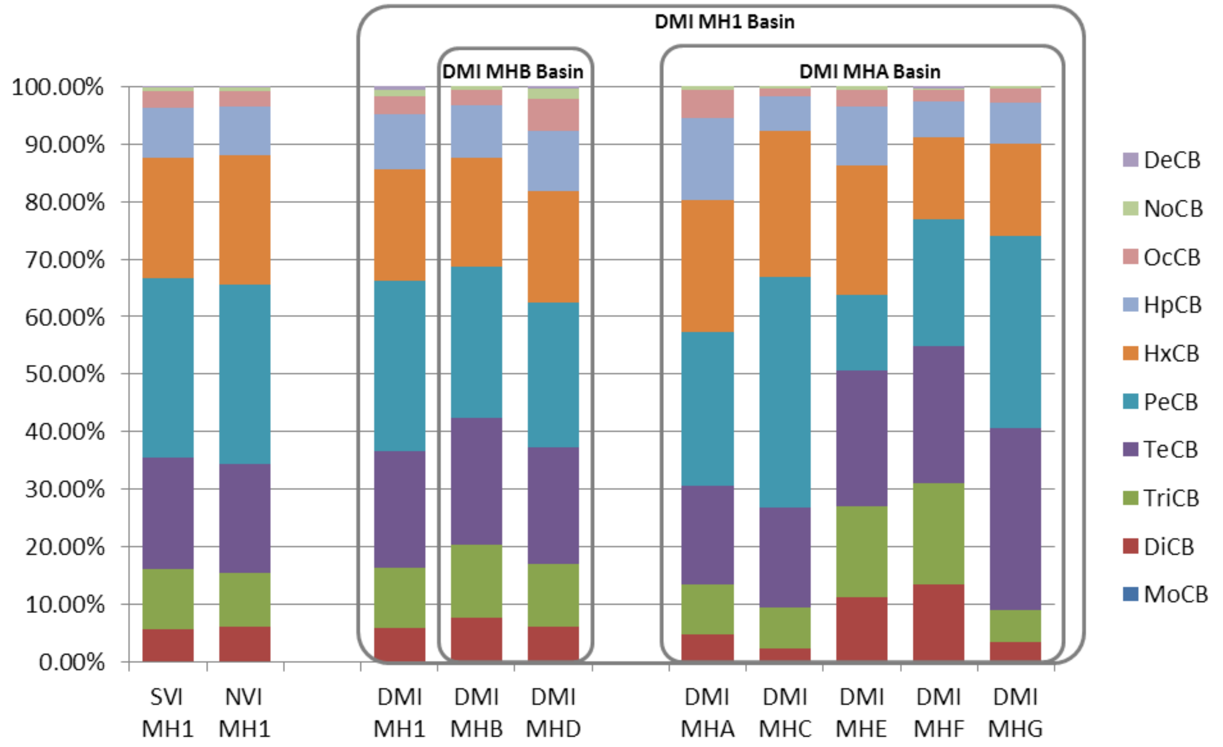

Figure 2-10. Comparison of PCB homolog composition for at track-down sampling locations

The amount of each homolog was compared to the total PCB concentrations.

Like PCBs, PBDEs may also be arranged into homolog groups. PBDEs are characterized by the number of bromine molecules attached to the diphenyl ether ring. Congeners with two bromine molecules compose the Dibromodiphenyl ether homolog group (DiBDE), congeners with three bromine molecules compose the Tribromodiphenyl ether homolog group (TriBDE), and so on. Figure 2-11 presents the composition of each homolog group when compared to the total brominated diphenyl ether concentration for the influent trunk lines, effluent, and track-down manholes. The percentages presented in Figure 2-10 are based on the average for each homolog group and the average total PBDE concentration for all of the data collected.

Tetrabromodiphenyl ether (TeBDE), pentabromodiphenyl ether (PeBDE), and decabromodiphenyl ether (DeBDE) compose the highest percentage of the influent trunk line samples. DeBDE is still produced in electronics, while the production of PeBDE has been phased out in the United States and most international markets (Ecology, 2006).

The effluent had high proportions of Nonabromodiphenyl ethers (NoBDE) and DeBDEs. However, this observation requires further discussion. The blank samples also typically registered relatively high concentrations of DeBDEs, specifically congener BDE-209. If the concentrations of PBDEs measured in the blanks are excluded, the majority of the effluent would be associated with the TeBDE and NoBDE homolog groups (specifically BDE-47, BDE-207, and BDE-208). However, congeners BDE-207 and BDE-208 were found only in two of the nine effluent samples. BDE-47 was found in all effluent samples, and this congener was not observed in high concentrations in the blanks.

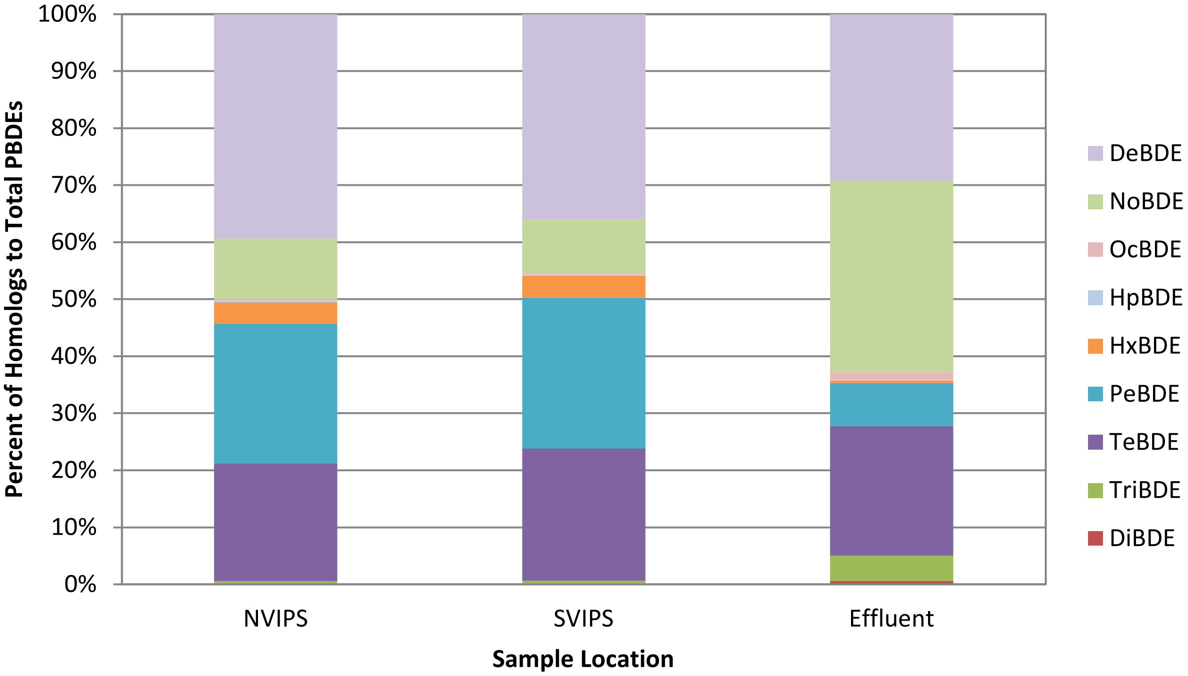

Figure 2-11. Comparison of PBDE homolog composition for each sample type

The amount of each homolog was compared to the total PBDE concentrations (excluding K flagged values).

The homolog group analysis demonstrates differences in homolog group levels in influent and track-down samples, but does not provide detailed evidence of potential PCB sources. To gain further insight into specific sources, differences between samples and sample locations can be analyzed at the congener level, using positive matrix factorization (PMF) as described in the following section.

2.3.4 Source Identification and Positive Matrix Factorization

The homolog evaluation was not able to discern potential sources. The County voluntarily performed an additional evaluation using Positive Matrix Factorization (PMF), an advanced source apportionment tool that has been used to identify PCB sources in water, sediment, and air. The PMF analysis was conducted to provide more definitive information on potential PCB and PBDE sources, even though this level of evaluation is not required by the Permit. This section describes the PMF analysis, which was performed by Dr. Lisa Rodenburg from Rutgers University.

2.3.4.1 PCB Positive Matrix Factorization

PMF is an advanced source apportionment tool developed by Paatero and Tapper (1994) that has been used to identify PCB sources in water, sediment, and air (Ding et al., 2013; Bzdusek et al., 2006a; Bzdusek et al., 2006b; Du et al., 2007; Du et al., 2008; Rodenburg et al., 2011; Qiu et al., 2012). The PMF2 software (YP-Tekniika KY Co., Helsinki, Finland) was used in this study.

PMF defines the sample matrix as a product of two unknown factor matrices with a residue matrix:

$$X = GF + E \qquad (1)$$

The sample matrix (X) is composed of n observed samples and m chemical species. F is a matrix of chemical profiles of p factors or sources. The G matrix describes the contribution of each factor to any given sample, while E is the matrix of residuals. The PMF solution, i.e., G and F matrices, are obtained by minimizing the objective function Q through the iterative algorithm:

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} (e_{ij} / s_{ij})^2 \qquad (2)$$

Q is the sum of the squares of the difference (i.e., e_{ij}) between the observations (*X*) and the model (*GF*), weighted by the measurement uncertainties (s_{ij}).

PMF analysis requires three input matrices. The concentration matrix contains the concentrations of the *m* chemical species (in this case, PCB congeners) in the *n* samples. None of the concentrations in this matrix can be zero, so a non-zero value must be estimated for any result that is missing or below the detection limit. The uncertainty matrix contains an estimate of uncertainty for each data point in the concentration matrix. Finally, the limits of detection (LOD) matrix contains the LOD for every data point.

In general, matrices used for factor analysis should not have more analytes (*m*) than samples (*n*). The data set contained 71 samples. including duplicates, the duplicates were treated as samples and 71 congeners were chosen for the PMF analysis. The 71 congeners were chosen based on their abundance in the Aroclors and in the data set, with care taken to retain congeners that are abundant in the effluent, even if they are not particularly abundant in the influent. This approach meant that low molecular weight congeners were retained in the data matrix at the expense of some high molecular weight congeners. The 71 congeners account for approximately 90 percent of all of the PCB mass in all samples, and 87 percent of the PCB mass in the effluent samples.

Concentration matrix: A unique blank correction method tailored to the PMF was used for this analysis. Concentrations were blank corrected by subtracting the average concentration in the blanks (travel, lab, and rinsate blanks) for each congener. These averages were calculated by setting non-detect values to zero and excluding blanks in which the sum of PCBs was greater than 1,000 pg/L. After blank correction, concentration values that were less than or equal to zero were defined as “below detection limit.” Values below the detection limit composed 373 out of 5,041 data points in the concentration matrix (7.4 percent). These values were replaced with one-half of the analytical detection limit on a congener basis.

LOD matrix: The LOD matrix used the congener- and sample-specific LOD as provided. In the small number of cases where the LOD was missing, the LOD was estimated based on similarity to other samples in the data matrix.

Uncertainty matrix: As in other studies (Du et al., 2008; Rodenburg et al., 2008; Rodenburg et al., 2010a), uncertainty was estimated from the surrogate recoveries. The standard deviation of the recoveries of each surrogate was calculated and used as the uncertainty for each congener quantified against that surrogate. The uncertainty for the values below the detection limit was three times the uncertainty of the detected concentrations (i.e., the [x,3x] uncertainty matrix was used).

2.3.4.2 Non-Aroclor PCB Sources

PCB-11 was measured at relatively high concentrations (compared to other congeners) in both the influent and effluent. PCB-11 is the single most abundant congener in the effluent. . This is true with or without blank correction (see above for details on blank correction). PCB-11 concentrations in the effluent average 25 ± 7 pg/L (all concentrations are after blank correction unless stated otherwise). Concentrations of PCB-11 are significantly higher in the NVIPS samples (1,734 ± 1,791 pg/L) than the SVIPS samples (441 ± 76 pg/L) according to the two-tailed t-test assuming unequal variances ($p < 0.05$).

PCB-11 is virtually absent in the Aroclors. It is thought to enter the environment primarily from the use of diarylide yellow and other pigments in printing on paper and textiles (Rodenburg, 2010b). PCB-11 has a low K_{ow} and low molecular weight. Compared to other congeners, PCB-11’s physical/chemical properties cause it to partition to a lesser extent to particles. This may explain why PCB-11 was found in the effluent at higher concentrations than other, less soluble congeners. When the duplicate NVIPS samples collected on December 17, 2013, are excluded, PCB-11 (3,3'-dichloro) is strongly correlated with PCB-35 (3,3',4-trichloro; $R^2 = 0.73$) and somewhat correlated with PCB-77 (3,3',4,4'-tetrachloro; $R^2 = 0.27$). These structurally related congeners have all been reported as trace contaminants in diarylide yellow pigments (Litten et al., 2002; Anezaki and Nakano, 2014).

Other than PCB-11, there is no evidence that non-Aroclor PCB sources are impacting the influent and/or effluent of this Facility. For example, in the Delaware River, production of $TiCl_4$ (a precursor to titanium dioxide [TiO_2]) led to the extensive contamination of the sediment of the Delaware River with PCBs 206, 208, and 209. Nothing of that kind is observed in the County data.

2.3.4.3 PCB PMF Factors Analysis

A major challenge of factor analysis is to choose the "correct" number of factors that adequately describe the data matrix without over- or under-fitting. In the present case, seven factors were isolated from the 71 x 71 data matrix. For comparison, the 38 x 38 data matrix analyzed in 2014 yielded six factors. The 2015 factors were similar to the 2014 factors.

The seven-factor PMF solution did an excellent job of reproducing the data. The correlation coefficient (R^2) for the modeled versus measured data was greater than 0.9 for 62 of the 71 congeners. It was above 0.8 for another three congeners. The congeners with lower R^2 values were: PCB-3 ($R^2 = 0.64$), PCB-5 (0.797), PCB-9 (0.69), PCB-27 (0.75), PCB-198 (0.65), and PCB-203 (0.68).

To determine whether any of the factors represented mixtures of Aroclors, a multiple linear regression was performed in which a congener pattern (excluding PCB-11) was calculated that represented a linear combination of the four main Aroclors:

$$C_f = aC_{1242} + bC_{1248} + cC_{1254} + dC_{1260} \quad (1)$$

where C is concentration of the resolved factor (f) or individual Aroclor and a, b, c, and d are partial regression coefficients, which were constrained to be positive. Correlation coefficients (R^2) between this best-fit composite Aroclor congener pattern and the factor congener pattern were calculated. The resolved factors were compared with the congener patterns of the Aroclors (Rushneck et al., 2004) in an attempt to identify them (Table 2-9). Each factor's best-fit was also compared to a combination of Aroclors (Table 2-10). All factors were reasonably well described as a combination of Aroclors, although the correlation is worst for Factors 1 and 5, suggesting that they have undergone the most weathering.

Table 2-9. Correlation Coefficients (R^2) between Factors and Single Aroclors

Factor	1016	1242	1248	1254	1260
F1	**0.73**	0.60	0.11	0.01	0.06
F2	0.16	0.34	**0.78**	0.32	0.02
F3	0.40	0.59	**0.75**	0.14	0.02
F4	0.01	0.03	0.15	**0.57**	0.32
F5	0.00	0.07	**0.53**	0.36	0.01
F6	0.04	0.00	0.10	**0.98**	0.12
F7	0.07	0.07	0.01	0.12	**0.84**

The R^2 value is the correlation coefficient for the best-fit Aroclor versus the actual congener pattern. Factors with lower R^2 values have probably undergone more weathering. Note PCB-11 is excluded from these correlations.

Table 2-10. Coefficients for the Best-fit Description of Each Factor as a Mixture of the Four Most Common Aroclors

Factor	1242	1248	1254	1260	R^2
F1	0.83	0.00	0.00	0.01	0.60
F2	0.07	0.25	0.12	0.00	0.88
F3	0.42	0.39	0.18	0.02	0.88
F4	0.22	0.10	0.39	0.27	0.79
F5	0.00	0.71	0.42	0.00	0.69
F6	0.01	0.00	0.97	0.02	0.98
F7	0.00	0.05	0.24	0.65	0.90

The R2 value is the correlation coefficient for the best-fit Aroclor combination versus the actual congener pattern. Factors with lower R2 values have probably undergone more weathering. Note PCB-11 is excluded from these correlations.

The fingerprints of the seven resolved factors are shown in Figures 2-11 through 2-15. Factors 1 and 2 resembled Aroclors only when PCB-11 was removed from the correlation. Each of the factors was at least somewhat similar to one of the Aroclors (i.e., R^2 greater than about 0.45). Factors 3, 6, and 7 appear to represent relatively fresh or unweathered Aroclors 1248, 1254, and 1260, respectively. Factors 4 and 5 were similar to Aroclors 1254 and 1248, respectively, but appear to have undergone more substantial weathering, as indicated by lower R^2 values.

Factor 1, which is dominant in the effluent but barely present in the influent, is similar to the individual Aroclors 1016 and 1242, but even when expressed as a sum of the four main Aroclors, this factor does not well resemble any of these formulations. It is likely that Factor 1 represents the dissolved-phase PCB concentration that is not removed during the wastewater treatment process (see Figure 2-12). In order to determine whether the congener pattern of Factor 1 (excluding PCB-11) is similar to any of the other Aroclors when the water/particle partitioning is taken into account, the congener patterns (i.e., the abundance of each congener) of the Aroclors were divided by the congener's octanol-water partition coefficient (Hansen et al., 1999). The new "dissolved" congener pattern was compared to the congener pattern of Factor 1. The R^2 values for the comparison of Factor 1 (without PCB-11) and the "dissolved" Aroclors 1016, 1242, and 1248 were all between 0.5 and 0.7. In addition, the concentration of Factor 1 in the effluent is relatively constant at 116 ± 14 pg/L. Taken together, these two lines of evidence suggest that Factor 1 represents the dissolved phase of a variety of low molecular weight Aroclor formulations, plus the dissolved fraction of PCB-11.

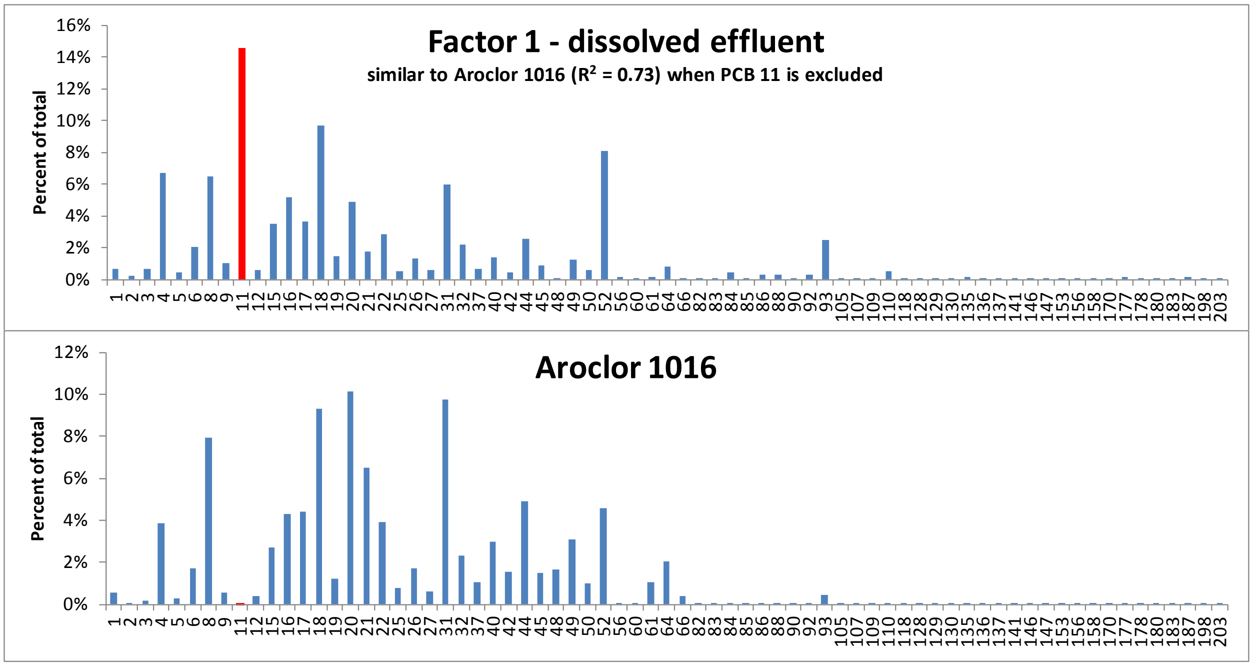

Figure 2-12. Fingerprint of Factor 1 compared to Aroclor 1016

Panel shows Factor 1 and each congener as percent of total mass in the data set.

Factor 2 is dominated by PCB-11 (Figure 2-13). When this congener is excluded, it resembles Aroclor 1248 (R^2 = 0.78). It is reasonably well described as a mixture of the four main Aroclors. As noted above, concentrations of this factor are significantly higher in NVIPS (1,845 ± 2,324 pg/L) than in SVIPS (589 ± 383 pg/L).

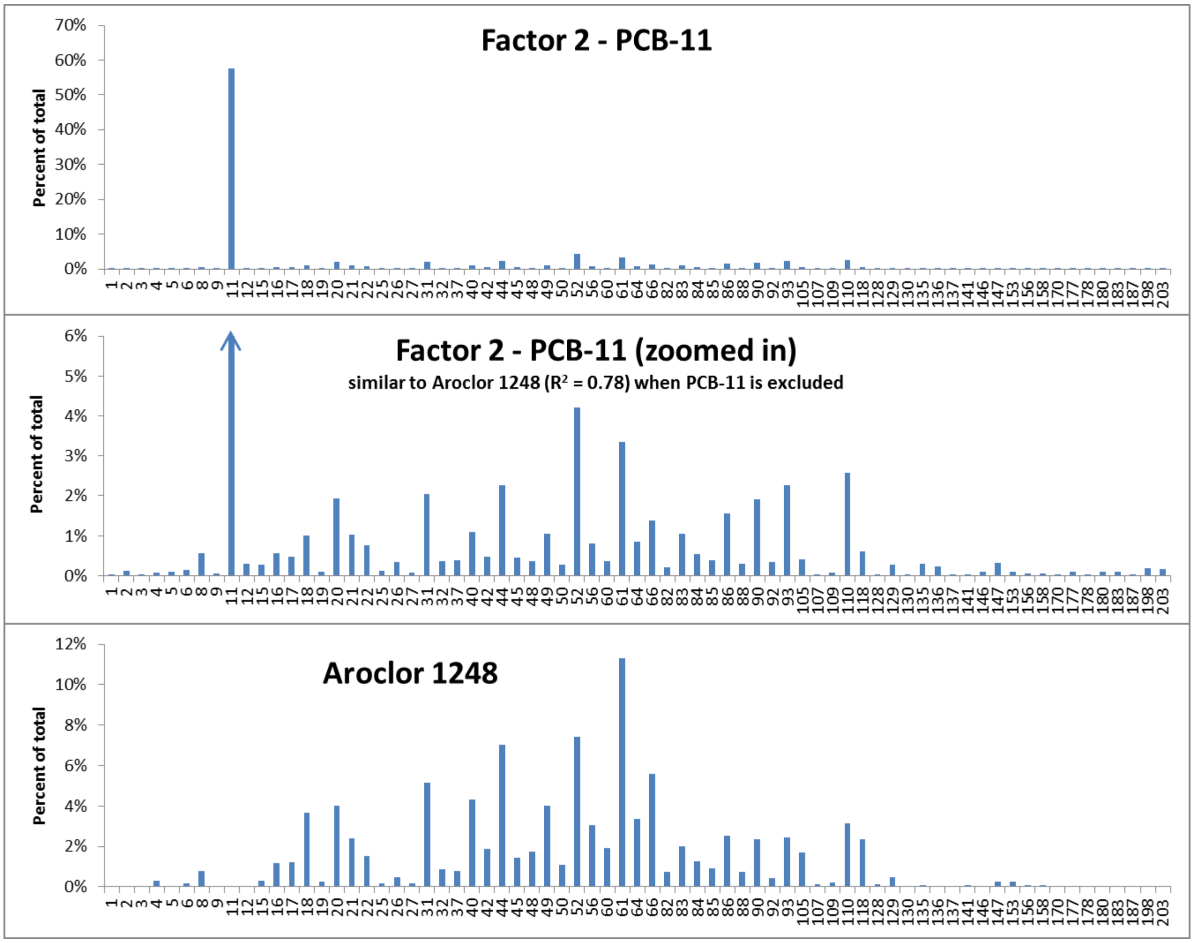

Figure 2-13. Fingerprint of Factor 2

Panel shows Factor 2 and each congener as percent of total mass in the data set. The bottom panel is the same fingerprint with the y-axis range modified to less than 6%.

Factor 3 is similar to Aroclor 1248 but, as Figure 2-14 shows, it contains a broader range of congeners at both the high and low MW ends of the spectrum. For this reason, Factor 3 is fairly well described as a mixture of the four main Aroclors. In contrast, Factor 5 also resembles Aroclor 1248, but it is “missing” congeners at both the high and low MW ends of the spectrum. It is similar to a mixture of Aroclors 1248 and 1254. Concentrations of Factor 3 are higher in SVIPS (3,268 ± 1,864 pg/L including track-down manholes, 2,827± 684 pg/L) than in NVIPS (1,815 ± 1,239 pg/L including track-down manhole samples, 1,854 ± 1,379 pg/L). Concentrations of Factor 5 are not different between NVIPS and SVIPS.

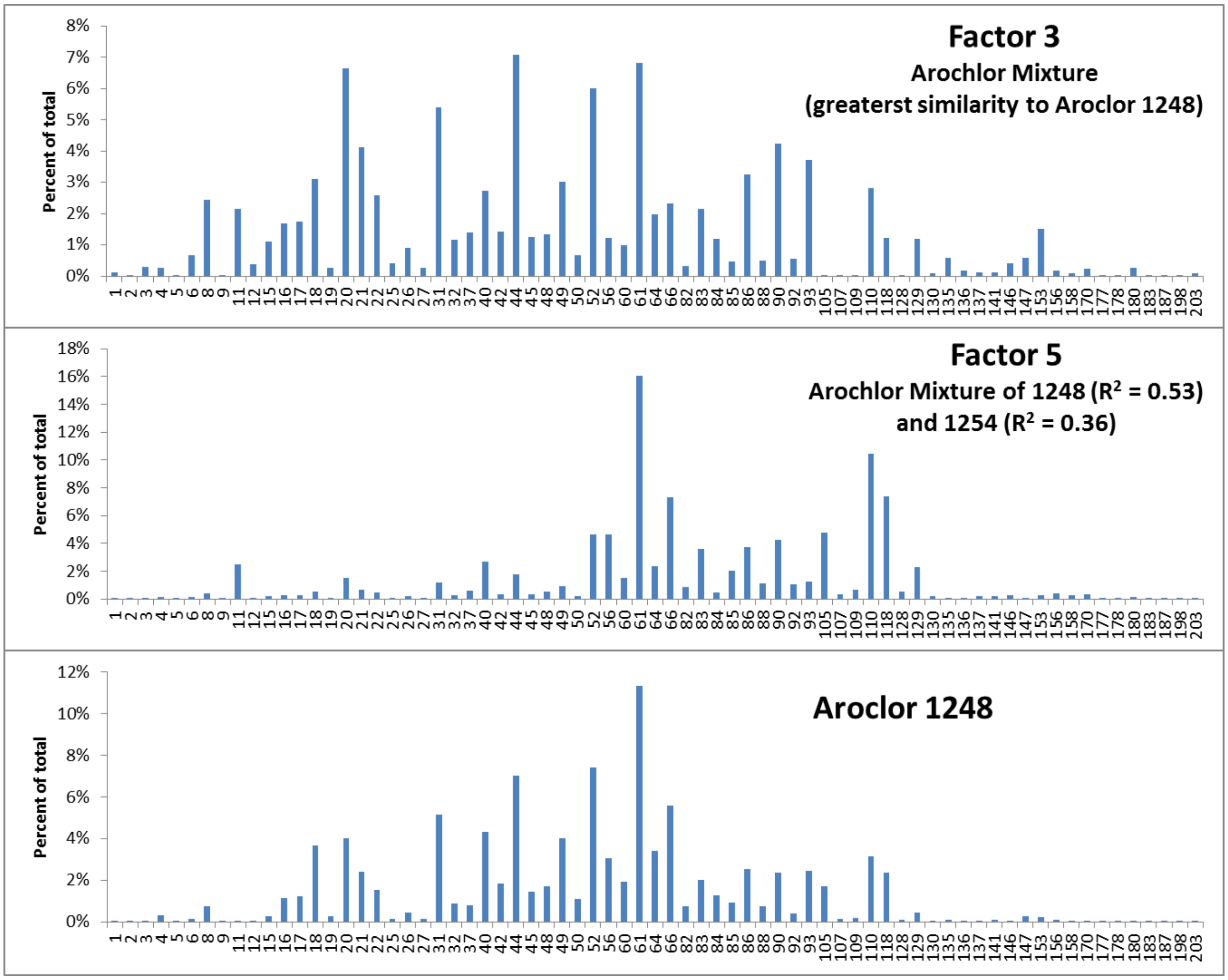

Figure 2-14. Fingerprints of Factors 3 and 5 compared to Aroclor 1248

Panel shows Factors 3 and 5, and each congener as percent of total mass in the data set.

Factor 4 resembles Aroclor 1254, but the correlation is not strong ($R^2 = 0.57$), and of all the factors, it is not well described as a mixture of Aroclors, indicating significant weathering. Concentrations of Factor 4 are not different between the NVIPS and SVIPS samples.

Factor 6 strongly resembles Aroclor 1254 ($R^2 = 0.98$). Such a strong resemblance implies virtually no weathering. Aroclor 1254 was the main Aroclor used in building materials such as caulk (Herrick et al., 2004). However, Aroclor 1254 was also used in a wide variety of other applications (Agency for Toxic Substances and Disease Registry [ATSDR], 2000). As noted in last year's report, this factor is particularly abundant in samples collected on August 20, 2013 at the NVIPS location. It is also abundant in the sample collected on December 9, 2014, at the DMI MHC location. Factors 4 and 6 are shown compared to Aroclor 1254 in Figure 2-15.

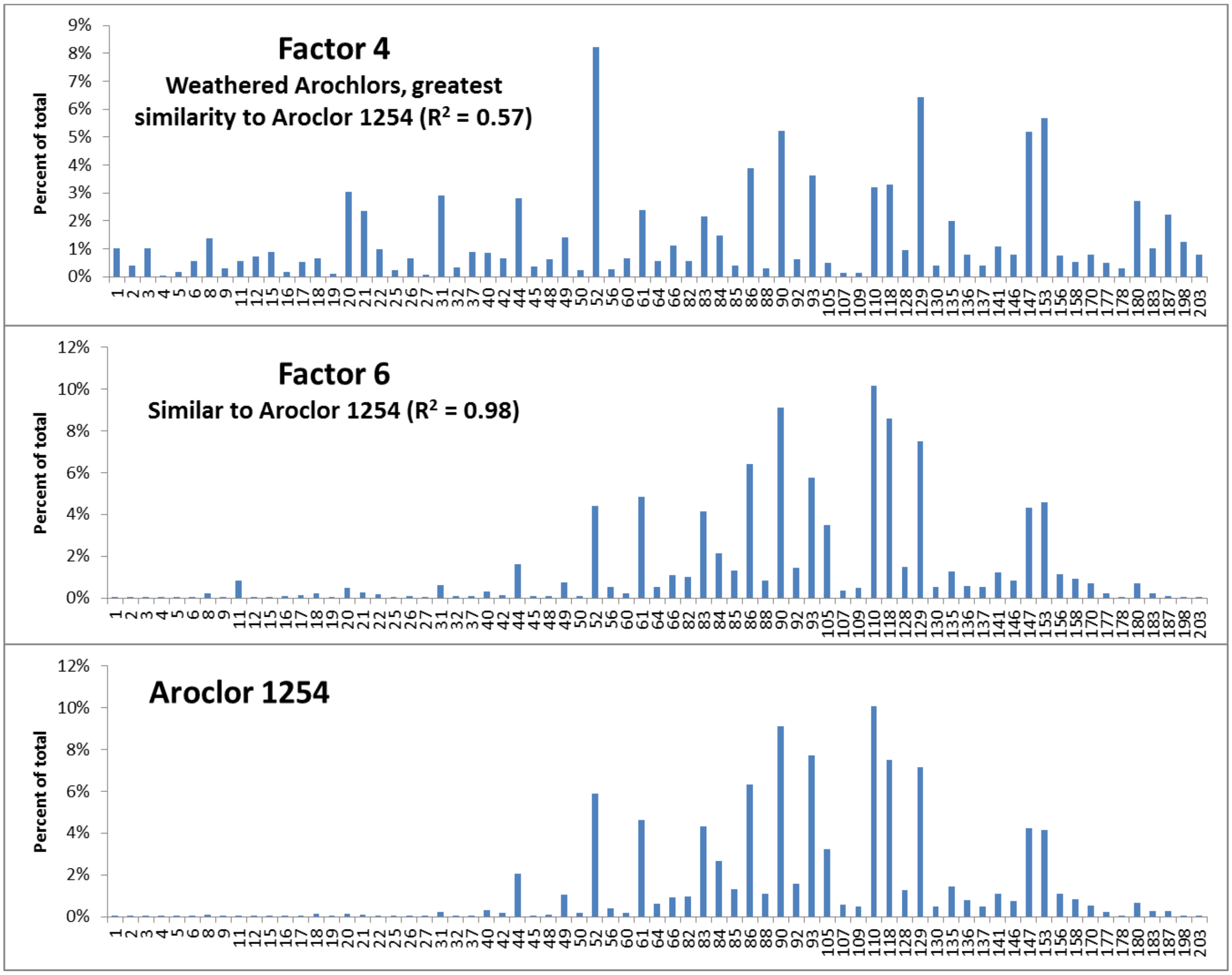

Figure 2-15. Fingerprints of Factors 4 and 6 compared to Aroclor 1254

Panel shows Factors 4 and 6, and each congener as percent of total mass in the data set.

Factor 7 somewhat resembles Aroclor 1260 (R^2 = 0.84), but contains more low molecular weight congeners (Figure 2-16). It is well described (R^2 = 0.90) as a mixture of Aroclors, especially Aroclors 1254 and 1260. Concentrations of Factor 7 are not different between NVIPS and SVIPS.

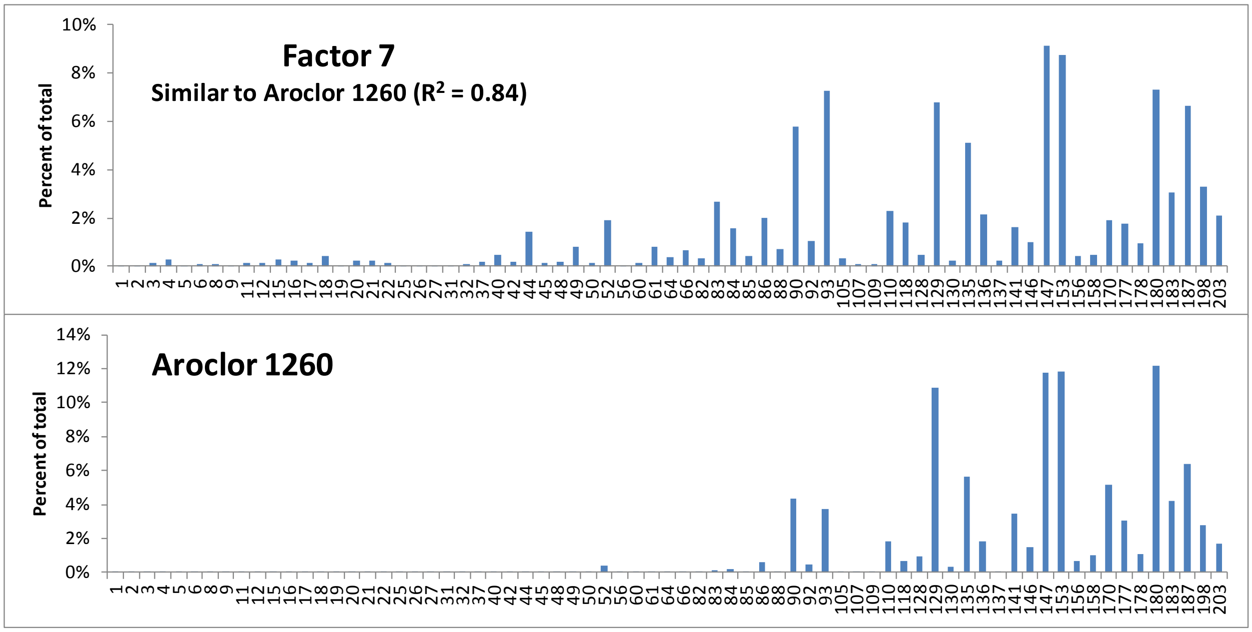

Figure 2-16. Fingerprint of Factor 7 compared to Aroclor 1260

Panel shows Factor 7 and each congener as percent of total mass in the data set.

The proportions of the seven factors in the influents (SVIPS and NVIPS) were similar to each other, but very different from the effluent. The following pie charts represent the average contribution of each factor to the total PCBs measured in selected samples. Figure 2-17 compares the factor profiles at the NVIPS and SVIPS. Factors 2 and 3 displayed significantly different concentrations in the NVIPS compared to the SVIPS samples. Concentrations of Factor 2 (which is dominated by PCB-11) were higher in the NVIPS samples, while concentrations of Factor 3 (which resembles Aroclor 1248) were higher in the SVIPS samples. This suggests that these two factors may be associated with specific contaminated locations, rather than regional background contamination. For this reason, these factors might be a priority for track-down. The Factor 3 concentration was noticeably elevated in the sample from DMI MHD collected on June 23, 2014.

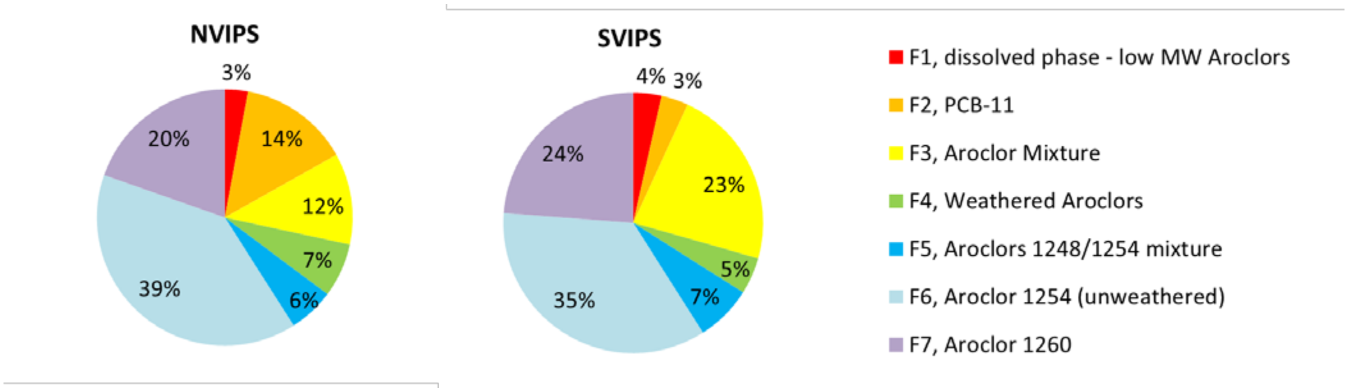

Figure 2-17. Contribution of each of the seven factors to the total PCB mass in the SVIPS and NVIPS

Figure 2-18 depicts the factor profiles in effluent samples. Factor 1, which correlates with dissolved phase low molecular weight Aroclors, is the most common factor. The other six factors are all present to varying degrees, with Factor 6 (unweathered Aroclor 1254) comprising the second-highest percentage. Factor 6 was the dominant factor at both influent locations.

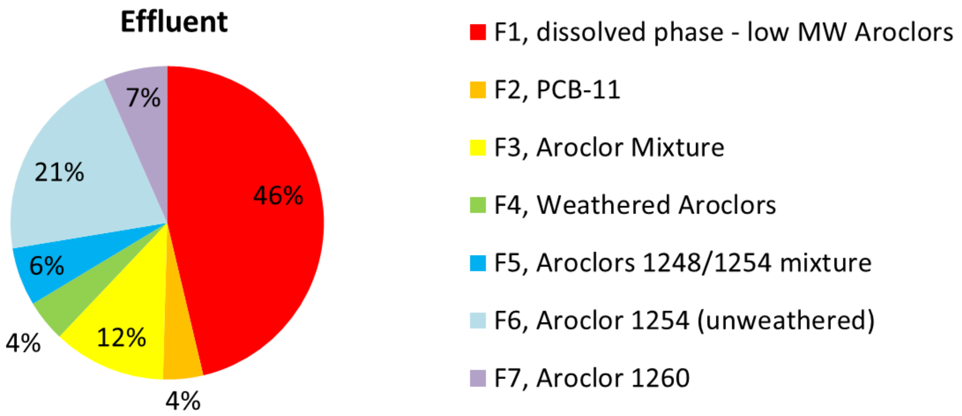

Figure 2-18. Contribution of each of the seven factors to the total PCB mass in the effluent

Figure 2-19 presents the factor profiles for the two highest total PCB concentrations observed to date: the August 2013 NVIPS sample (67,750 pg/L) and the June 2014 DMI MHD sample (53,900 pg/L). The August 2013 NVIPS sample is almost entirely comprised of Factors 6 and 7. Factor 6, which comprises 69 percent of the sample, correlates to a relatively pure (unweathered) profile of Aroclor 1254. This profile is consistent with an accidental point source discharge of one or two contaminated chemicals. In comparison, the June 2014 DMI MHD sample is much more varied, and resembles the overall profile observed at the downstream SVIPS and DMI MH1. A high TSS concentration was observed in this sample and this profile is consistent with a higher contamination due to the higher solids or sediment content.

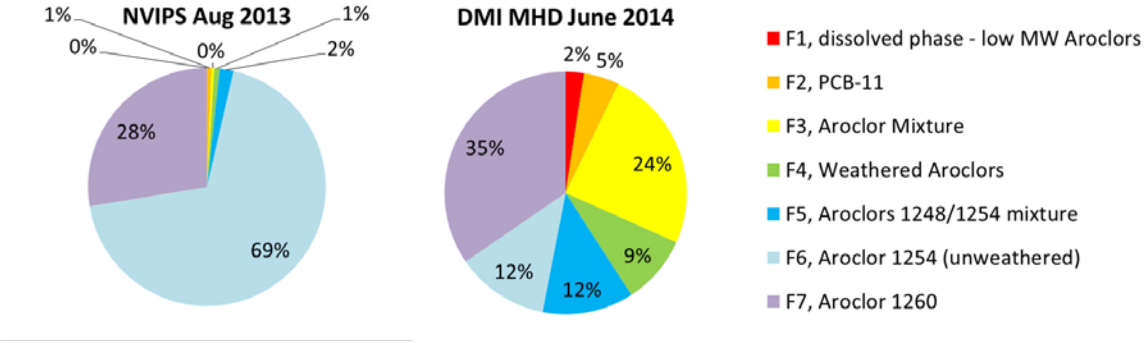

Figure 2-19. Contribution of each of the seven factors to the total PCB mass in the two most highly concentrated total PCB samples, to date

Figure 2-20 presents the factor profiles for the five track-down sampling locations in the DMI basin, which were selected on the basis of year of construction. Two samples from each DMI manhole location are presented in Figure 2-20. DMI-MHC, representing the oldest construction, shows a higher proportion of F6 (unweathered Aroclor 1254). Aroclor 1254 was commonly used in building materials, such as caulk and along with Aroclor 1260 were the main PCB mixtures used before 1950. DMI-MHD, representing homes built primarily in the 1960s and 1970s, has a profile similar to those observed at the influent pump stations and at the downstream DMI MH1. The three remaining sites, which represent newer developments, had varied profiles. DMI MHE had a high proportion of Factor 3, a mixture of four common Aroclors. DMI MHF, which represents the newest construction of all the sites, showed an even higher proportion of Factor 3, along with a relatively high proportion of Factor 2, which is associated with PCB-11. DMI MHG sampling results varied among the two samples taken. One sample from DMI MHG was dominated by Factor 5, which correlates to a mixture of Aroclors 1248 and 1254, with very little contribution from Factors 2 and 3. The DMI MHG profile is heavily influenced by the October 2014 event, with a total PCB concentration of 29,700 pg/L (compared to the August 2014 event which had a total PCB concentration of 3,670 pg/L). The October 2014 sample profile showed 66 percent Factor 5, and less than one percent of each of Factors 1, 2, 3, and 4.

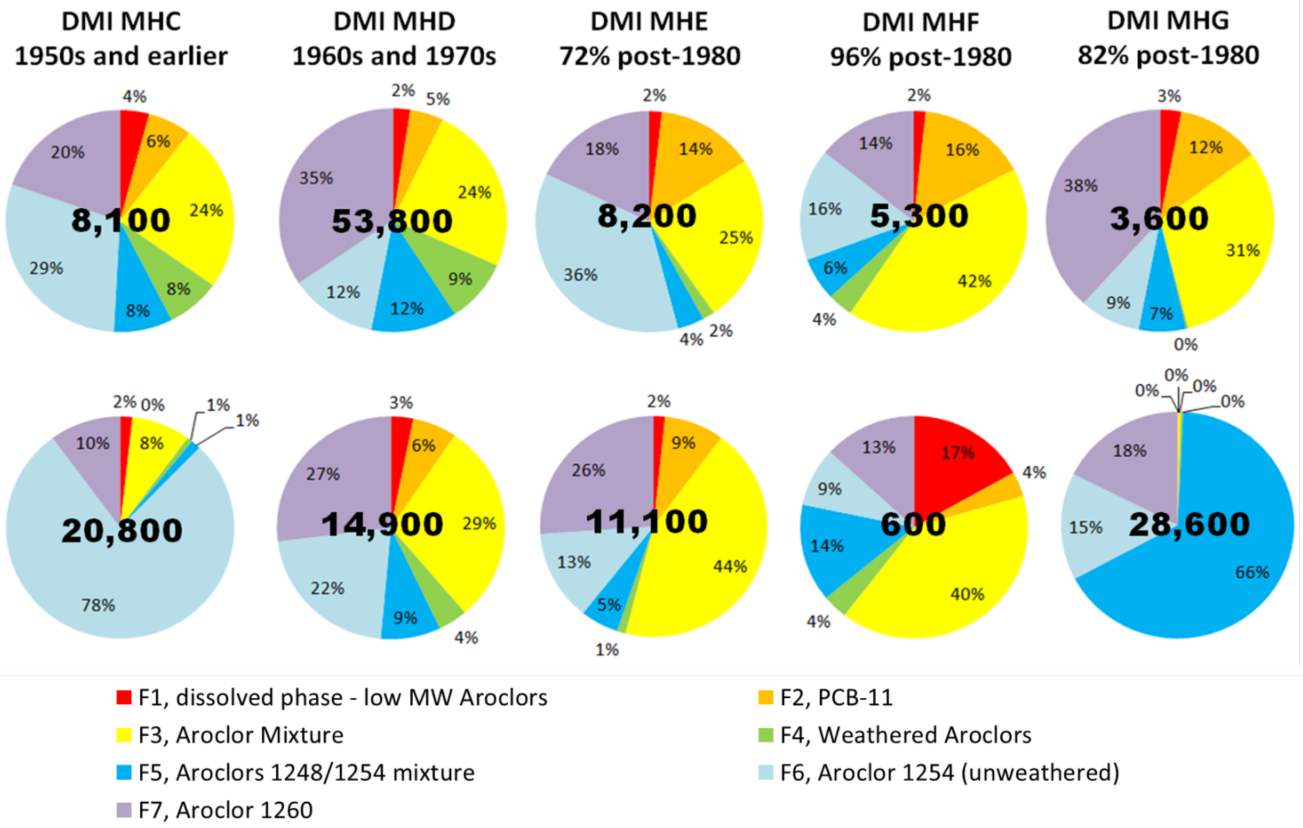

Figure 2-20. Contribution of each of the seven factors in the DMI subbasins

Note: the value bolded in black on each pie chart represents the total PCB concentration (pg/L) for each sample.

With only two samples per site in the 2014 DMI track-down, it is not possible to draw conclusions regarding the potential influence of year of construction. Impacts from individual or one-time point source discharges are amplified at sampling locations with small tributary areas. Events such as the October 2014 profile at DMI-MHG, dominated by 66 percent of Factor 5, and the December 2014 profile at DMI-MHC, which was 78 percent Factor 6, support this line of reasoning. Beyond that, the factor profiles suggest little correlation between the year of construction and the source of PCB contamination.

2.3.4.4 PCB PMF Summary and Conclusions

The PMF analysis yielded the following results and conclusions:

- The PMF analysis involved 71 congeners, totaling 90 percent of the total PCB mass across all samples.
- The seven-factor PMF solution did an excellent job of reproducing the data, based on congener correlation coefficients.
- Most of the factors are strongly correlated to Aroclors and Aroclor mixtures. The exception is Factor 2, which is mainly composed of PCB-11, which is often found in yellow dyes and pigments. Factor 2 was more prevalent at NVIPS than at SVIPS.
- Factor 1 comprised the majority of the effluent, and appears composed of dissolved-phase, low molecular weight Aroclors.
- Factor 6 appears similar to unweathered Aroclor 1254, which has been found in building materials such as caulk, and other applications. This factor was particularly abundant in the December 2014 sample at DMI MHC (20,900 pg/L total PCB concentration).
- Factor 3, which resembles a mixture of the four most common Aroclors, was much more prevalent in the SVIPS samples versus the NVIPS samples. It was also quite abundant in the June 2014 sample at DMI MHD (53,900 pg/L total PCB concentration).

2.3.4.5 PBDE Positive Matrix Factorization

PBDEs are produced and sold in three main types of formulations, the penta-, octa-, and deca-BDE formulations. Note that the name of the formulation does not necessarily correspond to the homologs of the BDEs that are present in the mixture. PeBDE is dominated by BDE-47, which is a TeBDE, as well as BDE-99 and BDE-100, which are both pentabromo congeners. Octa-BDE (OcBDE) contains primarily BDE-183 (hepta), although some octa formulations contain large amounts of BDE-206 and BDE-207 (nona), and BDE-209 (deca). DeBDE consists primarily of BDE-209.

The PBDE data set shows very little BDE-183; it is never more than 0.5 percent of the sum of BDEs in any sample. This may suggest that OcBDE was not used in significant quantities in this area.

Because BDEs in general have high octanol-water partition coefficients, they partition to the particulate matter in the water column to an even greater extent than PCBs. As a result, BDEs in general and especially the high molecular weight congeners are less likely to be found in the effluent because of the excellent solids removal of the Facility. Thus BDE-209 is undetectable in two of the nine effluent samples, despite its being the most abundant congener in many of the other samples (and in most environmental samples). Effluent BDE concentrations contain high proportions of TeBDEs, primarily BDE-47. BDE-47 is the dominant congener in the PeBDE commercial formulations, which include trade names such as DE-71 and 70-5DE, all sold under the name Bromkal.

BDE-28 and BDE-17 are also quite abundant in the effluent, composing up to 24 percent of the sum of BDEs. These two congeners are only very small contributors to the PeBDE technical mixtures. Bromkal DE-71 contains less than 0.1 percent BDE-17 and about 0.25 percent BDE-28 and BDE-33. Bromkal 70-5DE contains about 0.05 percent BDE-17 and 0.1 percent BDE-28. These two congeners are not detectable in the other commercial BDE formulations (La Guardia et al., 2006). Both of these congeners can be produced from the debromination of heavier BDE congeners. The photolysis of BDEs exhibits characteristic pathways and breakdown products (Wei et al., 2013; Fang et al., 2008; Sanchez-Prado et al., 2012; Sanchez-Prado et al., 2006). BDE-15 is a major photolysis product, with BDE-17 sometimes reported as a minor product (Wei et al., 2013; Sanchez-Prado et al., 2012). Several studies have noted that BDE-17 is a major product of microbial BDE debromination (Ding et al., 2013; La Guardia et al., 2007; Tokarz et al., 2008; Robrock et al., 2008). In contrast, Lee et al., 2011 studied the debromination of BDEs by a coculture consisting of Dehalococcoides and Desulfovibrio species, and found that debromination at the ortho position is preferred, with significant amounts of PBDE-15 formed.

Thus the abundance of BDE-17 and BDE-28 indicates that microbial debromination of BDEs is occurring in the system, most likely in the sewers (Rodenburg et al., 2010a and 2012a). The relative lack of BDE-15 suggests that photolysis is not important in this system.

PBDE PMF Analysis

The data set for PMF analysis included 27 of the 47 BDE congeners measured. The excluded congeners were below the detection limit in the majority of samples, so the data set included virtually 100 percent of the mass of all of the BDEs in the data set. As with the PCB PMF analysis, the BDE analysis was performed on blank corrected data and included the duplicates as separate samples. In the future when more samples are collected, duplicates can be excluded. The final matrix contained 27 congeners measured in 47 samples.

Concentration matrix: Values below detection limit composed 209 out of 1,269 data points in the concentration matrix (16 percent). These values were replaced with one-half of the detection limit. Blank correction was performed by subtracting the average concentration of each congener across all blanks from each sample.

LOD matrix: The LOD matrix used the congener- and sample-specific LOD as provided.

Uncertainty matrix: As in other studies (Du et al., 2008; Rodenburg et al., 2008; Rodenburg et al., 2010a), uncertainty was estimated from the surrogate recoveries. The standard deviation of the recoveries of each surrogate was calculated and used as the uncertainty for each congener quantified against that surrogate. For congeners that were quantified relative to more than one surrogate, the uncertainty was propagated for the average surrogate recovery (i.e., the uncertainty was the square root of the sum of the squared uncertainties of all surrogates used). The uncertainty for the values below the detection limit was three times the uncertainty of the detected concentrations (i.e., the [x,3x] uncertainty matrix was used).

PBDE PMF Results

Three factors were resolved from this data matrix. The three-factor model gave the best agreement between the nine seed runs (i.e., the relative standard deviation [RSD] of the G matrix was 1.4 percent) and the agreement between the modeled and measured concentrations was excellent. The correlation coefficient (R^2) for the measured vs. modeled concentrations was greater than 0.80 for 21 of the 27 congeners. The remaining congeners (BDEs 7, 8, 37, 71, 75, 199, and 183) had R^2 values greater than 0.85 when one to six of these outliers were removed from the correlation. The congener patterns for the three factors are shown in Figure 2-21.

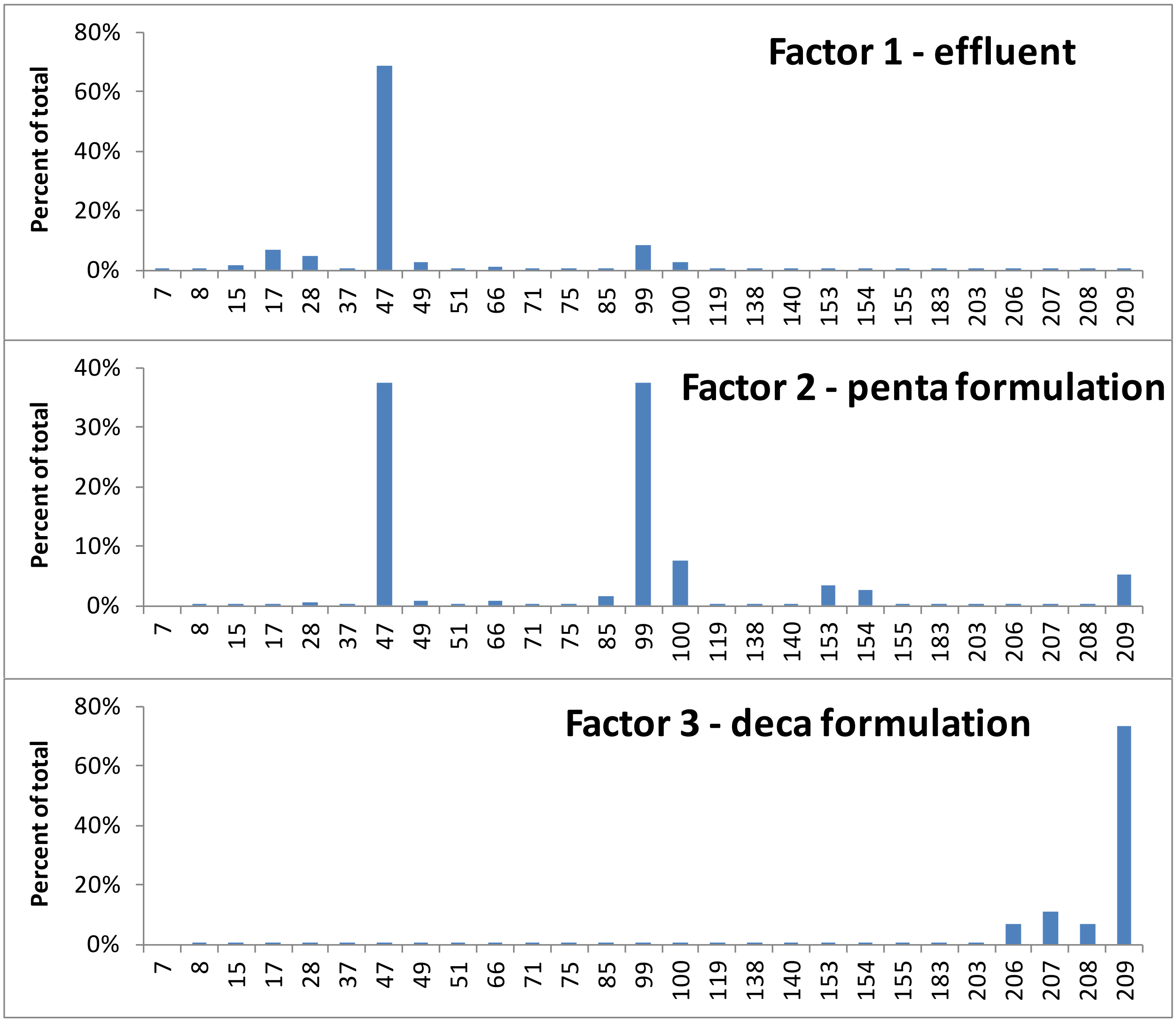

Figure 2-21. Fingerprints of the three resolved BDE factors

Numbers in parentheses are the percent contribution of each factor to the total mass in the data set.

Factor 1 does not strongly resemble any of the technical BDE formulations. Because it contains a relatively high amount (6.9 percent) of BDE-17 and the highest proportions of BDE-7 and BDE-8, it may represent debromination of higher molecular weight BDE congeners. It accounts for only 1 percent of the total mass in the data set, but it is the dominant factor in eight out of the nine effluent samples (Figure 2-19). In the effluent, concentrations of this factor are relatively constant averaging 689 ± 242 pg/L. In this sense, Factor BDE-1 is similar to Factor 1 of the PCB solution. Both appear to represent the dissolved phase. Factor 1 concentrations are significantly higher in SVIPS (4,714 ± 1,459 pg/L) than in NVIPS (2,679 ± 1,136 pg/L). This difference probably arises because Factor 2 is also higher in the SVIPS samples (see below) and Factor 1 represents the fraction of Factor 2 that partitions into the dissolved phase. This interpretation is supported by the fact that concentrations of Factor 1 are strongly correlated with concentrations of Factor 2 ($R^2 = 0.78$).

Factor 2 accounts for 62 percent of the mass in the NVIPS and SVIPS and represents the PeBDE formulations. Concentrations of this factor are significantly higher in SVIPS (273 ± 88 nanograms per liter [ng/L]) than in NVIPS (174 ± 53 ng/L). Note the change in units from pg/L to ng/L. Factor 2 is at low concentrations in the effluent and is removed by the Facility.

Factor 3 is dominated by high MW BDE congeners such as BDEs 206, 207, 208, and 209. It represents the deca-BDE formulation. Concentrations of this factor are not different between SVIPS and NVIPS. This factor is present only occasionally in the effluent, suggesting virtually complete removal

Figure 2-22 shows the contribution of each BDE factor compared to the total BDE mass of the NVIPS, SVIPS, and effluent samples. The PMF results suggest that the commercial PeBDE and DeBDE formulations are the dominant sources of BDEs to the influent.

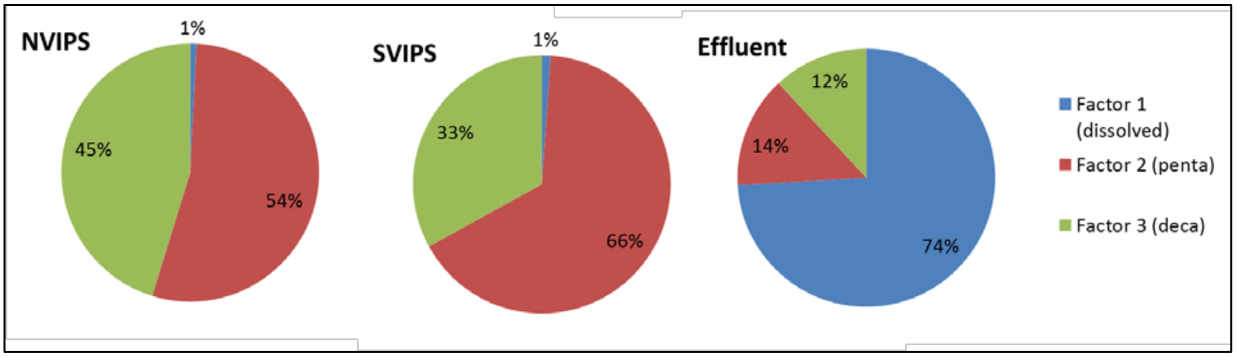

Figure 2-22. Contribution of each BDE factor to the total BDE mass in the NVIPS, SVIPS, and effluent samples

One effluent sample with high BDE-209 concentration was excluded.

PBDE PMF Conclusions

The BDE PMF accounted for nearly 100 percent of the PBDE mass found in the samples. The main source of PBDE is from commercial formulations, such as Bromkal. The 2014 results are similar to those of 2013; therefore, continued monitoring for PBDEs is unlikely to significantly improve the understanding of PBDE sources or management measures.

2.4 Source Assessment

This section discusses potential sources of PCB, Dioxin, and PBDE that could affect Spokane County's wastewater collection system. Potential PCB sources include legacy products, current products, and dispersed sources. These sources are described in the following sections.

Dioxin can be created as a by-product of certain industrial processes involving halogenated substances, such as herbicide or paper production. It can also be produced by combustion of municipal waste and other materials. As noted in Section 2.3, Dioxin has been detected only once in the samples collected to date, at a concentration close to the detection limit.

PBDEs have been used as flame retardants in a variety of household products. Because they are not chemically bound to plastic, foam, fabrics, and other products in which they are used, PBDEs can leach out of those products. There are no water quality or fish tissue standards for PBDEs. The manufacture and import of PeBDEs and OcBDEs were banned in the United States in 2004. The County is not aware of any industrial sources of PBDE within its service area. Ecology (2012) found that wastewater samples from new residential areas contained higher PBDE concentrations than wastewater samples collected from industrial or older residential areas in the Liberty Lake, Washington, study area. Based on the Liberty Lake pilot study, Ecology recommended that efforts to reduce PBDEs in wastewater focus on education of residents and businesses associated with residential work, such as carpet cleaners, laundromats, furniture shops, and re-upholsterers (Fernandez, 2012).

2.4.1 Legacy Products

PCBs are man-made compounds with no natural sources. PCBs were commercially produced in the United States as standard mixtures bearing the brand name Aroclor (Belton et al., 2007). Aroclors were produced from about 1929 until 1979, when EPA banned PCB manufacturing, distribution, and use. Because of the long service life of many PCB-containing items and the use of PCBs in some durable products, Aroclors are still found in some equipment and materials currently in use (Munoz, 2007).

Aroclors were used in a wide range of products, as summarized in Table 2-11 below. Specific Aroclors are defined by a four-digit number. The first two digits refer to the number of carbon atoms in the phenyl ring (for PCBs, this number is 12). The second two digits refer to the percentage of chlorine by mass in the mixture, except for Aroclor 1016, which has 12 carbon atoms but 42 percent chlorine by mass.

Table 2-11. Common Uses of Aroclors

Common uses	Aroclor						
	1016	1221	1232	1242	1248	1254	1260
Adhesives			✓				
Capacitors	✓	✓				✓	
Carbonless copy paper				✓			
Chlorinated rubber						✓	
Cutting oils						✓	
Dedusting agents						✓	✓
Epoxy resins		✓			✓		
Ethylene vinyl acetate						✓	
Gas transmission turbines		✓		✓			
Heat transfer				✓			
Hydraulic fluid			✓	✓	✓	✓	✓
Inks						✓	
Pesticide extenders						✓	
Polyester resin							✓
Polystyrene		✓					
Polyvinyl acetate		✓	✓	✓			
Polyvinyl chloride					✓	✓	✓
Rubber		✓	✓	✓	✓		
Sealants and caulking compounds						✓	
Styrene-butadiene co-polymers						✓	
Synthetic resins						✓	
Transformers				✓		✓	✓
Vacuum pumps					✓	✓	
Varnish							✓
Wax extenders				✓			

Sources: Nagpal (1992), ATSDR (2000).

Table 2-11 indicates the wide range of historical application of Aroclor products. The three Aroclors found in the samples could have originated from sources such as electrical transformers, capacitors, hydraulic fluids, rubber products, varnishes, and a variety of other products. Some of these products can be found in commercial or residential areas as well as industrial areas.

A land use map for the Facility's service area is presented in Figure 2-23. While there are areas of industrial use, at present the data are insufficient to link any of these areas with toxics entering the County's sanitary sewer system.

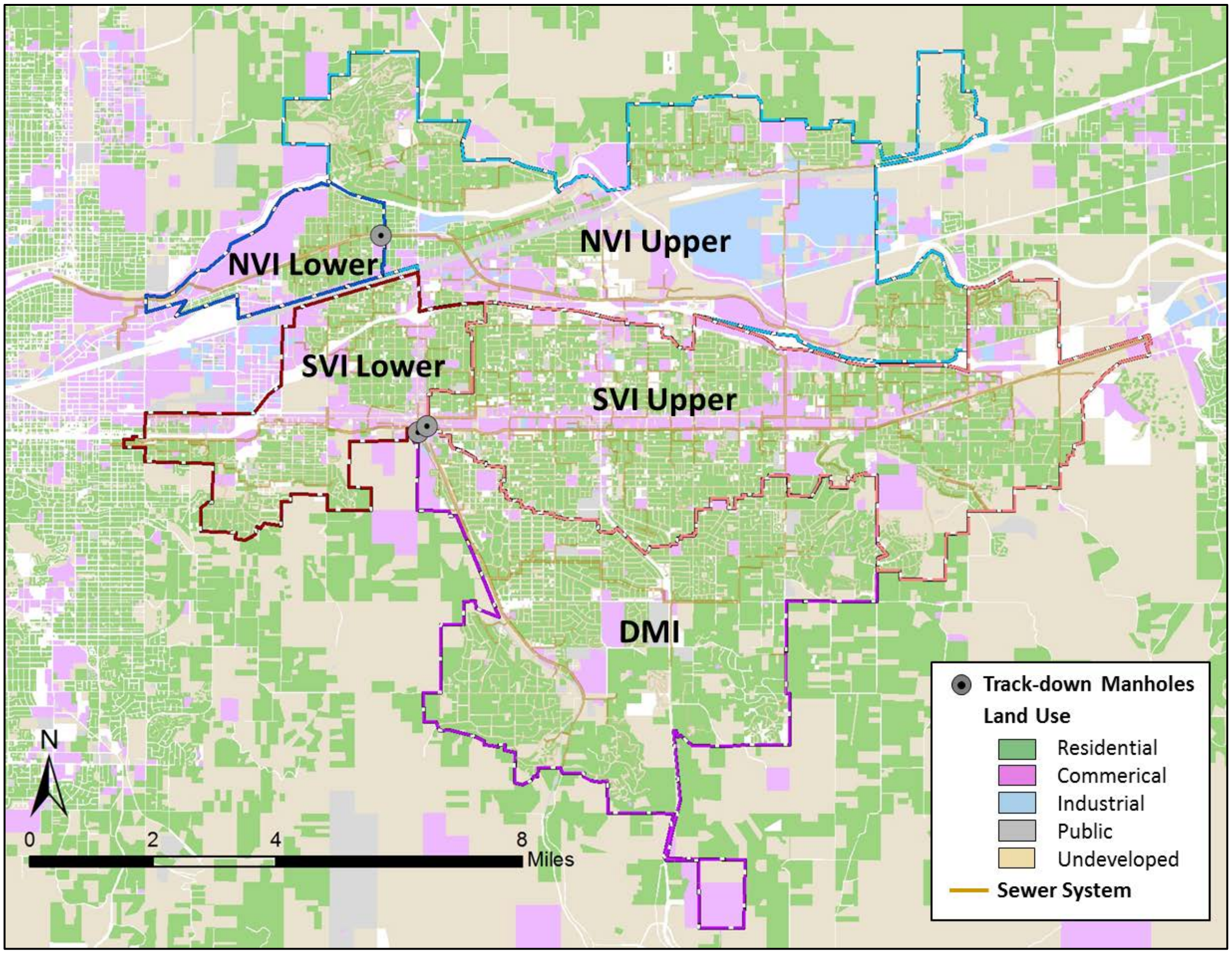

Figure 2-23. Land use in Facility service area

2.4.2 Current Products

Chemical processes involving carbon, chlorine, and high temperatures can inadvertently produce PCBs as by-products. For example, synthesis of diarylide yellow pigment, titanium dioxide white pigment, and silicone rubber tubing have the potential to generate PCB by-products (Rodenburg, 2012b). More than 200 chemical processes can generate PCBs as by-products (Munoz, 2007). The Toxic Substances Control Act (TSCA) allows concentrations of 5 to 50 parts per million (ppm) as manufacturing by-products.

2.4.3 Dispersed Sources

PCBs can enter the air through volatilization and combustion and be deposited on land or water via precipitation or dry deposition (NJDEP, 2009). Precipitation can contain significant concentrations of PCBs (Franz and Eisenreich, 1993; Gregor and Gummer, 1989; Los Alamos National Laboratory, 2012; Offenberg and Baker, 1997). PCBs in precipitation could enter the sewer system via stormwater inflow or groundwater infiltration. PCBs in dry deposition could enter the sewer system via hand-washing, washing of fruits and vegetables, laundry, or other domestic activities.

PCBs can be present in fatty fish and other foods. Some of the ingested PCBs are excreted in fecal matter (Juan et al., 2002; Harrad et al., 2003).

2.4.4 Potential Pathways

PCBs from the potential sources listed above could enter the County's collection system in a variety of ways:

- wastewater discharge from residential, commercial, or industrial land uses
- storm flow runoff that enters the wastewater system via cross-connections or leaky manholes
- groundwater that enters the wastewater system via cracks or leaks

The County's sewer system is relatively new (much of the pipe is less than 10–20 years old) and constructed in accordance with modern sewer codes designed to minimize inflow and infiltration. As a result, flows in the two influent trunk lines do not increase very much during wet weather. Flow and rainfall data were compared for 2012. On the days with the nine largest precipitation events (0.5 to 1.2 inches per day), the observed increase in flow to the Facility ranged from 1 to 11 percent. Larger flow increases were sometimes observed on days without rainfall. These flow and rainfall data suggest that stormwater runoff and groundwater infiltration volumes are relatively minor and are probably minor pathways for PCBs to enter the County's wastewater collection system.

2.4.5 Source Assessment Summary

No specific sources of toxic constituents were identified in 2014. While relatively high PCB concentrations were noted at several track-down sampling locations, those findings were not consistent over the two sampling events this year. As one moves upstream within the collection system toward a PCB source, one would expect the PCB concentration to increase as the sewage flow decreases. The DMI basin comprises approximately 10,000 parcels. Subbasin DMI MHD, which observed the highest PCB concentration recorded in 2014 (53,900 pg/L), comprises approximately 500 parcels. In order to account for the difference in PCB concentrations between the DMI basin (20,375 pg/L) and the other 2013 track-down locations (12,630 pg/L at NVI MH1 and 15,425 pg/L at SVI MH1), the DMI MHD subbasin would need to generate an average PCB concentration of over 120,000 pg/L on a consistent basis. This was not observed, nor was it observed in any of the other track-down subbasins within the DMI sewer basin. The evidence suggests that PCB contamination is more generalized, with a large number of small sources, rather than a small number of large sources, contributing to the influent loading from this basin.

If PCB contamination is from a large number of small sources, a reasonable approach to source assessment would be to group the County customers and assess whether certain groups are discharging disproportionately large amounts of PCBs in the sewage. With the 2014 track-down sampling, customers have been grouped according to the year of structure construction. The basis of this grouping was the supposition that structures built prior to PCB regulations in the late 1970s could discharge relatively more PCB contaminants through leaching from pipe and caulking material, or collection from paint, dust, and other surfaces through the collection and disposal of washwater. With one or two sampling events per track-down location completed to date, the data are inconclusive. The basin with the smallest proportion of older (pre-1980) construction has demonstrated very low levels of PCB contamination (average concentration of 3,940 pg/L at DMI MHF). However, relatively high concentrations have been observed in one basin dominated by homes built in the 1960s and 1970s (53,900 at DMI MHD) as well as in one basin dominated by homes built in the 1980s and 1990s (29,700 pg/L at DMI MHG).

Further track-down efforts will be directed at both stepwise track-down and customer grouping, with an emphasis on customer grouping based on the results observed to date.

The PMF and congener analysis showed that PCB-11 and four of the Aroclors (1242, 1248, 1254, and 1260) compose the bulk of the influent. PCB-11 is found as a manufacturing by-product in diarylide yellow and other pigments used in printing on paper and textiles (Rodenburg, 2011). The abundance of PCB-11 may be linked to dispersed sources (such as household laundries) or active sources. Examples of active sources could include paper and printing industries, textile and apparel manufacturers, paint manufacturers, chemical manufacturers, or manufacturing of miscellaneous materials where dyes or pigments may be used. Figure 2-24 presents a map of all industries in the service area that fit into these categories. The prevalence of such industries is similar in the SVI and NVI basins, with few such industries located in the DMI basin. The four printing locations within the DMI basin are all home-based businesses, and are unlikely to represent major sources of PCB contamination. The upcoming track-down effort will include directed sampling of areas with higher densities of such customers.

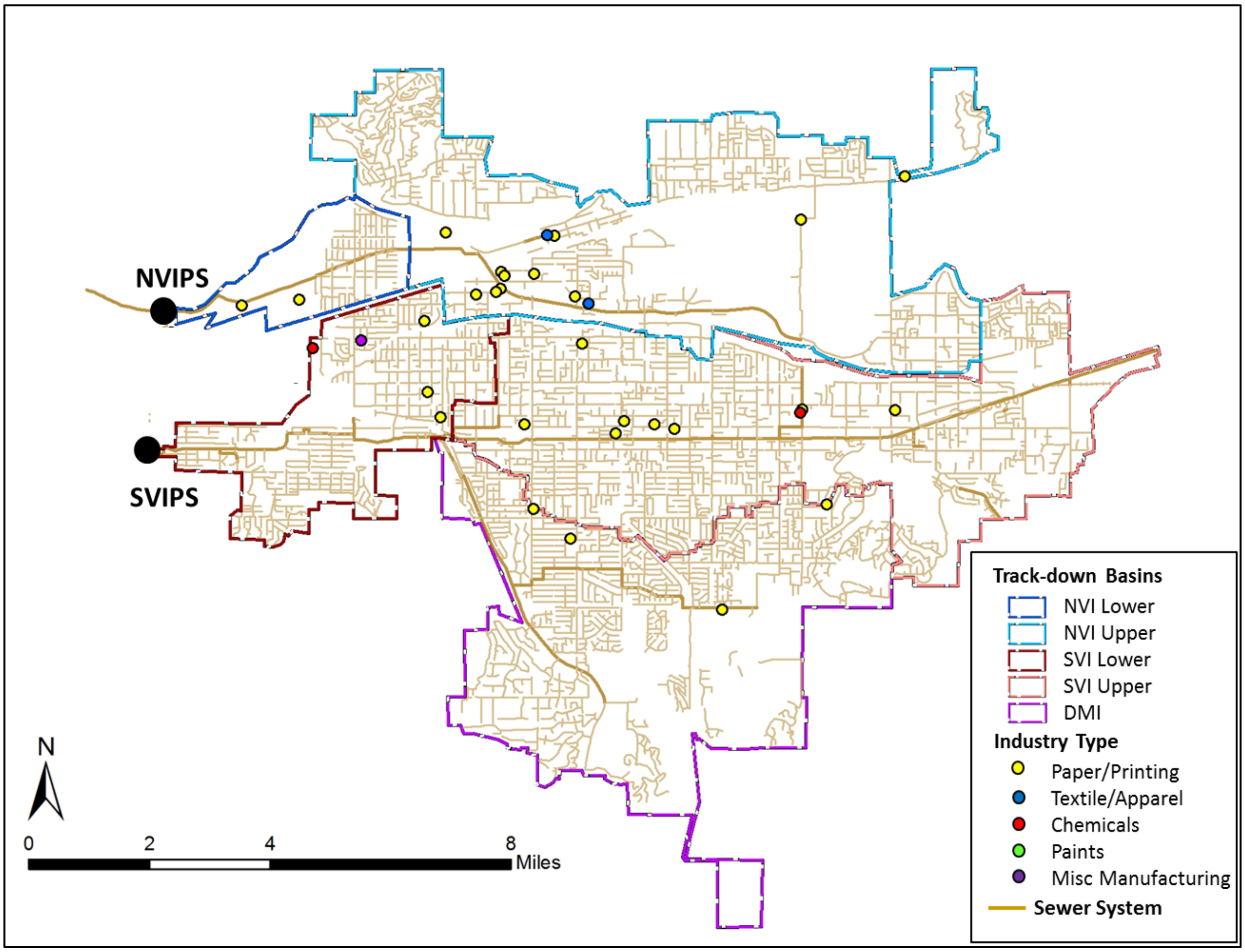

Figure 2-24. Industries that may use or produce dye or pigment

Ongoing collection system track-down sampling suggests that multiple small sources, rather than few large sources, are responsible for the bulk of PCB contamination in the influent. The Toxics Management Action Plan, presented in Section 3 of this Report, describes how Spokane County intends to move forward during the next 2 years to investigate, identify, and mitigate sources of pollutants.

Section 3

Toxics Management Action Plan

This section describes Spokane County's proposed Toxics Management Action Plan for reducing toxics entering the County's wastewater collection system. The County's 4-year plan includes the activities listed below:

1. Source investigation and identification
2. Remediation and/or mitigation of individual sources
3. Application of best management practices (BMPs) to all County sewer customers
4. Application of pretreatment regulations to industrial users

Section 3.1 describes the overall approach. Sections 3.2 through 3.4 describe the proposed activities for the remainder of the Permit term. Toxics Management Action Plans prepared for each subsequent year will be refined based on the increasing body of knowledge.

3.1 4-Year Program Approach

As discussed in Section 2 above, the pollutants targeted in this Toxics Management Action Plan could enter the sewer either via active disposal or passive transport.

<u>Sources of active disposal of toxic compounds of concern could include:</u>

- Industrial, commercial, and residential sites where products or equipment manufactured before 1979 that contain PCBs are still in use, such as older mechanical machinery, electrical equipment and components, and construction material content such as paints and caulking.
- Industrial, commercial, and residential sites with products containing inadvertently produced or unregulated levels of PCBs, such as inks, dyes, soaps, and cleaners from foreign as well as domestic manufacturers. As noted above, TSCA allows concentrations of 5 to 50 ppm as manufacturing by-products.
- Industrial sites where active manufacturing processes are inadvertently generating PCBs below the TSCA limits.

<u>Sources of passive entry of pollutants into the sewer via stormwater runoff, inflow, or infiltration could include</u>:

- locations where legacy products or equipment are still in use and exposed to rainfall or runoff: industrial sites, commercial locations, and private residences
- locations where legacy products have been discarded or disposed-of: vacant lots, open spaces, landfills, and junk yards
- locations where legacy products have been used in the past, and where leakage or spills may have taken place: industrial sites, commercial locations, private residences, vacant lots, and open spaces
- locations where products containing inadvertently produced or unregulated levels of pollutants are used, stored, disposed, or otherwise exposed to rainfall or runoff: industrial sites, commercial locations, and private residences
- locations where pollutants conveyed in the atmosphere or rainfall could enter sewers via inflow or infiltration

Based on the data collected to date, Aroclors 1242, 1248, 1252, and 1260, as well as PCB-11, appear to be potential sources of PCBs to the Facility. As noted in Table 2-11 above, these Aroclors were used in a wide range of commercial products before PCB production was banned in 1979. PCB-11 is virtually absent in Aroclor products, but occurs as a manufacturing by-product in diarylide yellow and other pigments in printing on paper and textiles. Notably, PCB-11 was the most abundant congener found in the effluent samples. It is possible that the most substantive long-term action to reduce PCB-11 loads may be an industry-wide product reformulation on a national or international scale, rather than local source control actions.

The data collected to date suggest that commercial formulations, such as Bromkal, may be important sources of PBDEs to the Facility (see Section 2.3.4.5). Industry-wide product reformulation may be the most effective long-term action to reduce PBDE loads to the Facility.

The County's toxics management program takes a systematic approach to source identification, with an investigative emphasis on tracking down sources of toxic compounds through sampling, and identification of potential products and activities through chemical fingerprinting. Other activities will be directed at remediation and/or mitigation of identified individual sources, and application of BMPs throughout the community.

3.1.1 Source Investigation and Identification

The 4-year approach to source investigation and identification is summarized on Figure 3-1. This approach features a track-down sampling program and chemical fingerprint analysis that is described in detail in the next two sections. This approach was first introduced in the 2013 Annual Toxics Management Report and the implementation of this continued approach is described in this section.

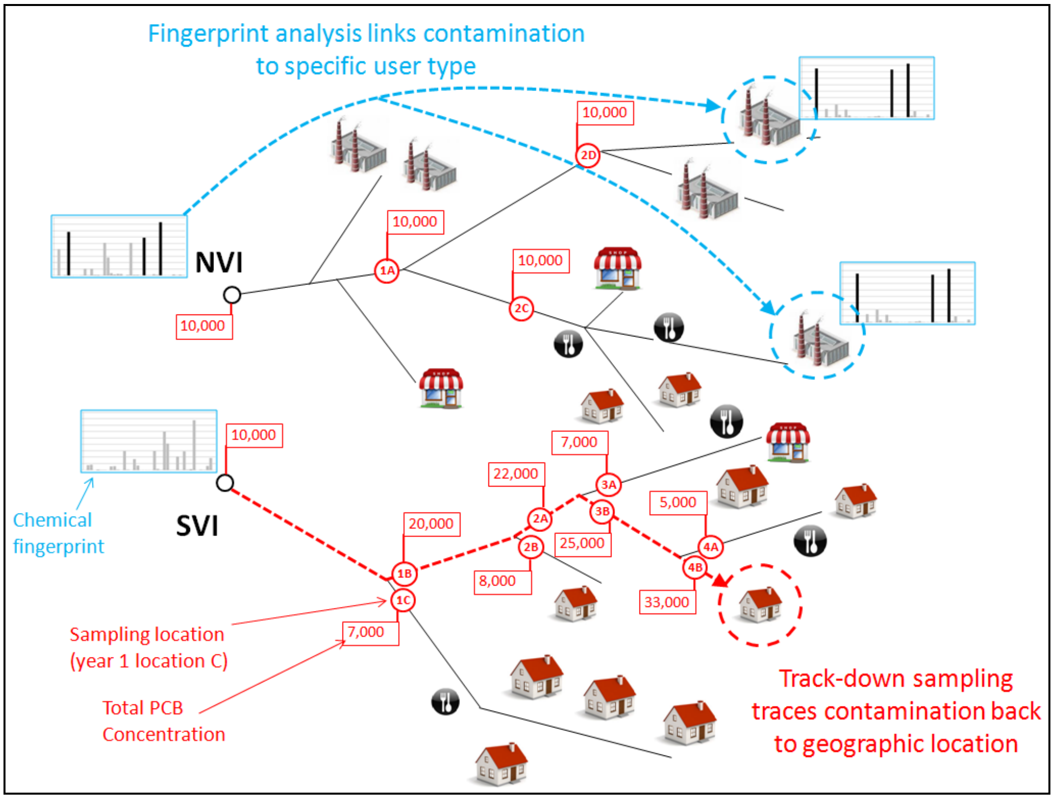

Figure 3-1. Approach to source investigation and identification

Locations, concentrations, and fingerprints on figure are conceptual and have no relation to actual data.

3.1.1.1 Track-Down Sampling

In addition to the ongoing sampling at the NVIPS and SVIPS, the County will collect samples at locations upstream in each interceptor. Each year, sampling locations will move farther upstream and investigate certain hypotheses to help identify potential sources of toxics (Figure 3-1). By tracing relative concentrations upstream and evaluating specific hypotheses related to user type or land use, the program aims to track down sources of toxic compounds and to inform public education programs.

Track-down sampling results will be evaluated during preparation of each annual report. Sampling parameters, locations, and frequency maybe adjusted based on the results.

The track-down sampling was first implemented in 2013. The 2013 sampling divided the service area into five basins. The 2013 track-down sampling focused on PCBs and PBDEs because Dioxin had been detected in only one influent sample since October 2012.

In 2014, track-down sampling was focused on PCBs in the DMI basin. PBDE track-down sampling was completed in 2013, as the PMF analysis accounted for nearly 100 percent of the mass. Section 3.2.2 describes the proposed 2015 track-down sampling.

At this time, the County envisions that 2015 track-down sampling will focus on PCBs in the NVI basin, as discussed in Section 3.3 below.

3.1.1.2 Chemical Fingerprinting and Positive Matrix Factorization

PCBs and PBDEs are groups of chemicals comprising hundreds of individual congeners. By comparing the relative concentrations of congeners in samples against legacy products and other pollutant-containing products, it may be possible to identify specific sources. For example, if samples taken at the NVIPS show a consistent pattern that relates to a specific product or industry, this would allow the targeting of specific sites for further assessment. The fingerprinting analysis could potentially lead to identification of individual sources, as depicted on Figure 3-1. It could also help focus application of BMPs if, for example, the fingerprint analysis indicated that a common construction material, such as paint or caulking, was a likely source.

Chemical fingerprinting was continued for this 2015 Annual Toxics Management Report following the initial analysis in the 2014 Annual Toxics Management Report. The PMF data for PCBs suggest a combination of legacy sources (Aroclors 1016, 1242, 1248, 1252, and 1260) and PCB-11, which is associated with pigments, and is the single most abundant congener in the effluent. The PMF results for PBDEs accounted for nearly 100 percent of the mass and suggest that commercial formulations such as Bromkal are contributing PBDEs to the Facility.

3.1.2 Remediation and/or Mitigation of Individual Sources

If the track-down sampling program or chemical fingerprinting identifies potential individual sources, the County will sample wastewater discharge from the potential source area. If the focused sampling confirms that the source area wastewater PCB concentrations are substantially elevated compared to the NVIPS or SVIPS sample concentrations, the County will notify the property owner about the issue and provide guidance for the property owner to remediate or mitigate the source (depending on the nature of the source [e.g., active process, passive runoff, soil contamination etc.]). Guidance will be based on standards provided by appropriate regulatory agencies and in coordination with the SRRTTF. This may involve educating the property owner about legacy sources (e.g., products containing Aroclors manufactured before 1979), as well as current products that can contain inadvertently produced PCBs (e.g., yellow pigment). Engagement with property owners may be done under the County's Industrial Pretreatment Program and related ordinances (Spokane County Code [SCC] 8.03A) for industrial sources and/or via the County's sewer ordinance (SCC 8.03) for domestic and commercial sources.

3.1.3 Application of Best Management Practices

The County used the track-down sampling and PMF results to help refine and focus its toxic management activities proposed in this Report for upcoming work.

Spokane County's accomplishments during 2014 included public education, participation in the SRRTTF, and other activities as follows:

- Public education on toxics management: Public education is a critical component of the County's ongoing efforts to reduce toxic pollutant loadings to the Facility. The County is an active participant in the SRRTTF and is developing a targeted, regional public education program in coordination with the SRRTTF. In 2014, the County began a targeted, multimedia public outreach program for residential and commercial/industrial sewer customers. The program identifies commonly used products known to contain PCBs and informs customers about the existing health advisories, effects of PCBs on public health, and measures that they can take to reduce PCB releases to the environment. The education program also promotes proper handling and disposal practices of materials that are known to contain PCBs. Information has been disseminated via various mailings and utilities billings inserts, the Spokane County Utilities Web site, and public events at the Spokane County Water Resource Center. Product-specific information is limited but is developed and disseminated when appropriate and reliable information is available. The following specific activities were accomplished by Spokane County in the past year:
  - Hired a water resources communications specialist to implement outreach and education and to participate on the SRRTTF
  - Updated County web presence to include PCB information
  - Developed and mailed a PCB primer to all County wastewater treatment customers, both commercial/industrial and residential (about 40,000 customers)
  - Developed a PCB informational poster for display in the Water Resource Center and other venues
  - Coordinated an Open House event at the Water Resource Center, including PCB information, in November 2014
  - Coordinated a meeting with other regional municipal wastewater treatment entities to discuss coordinated and consistent outreach to commercial and pretreatment customers
  - Prepared and sent a letter to County pretreatment customers requesting individual meetings to provide PCB information
  - Presented at several area conferences regarding the results thus far of the track-down sampling and treatment efficiency
  - Provided input to the Washington Legislature regarding the Toxics Management Act
  - Provided in-kind and financial support to the local EnviroStars program, a local source control/waste minimization program aimed at businesses
  - Provided financial support for PCB monitoring and education by the SRRTTF.
- Played an active role in the SRRTTF including financial support for administrative and technical tasks
- Supported industry-wide reformulation of products that can contain elevated concentrations of PCB-11 (e.g., diarylide yellow and other pigments used in printing and textiles), as well as commercial products that contain elevated PBDE concentrations (e.g., Bromkal).
- Elimination of older, County-owned, mechanical and electrical machinery: The County removed all known PCB-containing light ballasts and transformers from County-owned facilities in 1993 and 1995. The County Facilities Department will continue to remove and dispose of the remaining PCB-

containing materials and equipment as they are encountered. These materials are profiled and disposed of during annual hazardous waste identification and disposal activities.

- Regional clearinghouse: The County continued to contribute data on observed PCB concentrations and patterns from the County's monitoring program to the SRRTTF's regional clearinghouse. The County data, in combination with data submitted by others, will increase understanding of the potential sources of PCBs in the region and help focus regional management efforts.
- Procurement policies: The County supported the SRRTTF in identifying commercial products that could contain inadvertently produced PCBs. This past year the County passed a revised procurement practices ordinance that allows for PCB testing of products and preferential purchasing of non-PCB equivalents within cost controls, similar to the City of Spokane and State of Washington. The newly passed purchasing ordinance now allows the County to minimize purchase of PCB-containing products.

3.2 Toxics Management Action Plan for 2015

This section summarizes the sampling and analysis to be conducted from April 2015 through March 2016. The purpose of proposed actions for 2015 includes continued compliance with the Permit and continued systematic analysis and track-down of toxics in subbasins of the Facility's sewersheds. Actions to be conducted prior to the next annual report include the following:

- Continued sampling of the two influent trunk lines (NVIPS and SVIPS) and the Facility effluent per the terms of the Permit
- Year 3 of track-down sampling in the NVI collection system for PCBs only
- Continued chemical fingerprinting analysis
- Conducting initial source control measures

These actions were chosen as next steps in the continued systematic analysis and track-down approach and are described further in the following sections.

3.2.1 Continued Sampling at Influent Trunk Lines and Facility Effluent

NPDES-mandated sampling of the NVIPS, SVIPS, and Facility effluent will continue per the terms of the Permit. By the publication of the April 2016 annual report, the following data will have been collected during the period of study:

- 20 samples of PCB and Dioxin data at each influent trunk line (i.e., NVIPS and SVIPS), for a total of 80 samples
- 13 samples of PCB, Dioxin, and PBDE data at the Facility effluent, for a total of 39 samples
- 13 samples of PBDE at the NVIPS and SVIPS, for a total of 26 samples
- QA/QC samples per the approved QAPP

The additional data should allow for an assessment of variability over time. Continuing fingerprinting analysis of the PCB and PBDE congener data will also be performed in order to assess similarities and differences in the PCB makeup of the wastewater in each influent trunk line. These analyses may assist with point source identification and continuing track-down analysis. They may also provide guidance with respect to application of BMPs or industrial pretreatment regulations.

3.2.2 Year 3 of Track-Down Sampling (2015)

The County evaluated the first 2 years of track-down results in order to develop its strategy for future track-down sampling. The 2013 sampling plan focused on manholes upstream of the NVIPS and SVIPS locations, NVI MH1, SVI MH1, and DMI MH1.

The following bullets summarize the findings from the 2013 track-down sampling:

- PCB concentrations were higher at the DMI track-down location (DMI MH1) than at either of the other two track-down locations (SVI MH1 or NVI MH1) or at the SVIPS.
- PCB concentrations at the NVIPS appeared higher than those observed at NVI MH1, suggesting potential PCB sources between these two locations.
- The PCB PMF results identified six factors. The PMF was able to account for about 60 percent of the mass of PCBs.
- PBDE concentrations were more varied than PCB concentrations, and the differences between sites were less notable.
- The PMF results for PBDEs suggest dispersed sources related to commercial products that are still in widespread use. The PMF was able to account for nearly 100 percent of the PBDE mass.
- Based on the 2013 results, the County focusedits 2014 track-down sampling on PCBs in the DMI basin in 2014. The following bullets summarize the findings from the 2014 track-down sampling.The PCB PMF results identified seven factors. The PMF was able to account for about 90 percent of the mass of PCBs.
- Most of the factors are strongly correlated to Aroclors and Aroclor mixtures. The exception is Factor 2, which is mainly composed of PCB-11, which is often found in yellow dyes and pigments. Factor 2 was more prevalent at NVIPS than at SVIPS.
- Upstream sampling within the DMI noted relatively high variability in PCB concentrations over time and space, but the limited number of sampling events limits the statistical relevance of the findings. None of the track-down locations registered PCB concentrations high enough to independently account for the relatively high average concentration noted at the DMI MH1 in 2013. Rather, the high concentration appears more likely the result of moderately elevated concentrations from multiple sources.
- Track-down sampling efforts aimed to differentiate PCB contamination by the age of construction within the DMI subbasins. While the lowest overall concentrations were observed in the basin most dominated by new construction, no statistically relevant trend was observed in the other basins given the limited data.

Based on the 2013 and 2014 results, year 3 track-down sampling will wrap up analysis of the DMI basin and then focus on the NVI basin. Track-down sampling will have three directives:

1. Confirm the diffuse nature of PCBs in the DMI subbasins. The 2014 sampling developed a limited dataset for the DMI subbasins. A further round of sampling in these subbasins will be completed to support the evidence that PCBs are ubiquitous at relatively low levels in the DMI subbasins.
2. Sample the NVI Lower basin—the basin located between the NVIPS and NVI MH1. In 2013, PCB concentrations were consistently higher at the NVIPS than at the upstream NVI MH1, suggesting a relatively higher contribution of PCBs between the two sampling locations. Notably, the highest PCB concentration noted to date (67,600 pg/L) was noted at NVIPS, during an event where the PCB concentration at the upstream NVI MH1 was only 16,000 pg/L.
3. An attempt to discern relationships between customer type and average PCB concentration. The NVI basin has a relatively large industrial customer component. Track-down efforts will focus on industrial and light industrial zones. The data may be compared against residential sampling in the DMI basin in 2014 to determine whether the user class may be applied as an indicator or predictor of PCB contamination in the sewage. As part of this effort, areas with multiple textile and paper industries will be investigated throughout the NVI basin (Figure 2-24).

In line with these efforts, six potential sites have been identified for track-down sampling within the NVI basin (Figure 3-2). Two of these sites are located in the NVI Lower basin (NVI L-MHA and NVI L-MHB), while the others are located in the NVI Upper basin.

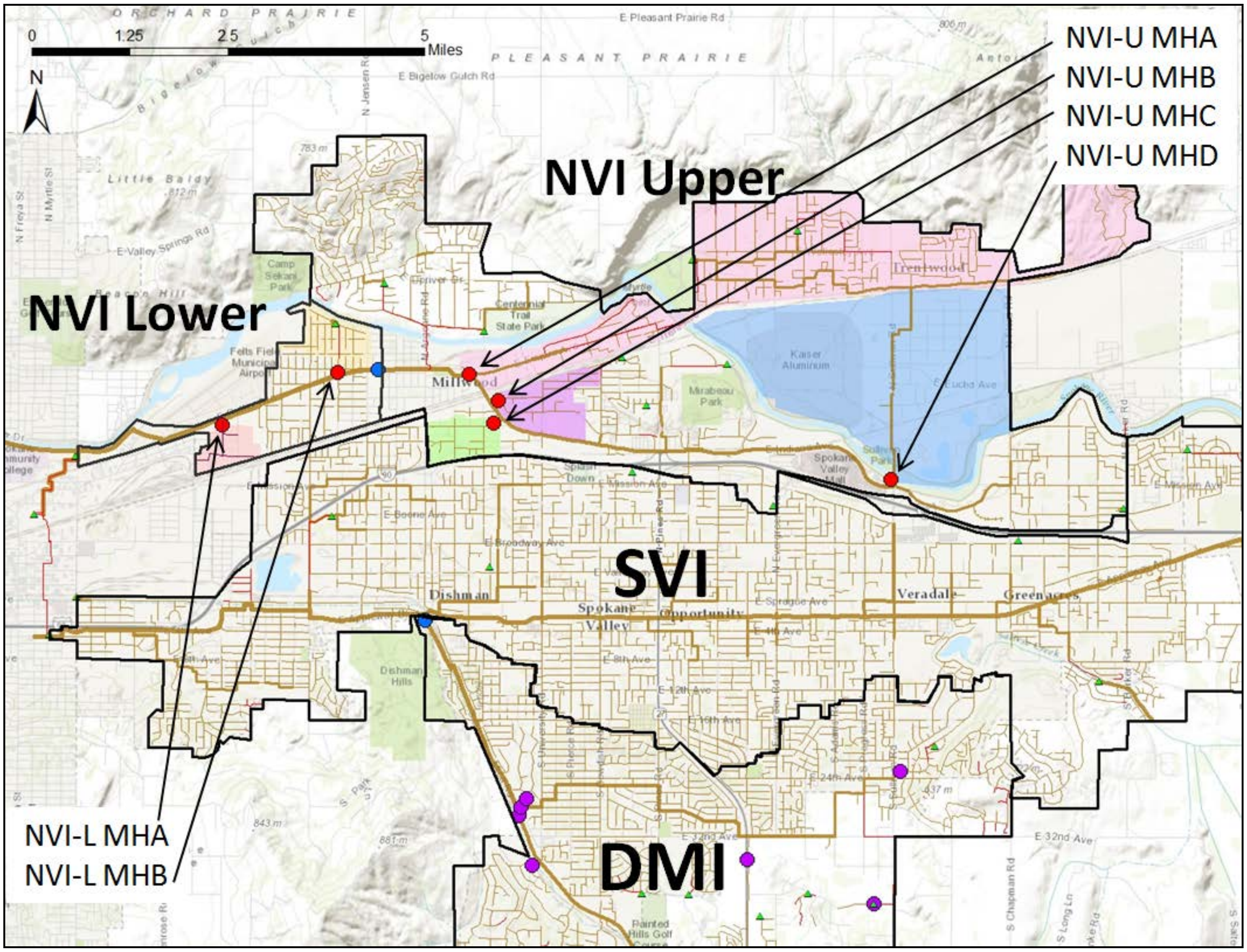

Figure 3-2. Potential sampling locations for track-down analysis for 2014

Based on field conditions, the number of sites sampled and the locations may be adjusted. The 2014 track-down sampling locations will be described in further detail in the 2015 revised QAPP. Additionally, an adaptive monitoring approach will be used based on the results from the sampling analysis to determine how many subsequent samples are taken at each proposed manhole location.

The QAPP will be amended to reflect the new track-down sampling approach. QA/QC samples will be collected in accordance with the approved QAPP. Each sample will be tested for PCBs. This sampling will allow for these upstream samples to be compared to the samples collected from the two influent trunk lines (i.e., at the NVIPS and SVIPS).

Track-down sampling will be evaluated during preparation of each annual report. Sampling locations and frequency may be adjusted based on the results.

3.2.3 Chemical Fingerprinting Analysis

Chemical fingerprinting analysis will be expanded to include the Year 3 (2015) track-down sampling locations. With each year, the database of results will increase, and the accuracy of the fingerprinting analysis will improve. With an increased number of sampling locations, the fingerprinting analysis may help to establish relationships between sources of toxics and specific locations within the collection system, and specific user characteristics.

3.2.4 Source Control Measures

The County will continue to apply the BMPs summarized in Section 3.1.3. These actions include active participation in the SRRTTF, development of a targeted public education program, ongoing removal of PCB-containing equipment and machinery, and revision of County procurement practices. Depending upon the results of chemical fingerprinting and track-down analysis, initial source control measures may extend to individual source remediation and/or mitigation, if individual sources are identified.

The County plans to expand its public education program. Planned education activities for 2015 include:

- Spring and fall open houses at the Water Resource Center
- Increase collaboration with non-dischargers to disseminate toxics management information (e.g., Spokane Riverkeeper)Provide updates as warranted to wastewater treatment customers regarding new and useful PCB information that can provide consumer guidance
- Updates to PCB information on the County website
- Meet with pretreatment customers to review latest information on PCBs
- Presentations at area conferences and to citizen groups
- Provide input to the Legislature regarding impending legislation regarding PCBs
- Continue in-kind and financial support to the local EnviroStars program

Additionally, Spokane County plans to:

- Support industry-wide reformulation of products that can contain elevated concentrations of PCB-11 as well as commercial products that contain elevated PBDE concentrations (e.g., Bromkal)
- Continue to contribute data on PCB concentrations and sources to the SRRTTF's regional clearinghouse to help increase understanding of the potential sources and to help regional management efforts
- Continue to play an active role in the SRRTTF including financial support for administrative and technical tasks
- Continue to support the SRRTTF in identifying commercial products that could contain inadvertently produced PCBs
- Continue to review the County wastewater customer database in light of the ongoing chemical fingerprinting analysis, and perform follow-up actions as appropriate.

3.3 Toxics Management Action Plan for 2016

In March and April 2016, the County will evaluate the results of the NVIPS and SVIPS sampling and track-down sampling conducted during 2015. The evaluation will look for differences in PCB concentrations related to land use and year of construction to discern potential sources. Chemical fingerprinting analyses will continue and expand to identify the types of products that could account for the observed PCB patterns. The analytical data and evaluation of potential sources will be presented in the April 2016 Annual Toxics Management Report.

At this time, it is envisioned that the 2016 track-down sampling will focus on the SVI sewersheds.

The April 2016 Toxics Management Action Plan will describe the proposed track-down sampling, source investigations, and focused control measures to be implemented in 2016 (if sources are identified). The County will update the QAPP as needed to guide the track-down sampling and source investigations.

The April 2016 Toxics Management Action Plan will also update the County's proposed BMPs for reducing use of products that could contain PCBs. The County will work with the SRRTTF to refine these BMPs and develop new BMPs based on the lessons learned during 2015.

3.4 Annual Toxics Management Report for 2016

The County will prepare the April 2016 Annual Toxics Management Report to summarize the County's toxic source control program, actions completed, BMPs implemented, and source identification results. In addition, the 2016 document will include a summary of all of the toxics sampling and laboratory results completed by the County under the current NPDES Permit.

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Section 4

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Appendix A: Quality Control Comment/Action Records

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Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polychlorinated Biphenyl (PCB)
Laboratory report checked by: Valerie Fuchs

Batch Date: 3/14/2014
Batch ID: WG46535
Check Date: 4/14/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	**BC Response**
1. Data are considered final. 2. Data are not blank corrected.	None.

Quality Control
Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polychlorinated Biphenyl (PCB)
Laboratory report checked by: Valerie Fuchs

Batch Date: 5/21/2014
Batch ID: WG47248
Check Date: 5/28/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	**BC Response**
Revised 21-May-14: 1. Revised the EDD to include omitted Homologue Totals and TEQ data. Please discard previously submitted data and accept this data as final. 2. Data are considered final. 3. Data are not blank corrected.	No action necessary.
4. A disturbance of the mass ion used to monitor instrument performance (lock-mass) greater than method specifications was observed in sample ‘SVIPS PCB’ (AXYS ID:L21382-7) near the retention time corresponding to PCB 197/200 and in the Laboratory Blank (AXYS ID: WG47248-102) near the retention time corresponding to PCB 2 and these targets have been flagged with a ‘G’. PCB 197/200 and PCB 2 are not major contributors to the total concentration of PCB in these samples, respectively, and data are not considered significantly affected.	None of the G-flagged data account for more than 2% percent of the total PCB concentration reported for the respective sample. The data are accepted, but G flags will be retained for future reference.

Brown AND Caldwell

Quality Control
Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polychlorinated Biphenyl (PCB)
Laboratory report checked by: Valerie Fuchs

Batch Date: 7/24/2014
Batch ID: WG47904
Check Date: 8/6/2014

DESCRIPTION:

QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

The total concentrations of the duplicate (split) sample were within 12% of each other, meeting the QAPP requirement of equal to or less than 50% relative percent difference.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	**BC Response**
1. Data are considered final. 2. Data are not blank corrected.	No action necessary.
3. The recovery of different 13C-labelled PCB congeners in different samples did not meet the method criteria; these compounds are flagged with a 'V'. As the isotope dilution method of quantification produces data that are recovery corrected, the slight variances from the method acceptance criteria are deemed not to affect the quantification of the analytes.	TBD. SVIPS and the Lab Blank both had 77% passing; all other samples were greater than 95%. The spiked matrix had 87% passing. All of the V-flagged congeners were below the 25% recovery acceptance limit. Most were between 20-25%. Congeners with recovery less than 20% are as follows: for the lab blank 104L was 18% and 155L was 16.3%. For DMI-MHA, 155L was 18.2% and 209L was 18.5%. The data are accepted, but V flags will be retained.

Brown AND Caldwell

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services	Batch Date: 9/24/2014
Laboratory analysis type: Polychlorinated Biphenyl (PCB)	Batch ID: WG48374
Laboratory report checked by: Valerie Fuchs	Check Date: 9/29/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.
3. A disturbance of the mass ion used to monitor instrument performance (lock-mass) greater than method specifications was observed in samples near the retention time corresponding to some targets and quantification standards and have been flagged with a ‘G’.	21 congeners from 5 samples (SVIPS, NVIPS, DMI-MHE, DMI-MHF, DMI-MHG) are flagged with a 'G'. The total mass of G-flagged congeners is less than 5% of the total sample mass for all samples. The data are accepted, but G flags will be retained.

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polychlorinated Biphenyl (PCB)
Laboratory report checked by: Valerie Fuchs

Batch Date: 11/20/2014
Batch ID: WG49261
Check Date: 11/25/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Additional comment: The effluent rinsate blank did not meet QA/QC requirements and the backup was analyzed in December 2014. Data for the effluent rinsate backup was included in the December 2014 laboratory report.

Quality Control

Comment/Action Record

CLIENT: County of Spokane, WA
PROJECT NAME: Spokane County PCB Study
PROJECT NUMBER: 142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polychlorinated Biphenyl (PCB)
Laboratory report checked by: Valerie Fuchs

Batch Date: 1/09/2015
Batch ID: WG49800
Check Date: 1/22/2015

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

The total concentrations of the duplicate (split) sample were within 17% of each other, meeting the QAPP requirement of equal to or less than 50% relative percent difference.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	**BC Response**
1. Data are considered final 2. Data are not blank corrected.	None.
3. Relative Retention Times (RRTs) corresponding to PCB 170 in sample Travel Blank PCB (AXYS ID L22546-1), PCB 123 in sample NVIPS PCB (AXYS ID L22546-3), PCB131, 132, 133, 134/143, 139/140, 144,145,147/149 and 148 for sample SVIPS PCB (AXYS ID: L21314-4) are outside the RRT QC limits provided in Form 4A for the short-list calibration verification and Form 3A for the long-list calibration (data filename: PB5C_005 S: 1 for both forms). These compounds were determined to be present by visual inspection and comparing to the calibration chromatogram pattern. Data are not considered affected.	Concentrations of affected congeners are relatively low; RRT is not considered to be significant.

Quality Control
Comment/Action Record

CLIENT: County of Spokane, WA
PROJECT NAME: Spokane County PCB Study
PROJECT NUMBER: 142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Dioxin/Furan
Laboratory report checked by: Valerie Fuchs

Batch Date: 3/13/2014
Batch ID: WG46537
Check Date: 3/26/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	**BC Response**
1. Data are considered final. 2. Data are not blank corrected.	None.
3. The recovery of 13C-labeled-2,3,7,8-TCDD in sample Travel Blank TCDD (AXYS ID L21009-2) is slightly outside the method acceptance criteria; this compound has been flagged with a 'V'. As the isotope dilution method of quantification produces data that are recovery corrected, the slight variances from the method acceptance criteria are deemed not to affect the quantification of these analytes. Percent surrogate recoveries are used as general method performance indicator only.	Recovery of 13C-labeled-2,3,7,8-TCDD was 36% (target 35%); does not appear to be outside of acceptance criteria. This congener is not flagged in the data file. 37CL-labeled-2,3,7,8-TCDD is flagged with V but also does not appear to be outside of acceptance criteria. The data are accepted but V flags are retained.

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Dioxin/Furan
Laboratory report checked by: Valerie Fuchs

Batch Date: 5/20/2014
Batch ID: WG47244
Check Date: 5/28/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Dioxin/Furan
Laboratory report checked by: Valerie Fuchs

Batch Date: 7/15/2014
Batch ID: WG47905
Check Date: 8/7/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Brown AND
Caldwell

Quality Control

Comment/Action Record

CLIENT: County of Spokane, WA
PROJECT NAME: Spokane County PCB Study
PROJECT NUMBER: 142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Dioxin/Furan
Laboratory report checked by: Valerie Fuchs

Batch Date: 10/30/2014
Batch ID: WG48981
Check Date: 12/19/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Additional comment: On September 24, 2014, AXYS notified BC that the TCDD samples did not pass AXYS QA/QC requirements, and recommended analyzing the backup. The data provided in the 2015 Annual Toxics Management Report is for the TCDD backup samples.

Brown AND Caldwell

Quality Control
Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Dioxin/Furan
Laboratory report checked by: Valerie Fuchs

Batch Date: 11/19/2014
Batch ID: WG49184
Check Date: 11/25/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Dioxin/Furan
Laboratory report checked by: Valerie Fuchs

Batch Date: 1/07/17
Batch ID: WG49801
Check Date: 1/22/2015

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data and data quality checks met the requirements of the QAPP.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	**BC Response**
1. Data are considered final. 2. Data are not blank corrected.	None.

Brown AND Caldwell

Quality Control
Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polybrominated Diphenylether (PBDE)
Laboratory report checked by: Valerie Fuchs

Batch Date: 3/05/2014
Batch ID: WG46538
Check Date: 4/14/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data were deemed usable for the intended purposes of this study.

The total concentrations of the duplicate (split) sample were within 16% of each other, meeting the QAPP requirement of equal to or less than 50% relative percent difference.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Brown AND Caldwell

Quality Control

Comment/Action Record

CLIENT: County of Spokane, WA
PROJECT NAME: Spokane County PCB Study
PROJECT NUMBER: 142892

Laboratory report prepared by: AXYS Analytical Services
Laboratory analysis type: Polybrominated Diphenylether (PBDE)
Laboratory report checked by: Valerie Fuchs

Batch Date: 5/20/2014
Batch ID: WG47245
Check Date: 5/28/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data were deemed usable for the intended purposes of this study.

The total concentrations of the duplicate (split) sample were within 5% of each other, meeting the QAPP requirement of equal to or less than 50% relative percent difference.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Brown AND Caldwell

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services	Batch Date: 9/22/2014
Laboratory analysis type: Polybrominated Diphenylether (PBDE)	Batch ID: WG48416
Laboratory report checked by: Valerie Fuchs	Check Date: 9/29/2014

DESCRIPTION:

QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data were deemed usable for the intended purposes of this study.

The total concentrations of the duplicate (split) sample were within 5% of each other, meeting the QAPP requirement of equal to or less than 50% relative percent difference.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected. Data are not blank corrected. Sample data should be evaluated with consideration of analyte levels in the Lab Blank (AXYS ID WG48416-101).	None.

Quality Control

Comment/Action Record

CLIENT:	County of Spokane, WA
PROJECT NAME:	Spokane County PCB Study
PROJECT NUMBER:	142892

Laboratory report prepared by: AXYS Analytical Services	Batch Date: 11/22/2014
Laboratory analysis type: Polybrominated Diphenylether (PBDE)	Batch ID: WG49260
Laboratory report checked by: Valerie Fuchs	Check Date: 12/05/2014

DESCRIPTION:
QA/QC was performed on the AXYS laboratory data based on the measurement quality objectives detailed in the QAPP. All data were deemed usable for the intended purposes of this study.

The total concentrations of the duplicate (split) sample were within 5% of each other, meeting the QAPP requirement of equal to or less than 50% relative percent difference.

Laboratory check/spiked samples were within the percent recovery range required in the QAPP.

ADDITIONAL REMARKS / COMMENTS:

AXYS Comments	BC Response
1. Data are considered final. 2. Data are not blank corrected.	None.

Appendix B: Laboratory Results from AXYS and Anatek

Submitted electronically

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Draft response to downstream waters comments

Comments paraphrased:

Comments from tribes, enviro groups, public: The new HHC will not protect the consumption uses of downstream tribal waters, usual and accustomed waters, and waters shared with other states.

Comments from EPA: explain how narrative provision protects downstream waters - provide rationale detailing how use of a narrative downstream protection criterion alone will protect Oregon's more stringent water quality standards.

Also from EPA:

> *"...most of Washington's rivers are in the Columbia River basin and are, therefore, upstream of Oregon's portion of the Columbia River. In addition, the Columbia River creates most ofthe Washington-Oregon border. Since approximately 90% ofWA's proposed human health criteria are higher than Oregon's EPA-approved criteria for the same pollutants, the EPA strongly encourages Ecology to consider adopting numeric criteria (either in addition to or instead of narrative criteria) that ensure the attainment and maintenance of Oregon's downstream WQS, or to provide additional rationale detailing how the use of a narrative downstream protection criterion alone will protect Oregon's more stringent WQS. For waters flowing into Oregon, criteria that are equally stringent or more stringent than Oregon's human health criteria would better ensure the attainment and maintenance of Oregon's downstream WQS consistent with 40 CFR 131.10(b). This aligns with the EPA's previous statements regarding a desire for regional consistency in human health criteria among Region 10 states."*

RESPONSE STARTS BELOW

Responses to comments on protection of downstream waters are addressed in the discussion below:

What are the requirements on downstream waters protection that are in the federal water quality standards regulation (40CFR131)?

The federal regulations specify how states are to address downstream waters in development of state water quality standards. These two requirements are found in 40 CFR 131.10 as follows:

> *"Subpart B—Establishment of Water Quality Standards*
> *§ 131.10 Designation of uses.*
> *(b) In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."*

These requirements are broken out as:

- ...the State shall take into consideration the water quality standards of downstream waters
- ...the State... shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters.

These two specific requirements of states are addressed more fully below.

Has Ecology fulfilled the federal requirements? Yes, as explained in 1 and 2 below.

1. …the State shall take into consideration the water quality standards of downstream waters

Washington formally took into consideration the water quality standards of downstream waters by (1) placing language requiring protection of downstream waters in the draft rule and (2) by considering all public comments that were received during the public comment period, regarding downstream waters protection, as the final rule was developed.

2. …the State… shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters.

Rule narrative language in WAC 173-201A ensures that Washington's water quality standards provide for attainment and maintenance of the water quality standards of downstream waters as follows (relevant section in boldface):

Washington water quality standard from WAC 173-201A-260 that provides for attainment and maintenance of the water quality standards of downstream waters	What does this language mean?
New language: WAC 173-201A-240 Toxic substances. (b) Human health protection. The following provisions *apply to the human health criteria in Table 240. All waters shall maintain a level of water quality when entering downstream waters that provides for the attainment and maintenance of the water quality standards of those downstream waters, including the waters of another state.*	This language explicitly requires upstream water quality to provide for attainment and maintenance of downstream water quality standards. This language was taken from EPA's *Templates for Narrative Downstream Protection Criteria in State Water Quality Standards* (EPA 2014, 820-F-14-002) at http://water.epa.gov/scitech/swguidance/standards/narrative.cfm .
WAC 173-201A-260 Natural conditions and other water quality criteria and applications. (3) Procedures for applying water quality criteria. *In applying the appropriate water quality*	This language allows for case-by-case establishment of additional requirements to fully support designated and existing uses.

criteria for a water body, the department will use the following procedure: *(a) The department will establish water quality requirements for water bodies, in addition* *to those specifically listed in this chapter, on a case-specific basis where determined* *necessary to provide full support for designated and existing uses.*	
WAC 173-201A-260 Natural conditions and other water quality criteria and applications. (3) Procedures for applying water quality criteria. *In applying the appropriate water quality* *criteria for a water body, the department will use the following procedure:* *(b) Upstream actions must be conducted in manners that meet downstream water body* *criteria....*	This language directs that upstream actions (such as discharges into waters) must be conducted in a manner to meet downstream criteria.

Does Ecology's approach align with federal guidance and federal precedent?

Federal Guidance: Ecology did not follow the approach to downstream waters protection that is the focus of the EPA 2014 guidance FAQ. The language in EPA's downstream guidance FAQ, which is not a rule and is thus not binding on states, addresses the uses and criteria sections of the water quality standards (and acknowledges the antidegradation section), but does not mention or take into account the General Provisions portions of the standards, described in EPA's Water Quality Standards Handbook (Chapter 1: General Provisions (40 CFR 131.1-131.6; http://water.epa.gov/scitech/swguidance/standards/handbook/chapter01.cfm) as follows:

> *"WQS consist of the following elements:*
>
> - *Designated use or uses such as "supporting aquatic life" or "recreation" (which are described in Chapter 2 of this Handbook).*
> - *Water quality criteria necessary to protect the designated uses (which are described in Chapter 3 of this Handbook).*
> - *Antidegradation requirements (which are described in Chapter 4 of this Handbook).*
> - *General policies affecting the application and implementation of WQS that states and authorized tribes may include at their discretion (e.g., mixing zone, variance, and critical low-flow policies, which are described in Chapter 5 of this Handbook)."*

The downstream waters protection approach that is used in the Washington standards (language in table above) is best described by language developed by EPA (2004; http://water.epa.gov/scitech/swguidance/standards/upload/Sierra-Club-Petition-Response-signed-2004-06-25.pdf) in its decision on how to address a settlement agreement petition: *"Decision on petition for rulemaking to publish water quality standards for the Mississippi and Missouri Rivers within Arkansas, Illinois,* *Iowa, Kansas, Kentucky, Missouri, Nebraska and Tennessee."* The language from that document addresses a situation where, because of issues surrounding downstream waters protection, EPA was petitioned by the Ozark Chapter of the Sierra Club to *"publish water quality standards for the Mississippi and Missouri Rivers within the petition area states. Such standards should be: 1) Consistent among the states on each river, such that no state impairs the ability of any other affected state (whether across-stream or downstream) to achieve its water quality standards; and..."* (EPA 2014).

EPA's response to that petition includes:

> *Protection of Downstream Uses*
> *The federal regulations state, "In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters." 40 C.F.R. §131.10(b).* ***The regulations do not compel states to adopt the same criteria and uses, nor do they suggest that this is the only way a state can meet these requirements. The water quality program is structured to provide states with flexibility to determine the best way to meet their obligations under § 131.10(b).***
>
> *Under the NPDES permitting regulations, no permit may be issued "when the imposition of conditions cannot ensure compliance with applicable water quality requirements of all affected States[.]" 40 C.F.R. §122.4(d). To obtain approval of a state NPDES program, the CWA requires the state to have the authority to notify other affected states of applications for permits and provide an opportunity for a hearing. CWA section 402(b)(3). Further, the state must allow any state whose waters may be affected by the discharge to submit recommendations. If the permitting state rejects the recommendations, it must notify the affected state and EPA Administrator. CWA section 402(b)(5). Where EPA determines the permitting state rejected the recommendations for inadequate reasons, EPA may exercise its discretionary authority to object to the permit. If the objection is not resolved, EPA may issue a federal permit. 40 C.F.R. §123.44(c)(2).*
> *(Page 4, EPA 2004)*

In this response EPA states that the federal regulations do not compel states to adopt the same criteria and uses, or even suggest that this is the only way a state can meet the requirements to protect downstream waters, and that the federal water quality program is structured to provide states with flexibility to determine the best way to meet their obligations under § 131.10(b). The Washington water quality standards contain the combination of a direct statement on downstream protection (new proposed language), an allowance for additional requirements, and requirements for upstream actions implemented under various CWA permitting programs.

What about the general comment that water quality standards upstream should be as stringent as the downstream standards in order to protect downstream uses, especially with regard to the risk levels used in criteria calculations?

This is best responded to by language developed by EPA (2004; http://water.epa.gov/scitech/swguidance/standards/upload/Sierra-Club-Petition-Response-signed-2004-06-25.pdf) in its decision on how to address a settlement agreement petition: *"Decision on petition for rulemaking to publish water quality standards for the Mississippi and Missouri Rivers within Arkansas, Illinois, Iowa, Kansas, Kentucky, Missouri, Nebraska and Tennessee."* The language from that document addresses a situation where, because of issues surrounding downstream waters protection, EPA was petitioned by the Ozark Chapter of the Sierra Club to *"publish water quality standards for the Mississippi and Missouri Rivers within the petition area states. Such standards should be: 1) Consistent among the states on each river, such that no state impairs the ability of any other affected state (whether across-stream or downstream) to achieve its water quality standards; and..."* (EPA 2014).

The states along the Mississippi River have differing risk levels (PCB example given):

> *"EPA acknowledges there are variations in the numeric PCB criteria adopted by the petition states. There are four legitimate reasons why the numeric PCB criteria vary within the petition area:...*
>
> *...(3) As discussed in the "Statutory and Regulatory Background" section, EPA publishes section 304(a) criteria based on a 10–6 risk level for carcinogens; states may select a specific risk level based on their own risk management decisions. EPA believes that adoption of criteria within a risk level of 10–6 (one in a million incremental risk for cancer) or 10–5 (one in one hundred thousand incremental risk for cancer) represents an acceptable range of risk management discretion for states and tribes.[24] Within the petition states, each state adopts criteria to protect human health based on risk management decisions. Iowa, Arkansas, Tennessee, and Nebraska have adopted PCB criteria based on a 10-5 risk level; Illinois, Kentucky and Missouri have adopted PCB criteria based on a 10-6 risk level; and Kansas chose to adopt a PCB criterion to protect human health at a 10-7 risk level.*
>
> *[24] U.S. Environmental Protection Agency. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). Office of Water. Washington, D.C. EPA-822-B-00-004. <http://www.epa.gov/waterscience/humanhealth/method > October 2000."*
>
> *(Pages 17-18, EPA 2004)*

The human health criteria differed among states for a number of valid reasons, among them the differing risk levels. EPA language for PCBs is below:

> *"As discussed above, Iowa and Missouri adopted a numeric PCB criterion to protect human health based on the toxicity information available in IRIS that was updated in 1989. With regard to the Sierra Club's specific concern about Iowa's PCB criterion as compared to Missouri's criterion, EPA found that Iowa's criterion is an order of magnitude greater than Missouri's because Iowa has chosen to protect human health at a 10-5 risk level while Missouri protects human health at a 10-6 risk level. With regard to the Sierra Club's specific concern about Nebraska's PCB criterion as compared to Missouri, EPA found that Nebraska adopted a numeric PCB criterion to protect human health based on EPA's section 304(a) criteria recommendations published in 1999 (Missouri used the updated 1999 IRIS data), but chose a 10-5 risk level. As a result, Nebraska's PCB criterion is greater than Missouri's criterion."*
>
> *(Page 18, EPA 2004)*

These differences in criteria were not found to be cause for EPA to promulgate consistent criteria across the states:

> *"…the regulations do not compel states to adopt the same criteria and uses in order to provide for attainment and maintenance of downstream water quality standards (40 C.F.R. §131.10(b)), nor do the regulations suggest that this is the only way a state can meet the requirements under § 131.10(b). The water quality program is structured to provide states with flexibility to determine the best way to protect their designated uses and meet their obligations under § 131.10(b)."*
>
> *(Page 19, EPA 2004)*

How does Ecology protect downstream uses as it implements the water quality standards?

Ecology implements the standards in its permitting and certification processes, as well as in its Water Clean-up (Total Maximum Daily Load) program. The requirements for downstream protection (as per WAC 173-201A-260) apply to all criteria, including toxic and conventional pollutants. An example for each are below.

Example 1 – NPDES permit – Human health criteria pollutants (XXX Have Vince fill in table)	
NPDES permit reissuance	Weyerhaeuser permit and number and date
Receiving water (shared with Oregon)	Columbia River
Human health criteria pollutants found in discharge	PCBs
Reasonable potential determination	
Effluent limits	
Verification that Oregon standards would be met	

Example 2 – TMDL – conventional pollutants (nutrients)	
TMDL	*Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load: Water Quality Improvement Report* (2007, as revised in 2010)
Receiving water	Discharges to Spokane River. Downstream impacts occurring in Long lake
Conventional pollutants found in point and non-point source discharges	Nutrients causing downstream dissolved oxygen depletion
Basis of allowable loading of phosphorus and nitrogen	The allowable loads to the Spokane River were based on meeting the dissolved oxygen criteria in downstream Long Lake
Effluent limits	Based on meeting the load allocations in the TMDL
Verification that downstream standards will be met	The TMDL and effluent limits are based on meeting dissolved oxygen standards in Long Lake. Effectiveness monitoring will verify improvements in water quality over time.

Environ Monit Assess
DOI 10.1007/s10661-006-9216-7

ORIGINAL ARTICLE

Contaminant exposure in outmigrant juvenile salmon from Pacific Northwest estuaries of the United States[1]

Lyndal L. Johnson · Gina M. Ylitalo · Mary R. Arkoosh · Anna N. Kagley · Coral Stafford · Jennie L. Bolton · Jon Buzitis · Bernadita F. Anulacion · Tracy K. Collier

Received: 5 October 2005 / Accepted: 17 February 2006

Abstract To better understand the dynamics of contaminant uptake in outmigrant juvenile salmon in the Pacific Northwest, concentrations of polychlorinated biphenyls (PCBs), DDTs, polycylic aromatic hydrocarbons (PAHs) and organochlorine pesticides were measured in tissues and prey of juvenile chinook and coho salmon from several estuaries and hatcheries in the US Pacific Northwest. PCBs, DDTs, and PAHs were found in tissues (whole bodies or bile) and stomach contents of chinook and coho salmon sampled from all estuaries, as well as in chinook salmon from hatcheries. Organochlorine pesticides were detected less frequently. Of the two species sampled, chinook salmon had the highest whole body contaminant concentrations, typically 2–5 times higher than coho salmon from the same sites. In comparison to estuarine chinook salmon, body burdens of PCBs and DDTs in hatchery chinook were relatively high, in part because of the high lipid content of the hatchery fish. Concentrations of PCBs were highest in chinook salmon from the Duwamish Estuary, the Columbia River and Yaquina Bay, exceeding the NOAA Fisheries' estimated threshold for adverse health effects of 2400 ng/g lipid. Concentrations of DDTs were especially high in juvenile chinook salmon from the Columbia River and Nisqually Estuary; concentrations of PAH metabolites in bile were highest in chinook salmon from the Duwamish Estuary and Grays Harbor. Juvenile chinook salmon are likely absorbing some contaminants during estuarine residence through their prey, as PCBs, PAHs, and DDTs were consistently present in stomach contents, at concentrations significantly correlated with contaminant body burdens in fish from the same sites.

Keywords Chinook salmon · Coho salmon · Contaminants · PAHs · PCBs · DDTs · Pesticides · Washington · Oregon · Estuary

1 Introduction

Estuaries are important habitats for salmon during the juvenile stage of their life cycle, when they make the transition from freshwater to the ocean (Healey, 1982). Estuaries provide outmigrating juvenile salmon with a refuge from predators, a rich food supply that supports rapid growth, and appropriate conditions for the physiological adaptation to saltwater (Dorcey *et al.*, 1978; Simenstad *et al.*, 1982). However, urban and industrial development may impair the quality of estuarine habitats. Estuaries located near urban centers often receive inputs of toxic contaminants from municipal and industrial activities (Brown *et al.*, 1998; USEPA,

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[1] Environmental Monitoring and Assessment

1997), which may be taken up by juvenile salmon and their prey. Because juvenile salmon are in a period of rapid development, and undergoing many physiological changes during their residence in estuarine environments, they may be especially vulnerable to the deleterious effects of toxic chemicals.

The well-documented presence of chemically contaminated sediments in Puget Sound urban estuaries (e.g., Malins *et al*., 1982) prompted a series of studies to examine the degree to which juvenile salmon were exposed to toxic chemicals during estuarine residence (McCain *et al*., 1990; Varanasi *et al*., 1993; Stein *et al*., 1995; Stehr *et al*., 2000). Juvenile salmon (primarily chinook and coho, *Onchorhynchus tshawytscha* and *O. kisutch)* were sampled from several urban and non-urban estuaries in Puget Sound including the Green River/Duwamish Estuary system in Seattle, the Puyallup River/Hylebos Waterway system in Tacoma, and the more rural Snohomish River and Nisqually River Estuaries. Juvenile chinook salmon from hatcheries associated with sampled estuaries were also collected and whole bodies and stomach contents were analyzed for chemical concentrations. Results of these surveys showed that outmigrating juvenile chinook salmon from the Duwamish and Hylebos Waterways exhibited consistent evidence of exposure to contaminants. Juvenile chinook salmon from the Snohomish Estuary, which has some urban development, also appeared to be exposed to contaminants, but to a much lesser degree than salmon from the Duwamish and Hylebos Waterways. In addition, when held in tanks with flow-through seawater for a period of several months, juvenile salmon from the Duwamish Estuary exhibited reduced growth and reduced disease resistance when compared to salmon from either the Green River Hatchery (the primary source of salmon for the Duwamish Estuary) or to salmon from the nonurban Nisqually system (Arkoosh *et al*., 1998; Casillas *et al*., 1995). Similar effects were observed for juvenile salmon from the Hylebos Waterway (Arkoosh *et al*., 2001; Casillas *et al*., 1998). Chemical contaminant exposure in the estuary appeared to place additional stresses on juvenile chinook salmon that could affect their long-term health and survival as they enter the marine environment.

To increase our knowledge of concentrations of chemical contaminants in outmigrant salmon in the Pacific Northwest, we carried out an expanded study from 1996–2001 in which juvenile coho and chinook salmon were collected for contaminant analyses from a number estuaries in Washington and Oregon. Classified by the overall level of development and channel alteration in each estuary (Cortright *et al*., 1987), the sampling areas included: five deep draft estuaries, with the maximum level channel alteration and urban development (Duwamish Estuary, Columbia River, Grays Harbor, Yaquina Bay, and Coos Bay); two shallow draft estuaries with less extensive channel alteration and some urban and industrial development (Tillamook Bay and Coquille River), four conservation estuaries, where channel alteration is minimal and development is limited (Skokomish Estuary, Nisqually Estuary, Willapa Bay and Alsea Bay); and two natural estuaries, which are largely undeveloped for residential, commercial or industrial uses (Elk River and Salmon River). Predominantly wild fish were collected in the estuaries, although some fish of hatchery origin may have been sampled due to incomplete marking of hatchery fish. Juvenile chinook salmon were also sampled from regional hatcheries to evaluate contaminant uptake during rearing but prior to release. Our results indicate that exposure to chemical contaminants is widespread in outmigrant juvenile chinook and coho salmon, and concentrations in tissues of chinook salmon from several estuaries are high enough to pose a potential threat to their health and survival.

2 Materials and methods

2.1 Collecting juvenile salmon

Juvenile, subyearling chinook salmon were collected from a number of Washington and Oregon estuaries over a 6-year period (1996–2001; Fig. 1; Table 1). The Washington estuaries included: Skokomish and Nisqually Estuaries; Duwamish Estuary, and Grays Harbor and Willapa Bay. The Oregon estuaries included the Columbia, Salmon, Coquille, and Elk Rivers; and Yaquina, Alsea, and Coos Bays. Juvenile coho were also collected from Grays Harbor and Willapa, Yaquina, Alsea, and Coos Bays during 1998 (Fig. 1; Table 1). Due to the pattern of salmon movement in the estuaries, we generally sampled on early morning outgoing tides. Salmon were caught with a beach seine net 36.6 meters in length. The wings of

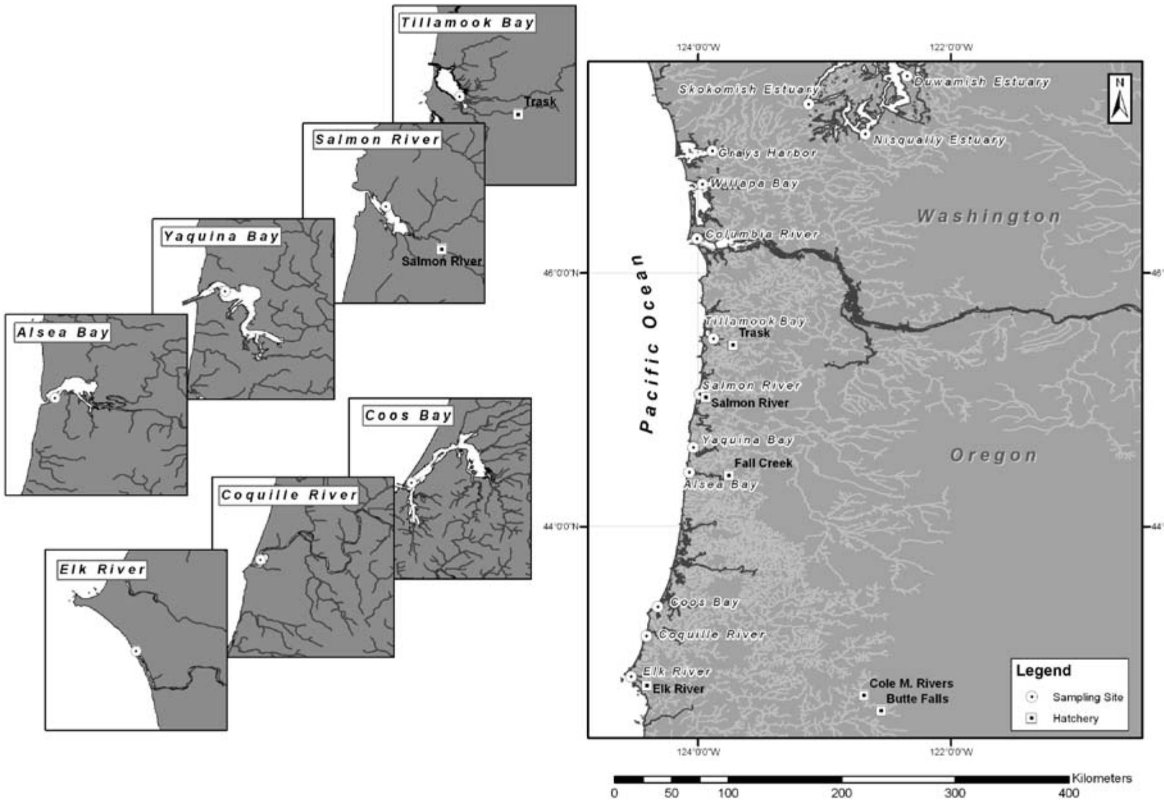

Fig. 1 Locations of hatcheries and estuaries where juvenile coho and chinook salmon were collected

the net were 18 meters long by 2.3 meters deep with 0.6 cm mesh.

Appropriate sampling permits were obtained from the National Marine Fisheries Service (NMFS), and the Oregon and Washington Departments of Fish & Wildlife prior to sampling. To ensure sampling of wild fish instead of hatchery-reared fish we attempted to collect fish from field sites prior to releases from hatcheries or other programs (such as the Salmon and Trout Enhancement Program or STEP). Although a few fin-clipped hatchery fish were collected and sampled, we did not include these fish in our analyses. Once target salmonids were removed from the net they were placed in insulated aerated tanks and transported live to the nearest laboratory, either the Hatfield Marine Science Center in Newport, Oregon; the University of Oregon's Oregon Institute of Marine Biology in Charleston, Oregon; the U.S. Fish and Wildlife's Olympia Fish Health Center in Olympia, Washington, the Point Adams Field Station in Hammond, Oregon or the Northwest Fisheries Science Center in Seattle, Washington, where they were necropsied within a few hours of collection. Juvenile chinook salmon were also obtained directly from several hatcheries (Fall Creek, Butte Falls, Cole M. Rivers, Elk River, Salmon River, and Trask; see Fig. 1 for locations) to evaluate contaminant uptake during hatchery rearing. Juvenile hatchery coho salmon were not available for sampling at the time of the survey.

Fish to be necropsied were measured (to the nearest mm) and weighed (to the nearest 0.1 g), then sacrificed by a blow to the head. Bile and stomach contents were removed, and composites of 10–15 fish each were generated. Whole gutted bodies from 10 fish were also collected and composited. Bile and stomach contents samples were frozen and stored at −80 °C and whole body samples were frozen and stored at −20 °C until chemical analyses were performed. Sampling sites, dates, and sample types collected are listed in Table 1. Because of limitations associated with fish availability and tissue requirements for analysis, not all samples types could be collected each year from all sites.

Table 1 Sites sampled in Washington and Oregon for juvenile salmonids. Sites were classified by estuary type according to Cortright *et al*. (1987). N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary NS = not sampled; CH = chinook sampled; CO = coho sampled. wb = whole body sampled; b = bile sampled; s = stomach contents sampled

	1996	1997	1998	1999	2000	2001
WA						
Skokomish Estuary (C)	NS	NS	CH (wb,b)	CH (wb,b)	CH (b)	NS
Duwamish Estuary (D)	NS	NS	CH (wb,b)	CH (wb,b,s)	NS	NS
Nisqually Estuary (C)	NS	NS	CH (wb,b,s)	CH (wb,b,s)	NS	NS
Grays Harbor (D)	NS	NS	CH (wb,b.s) CO (wb,b,s)	CH (wb,b,s)	NS	NS
Willapa Bay (C)	NS	NS	CH (wb,b,s) CO (wb,b,s)	CH (wb,b,s)	NS	NS
Columbia River (D)	NS	NS	CH (wb,s)	CH (wb,b,s)	CH(b,s)	CH (b)
OR						
Salmon River (N)	CH (wb)	NS	CH (b)	CH (wb,s)	CH (wb,s)	CH (wb,s)
Yaquina Bay (D)	NS	NS	CH (wb,b,s) CO (wb,b,s)	CH (wb,b,s)	CH (wb,s)	CH (b) CO (wb,s)
Alsea Bay (C)	CH (wb,b)	NS	CH (wb,s) CO (wb,b,s)	CH (wb,b,s)	CH (wb,b,s)	CH (wb,b,s) CO (wb,s)
Coos Bay (D)	CH (wb)	NS	CH (wb,b,s) CO (wb,b,s)	CH (wb,b,s)	CH (wb,s)	NS
Coquille River (S)	CH (wb)	NS	NS	NS	NS	NS
Elk River (N)	CH (wb)	NS	CH (wb,b.s)	NS	CH (wb,s)	CH (wb,b,s)
Salmon River Hatchery	CH (wb)	NS	NS	NS	NS	NS
Fall Creek Hatchery	CH (wb)	NS	NS	NS	NS	NS
Trask Hatchery	CH (wb)	NS	NS	NS	NS	NS
Butte Falls Hatchery	CH (wb)	NS	NS	NS	NS	NS
Cole M. Rivers Hatchery	CH (wb)	NS	NS	NS	NS	NS
Elk River Hatchery	CH (wb)	NS	CH (wb,s)	NS	NS	NS

2.2 Sample analyses

2.2.1 *Organochlorine and aromatic hydrocarbon analyses of composite whole body and stomach content samples*

Samples in this study were analyzed using a performance-based measurement system (Telliard, 1999), described in detail by Sloan *et al*. (1993) and updated in Sloan *et al*. (2005). Briefly, after the addition of surrogate standards, samples of up to 3 g were extracted with dichloromethane either by homogenizing in the presence of sodium sulfate (Sloan *et al*., 1993) or utilizing accelerated solvent extraction (Sloan *et al*., 2005). For composite whole body samples, a portion of the extract was taken for gravimetric lipid determination. The portion of the extract to be analyzed underwent initial cleanup by filtering through silica gel and neutral alumina, followed by the addition of a recovery standard to determine the fraction of the total extract analyzed. After further sample cleanup using high-performance liquid chromatography with size-exclusion chromatography, the sample fraction containing organochlorines (OCs) and 2–6 ring aromatic hydrocarbons was collected. The fraction was reduced in volume, a GC standard was added, and the sample was analyzed using high-resolution gas chromatography coupled with electron capture detection (samples analyzed for OCs 1996–1998; Sloan *et al*., 1993) or mass spectrometry with selected-ion monitoring (samples analyzed for OCs 1999–2001; Sloan *et al*., 2005) with 5–10 levels of calibration standards. Concentrations of aromatic hydrocarbons (stomach contents samples only) were analyzed in all sampling years by high-resolution gas chromatography with mass spectrometry using selected ion monitoring and 5–6 levels of calibration standards. Quality assurance measures included analysis of a certified reference material and a laboratory blank with each batch of samples. Performance criteria were met for all samples and sample batches.

Analyses for OCs included individual PCB (polychlorinated biphenyl) congeners, DDTs, chlordanes, lindane, aldrin, dieldrin and mirex. PCBs measured over all years included a standard list of 17 congeners (IUPAC numbers 18, 28, 44, 52, 95, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, and 209). Total PCBs was calculated by summing the concentrations of these individual congeners and multiplying the result by two. This formula provides a good estimate of the total PCBs in a typical environmental sample of sediments or animals feeding on lower trophic levels, where a mixture of Aroclors 1254 and 1260 is the predominant pattern (Lauenstein *et al.*, 1993). Summed DDTs (ΣDDTs) levels were calculated by summing the concentrations of o,p'- and p,p'-DDD, o,p'- and p,p'-DDE, and o,p'- and p,p'-DDT. Summed chlordanes (ΣCHLDs) were calculated by summing the concentrations of heptachlor, heptachlor epoxide, γ-chlordane, α-chlordane, oxychlordane, *cis*-nonachlor, *trans*-nonachlor and nonachlor III. Summed low molecular weight aromatic hydrocarbons (ΣLAHs) were determined by adding the concentrations of biphenyl, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, 2,6-dimethylnapthalene, acenaphthene, fluorene, phenanthrene; 1-methylphenanthrene, and anthracene. Summed high molecular weight aromatic hydrocarbons (ΣHAHs) were calculated by adding the concentrations of fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene, benzo[e]pyrene, perylene, dibenz[a,h]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, indenopyrene, and benzo[ghi]perylene. Summed total aromatic hydrocarbons (ΣAHs) were calculated by adding ΣHAHs and ΣLAHs.

2.2.2 PAH metabolites in bile

Composite samples of bile were analyzed by high-performance liquid chromatography with fluorescence detection (HPLC/uvf) for aromatic hydrocarbon (AH) metabolites as described in Krahn *et al.* (1986). In brief, bile was injected directly onto a C18 reverse-phase column (Phenomenex Synergi Hydro) and eluted with a linear gradient from 100% water (containing a trace amount of acetic acid) to 100% methanol at a flow of 1.0 mL/min. Chromatograms were recorded at the following wavelength pairs: 1) 260/380 nm where several 3–4 ring compounds (e.g., phenanthrene) fluoresce and 2) 380/430 nm where 4–5 ring compounds (e.g., benzo[a]pyrene) fluoresce. Peaks eluting after 5 minutes were integrated and the areas of these peaks were summed. The concentrations of fluorescent AHs in bile were determined using phenanthrene (PHN) and benzo[a]pyrene (BaP) as external standards and converting the fluorescence response of bile to phenanthrene (ng PHN equivalents/g bile), and benzo[a]pyrene (ng BaP equivalents/g bile) equivalents. Bile metabolites fluorescing at phenanthrene wavelengths were considered an indicator of exposure to low molecular weight PAHs, while metabolites fluorescing at benzo[a]pyrene (BaP) wavelengths were considered as an indicator of exposure to high molecular weight PAHs.

2.2.3 Statistical methods

Statistical analyses were conducted with the Statview©statistical software package (SAS Institute, Inc., Cary, NC, USA). Temporal and intersite differences in tissue, stomach contents, and bile contaminant concentrations were determined by ANOVA. Data were log-transformed as necessary to achieve a normal distribution. The significance level for all analyses was set at $\alpha = 0.05$.

3 Results

3.1 Lipid content in whole bodies

Lipid content (as total extractable organics) in bodies of chinook salmon collected from the estuaries varied from 0.8% in fish from Tillamook Bay to 3.5% in fish from Coquille River, with an average concentration of 2.4% (Fig. 2; Table 2). Lipid levels in juvenile coho salmon were slightly lower, with an average concentration of 1.2% (Fig. 2; Table 2), but not significantly different than levels in estuarine chinook salmon (ANOVA, $p = 0.08$). Lipid concentrations in hatchery chinook salmon were significantly higher than in estuary chinook (ANOVA, $p = 0.001$), with an average concentration of 7.9% (Fig. 2; Table 2). The number of samples collected (typically one composite per site or hatchery) was too small for intersite or interhatchery differences to be meaningfully evaluated,

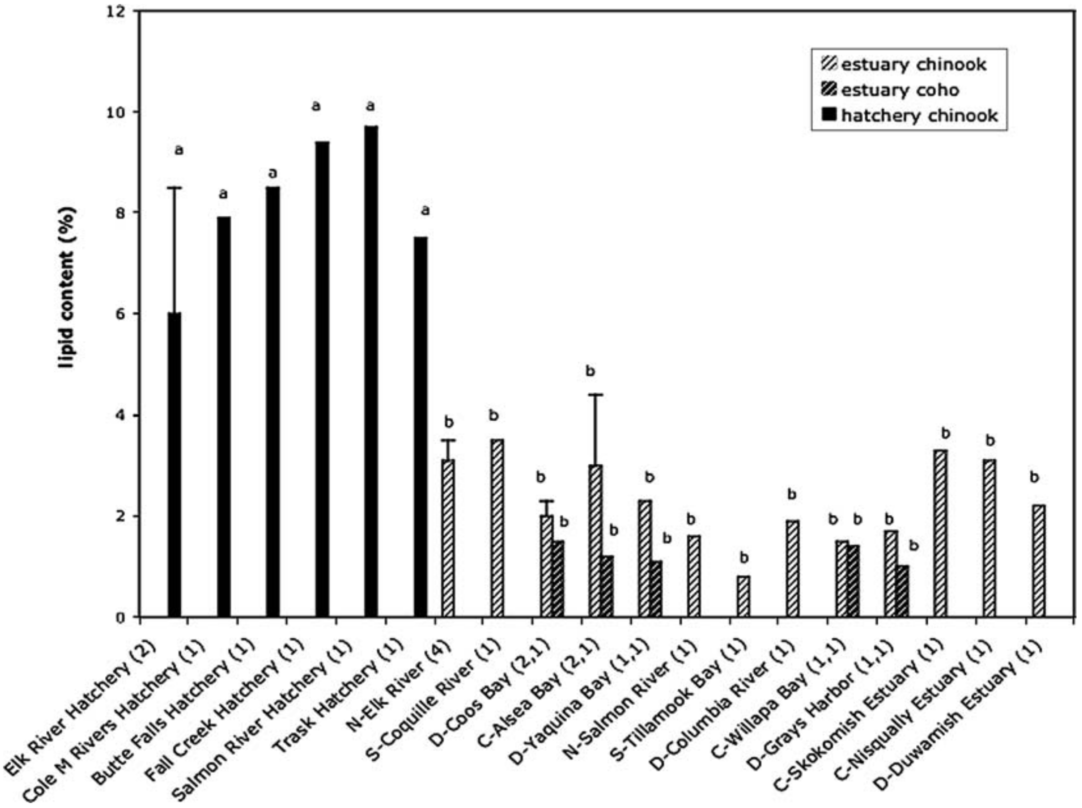

Fig. 2 Mean lipid content (%, as total extractable organics, ± SE) in whole bodies of chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from associated hatcheries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

but concentrations tended to be fairly uniform within the sampling groups (i.e, estuarine chinook, estuarine coho, and hatchery chinook).

3.2 Organochlorine contaminants in whole bodies

Concentrations of PCBs in whole bodies of estuarine chinook salmon (Fig. 3, Tables 2 and 3) were quite variable, ranging from ∼500 ng/g lipid weight (lw) in salmon from Elk River and Coquille Estuaries to 3100 ng/g lw in salmon from the Duwamish Estuary in Seattle (or from 3.6 ng/g wet weight (ww) at Salmon River to 103 ng/g ww at Duwamish). The lowest concentrations of PCBs were found in chinook salmon from Elk River Estuary, Coquille River, Alsea Bay Estuary, Salmon River, and Tillamook Bay; wet weight PCB concentrations were less than 20 ng/g ww at all these sites, and lipid weight PCB concentrations were below 600 ng/g lw in chinook from Elk River Estuary, Coquille River, and Tillamook. The highest PCB concentrations (2500–3100 ng/g lw or 45–103 ng/g ww) were found in salmon from Yaquina Bay, the Columbia River, and the Duwamish Estuary.

Concentrations of PCBs in juvenile coho salmon (Fig. 3, Tables 2 and 3) tended to be lower than those in chinook salmon. At sites where both species were collected, the mean PCB concentration overall was significantly lower in coho than in chinook on both a lipid weight and wet weight basis (1030 vs. 1650 ng/g lw, $p = 0.018$; 10 vs. 30 ng/g ww; $p = 0.0026$). No significant differences were observed in PCB concentrations in coho salmon from different sampling sites, but the number of samples was very small.

The mean concentration of PCBs in juvenile chinook salmon from hatcheries (Fig. 3, Tables 2 and 3) was relatively low on a lipid weight basis (620 ng/g lw),

Table 2 Contaminant concentration mean values (± SE), ranges, and sites where high and low values were observed in juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from Pacific Northwest hatcheries. Values with different superscripts are significantly different (ANOVA, $p = 0.05$) in estuarine chinook, estuarine coho, and hatchery chinook

	Estuaries		Hatcheries
	Chinook	Coho	Chinook
% lipid	2.4 ± 0.2 (n = 19)^{a} 0.8–3.5.% Tillamook–Coquille	1.2 ± 0.1 (n = 5)^{a} 1.1–1.5% Grays Hbr.-Coos	7.9 ± 0.8 (n = 7)^{b} 6–9.7%^{1} Elk–Salmon
Body PCBs (ng/g wet wt)	27 ± 4 (n = 65)^{a} 3.6–103 Salmon–Duwamish	9.7 ± 1.6 (n = 9)^{b} 6–16 Alsea–Grays Hbr.	46 ± 3 (n = 7)^{c} 39–59 Trask–Salmon
Body PCBs (ng/g lipid)	1650 ± 190 (n = 19)^{a} 516–3099 Elk R.–Duwamish	1030 ± 230 (n = 5)^{a} 470–1564 Willapa-Grays Hbr.	620 ± 50 (n = 7)^{b} 521–760 Fall Cr.–Elk
Body DDTs (ng/g wet wt)	13 ± 2 (n = 65)^{a} 0.5–41 Tillamook–Columbia.	1.7 ± 0.3 (9)^{b} 0.9–3.4 Willapa-Grays Hbr.	34 ± 3 (7)^{c} 27–45 Trask–Salmon
Body DDTs (ng/g lipid)	550 + 120 (n = 19) 62–2280 Tillamook–Columbia	140 + 50 (n = 5) 66–333 Willapa-Grays Hbr.	436 + 234 (n = 7) 354–507 Trask–Elk
Whole body DDT/PCB ratio	0.63 ± 0.06 (n = 65)^{a} 0.10–1.1 Tillamook–Salmon	0.21 ± 0.03 (n = 9)^{b} 0.13–0.26 Coos-Alsea	0.72 ± 0.03 (n = 7)^{a} 0.68–0.75 Elk/Trask–Salmon
FACs-BaP (ng/g bile)	364 ± 96 (n = 47) 108–1925 Alsea–Duwamish	218 ± 26 (n = 10) 136–298 Yaquina–Grays Hbr.	ND
FACs-PHN (ng/g bile)	44600 ± 15900 (n = 47) 9270–359000 Nisqually-Duwamish	17600 ± 2040 (n = 10) 12900–25400 Yaquina–Coos Bay	ND
Stomach contents PCBs (ng/g wet wt)	18.6 ± 5.7 (n = 35) 4.5–200 Salmon–Duwamish	11.6 ± 2.5 (n = 9) 5.4–22 Alsea–Grays Hbr.	13 (n = 1) Elk
Stomach contents DDTs (ng/g wet wt)	8.3 ± 2.9 (n = 35) 0.6–45 Elk.–Grays Hbr.	1.5 ± 0.4 (n = 9) 0.9–2.3 Alsea–Grays Hbr.	4.5 (n = 1) Elk
Stomach contents ΣLAHs (ng/g wet wt)	415 ± 235 (n = 35)^{a} 12–8000 Elk-Duwamish	40 ± 19 (n = 9)^{b} 10–69 Coos Bay-Alsea Bay	28 (n = 1)^{b} Elk
Stomach contents ΣHAHs (ng/g wet wt)	594 ± 353 (n = 35)^{a} 1.3–6300 Elk/Salmon-Willapa	5.4 ± 1.7 (n = 35)^{b} 1.3–10 Coos Bay–Grays Hbr.	5 (n = 1)^{b} Elk

comparable to concentrations observed in estuary chinook and coho salmon from rural estuaries (e.g., Elk River, Coquille River, Alsea Bay). On a wet weight basis, however, the mean PCB concentration in hatchery chinook was quite high (47 ng/g ww), comparable to concentrations in moderately to heavily urbanized estuaries (Table 3).

Concentrations of ΣDDTs in estuarine chinook salmon bodies ranged from 62 ng/g lw at Tillamook Bay to 2280 ng/g lw in the Columbia River (or from below 0.5 ng/g ww in fish from Tillamook Bay to 41 ng/g ww in fish from the Columbia River) (Fig. 4, Tables 2 and 3), with a mean concentration of 550 ng/g lw or 13 n/g ww (Fig. 4; Tables 2 and 3). Concentrations

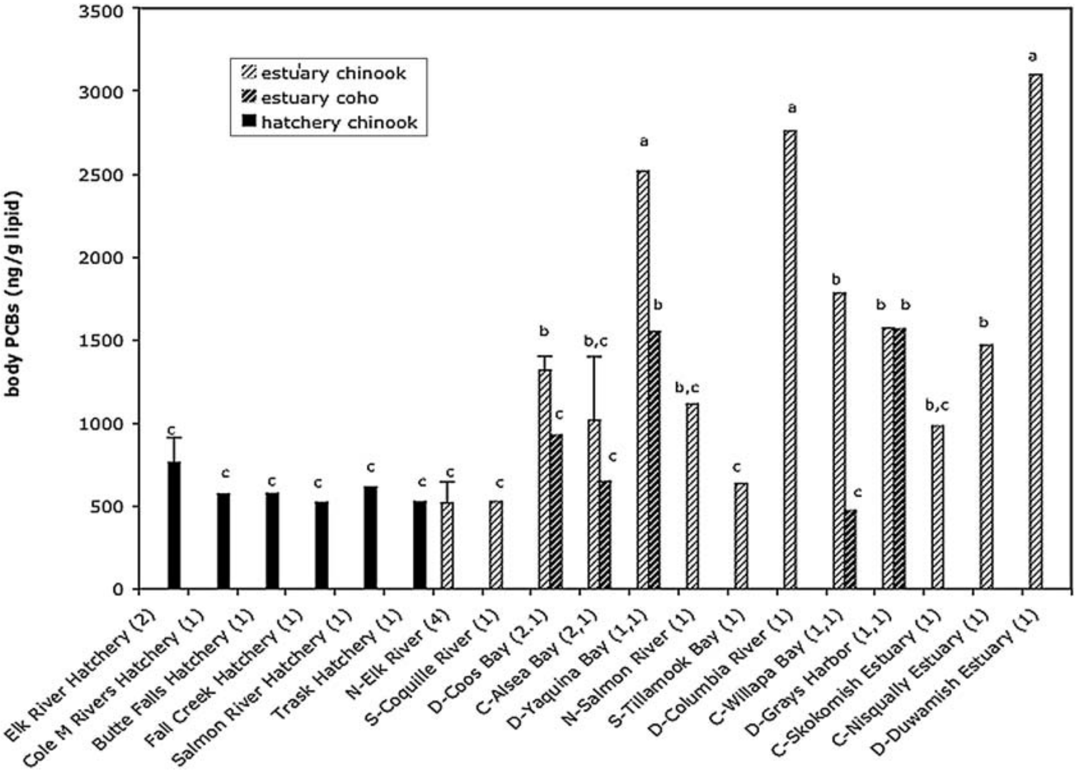

Fig. 3 Mean concentrations of ΣPCBs (ng/g lipid, ± SE) in whole bodies of juvenile chinook and coho salmon from Pacific Northwest Estuaries and juvenile chinook salmon from associated hatcheries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

of ΣDDTs were low in fish from Tillamook Bay, Alsea Bay, and Elk River on both a wet wt and lipid wt basis (below 250 ng/g lw and 5 ng/g ww); at Coquille River lipid wt DDT concentrations were comparable but wet wt concentrations were higher, while the reverse was true for chinook from Salmon River. Concentrations of ΣDDTs were relatively high (over 1000 ng/g lw or 25 ng/g ww) in fish from the Nisqually, Duwamish, and Columbia River Estuaries. Fish with the highest ΣDDT concentrations were from the Columbia River, where levels were over 2200 ng/g lw or 40 ng/g ww.

In juvenile coho salmon, the maximum ΣDDT concentration was 333 ng/g lw or 3.4 n/g ww in fish from Grays Harbor (Fig. 4; Tables 2 and 3), while the mean concentration was 140 ng/g lw or 1.7 ng/g ww. When coho and chinook salmon collected from the same sites were compared, ΣDDT concentrations were much lower in coho salmon (1.7 ± 0.3 ng/g ww vs. 8.8 ng/g ww, $p = 0.0026$; or 137 ng/g lw vs. 551 ± 95 ng/g lw, $p \leq 0.001$).

On a wet weight basis, concentrations of ΣDDTs in whole bodies of juvenile Chinook collected from the hatcheries were fairly high, with the mean concentrations for all hatcheries significantly above the mean concentrations measured in estuarine chinook and coho (Tables 2 and 3). However, because of the high lipid content of the hatchery fish, their whole body ΣDDT concentrations on a lipid weight basis were more moderate (400–500 ng/g lw), and did not differ significantly from mean concentrations in estuarine salmon (Fig. 4; Tables 2 and 3).

Of the six DDTs measured in salmon whole bodies, *p,p′*-DDE predominated in whole bodies of both coho and chinook salmon from all estuaries and hatcheries sampled, accounting for 75–100% of DDTs measured (Fig. 5; Table 3). The second most prominent DDT was *p,p′*-DDD; it accounted for 10–20% of DDTs measured in chinook and coho salmon from most sites. Additionally, *p,p′*-DDT was present at several sites, accounting for 3–6% of total DDTs in chinook salmon

Table 3 Mean concentrations ($\pm$ SE) in ng/g, wet wt of ΣPCBs, ΣDDTs, and DDT isomers in whole bodies of juvenile chinook and coho salmon collected from Pacific Northwest estuaries and juvenile chinook salmon from Pacific Northwest hatcheries. Compounds were measured by GC/ECD in samples collected from 1996–1998 and by GC/MS in samples collected from 1999–2001. Values with different letter superscripts are significantly different (ANOVA, $p \leq 0.05$)

Site	ΣPCBs	ΣDDTs	*o,p′*-DDD	*o,p′*-DDE	*o,p′*-DDT	*p,p′*DDD	*p,p′*-DDE	*p,p′*-DDT
Estuary chinook								
Columbia River (6)	50 ± 14^{b}	41 ± 3^{a}	0.6 ± 0.1^{a}	0.27 ± 0.0^{a}	0.71 ± 0.15^{a}	6.2 ± 0.64^{a}	31 ± 2.3^{a}	2.4 ± 0.6^{a}
Alsea Bay (8)	11 ± 3^{c}	2.4 ± 0.5^{d}	$<\mathrm{DL}^{b}$	0.05 ± 0.05^{b}	$<\mathrm{DL}^{c}$	0.32 ± 0.25^{b}	2.8 ± 0.8^{c}	0.11 ± 0.09^{b}
Elk River (2)	9.9 ± 3.9^{c}	4.7 ± 2.6^{d}	0.04 ± 0.03^{b}	$<\mathrm{DL}^{b}$	0.02 ± 0.03^{c}	0.5 ± 0.4^{b}	4.1 ± 2.1^{c}	0.21 ± 0.15^{b}
Grays Harbor (3)	$27 \pm 8^{b,c}$	11.3 ± 4^{c}	0.07 ± 0.07^{b}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	1.1 ± 0.6^{b}	9.9 ± 3.3^{b}	0.1 ± 0.1^{b}
Salmon River (11)	3.6 ± 1.6^{c}	1.9 ± 0.5^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	0.16 ± 0.09^{b}	1.7 ± 0.4^{c}	0.11 ± 0.06^{b}
Skokomish Estuary (3)	$29 \pm 2^{b,c}$	19.9 ± 1.5^{b}	0.08 ± 0.08^{b}	$<\mathrm{DL}^{b}$	0.05 ± 0.05^{c}	1.9 ± 0.15^{b}	17.3 ± 1.2^{b}	0.27 ± 0.18^{b}
Willapa Bay (3)	$24^{b.c}$	12.3 ± 0.4^{c}	<DLb	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	0.62 ± 0.14^{b}	11.2 ± 0.7^{b}	0.14 ± 0.14^{b}
Yaquina Bay (7)	46 ± 1^{b}	7.8 ± 2.2^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	0.07 ± 0.07^{b}	0.48 ± 0.11^{b}	6.8 ± 1.8^{b}	0.41 ± 0.14^{b}
Coos Bay (3)	$22 \pm 3^{b,c}$	10.8 ± 1.3^{c}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	0.02 ± 0.02^{c}	0.59 ± 0.09^{b}	9.8 ± 1.1^{b}	0.45 ± 0.12^{b}
Duwamish Estuary (3)	103 ± 29^{a}	27 ± 1^{b}	0.36 ± 0.03	0.18 ± 0.09^{a}	$0.09 \pm .09^{b}$	3.5 ± 0.4^{a}	22 ± 0.6^{a}	0.61 ± 0.14^{b}
Nisqually Esuary (3)	40 ± 4^{b}	30 ± 4^{b}	0.26 ± 0.03	0.09 ± 0.09^{b}	0.04 ± 0.04^{c}	3.4 ± 0.5^{a}	26 ± 3.5^{a}	0.34 ± 0.09^{b}
Coquille River (1)	$18^{b.c}$	$9.2^{c,d}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	1.3^{b}	7.3^{b}	0.58^{b}
Tillamook Bay (1)	5.1^{c}	0.5^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	$<\mathrm{DL}^{b}$	0.47^{c}	<DL
Hatchery chinook								
Fall Creek (1)	49^{b}	39^{a}	0.51^{a}	$<\mathrm{DL}^{b}$	0.03^{c}	5.4^{a}	32^{a}	1.3^{a}
Butte Falls (1)	49^{b}	35^{a}	0.56^{a}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	4.9^{a}	28^{a}	1.5^{a}
Cole M. Rivers (1)	45^{b}	31^{a}	0.8^{a}	$<\mathrm{DL}^{b}$	0.09^{b}	6.1^{a}	22^{a}	2.0^{a}
Elk River (2)	42^{b}	30 ± 10^{b}	0.04^{b}	$<\mathrm{DL}^{b}$	0.21^{a}	4.2^{a}	23^{a}	1.7^{a}
Salmon River (1)	59^{b}	45^{a}	0.9^{a}	$<\mathrm{DL}^{b}$	0.26^{a}	8.3^{a}	32^{a}	3.0^{a}
Trask (1)	39^{b}	27^{b}	0.67^{a}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	4.5^{a}	20^{a}	1.3^{a}
Estuary Coho								
Alsea Bay (3)	5.9 ± 1^{c}	1.4 ± 0.2^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	0.08 ± 0.04^{b}	1.3 ± 0.2^{c}	$<\mathrm{DL}^{b}$
Coos Bay (1)	14^{c}	1.8^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	$<\mathrm{DL}^{b}$	1.8^{c}	$<\mathrm{DL}^{b}$
Grays Harbor (1)	$27^{b,c}$	3.4^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	0.26^{b}	3.0^{c}	0.13^{b}
Willapa Bay (1)	6.4^{c}	0.9^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	0.13^{b}	0.63^{c}	0.12^{b}
Yaquina Bay (3)	11^{c}	1.7 ± 0.4^{d}	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	0.13 ± 0.07^{b}	1.6 ± 0.4^{c}	0.4 ± 0.02^{b}

from the Columbia River, Yaquina Bay, Grays Harbor, and Salmon River, 4% of total DDTs in juvenile coho from Grays Harbor, and 13% of total DDTs in coho from Willapa Bay. In hatchery chinook salmon, *p,p′*-DDT accounted for an average of 5% of total DDTs. Concentrations of estrogenic *o,p′*-DDT, *o,p′*-DDD, and *o,p′*-DDE (Fig. 6) were below detection limits in all coho and many chinook salmon sampled, but were present at concentrations above 0.1 ng/g ww or 10 n/g lw in chinook salmon from the Columbia, Nisqually, Duwamish and Yaquina Bay Estuaries. As with ΣDDTs, concentrations of the *o,p′* isomers were highest in chinook from the Columbia River. In hatchery chinook salmon, they averaged 8 ng/g lw.

We calculated the ΣDDTs/ΣPCBs ratios in whole body samples of chinook and coho salmon to identify groups of fish with distinct contaminant profiles (Fig. 7). In coho salmon, the mean ΣDDTs/ΣPCBs ratio was 0.2, and in estuarine chinook salmon, the mean ratio was 0.4. In both coho and chinook salmon from most of the sites we sampled (Nisqually, Skokomish, Coos Bay, Alsea Bay Estuary, Salmon River Estuary, Willapa Bay, Elk River Estuary, Duwamish Estuary, Tillamook Bay, Yaquina Bay), ΣDDT/ΣPCB ratios were 0.5 or lower. This was not true, however, of chinook salmon from the Columbia River, whose ΣDDTs/ΣPCBs ratios were 1.0–1.1. In hatchery chinook, the mean ΣDDTs/ΣPCBs ratio was ~0.7.

In addition to PCBs and DDTs, chlordanes, hexachlorobenzene, and dieldrin were detected in whole bodies of estuarine chinook and coho salmon from one or more sampling sites, but at much lower concentrations than PCBs or DDTs (mean concentrations ranging from <1 ng/g ww to 4 ng/g ww; Table 4). Of the

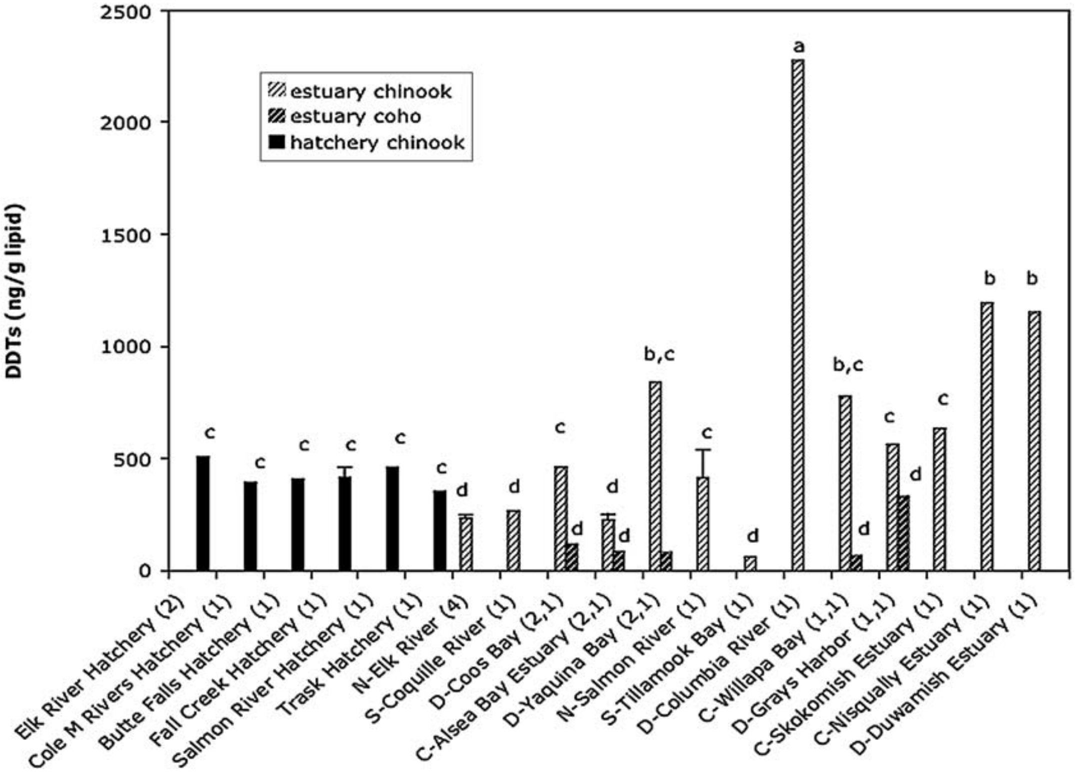

Fig. 4 Mean concentrations of ΣDDTs (ng/g lipid, ± SE) in whole bodies of juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from associated hatcheries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

pesticides detected, chlordanes were generally found at the highest concentrations. Other OC pesticides (i.e., lindane, mirex and aldrin) were below the limits of detection (generally <0.5 ng/g ww) in all samples. Dieldrin, chlordanes, and HCB were detected in whole bodies of juvenile chinook from all sampled hatcheries, typically at concentrations in the 1–5 ng/g ww range. Concentrations were comparable to the highest levels reported in estuarine chinook and coho (Table 4).

3.3 Bile metabolites

Levels of high molecular weight AH metabolites in bile (FACs-BaP) were low to moderate (100–400 ng/g bile) in juvenile fall chinook and coho salmon collected from most of the estuaries sampled along the Washington and Oregon Coast (Fig. 8). Concentrations in chinook salmon from the Duwamish Estuary (~1930 ng BaP equiv/g bile) were significantly higher than in fish from any other sites. FAC-BaP levels were also somewhat elevated (350–500 ng/g bile) in chinook salmon from the Columbia River, Skokomish Estuary, Grays Harbor, and Willapa Bay, and in coho salmon from Grays Harbor. Lowest concentrations were observed in chinook and coho salmon from Elk River Estuary, Yaquina Bay Estuary, and Alsea Bay Estuary. At 100–200 ng BaP equiv/g bile, concentrations of FACs-BaP in fish at these sites were significantly lower than in chinook salmon from the Columbia, Skokomish, Willapa Bay, and Duwamish sites, and in chinook and coho salmon from Grays Harbor.

Concentrations of metabolites of low molecular weight PAHs (FAC-PHN; Fig. 8) were also significantly higher in chinook salmon from the Duwamish Estuary (359,000 ng PHN equiv/g bile) than in fish from any other sites. Concentrations in chinook salmon from Grays Harbor, Coos Bay, and the Columbia River (60,000–70,000 ng PHN equiv/g bile) were much lower than in the Duwamish chinook, but significantly above levels in either coho or

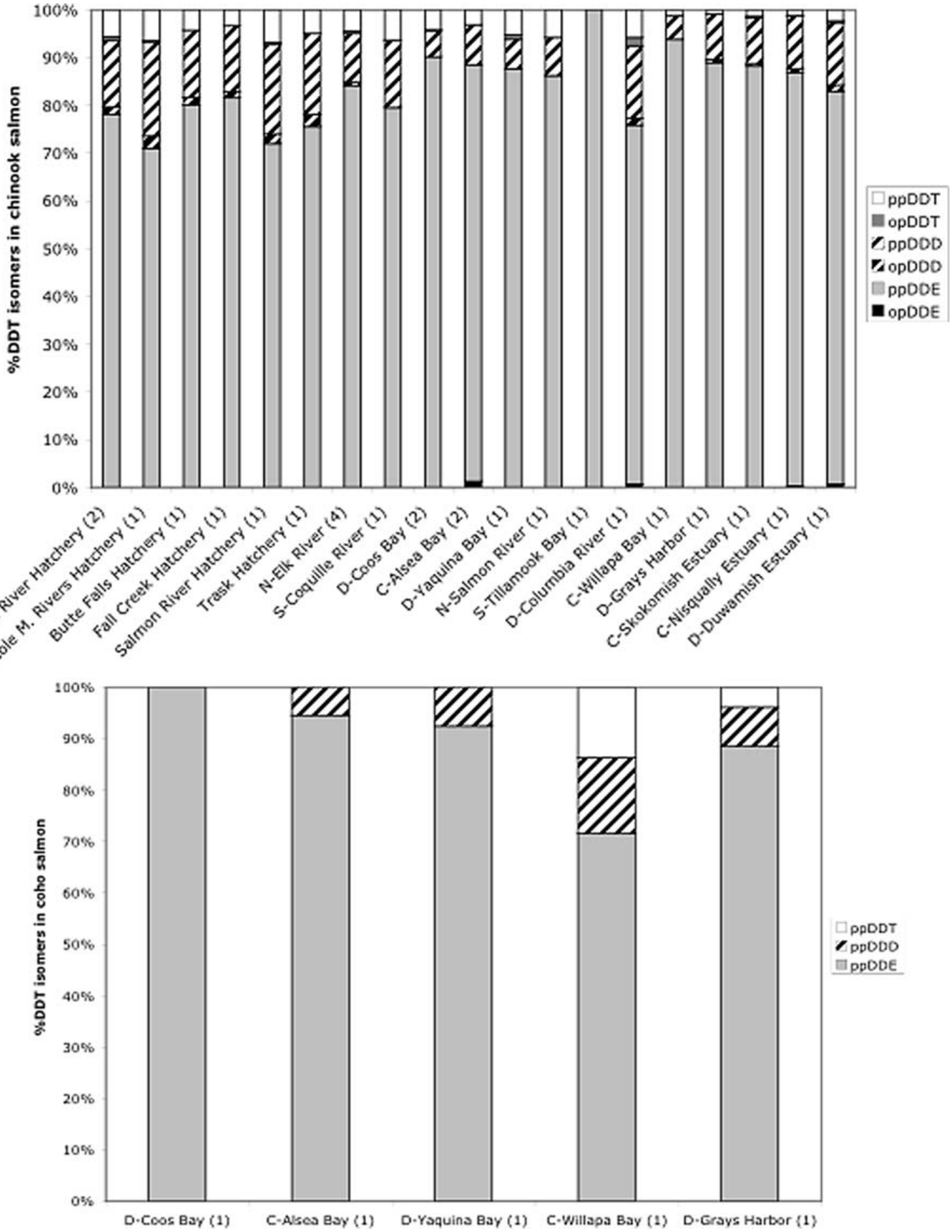

Fig. 5 Proportions of various DDTs in composite whole body samples of juvenile chinook and coho salmon collected from Pacific Northwest estuaries and hatcheries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group

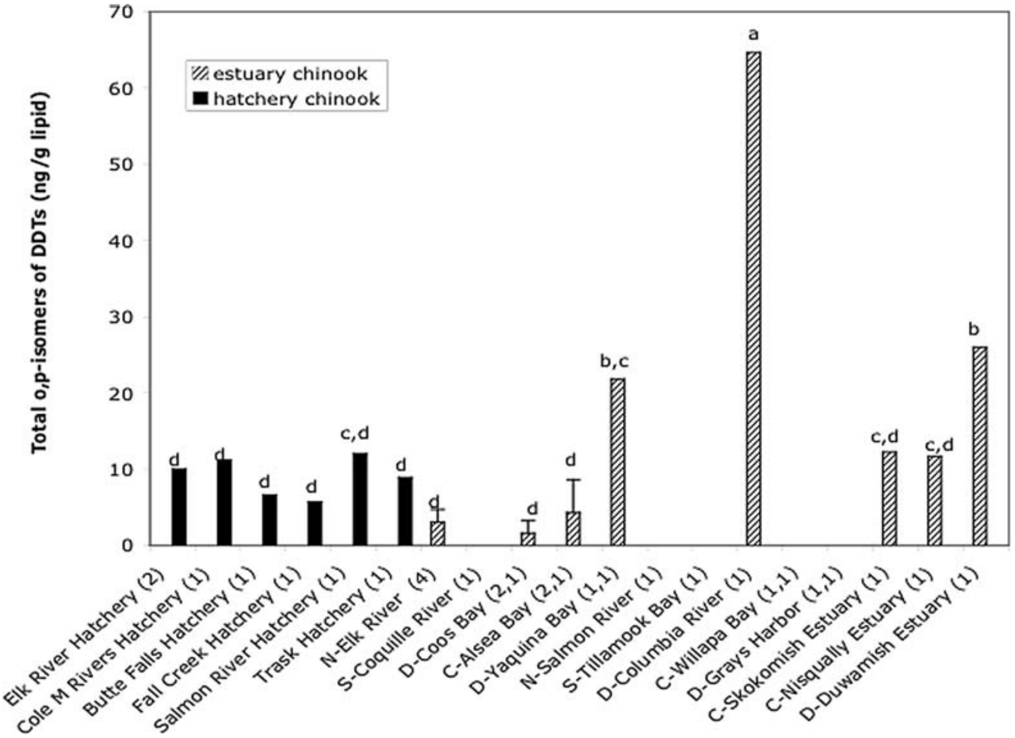

Fig. 6 Mean concentrations of $\Sigma o, p'$-isomers of DDTs (ng/g lipid, ± SE) in whole bodies of juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from associated hatcheries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$). Values were below detection limits for coho from all sites where they were sampled, and for chinook from Coquille River

chinook salmon from the other sampling sites, whose biliary FACs-PHN concentrations were 30,000 ng PHN equiv/g bile or less. Bile sample could not be collected from chinook salmon at the hatcheries.

3.4 Contaminants in stomach contents

Several classes of contaminants, including PCBs, DDTs, and low and high molecular weight PAHs, were present at detectable concentrations in stomach contents of outmigrant juvenile chinook and coho salmon. Concentrations of ΣLAHs in stomach contents of estuarine chinook salmon (Fig. 9; Table 2) ranged from 12 ng/g ww at the Elk River Estuary to 8000 ng/g ww at the Duwamish Estuary. Concentrations of ΣLAHs were also fairly high in fish from Willapa Bay, Yaquina Bay, and Grays Harbor in comparison to other sites, ranging from 350 to 1400 ng/g ww. Concentrations of ΣLAHs in stomach contents of chinook and coho salmon from all other sites were <100 ng/g ww (Fig. 9; Table 2). At sites where both species were collected, average ΣLAH concentrations in stomach contents of chinook salmon were higher than in coho salmon (920 ng/g ww vs. 5 ng/g ww). In chinook salmon from Elk River Hatchery, the concentration of ΣLAHs in stomach contents was 28 ng/g ww (Fig. 9; Table 2).

Concentrations of ΣHAHs in stomach contents of juvenile chinook salmon (Fig. 9, Table 2) were highest in fish from the Duwamish Estuary and Willapa Bay (6000–6300 ng/g ww). Concentrations of ΣHAHs at Grays Harbor and Yaquina Bay (330–340 ng/g ww) were also relatively high in comparison to other sites, where concentrations were ~20 ng/g ww and below. The lowest levels ΣHAHs (1–2 ng/g ww) were observed in chinook from Salmon River and Elk River Estuary sites. In coho salmon (Fig. 9; Table 2) concentrations of ΣHAHs in stomach contents were ~10 ng/g ww or below in fish from all sites; at sites where both species were collected, ΣHAH concentrations were higher in chinook salmon than in coho salmon (323 ng/g ww vs. 40 ng/g ww). In chinook and coho salmon from most sampling sites, HAHs accounted for

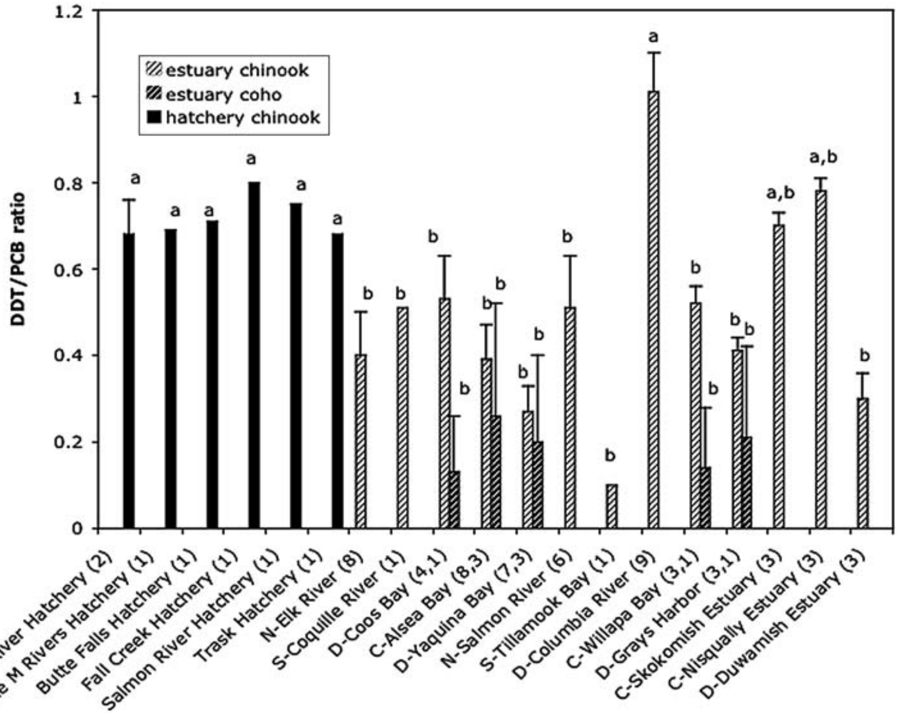

Fig. 7 Mean ΣDDT/ΣPCB ratios (± SE) in whole bodies of juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from associated hatcheries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

10–20% of total AHs. However, in chinook salmon from the Duwamish, Grays Harbor, Yaquina Bay, and Willapa Bay, HAHs were more predominant, accounting for 30–70% of total AHs. In chinook salmon from the Elk River Hatchery (Fig. 9), ΣHAH concentrations were relatively low (5 ng/g ww) and accounted for about 15% of total AHs.

Concentrations of ΣPCBs in stomach contents of estuarine chinook salmon (Fig. 10; Table 2) ranged from 5 ng/g ww in fish from the Salmon River Estuary to 200 ng/g ww in fish from the Duwamish Estuary. Concentrations of PCBs in salmon from the Columbia River and Grays Harbor were about 40 ng/g ww, and concentrations were about 20 ng/g ww or less at all other sampling sites. Lowest levels (5–10 ng/g ww) were observed at Yaquina Bay, Alsea Bay, Coos Bay, Elk River, and Salmon River Estuaries. In coho salmon (Fig. 10, Table 2), PCB concentrations in stomach contents ranged from 5 ng/g ww in fish from Alsea Bay Estuary to 22 ng/g ww in fish from Willapa Bay. At sites where both species were collected, PCB concentrations were similar in stomach contents of chinook salmon and coho salmon, 14 ng/g ww vs. 12 ng/g ww. At the Elk River Hatchery, PCB concentrations in stomach contents were 13 ng/g ww, comparable to levels in estuarine chinook salmon from non-urban sites (Fig. 10; Table 2).

Concentrations of ΣDDTs in stomach contents of estuarine chinook salmon (Fig. 11; Table 2) were highest in fish from Grays Harbor (45 ng/g ww) and the Columbia River (39 ng/g ww), significantly higher than in fish from all other sites. In stomach contents of chinook from all sampling sites except for the Columbia River and Grays Harbor, ΣDDT concentrations were <10 ng/g ww. Concentrations of ΣDDTs in stomach contents of coho salmon (Fig. 11, Table 2) were low (3 ng/g ww) in fish from all sites. At sites where both species were collected, ΣDDT concentrations were higher in chinook salmon than in coho salmon (9 ng/g ww vs. 1.5 ng/g ww). In chinook salmon from the Elk River Hatchery (Fig. 11, Table 2), concentrations of DDTs were also relatively low, 4.5 ng/g ww.

In stomach contents, as in tissues, *p,p′*-DDE was the predominant isomer detected, accounting for about

Table 4 Mean concentrations (± SE) in ng/g, wet wt of selected organochlorine pesticides in bodies of juvenile chinook and coho salmon collected from Pacific Northwest estuaries and hatcheries. Σchlordanes = summed concentrations of heptachlor, heptachlor epoxide, γ-chlordane, α-chlordane, *cis*-nonachlor, *trans*-nonachlor and nonachlor III. DL = detection limit. Pesticides were measured by GC/ECD in samples collected from 1996–1998 and by GC/MS in samples collected from 1999–2001. Values with different letter superscripts are significantly different (ANOVA, $p < 0.05$). Lindane was also measured, but was below DL (generally < 0.5 ng/g ww) in all samples

Site	dieldrin	aldrin	Σchlordanes	HCB	Mirex
Estuary Chinook					
Columbia River (6)	1.9 ± 0.88^{a}	$<\mathrm{DL}^{b}$	3.1 ± 0.26^{b}	0.63 ± 0.05^{b}	$<\mathrm{DL}^{a}$
Coquille River (1)	0.56^{b}	0.29^{a}	1.5^{c}	$0.65^{a,b}$	0.35^{c}
Alsea Bay (8)	0.69 ± 0.39^{b}	$<\mathrm{DL}^{b}$	0.47 ± 0.30^{c}	0.21 ± 0.11^{b}	$<\mathrm{DL}^{a}$
Coos Bay (4)	$0.83 \pm 0.83^{a,b}$	$<\mathrm{DL}^{b}$	0.73 ± 0.12^{c}	0.33 ± 0.09^{b}	$<\mathrm{DL}^{a}$
Duwamish Estuary (3)	$0.97 \pm 0.08^{a,b}$	$<\mathrm{DL}^{b}$	4.3 ± 0.18^{a}	0.74 ± 0.09^{b}	$<\mathrm{DL}^{a}$
Elk River (2)	0.14 ± 0.11^{b}	$<\mathrm{DL}^{b}$	0.64 ± 0.33^{c}	0.21 ± 0.09^{b}	0.06 ± 0.06^{a}
Grays Harbor (3)	0.04 ± 0.04^{b}	$<\mathrm{DL}^{b}$	1.53 ± 0.67^{c}	0.26 ± 0.06^{b}	$<\mathrm{DL}^{a}$
Nisqually Estuary (3)	$0.71 \pm 0.14^{a,b}$	$<\mathrm{DL}^{b}$	3.2 ± 0.46^{b}	0.59 ± 0.12^{b}	0.05 ± 0.05^{a}
Salmon River (11)	$0.78 \pm 0.38^{a,b}$	$<\mathrm{DL}^{b}$	0.15 ± 0.09^{c}	0.08 ± 0.04^{c}	$<\mathrm{DL}^{a}$
Skokomish Estuary (3)	0.28 ± 0.09^{b}	$<\mathrm{DL}^{b}$	2.45 ± 0.51^{b}	0.46 ± 0.15^{b}	0.04 ± 0.04^{a}
Tillamook Bay (1)	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{c}$	$<\mathrm{DL}^{c}$	$<\mathrm{DL}^{a}$
Yaquina Bay (7)	0.06 ± 0.06^{b}	$<\mathrm{DL}^{b}$	1.1 ± 0.6^{c}	0.18 ± 0.08^{b}	$<\mathrm{DL}^{a}$
Willapa Bay (3)	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	0.32 ± 0.04^{c}	0.13 ± 0.07^{b}	$<\mathrm{DL}^{a}$
Hatchery chinook					
Fall Creek (1)	2.1^{a}	0.22^{a}	4.5^{a}	1.2^{a}	$<\mathrm{DL}^{a}$
Butte Falls (1)	1.9^{a}	0.25^{a}	4.7^{a}	1.1^{a}	$<\mathrm{DL}^{a}$
Cole M. Rivers (1)	2.3^{a}	$<\mathrm{DL}^{b}$	4.2^{a}	$0.88^{a,b}$	$<\mathrm{DL}^{a}$
Elk River (2)	1.4 ± 0.9^{a}	$<\mathrm{DL}^{b}$	3.7^{a}	$0.65^{a,b}$	0.13 ± 0.13^{b}
Trask (1)	1.7^{a}	$<\mathrm{DL}^{b}$	3.6^{a}	$0.87^{a,b}$	$<\mathrm{DL}^{a}$
Salmon River (1)	3.7^{a}	$<\mathrm{DL}^{b}$	4.4^{a}	1.1^{a}	$<\mathrm{DL}^{a}$
Estuary coho					
Alsea Bay (3)	2.5 ± 0.3^{a}	$<\mathrm{DL}^{b}$	0.17 ± 0.04^{c}	0.2 ± 0.03b	$<\mathrm{DL}^{a}$
Coos Bay (1)	3.3 ± 0.3^{a}	$<\mathrm{DL}^{b}$	0.2^{c}	0.16^{b}	0.64^{d}
Grays Harbor (1)	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	0.35^{c}	0.13^{b}	$<\mathrm{DL}^{a}$
Willapa Bay (1)	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	0.44 ± 0.26^{c}	0.13 ± 0.0^{b}	$<\mathrm{DL}^{a}$
Yaquina Bay (3)	$<\mathrm{DL}^{b}$	$<\mathrm{DL}^{b}$	0.10^{c}	0.09^{b}	$<\mathrm{DL}^{a}$

60–100% of ΣDDTs in stomach contents of both coho and chinook salmon from all sites (Fig. 12; Table 5). Additionally, *p,p′*-DDD and *p,p′*-DDT were found in both chinook and coho salmon stomach contents from several sites, with highest concentrations in juvenile chinook from the Columbia River (5.9 and 2.5 ng/g ww for *p,p′*-DDD and *p,p′*-DDT, respectively). These isomers accounted for 5–25% of total DDTs. In comparison with salmon whole bodies, *p,p′*-DDT was found at higher concentrations in stomach contents. The *o,p*’-DDTs were found only in stomach contents of chinook salmon from the Columbia River, which had measurable concentrations (0.6–1.1 ng/g ww) of both *o,p′*-DDT and *o,p′*-DDD. In stomach contents of juvenile chinook from the Elk River Hatchery, the only DDT isomer found was *p,p′*-DDE, which was present at a concentration of 4.5 ng/g ww.

In addition to PCBs, DDTs, and PAHs, chlordanes HCBs, HCHs, dieldrin, and mirex were detected in stomach contents of estuarine chinook or coho from one or more sampling sites (Table 6). In stomach contents of chinook from the Elk River Hatchery, chlordanes, HCB, and mirex were detected, all at relatively low levels (0.7–1.4 ng/g ww). Aldrin was below the limits of detection in all samples.

3.5 Relationship between contaminants in stomach contents and in salmon bodies

In chinook salmon, concentrations of PCBs and DDTs in stomach contents were significantly and positively

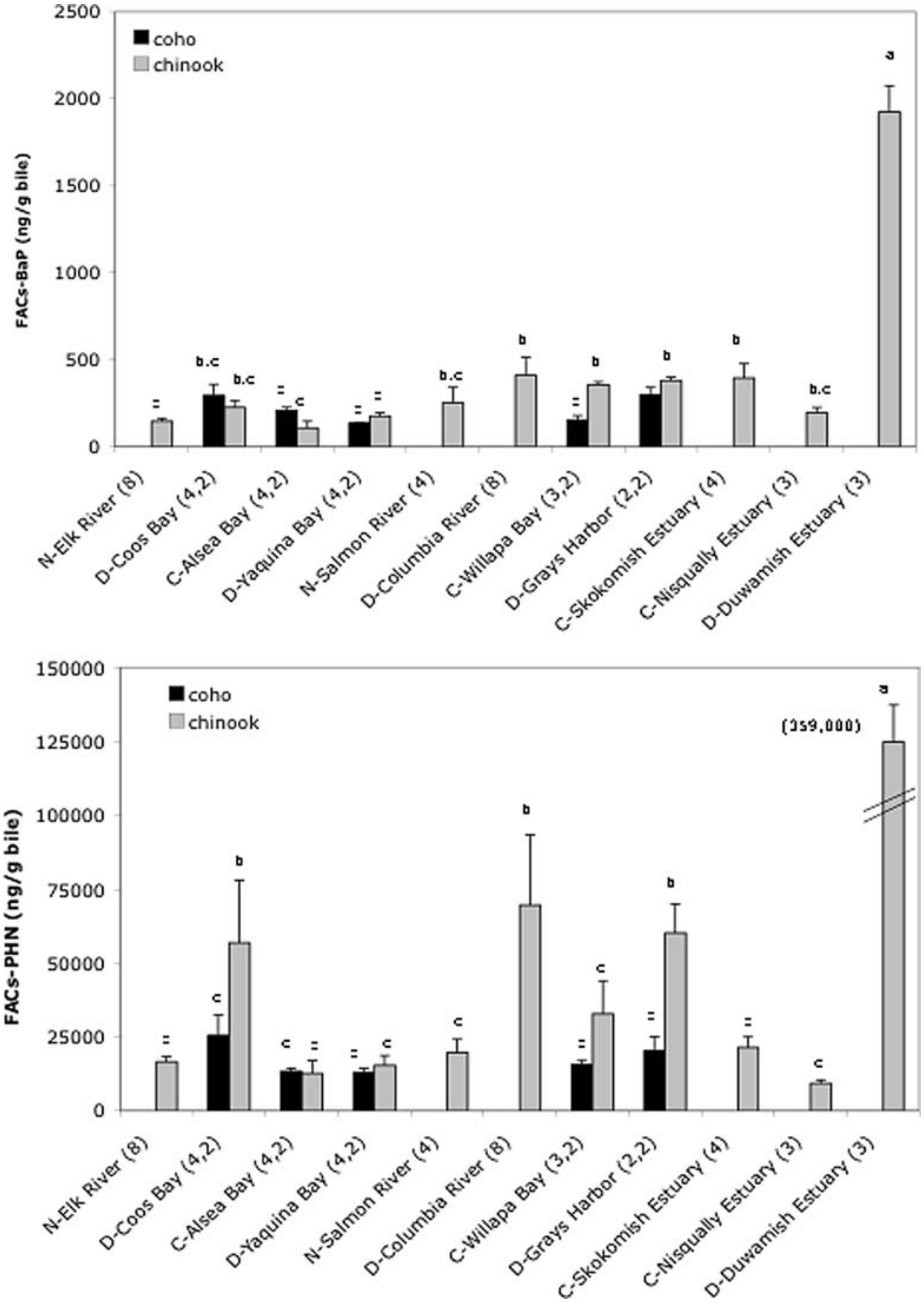

Fig. 8 Mean concentrations of fluorescent aromatic compounds (± SE) measured at phenanthrene wavelengths (FACs-PHN) and benzo[a]pyrene wavelengths (BaP-FACs) in bile of juvenile chinook and coho almon from Pacific Northwest estuaries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Bile metabolites measured at PHN and BaP wavelengths are representative of metabolites of low and high molecular weight PAHs, respectively. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

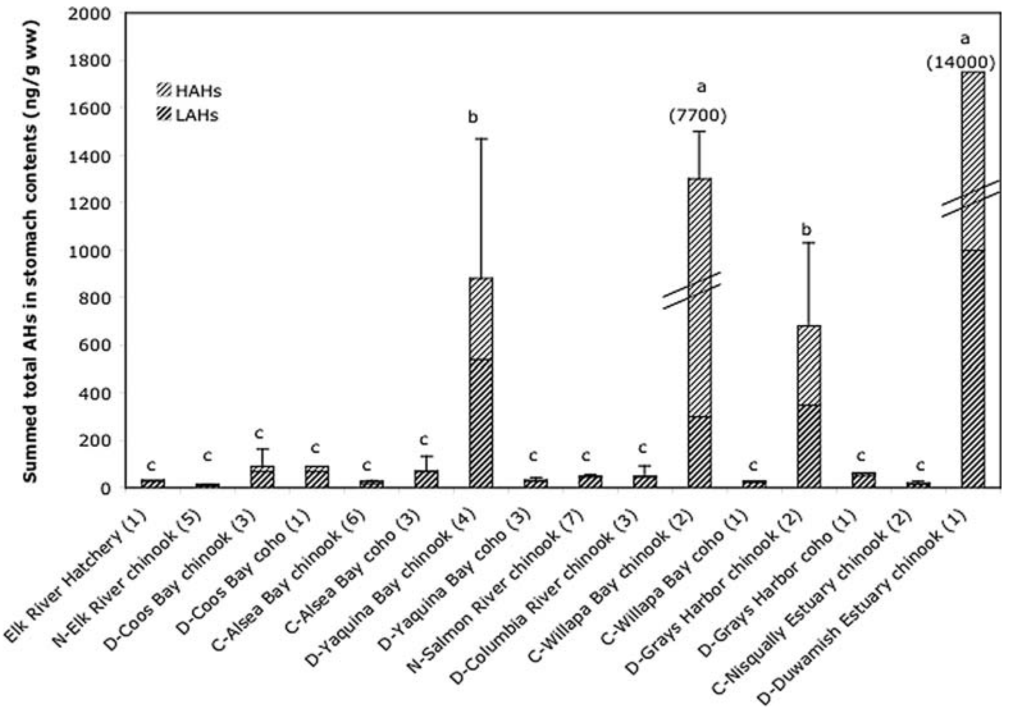

Fig. 9 Mean concentrations of total aromatic hydrocarbons (ΣAHs) (ng/g wet wt, ± SE) in stomach contents of juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from Elk River hatchery. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Contributions of low molecular weight and high molecular weight AHs (LAHs and HAHs) to totals are indicated. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

correlated with body burdens of the same contaminants. For PCBs ($n = 46$), $r^2 = 0.32$, $p = 0.0001$; while for DDTs ($n = 40$), $r^2 = 0.38, p = 0.0001$. In coho salmon, concentrations of contaminant in bodies and stomach contents were also positively correlated, but relationships were marginally significant ($0.06 \leq p \leq 0.08$), in part because of smaller sample size. For body DDTs vs. stomach DDTs ($n = 9$), $r^2 = 0.34, p = 0.06$. For body PCBs vs. stomach PCBs ($n = 9$), $r^2 = 0.29$, $p = 0.08$.

In estuarine chinook salmon, concentrations of PCBs and DDTs (ng/g ww) in whole bodies were 3–4 times as high as in stomach contents on average, while in coho salmon, concentrations of PCBs and DDTs in whole bodies and stomach contents were about the same or only slightly higher (1–1.3 times). For chinook salmon from the Elk River Hatchery (the only hatchery where stomach contents data were available), concentrations of PCBs (ng/g ww) were 4.7 times as high in bodies as in stomach contents, while concentrations of DDTs (ng/g ww) were 25 times as high in bodies as in stomach contents.

In chinook salmon, concentrations of PAH metabolites in bile and PAHs in stomach contents were significantly, positively correlated. For ΣLAHs vs. FACs-PHN, $n = 35$, $p = 0.0001$, $r^2 = 0.56$, and for ΣHAHs vs. FACs-BaP, $n = 35$, $p = 0.0006$, $r^2 = 0.28$. In coho salmon, on the other hand, there was no significant correlation between concentrations of either ΣHAHs or ΣLAHs in stomach contents and concentrations of PAH metabolites in bile. For ΣHAHs, $n = 5, r^2 = 0.07$, $p = 0.33$. For ΣLAHs, $n = 5$, $r^2 = 0.18$, $p = 0.26$.

4 Discussion

Estuarine and nearshore ecosystems provide a vital role as juvenile rearing habitat for salmonid species (Levy and Northcote, 1982; Gray *et al.*, 2002; Rice *et al.*, 2005), and can be particularly important in the recovery of species at risk (Feist *et al.*, 2003; Fresh *et al.*, 2005). Unfortunately, estuarine and coastal ecosystems are also among the environments that are most heavily

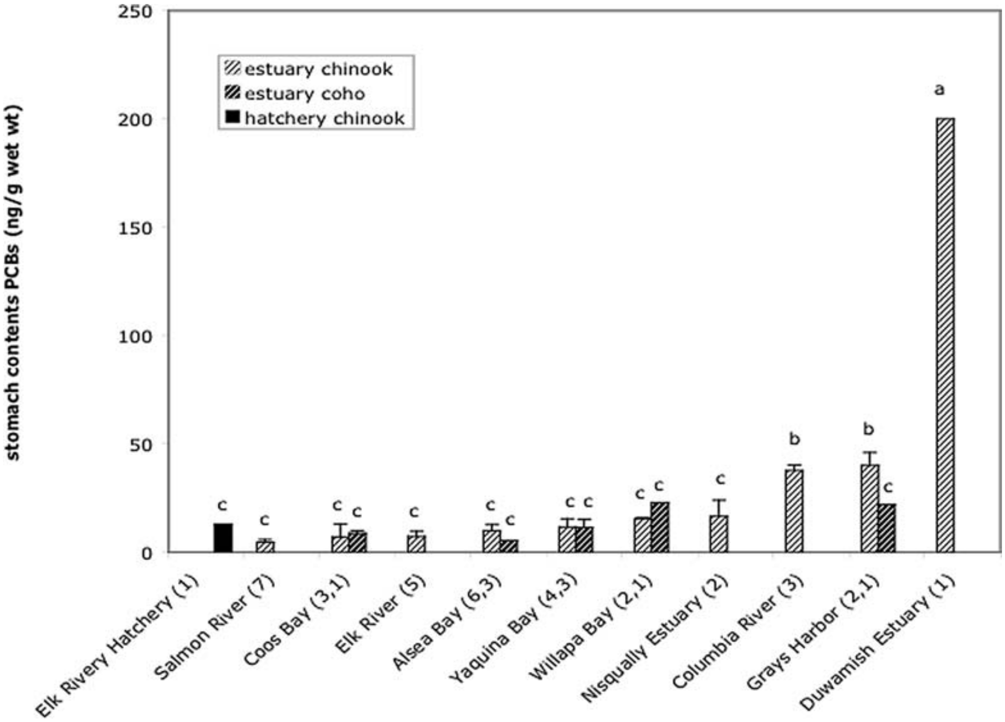

Fig. 10 Mean concentrations of ΣPCBs (ng/g wet wt. ± SE) in stomach contents of juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from Elk River hatchery. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

impacted by anthropogenic activities (Shreffler *et al*., 1990; Beck *et al*., 2001; Rice *et al*., 2005). Analyses of risks to salmon populations in estuarine environments have focused largely on alterations to or loss of physical habitat attributes (Bottom *et al*., 2005; Gray *et al*., 2002; Fresh *et al*., 2005), but it is increasingly recognized that habitat degradation associated with chemical contaminants may also pose a significant risk to salmon populations (Spromberg and Meador, 2005; Fresh *et al*., 2005; Loge *et al*., 2005).

The importance of estuarine contamination in terms of the health of salmonid species depends in part on the life history strategy of the species in question. In general, ocean-type stocks, such as fall chinook, which spend an extended period during their first year of life in the estuary, are more vulnerable to the impacts of contaminants in this environment than stream-type stocks, such as coho salmon, which pass through the estuary relatively quickly (Fresh *et al*., 2005). The same may be true of chum salmon, which have a long estuarine residence time (Dorcey *et al*., 1978; Healey, 1982). Juvenile chum have shown relatively high contaminant body burdens at urban sites in previous surveys in Puget Sound, WA (Stehr *et al*., 2000).

The results of the current study confirm that chemical contaminants are present in the prey and tissues of outmigrant juvenile salmon from a number of estuaries in the Pacific Northwest. The most widespread contaminants were PCBs, DDTs, and PAHs, which were observed in both tissues and stomach contents of chinook and coho salmon from all estuarine sampling sites, as well as in chinook salmon from local hatcheries. Although additional organochlorine pesticides (chlordanes, lindane, hexachlorobenzene, dieldrin, aldrin and mirex) were also detected in salmon tissues or stomach contents, the measured concentrations were relatively low. Like earlier studies in Puget Sound, the present study highlights the importance of the estuary as a source of exposure to chemical contaminants, especially for juvenile chinook salmon. The observation of elevated contaminant concentrations in stomach contents of salmon from sites in several estuaries indicates that fish are being exposed to these contaminants during estuarine residence through their

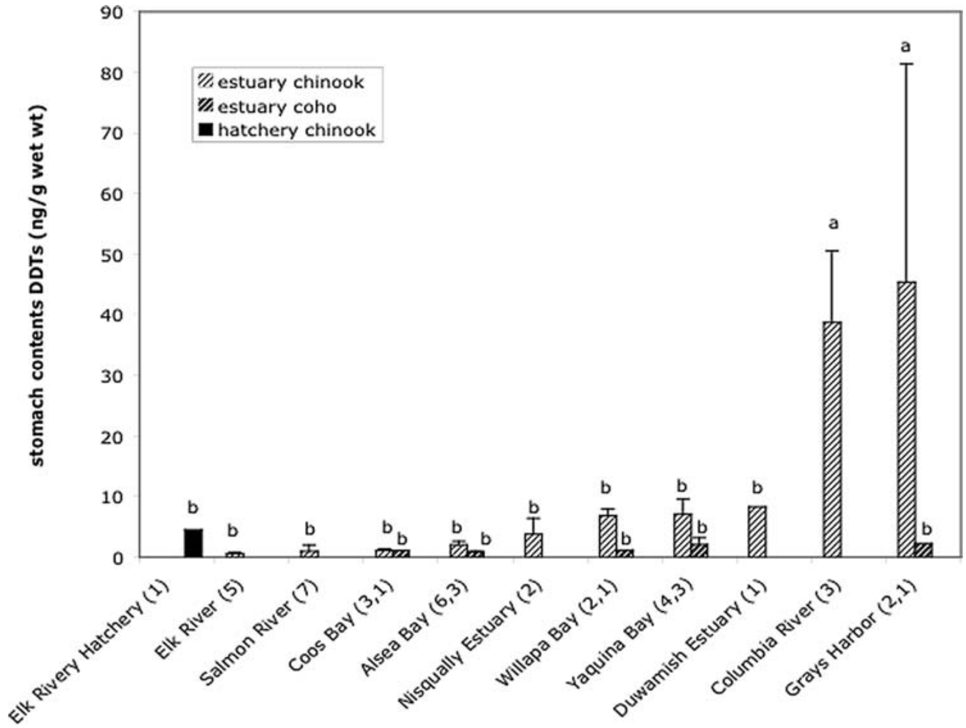

Fig. 11 Mean concentrations of ΣDDTs (ng/g ww, ± SE) in stomach contents of juvenile chinook and coho salmon from Pacific Northwest estuaries and juvenile chinook salmon from Elk River hatchery. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group. Measurements with different letters are significantly different (ANOVA, $p < 0.05$)

prey. The hypothesis that this could be an important source of uptake is further supported by the significant correlations between concentrations of PCBs and DDTs in stomach contents and whole bodies of juvenile chinook salmon, and between PAHs in stomach contents and PAH metabolites in bile. Contaminants in the water column, and in suspended particulate material, are also potential sources of exposure, although they were not measured in this study. Depending on their origin, chinook and coho salmon from some populations could also be taking up certain contaminants through the water column or the diet in freshwater before entering the estuary. This is especially true if they are passing through urbanized watersheds. However, the potential contribution of contaminants in freshwater habitats to juvenile salmon body burdens cannot be evaluated based on the samples collected in the present study.

4.1 Species differences in contaminant uptake

Of the two species we examined, chinook salmon exhibited the highest degree of uptake and accumulation of contaminants. On both a lipid weight and a wet weight basis, contaminant concentrations in whole bodies of chinook salmon were significantly higher than in coho salmon sampled from the same sites, with levels typically 2–5 times as great in chinook than in coho salmon collected at the same sites. Concentrations of contaminants in chinook salmon stomach contents tended to be higher as well, although the difference was less marked. Additionally, correlations between contaminant body burdens and contaminant concentrations in stomach contents were stronger in chinook than in coho salmon.

These findings are consistent with results of other studies on chinook and coho salmon in the Great Lakes (Manchester-Neesvig *et al.*, 2001; Jackson *et al.*, 2001; Rohrer *et al.*, 1982), and are likely related to differences in life history and habitat use, as well as diet and metabolism. Assuming that the estuary is an important source of contaminants for outmigrant salmonids, these differences are consistent with the more prolonged period of estuarine residence in chinook salmon. Of the five species of Pacific salmon, chinook salmon

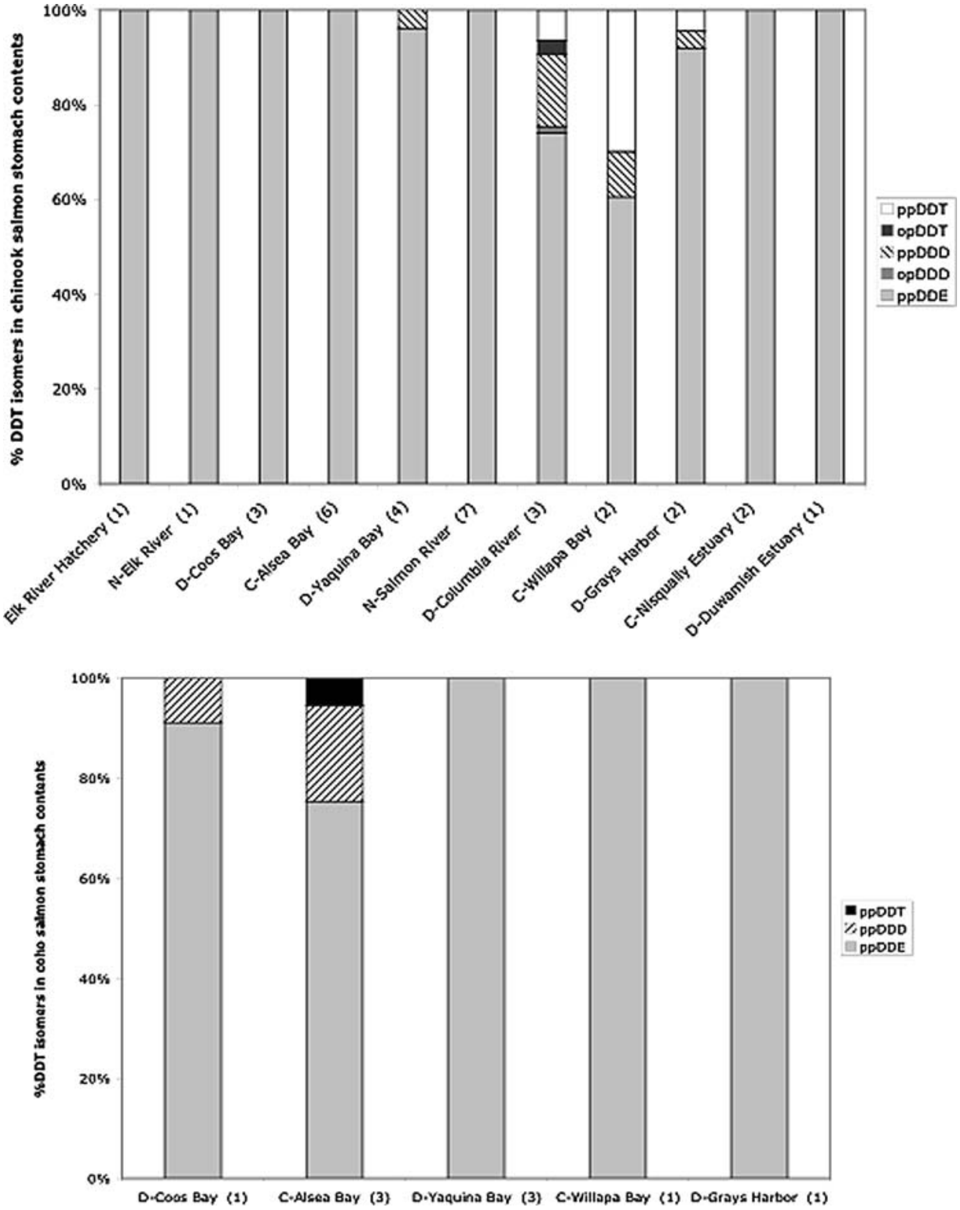

Fig. 12 Proportions of different DDTs in composite stomach contents samples of juvenile chinook and coho salmon collected from Pacific Northwest Estuaries. N = natural estuary; C = conservation estuary; S = shallow draft estuary; D = deep draft estuary. Numbers in parentheses indicate number of composite samples (10–15 fish each) analyzed per site or group

are most dependent upon estuaries during the early stages of their life cycle (Healey, 1982; 1991; Healey and Prince, 1995), typically residing in estuaries for one to two months (Simenstead *et al*., 1982), but in some cases for up to 6 months (Healey, 1982; Reimers, 1973; Levy and Northcote, 1982; Simenstad *et al*., 1982). Outmigrant juvenile coho, on the other hand, are much less estuarine-dependent, typically passing through the estuary within a few days (Moser *et al*., 1991; McMahon and Holtby, 1992; Magnusson, 2003; Duffy *et al*., 2005). Increased bioaccumulation in chinook salmon may also indicate that they are feeding at a higher trophic level than coho salmon, which would be supported by the generally higher concentrations of PCBs and DDTs in stomach contents of chinook salmon in comparison with levels in stomach contents of coho salmon collected from the same sites. This is consistent with dietary studies showing that,

Table 5 Mean concentrations (± SE) in ng/g wet wt of DDT isomers in stomach contents composites of juvenile chinook and coho salmon from Pacific Northwest estuaries, and juvenile chinook salmon from Elk River Hatchery. DDTs were measured by GC/ECD in samples collected from 1996–1998 and by GC/MS in samples collected from 1999–2001. Composites contain stomach contents from 10–15 fish. Values with different letter superscripts are significantly different (ANOVA, $p \leq 0.05$)

Site	o,p'-DDD	o,p'-DDT	p,p'-DDE	p,p'-DDD	p,p'-DDT
Hatchery chinook					
Elk River (1)	<DL^{b}	<DL^{b}	4.5^{b}	<DL^{b}	<DL^{b}
Estuary chinook					
Alsea Bay (6)	<DL^{b}	<DL^{b}	2.0 ± 0.6^{b}	<DL^{b}	<DL^{b}
Columbia River (3)	0.6 ± 0.6^{a}	1.1 ± 0.6^{a}	28.7 ± 9.1^{a}	5.9 ± 0.7^{a}	2.5 ± 1.4^{a}
Coos Bay (3)	<DL^{b}	<DL^{b}	1.1 ± 0.3^{b}	<DL^{b}	<DL^{b}
Duwamish Estuary (1)	<DL^{b}	<DL^{b}	5.8^{b}	<DL^{b}	2.5^{a}
Elk River (5)	<DL^{b}	<DL^{b}	0.6 ± 0.2^{b}	<DL^{b}	<DL^{b}
Grays Harbor (2)	<DL^{b}	<DL^{b}	41.7 ± 32.3^{a}	1.6 ± 1.6^{b}	2.1 ± 2.1^{a}
Nisqually Estuary (2)	<DL^{b}	<DL^{b}	3.5 ± 2.3^{b}	0.3 ± 0.3^{b}	<DL^{b}
Salmon River (7)	<DL^{b}	<DL^{b}	1.0 ± 1.0^{b}	<DL^{b}	<DL^{b}
Willapa Bay (2)	<DL^{b}	<DL^{b}	4.2 ± 0.4^{b}	0.7 ± 0.7^{b}	2.1 ± 2.1^{a}
Yaquina Bay (3)	<DL^{b}	<DL^{b}	6.9 ± 2.2^{b}	0.3 ± 0.3^{b}	<DL^{b}
Estuary coho					
Alsea Bay (3)	<DL^{b}	<DL^{b}	0.8 ± 0.1^{b}	0.11 ± 0.1^{b}	<DL^{b}
Coos Bay (1)	<DL^{b}	<DL^{b}	1.1^{b}	<DL^{b}	<DL^{b}
Grays Harbor (1)	<DL^{b}	<DL^{b}	2.3^{b}	<DL^{b}	<DL^{b}
Willapa Bay (1)	<DL^{b}	<DL^{b}	1.2^{b}	<DL^{b}	2.5^{a}
Yaquina Bay (3)	<DL^{b}	<DL^{b}	1.9 ± 0.9^{b}	0.2 ± 0.1^{b}	0.1 ± 0.1^{b}

Table 6 Mean concentrations (± SE) in ng/g, wet wt of selected organochlorine pesticides measured in stomach contents of juvenile chinook and coho salmon collected from the Pacific Northwest estuaries and hatcheries. Σchlordanes = summed concentrations of heptachlor, heptachlor epoxide, γ-chlordane, α-chlordane, *cis*-nonachlor, *trans*-nonachlor and nonachlor III. DL = detection limit. Pesticides were measured by GC/ECD in samples collected from 1996–1998 and by GC/MS in samples collected from 1999–2001. Values with different letter superscripts are significantly different (ANOVA, $p \leq 0.05$)

Site	lindane	dieldrin	Σchlordanes	HCB	mirex
Hatchery chinook					
Elk River (1)	<DL^{b}	<DL^{b}	1.4^{c}	0.7^{b}	0.7^{b}
Estuary chinook					
Alsea Bay (6)	<DL^{b}	<DL^{b}	<DL^{c}	0.6 ± 0.3^{b,c}	0.2 ± 0.2^{b}
Columbia River (3)	<DL^{b}	6.0 ± 6.0^{a}	0.8 ± 0.5^{c}	1.5 ± 0.8^{a,b}	0.3 ± 0.3^{b}
Coos Bay (3)	<DL^{b}	<DL^{b}	<DL^{c}	0.3 ± 0.2^{c}	0.6 ± 0.6^{b}
Duwamish Estuary (1)	<DL^{b}	<DL^{b}	12^{a}	<DL^{c}	2.5^{b}
Elk River (5)	<DL^{b}	<DL^{b}	1.4^{c}	0.3 ± 0.2^{c}	0.24 ± 0.25^{b}
Grays Harbor (2)	1.8 + 1.8^{a}	1.5 ± 1.5^{a,b}	6.1 ± 0.6^{b}	1.9 ± 1.9^{a}	2.7 ± 2.7^{b}
Nisqually Estuary (2)	<DL^{b}	0.9^{b}	0.5 ± 0.5^{c}	0.17 ± 0.17^{c}	<DL^{b}
Salmon River (7)	<DL^{b}	<DL^{b}	<DL^{c}	<DL^{c}	<DL^{b}
Willapa Bay (2)	<DL^{b}	6.5 ± 6.5^{a}	<DL^{c}	<DL^{c}	6 ± 6^{a}
Yaquina Bay (3)	0.6 + 0.6^{a}	<DL^{b}	1.8 ± 1.8^{c}	0.24 ± 0.24^{c}	0.4 ± 0.4^{b}
Estuary coho					
Alsea Bay (3)	<DL^{b}	<DL^{b}	0.17 ± 0.06^{c}	0.72 ± 0.22^{b}	<DL^{b}
Coos Bay (1)	<DL^{b}	4.0 ± 4.0^{b}	0.31^{c}	0.25^{c}	<DL^{b}
Grays Harbor (1)	<DL^{b}	<DL^{b}	<DL^{c}	<DL^{c}	<DL^{b}
Willapa Bay (1)	<DL^{b}	<DL^{b}	0.65^{c}	0.65^{b}	<DL^{b}
Yaquina Bay (3)	<DL^{b}	<DL^{b}	0.69 ± 0.36^{c}	0.12 ± 0.07^{c}	<DL^{b}

while there is considerable overlap in the diet of juvenile coho and chinook salmon, coho tend to consume a lower proportion of juvenile and larval fish and a higher proportion of invertebrates than chinook (Schabetsberger *et al*., 2003; Brodeur and Pearcy, 1990).

4.2 Site-related differences in contaminant body burdens

Although contaminant concentrations in coho salmon showed no strong spatial trends, in chinook salmon there were marked intersite differences in contaminant concentrations in tissues and stomach contents, with highest exposure levels in the industrial and urbanized estuaries. Concentrations of PCBs were highest in samples from the Duwamish Estuary, and were similar to or somewhat lower than concentrations reported in earlier Puget Sound studies at this location (Stein *et al*., 1995; Varanasi *et al*., 1993; Meador *et al*., 2002). Total PCB concentrations 2 to 3 times higher than those reported in this study have been measured in juvenile chinook collected from heavily contaminated Duwamish Estuary sites (Varanasi *et al*., 1993; Meador *et al*., 2002). The somewhat lower concentrations of PCBs observed in juvenile salmon sampled in the present study may be due to differences in sampling location, or because sampling occurred early in the season, when juvenile salmon may have only recently entered the estuary (Bottom *et al*., 2005). The lower concentrations may also be reflective of a low proportion of hatchery fish in this sample. Such differences in contaminant concentrations between wild and hatchery-released fish have been noted in other studies (Meador *et al*., 2002). In addition to Duwamish chinook, concentrations of PCBs were also relatively high in chinook salmon from the Columbia River and Yaquina Bay.

Interestingly, PCB concentrations in the juvenile chinook salmon we sampled were quite similar to concentrations reported in returning adult chinook salmon from Washington State (Missildine *et al*., 2005). Mean concentrations of PCBs in adult chinook ranged from 48–50 ng/g ww in salmon returning to Puget Sound hatcheries (Deschutes and Issaquah), and from 15–29 ng/g ww in salmon returning to coastal hatcheries (Makah and Quinault). Although it is unlikely that exposures occurring in the juvenile stage make a major contribution to adult contaminant body burdens (O'Neill *et al*., 1998), these data do suggest consistent exposure at multiple life stages for salmon from urban estuaries.

Concentrations of DDTs were especially high in juvenile chinook salmon from the Lower Columbia River and in the Nisqually Estuary in Puget Sound. The high DDT concentrations in Columbia River chinook are consistent with elevated DDT concentrations observed in other resident marine and freshwater fish from the Columbia River in earlier studies by EPA, NOAA, and USGS, and the States of Washington and Oregon (USEPA, 2000; Tetra-Tech Inc., 1993, 1994, 1996; LCREP, 1999; Brown *et al*., 1998; Foster *et al*., 2001a,b). As in most environmental samples, DDT breakdown products, especially p,p'-DDE, predominated in coho and chinook salmon body and stomach contents samples. However, p,p'-DDT and o,p'-DDT were also detected in samples from some sites, particularly chinook salmon from the Columbia River and Yaquina Bay, and coho salmon from Willapa Bay. The presence of these parent compounds suggests that there may be fresher sources of DDT in these areas, although the half-lives of p,p'- and o,p'-DDT in soils can be quite variable (ATSDR, 2002).

Concentrations of PAHs were especially high in stomach contents of fish from the Duwamish Estuary, Willapa Bay, Grays Harbor and Yaquina Bay, although very high concentrations of PAH metabolites in bile (i.e., >1000 ng/g bile for FACs-BaP and $>200{,}000$ ng/g bile for FACs-PHN) were observed only in fish from the Duwamish Estuary. In fish from more pristine estuaries such as Alsea Bay, Salmon River, Elk River, and Tillamook, PAH concentrations were lower than any of those previously reported in Puget Sound (Stein *et al*., 1995; Varanasi *et al*., 1993; McCain *et al*., 1990). High molecular weight AHs, which originate primarily from combustion products (Varanasi *et al*., 1992; MacDonald and Crecelius, 1994), accounted for a higher proportion of total AHs in stomach contents of fish from the Duwamish Estuary, Willapa Bay, Grays Harbor and Yaquina Bay, than in fish from other estuaries. This suggests that atmospheric emissions from incineration and automobile emissions may be major contamination sources in these areas, as well as releases from industries that generate high molecular weight PAHs (e.g., aluminum smelters, oil refineries, creosote plants; Varanasi *et al*., 1992; MacDonald and Crecelius, 1994). The predominance of LAHs, which are primarily associated with petroleum products (Varanasi *et al*., 1992; MacDonald and Crecelius, 1994), in stomach contents of salmon from Alsea Bay, Coos Bay, Nisqually, Salmon River, the Columbia River, and Elk River, suggests that PAHs in these areas come mainly from releases of fuel oil, crude oil, and related materials into the environment.

Ratios of ΣDDT/ΣPCB varied from site to site, indicating differences in contaminant profiles among different groups of fish. For example, the ΣDDT/ΣPCB ratio in bodies of salmon from the Columbia Estuary site (∼1.1) was higher than in juvenile chinook salmon the other estuarine sites, suggesting particularly high uptake of DDTs from the environment at this site. Fish from the Duwamish Estuary, the other hand, had one of the lowest DDT/PCB ratios, reflecting the very high concentrations of PCBs in fish from this site.

4.3 Contaminants in hatchery salmon

Measurable concentrations of PCBs and DDTs were also present in bodies of juvenile chinook salmon sampled directly from Pacific Northwest hatcheries. On a wet weight basis, concentrations of both PCBs and DDTs in hatchery chinook were relatively high, comparable to those in juvenile chinook from the more contaminated estuarine sites. However, as the lipid content of hatchery fish was also quite high (8% as compared to 1–3% in estuarine fish), when PCB and DDT body burdens were calculated on a lipid weight basis, concentrations in hatchery chinook were relatively low in comparison to levels in chinook from urban and industrialized estuaries. In stomach contents of juvenile hatchery chinook, levels of PAHs, PCBs, DDTs, were also relatively low, similar to concentrations in rural estuaries such as Elk River and Alsea Bay. This suggests that elevated contaminant concentrations in the hatchery fish we sampled are due not so much to high concentrations of contaminants in feed, but to the high body fat levels in hatchery reared juveniles that facilitate the uptake of lipid soluble contaminants. It is uncertain, though, whether the Elk River Hatchery sample is representative of feed from other sampled hatcheries, or of feeds in current use.

Chemical contaminants, especially PCBs, have been detected in hatchery fish and feed and in farmed fish in several other studies (Easton *et al.*, 2002; Parkins, 2003; Karl *et al.*, 2003; Hites *et al.*, 2004). Available data suggest that the problem is widespread, and also that contaminant concentrations in different lots of feed and in fish from different hatcheries are highly variable. Concentrations of PCBs in juvenile salmon from the Pacific Northwest hatcheries sampled in this study were similar to mean levels (∼50 ng/g ww) reported by Easton *et al.* (2002) and Hites *et al.* (2004) in farmed salmon. However, PCB concentrations in commercial feed analyzed by Easton *et al.* (2002) and Hites *et al.* (2004) were generally higher than PCB concentrations in stomach contents of Elk River Hatchery salmon, with a number of samples in the 30–90 ng/g ww range.

In the hatchery chinook we analyzed, the DDT isomers *p,p′*-DDT and *o,p′*-DDT made up a substantial proportion of DDTs present. This appears to be common in farmed and hatchery fish, and may indicate use of oils or fish meals from sources where there was relatively recent usage of DDTs (Jacobs *et al.*, 2002).

The observation of chemical contaminants in prerelease hatchery fish is likely to be a concern for the management of these animals. If contaminant body burdens are already moderate to high when fish leave the hatchery, they have an increased risk of reaching exposure concentrations during estuarine residence that could significantly reduce their likelihood of survival. Moreover, contaminated salmon may be a significant source of toxicants in the environment and in the food chain (Kreummel *et al.*, 2003). This represents a hazard for birds and other piscivorous wildlife. More comprehensive sampling of fish and feed from hatcheries is needed to determine the extent of this problem in the Pacific Northwest.

4.4 Potential health effects of contaminants on salmon

For some contaminants, exposure levels in juvenile salmon from selected sites are approaching concentrations that could affect their health and survival. Indeed, adverse health effects have been observed in juvenile salmon from the Duwamish Estuary, which is contaminated with PAHs and PCBs. Fish from this area showed immunosuppression, reduced disease resistance and decreased growth rates (Arkoosh *et al.*, 1991, 1994, 1998, 2001; Varanasi *et al.*, 1993; Casillas *et al.*, 1995, 1998), as well as biochemical alterations such as DNA damage (i.e., PAH-DNA adducts in liver) and induction of cytochrome P4501A (CYP1A), an enzyme that metabolizes selected contaminants including PAHs, dioxins and furans, and dioxin-like PCB congeners (Stein *et al.*, 1995; McCain *et al.*, 1990; Varanasi *et al.*, 1993; Collier *et al.*, 1998; Stehr *et al.*, 2000). These biochemical alterations are not necessarily indicative of adverse health effects in themselves, but are associated with disease conditions including reproductive and developmental abnormalities and liver disease (Williams *et al.*, 1998; Whyte *et al.*, 2000; Myers *et al.*, 2003). Fish from several sites sampled in the present study (Grays Harbor, Yaquina Bay, the Columbia River) had concentrations of PCBs, PAHs or both in tissues or stomach contents that were comparable to those found in Duwamish Estuary fish, suggesting that they may also be at risk for the types of adverse health effects documented in fish from that Puget Sound site. The possibility of increased disease-induced mortality is increased by recent finding of widespread occurrence of potentially lethal parasites and pathogens in juvenile chinook and coho salmon from the estuaries sampled in this study (Arkoosh *et al.*, 2004).

The potential for health risks in Pacific Northwest salmon can also be evaluated by comparing measured tissue contaminant concentrations against established effects thresholds. For PCBs, Meador *et al.* (2002) estimated a critical body residue of 2400 ng/g lipid for protection against 95% of effects ranging from enzyme induction to mortality, based on a range of sublethal effects observed in salmonids in peer-reviewed studies conducted by NMFS and other researchers. Mean PCB body burdens in juvenile salmon analyzed in this study were near or above 2400 ng/g lw in fish from three sampling sites, the Columbia River, the Duwamish Estuary, and Willapa Bay. These findings suggest that a significant portion of outmigrant juvenile chinook salmon from these sites may be at risk of some type of health impairment due to PCB exposure.

A threshold concentration for the impact of DDTs on listed salmon has not been systematically determined, unlike the PCBs (Meador *et al.*, 2002). Most reported effects in salmonids are associated with whole body tissue total DDT concentrations at or above 500 ng/g ww (Allison *et al.*, 1963; Burdick *et al.*, 1964; Buhler *et al.*, 1969; Johnson and Pecor, 1969; Peterson, 1976; Poels *et al.*, 1980), or about 5000 ng/g lipid, assuming that the test fish had a lipid content of around 10%, which is typical of laboratory-reared salmonids (Meador *et al.*, 2002). A number of recent studies suggest that certain DDT isomers, such as *o,p′*-DDT and *o,p′*-DDE, have estrogenic activity, and may have endocrine-disrupting or immunotoxic effects (Donohoe and Curtis, 1996; Arukwe *et al.*, 1998; Celius and Walther, 1998; Khan and Thomas, 1998; Christiansen *et al.*, 2000; Zaroogian *et al.*, 2001; Milston *et al.*, 2003; Papoulias *et al.*, 2003). However, measured or estimated body burdens associated with these effects are typically in the 10–20 ng/g ww or 100–200 ng/g lipid range or above. Lipid-adjusted concentrations of total DDTs and *o,p′*-isomers of DDTs approached these concentrations in some fish from the Columbia River, but DDT body burdens typically found in estuarine chinook and coho salmon were substantially lower. This suggests that, by themselves, body burdens of DDTs would be unlikely to cause adverse health effects in most Pacific Northwest juvenile salmon. However, DDTs do not occur in isolation in Pacific Northwest estuaries, but are present with a variety of other contaminants. Estrogenic DDT metabolites, for example, even at low concentrations, could act in concert with other estrogenic contaminants (e.g., plasticizers, pharmaceuticals, and surfactants) to alter reproductive processes or other physiological functions. In fact, some field studies have reported effect thresholds for DDTs lower than those observed in laboratory exposure studies [e.g., maternal muscle concentrations of 25–30 ng/g ww for increased yolk sac fry mortality in Baltic salmon; Vuorinen *et al.* (1997)], possibly because of the presence of other contaminants, as well as lower lipid concentrations in wild fish. More work is needed to understand the potential cumulative effects of DDTs and other contaminants present in salmon habitats.

Exposure to PAHs may also contribute to health risks in juvenile chinook salmon from some of the sampling sites. In juvenile chinook salmon from Puget Sound sites where immunosuppression and other health effects have been observed (Arkoosh *et al.*, 1991, 1994, 1998, 2001; Varanasi *et al.*, 1993; Stein *et al.*, 1995; Casillas *et al.*, 1995, 1998; Stehr *et al.*, 2000), concentrations of total PAHs in stomach contents of these fish were in the 1,200 to 8,000 ng/g ww range for ΣLAHs and in the 2,000 to 6,000 ng/g ww range for ΣHAHs, or 4,000 to 15,000 ng/g ww for total PAHs (Stein *et al.*, 1995; Varanasi *et al.*, 1993; Stehr *et al.*, 2000). In the present study, PAH concentrations in this range were detected once again in chinook salmon from the Duwamish Estuary, suggesting a potential for health risks to fish from this site. Concentrations of ΣHAHs were also surprisingly high in stomach contents of chinook salmon from Willapa Bay, but this was not reflected in bile metabolite levels of fish from this site. Additional sampling may be needed to determine if there is consistent exposure to PAHs in Willapa Bay salmon.

In laboratory feeding studies where fish were exposed to PAHs alone, reported effect concentrations are somewhat higher than levels of PAHs measured in stomach contents of salmon from sites in where biological effects have been reported in the field, or PAH levels measured in the present study. Meador *et al.* (2005) found physiological changes in juvenile chinook exposed to 120 ppm total PAHs dry wt, or about 25,000 ng/g ww, while Bravo *et al.* (2005) observed immunosuppression, CYP1A induction and DNA damage in rainbow trout exposed to concentrations of 40,000 ng/g ww PAH in diet. Reported no effect doses for immunosuppressive and other physiological effects are in the 8,000–16,000 ng/g ww range (Palm *et al.*, 2004; Meador *et al.*, 2005). Total PAH concentrations in stomach contents of juvenile chinook collected from the Duwamish Estuary and Willapa Bay as part of this study are similar, and thus might be considered as being close to a threshold effect level. Moreover, PAHs may contribute to immunosuppressive or growth-altering impacts of other contaminants in environmental mixtures, even if they are below toxicity thresholds when considered alone (e.g., see Loge *et al.* (2005).

4.5 Trophic transfer and health effects on wildlife

Even if levels of bioaccumulative compounds such as DDTs and PCBs are not sufficient to cause direct effects on juvenile salmonids, they may represent a hazard to fish-eating predators through bioaccumulation and bioconcentration. The U.S. Fish and Wildlife Service (2004) estimated a no-observable adverse effects level (NOAEL) for impacts of fish prey on bald eagles of 60 ng/g ww for PCBs and 40 ng/g ww for DDTs, while Nendza *et al.* (1997) estimated a ΣDDTs NOAEL of 22–50 ng/g ww in fish tissue for impacts of related to bioaccumulation and bioconcentration of DDTs in estuarine systems. Juvenile chinook salmon sampled in this study from the Columbia River, the Duwamish Estuary, and the Nisqually Estuary had whole body DDT concentrations in the 20–50 ng/g ww range, and chinook salmon from the Duwamish Estuary had PCB concentrations above 60 ng/g ww, suggesting these fish may pose a hazard to fish-eating wildlife. Indeed, there is considerable evidence of bioconcentration of DDTs in birds and other wildlife that use the Columbia River, resulting in body burdens high enough to cause reproductive problems (Anthony *et al.*, 1993; USFWS, 1999, 2004; Thomas and Anthony, 2003; Henny *et al.*, 2003; Buck *et al.*, 2005).

4.6 Summary

Overall, the results of this study indicate significant exposure to PCBs, DDTs, and PAHs in outmigrant juvenile chinook salmon from several Pacific Northwest estuaries. Contaminant concentrations were generally highest in stomach contents and tissues of salmon from the deep draft estuaries, with the highest levels of urban and industrial development (i.e., the Duwamish Estuary, the Columbia River, Yaquina Bay, Coos Bay and Grays Harbor), and lowest in the natural estuaries (Elk River and Salmon River), which are largely undeveloped. However, relatively high concentrations of contaminants were detected in juvenile chinook from some of the conservation estuaries (Nisqually Estuary, Skokomish Estuary, Willapa Bay, and Alsea Bay), where land use is primarily agricultural. For example, concentrations of DDTs in salmon from the Nisqually Estuary were among the highest observed in this survey. For juvenile chinook salmon from the Duwamish Estuary, the Columbia River, and Yaquina Bay, whole body PCBs were within the range where they could potentially affect fish health and survival. In juvenile coho salmon, on the other hand, contaminant concentrations were relatively low, below estimated biological effects thresholds, and showed minimal variation from site to site. Juvenile chinook salmon are likely absorbing some contamination during estuarine residence through their prey, as PCBs, PAHs, and DDTs were consistently present in stomach contents, and PCBs and DDTs were significantly correlated with contaminant body burdens in fish from the same sites. Hatchery chinook also showed evidence of contaminant uptake. Although contaminant concentrations were not especially high in stomach contents of fish from the hatchery we tested, body burdens were elevated, in part because of the high lipid content of the fish. More research is needed to document exposure and associated effects of chemical contaminants on endangered Pacific Northwest salmon, but the available data show clearly that tissue burdens of some classes of contaminants are within the range where they could potentially affect survival and productivity of listed stocks or have adverse effects on the ecosystem of which salmon are a part.

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Circular A-4

September 17, 2003

TO THE HEADS OF EXECUTIVE AGENCIES AND ESTABLISHMENTS

Subject: Regulatory Analysis

This Circular provides the Office of Management and Budget's (OMB's) guidance to Federal agencies on the development of regulatory analysis as required under Section 6(a)(3)(c) of Executive Order12866, "Regulatory Planning and Review," the Regulatory Right-to-Know Act, and a variety of related authorities. The Circular also provides guidance to agencies on the regulatory accounting statements that are required under the Regulatory Right-to-Know Act.

This Circular refines OMB's "best practices" document of 1996 (http://www.whitehouse.gov/omb/inforeg/riaguide.html), which was issued as a guidance in 2000 (http://www.whitehouse.gov/omb/memoranda/m00-08.pdf), and reaffirmed in 2001 (http://www.whitehouse.gov/omb/memoranda/m01-23.html). It replaces both the 1996 "best practices" and the 2000 guidance.

In developing this Circular, OMB first developed a draft that was subject to public comment, interagency review, and peer review. Peer reviewers included Cass Sunstein, University of Chicago; Lester Lave, Carnegie Mellon University; Milton C. Weinstein and James K. Hammitt of the Harvard School of Public Health; Kerry Smith, North Carolina State University; Jonathan Weiner, Duke University Law School; Douglas K. Owens, Stanford University; and W. Kip Viscusi, Harvard Law School. Although these individuals submitted comments, OMB is solely responsible for the final content of this Circular.

A. Introduction

This Circular is designed to assist analysts in the regulatory agencies by defining good regulatory analysis – called either "regulatory analysis" or "analysis" for brevity – and standardizing the way benefits and costs of Federal regulatory actions are measured and reported. Executive Order 12866 requires agencies to conduct a regulatory analysis for economically significant regulatory actions as defined by Section 3(f)(1). This requirement applies to rulemakings that rescind or modify existing rules as well as to rulemakings that establish new requirements.

The Need for Analysis of Proposed Regulatory Actions[1]

Regulatory analysis is a tool regulatory agencies use to anticipate and evaluate the likely consequences of rules. It provides a formal way of organizing the evidence on the key effects –

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[1] We use the term "proposed" to refer to any regulatory actions under consideration regardless of the stage of the regulatory process.

good and bad – of the various alternatives that should be considered in developing regulations. The motivation is to (1) learn if the benefits of an action are likely to justify the costs or (2) discover which of various possible alternatives would be the most cost-effective.

A good regulatory analysis is designed to inform the public and other parts of the Government (as well as the agency conducting the analysis) of the effects of alternative actions. Regulatory analysis sometimes will show that a proposed action is misguided, but it can also demonstrate that well-conceived actions are reasonable and justified.

Benefit-cost analysis is a primary tool used for regulatory analysis.[2] Where all benefits and costs can be quantified and expressed in monetary units, benefit-cost analysis provides decision makers with a clear indication of the most efficient alternative, that is, the alternative that generates the largest net benefits to society (ignoring distributional effects). This is useful information for decision makers and the public to receive, even when economic efficiency is not the only or the overriding public policy objective.

It will not always be possible to express in monetary units all of the important benefits and costs. When it is not, the most efficient alternative will not necessarily be the one with the largest quantified and monetized net-benefit estimate. In such cases, you should exercise professional judgment in determining how important the non-quantified benefits or costs may be in the context of the overall analysis. If the non-quantified benefits and costs are likely to be important, you should carry out a "threshold" analysis to evaluate their significance. Threshold or "break-even" analysis answers the question, "How small could the value of the non-quantified benefits be (or how large would the value of the non-quantified costs need to be) before the rule would yield zero net benefits?" In addition to threshold analysis you should indicate, where possible, which non-quantified effects are most important and why.

Key Elements of a Regulatory Analysis

A good regulatory analysis should include the following three basic elements: (1) a statement of the need for the proposed action, (2) an examination of alternative approaches, and (3) an evaluation of the benefits and costs—quantitative and qualitative—of the proposed action and the main alternatives identified by the analysis.

To evaluate properly the benefits and costs of regulations and their alternatives, you will need to do the following:

- Explain how the actions required by the rule are linked to the expected benefits. For example, indicate how additional safety equipment will reduce safety risks. A similar analysis should be done for each of the alternatives.
- Identify a baseline. Benefits and costs are defined in comparison with a clearly stated alternative. This normally will be a "no action" baseline: what the world will be like if the proposed rule is not adopted. Comparisons to a "next best" alternative are also especially useful.

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[2] See Mishan EJ (1994), *Cost-Benefit Analysis*, fourth edition, Routledge, New York.

- Identify the expected undesirable side-effects and ancillary benefits of the proposed regulatory action and the alternatives. These should be added to the direct benefits and costs as appropriate.

With this information, you should be able to assess quantitatively the benefits and costs of the proposed rule and its alternatives. A complete regulatory analysis includes a discussion of non-quantified as well as quantified benefits and costs. A non-quantified outcome is a benefit or cost that has not been quantified or monetized in the analysis. When there are important non-monetary values at stake, you should also identify them in your analysis so policymakers can compare them with the monetary benefits and costs. When your analysis is complete, you should present a summary of the benefit and cost estimates for each alternative, including the qualitative and non-monetized factors affected by the rule, so that readers can evaluate them.

As you design, execute, and write your regulatory analysis, you should seek out the opinions of those who will be affected by the regulation as well as the views of those individuals and organizations who may not be affected but have special knowledge or insight into the regulatory issues. Consultation can be useful in ensuring that your analysis addresses all of the relevant issues and that you have access to all pertinent data. Early consultation can be especially helpful. You should not limit consultation to the final stages of your analytical efforts.

You will find that you cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment. Different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions.

A good analysis is transparent. It should be possible for a qualified third party reading the report to see clearly how you arrived at your estimates and conclusions. For transparency's sake, you should state in your report what assumptions were used, such as the time horizon for the analysis and the discount rates applied to future benefits and costs. It is usually necessary to provide a sensitivity analysis to reveal whether, and to what extent, the results of the analysis are sensitive to plausible changes in the main assumptions and numeric inputs.

A good analysis provides specific references to all sources of data, appendices with documentation of models (where necessary), and the results of formal sensitivity and other uncertainty analyses. Your analysis should also have an executive summary, including a standardized accounting statement.

B. The Need for Federal Regulatory Action

Before recommending Federal regulatory action, an agency must demonstrate that the proposed action is necessary. If the regulatory intervention results from a statutory or judicial directive, you should describe the specific authority for your action, the extent of discretion available to you, and the regulatory instruments you might use. Executive Order 12866 states that "Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well being of the American people ... ."

Executive Order 12866 also states that "Each agency shall identify the problem that it intends to address (including, where applicable, the failures of private markets or public institutions that warrant new agency action) as well as assess the significance of that problem." Thus, you should try to explain whether the action is intended to address a significant market failure or to meet some other compelling public need such as improving governmental processes or promoting intangible values such as distributional fairness or privacy. If the regulation is designed to correct a significant market failure, you should describe the failure both qualitatively and (where feasible) quantitatively. You should show that a government intervention is likely to do more good than harm. For other interventions, you should also provide a demonstration of compelling social purpose and the likelihood of effective action. Although intangible rationales do not need to be quantified, the analysis should present and evaluate the strengths and limitations of the relevant arguments for these intangible values.

Market Failure or Other Social Purpose

The major types of market failure include: externality, market power, and inadequate or asymmetric information. Correcting market failures is a reason for regulation, but it is not the only reason. Other possible justifications include improving the functioning of government, removing distributional unfairness, or promoting privacy and personal freedom.

1. Externality, common property resource and public good

An externality occurs when one party's actions impose uncompensated benefits or costs on another party. Environmental problems are a classic case of externality. For example, the smoke from a factory may adversely affect the health of local residents while soiling the property in nearby neighborhoods. If bargaining were costless and all property rights were well defined, people would eliminate externalities through bargaining without the need for government regulation.[3] From this perspective, externalities arise from high transactions costs and/or poorly defined property rights that prevent people from reaching efficient outcomes through market transactions.

Resources that may become congested or overused, such as fisheries or the broadcast spectrum, represent common property resources. "Public goods," such as defense or basic scientific research, are goods where provision of the good to some individuals cannot occur without providing the same level of benefits free of charge to other individuals.

2. Market Power

Firms exercise market power when they reduce output below what would be offered in a competitive industry in order to obtain higher prices. They may exercise market power collectively or unilaterally. Government action can be a source of market power, such as when regulatory actions exclude low-cost imports. Generally, regulations that increase market power

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[3] See Coase RH (1960), *Journal of Law and Economics*, 3, 1-44.

for selected entities should be avoided. However, there are some circumstances in which government may choose to validate a monopoly. If a market can be served at lowest cost only when production is limited to a single producer – local gas and electricity distribution services, for example – a natural monopoly is said to exist. In such cases, the government may choose to approve the monopoly and to regulate its prices and/or production decisions. Nevertheless, you should keep in mind that technological advances often affect economies of scale. This can, in turn, transform what was once considered a natural monopoly into a market where competition can flourish.

3. Inadequate or Asymmetric Information

Market failures may also result from inadequate or asymmetric information. Because information, like other goods, is costly to produce and disseminate, your evaluation will need to do more than demonstrate the possible existence of incomplete or asymmetric information. Even though the market may supply less than the full amount of information, the amount it does supply may be reasonably adequate and therefore not require government regulation. Sellers have an incentive to provide information through advertising that can increase sales by highlighting distinctive characteristics of their products. Buyers may also obtain reasonably adequate information about product characteristics through other channels, such as a seller offering a warranty or a third party providing information.

Even when adequate information is available, people can make mistakes by processing it poorly. Poor information-processing often occurs in cases of low probability, high-consequence events, but it is not limited to such situations. For instance, people sometimes rely on mental rules-of-thumb that produce errors. If they have a clear mental image of an incident which makes it cognitively "available," they might overstate the probability that it will occur. Individuals sometimes process information in a biased manner, by being too optimistic or pessimistic, without taking sufficient account of the fact that the outcome is exceedingly unlikely to occur. When mistakes in information processing occur, markets may overreact. When it is time-consuming or costly for consumers to evaluate complex information about products or services (e.g., medical therapies), they may expect government to ensure that minimum quality standards are met. However, the mere possibility of poor information processing is not enough to justify regulation. If you think there is a problem of information processing that needs to be addressed, it should be carefully documented.

4. Other Social Purposes

There are justifications for regulations in addition to correcting market failures. A regulation may be appropriate when you have a clearly identified measure that can make government operate more efficiently. In addition, Congress establishes some regulatory programs to redistribute resources to select groups. Such regulations should be examined to ensure that they are both effective and cost-effective. Congress also authorizes some regulations to prohibit discrimination that conflicts with generally accepted norms within our society. Rulemaking may also be appropriate to protect privacy, permit more personal freedom or promote other democratic aspirations.

Showing That Regulation at the Federal Level Is the Best Way to Solve the Problem

Even where a market failure clearly exists, you should consider other means of dealing with the failure before turning to Federal regulation. Alternatives to Federal regulation include antitrust enforcement, consumer-initiated litigation in the product liability system, or administrative compensation systems.

In assessing whether Federal regulation is the best solution, you should also consider the possibility of regulation at the State or local level. In some cases, the nature of the market failure may itself suggest the most appropriate governmental level of regulation. For example, problems that spill across State lines (such as acid rain whose precursors are transported widely in the atmosphere) are probably best addressed by Federal regulation. More localized problems, including those that are common to many areas, may be more efficiently addressed locally.

The advantages of leaving regulatory issues to State and local authorities can be substantial. If public values and preferences differ by region, those differences can be reflected in varying State and local regulatory policies. Moreover, States and localities can serve as a testing ground for experimentation with alternative regulatory policies. One State can learn from another's experience while local jurisdictions may compete with each other to establish the best regulatory policies. You should examine the proper extent of State and local discretion in your rulemaking context.

A diversity of rules may generate gains for the public as governmental units compete with each other to serve the public, but duplicative regulations can also be costly. Where Federal regulation is clearly appropriate to address interstate commerce issues, you should try to examine whether it would be more efficient to retain or reduce State and local regulation. The local benefits of State regulation may not justify the national costs of a fragmented regulatory system. For example, the increased compliance costs for firms to meet different State and local regulations may exceed any advantages associated with the diversity of State and local regulation. Your analysis should consider the possibility of reducing as well as expanding State and local rulemaking.

The role of Federal regulation in facilitating U.S. participation in global markets should also be considered. Harmonization of U.S. and international rules may require a strong Federal regulatory role. Concerns that new U.S. rules could act as non-tariff barriers to imported goods should be evaluated carefully.

The Presumption Against Economic Regulation

Government actions can be unintentionally harmful, and even useful regulations can impede market efficiency. For this reason, there is a presumption against certain types of regulatory action. In light of both economic theory and actual experience, a particularly demanding burden of proof is required to demonstrate the need for any of the following types of regulations:

- price controls in competitive markets;

- production or sales quotas in competitive markets;
- mandatory uniform quality standards for goods or services if the potential problem can be adequately dealt with through voluntary standards or by disclosing information of the hazard to buyers or users; or
- controls on entry into employment or production, except (a) where indispensable to protect health and safety (e.g., FAA tests for commercial pilots) or (b) to manage the use of common property resources (e.g., fisheries, airwaves, Federal lands, and offshore areas).

C. Alternative Regulatory Approaches

Once you have determined that Federal regulatory action is appropriate, you will need to consider alternative regulatory approaches. Ordinarily, you will be able to eliminate some alternatives through a preliminary analysis, leaving a manageable number of alternatives to be evaluated according to the formal principles of the Executive Order. The number and choice of alternatives selected for detailed analysis is a matter of judgment. There must be some balance between thoroughness and the practical limits on your analytical capacity. With this qualification in mind, you should nevertheless explore modifications of some or all of a regulation's attributes or provisions to identify appropriate alternatives. The following is a list of alternative regulatory actions that you should consider.

Different Choices Defined by Statute

When a statute establishes a specific regulatory requirement and the agency is considering a more stringent standard, you should examine the benefits and costs of reasonable alternatives that reflect the range of the agency's statutory discretion, including the specific statutory requirement.

Different Compliance Dates

The timing of a regulation may also have an important effect on its net benefits. Benefits may vary significantly with different compliance dates where a delay in implementation may result in a substantial loss in future benefits (e.g., a delay in implementation could result in a significant reduction in spawning stock and jeopardize a fishery). Similarly, the cost of a regulation may vary substantially with different compliance dates for an industry that requires a year or more to plan its production runs. In this instance, a regulation that provides sufficient lead time is likely to achieve its goals at a much lower overall cost than a regulation that is effective immediately.

Different Enforcement Methods

Compliance alternatives for Federal, State, or local enforcement include on-site inspections, periodic reporting, and noncompliance penalties structured to provide the most appropriate incentives. When alternative monitoring and reporting methods vary in their benefits and costs, you should identify the most appropriate enforcement framework. For example, in some circumstances random monitoring or parametric monitoring will be less expensive and nearly as effective as continuous monitoring.

Different Degrees of Stringency

In general, both the benefits and costs associated with a regulation will increase with the level of stringency (although marginal costs generally increase with stringency, whereas marginal benefits may decrease). You should study alternative levels of stringency to understand more fully the relationship between stringency and the size and distribution of benefits and costs among different groups.

Different Requirements for Different Sized Firms

You should consider setting different requirements for large and small firms, basing the requirements on estimated differences in the expected costs of compliance or in the expected benefits. The balance of benefits and costs can shift depending on the size of the firms being regulated. Small firms may find it more costly to comply with regulation, especially if there are large fixed costs required for regulatory compliance. On the other hand, it is not efficient to place a heavier burden on one segment of a regulated industry solely because it can better afford the higher cost. This has the potential to load costs on the most productive firms, costs that are disproportionate to the damages they create. You should also remember that a rule with a significant impact on a substantial number of small entities will trigger the requirements set forth in the Regulatory Flexibility Act. (5 U.S.C. 603(c), 604).

Different Requirements for Different Geographic Regions

Rarely do all regions of the country benefit uniformly from government regulation. It is also unlikely that costs will be uniformly distributed across the country. Where there are significant regional variations in benefits and/or costs, you should consider the possibility of setting different requirements for the different regions.

Performance Standards Rather than Design Standards

Performance standards express requirements in terms of outcomes rather than specifying the means to those ends. They are generally superior to engineering or design standards because performance standards give the regulated parties the flexibility to achieve regulatory objectives in the most cost-effective way. In general, you should take into account both the cost savings to the regulated parties of the greater flexibility and the costs of assuring compliance through monitoring or some other means.

Market-Oriented Approaches Rather than Direct Controls

Market-oriented approaches that use economic incentives should be explored. These alternatives include fees, penalties, subsidies, marketable permits or offsets, changes in liability or property rights (including policies that alter the incentives of insurers and insured parties), and required bonds, insurance or warranties. One example of a market-oriented approach is a program that allows for averaging, banking, and/or trading (ABT) of credits for achieving additional emission reductions beyond the required air emission standards. ABT programs can be extremely valuable in reducing costs or achieving earlier or greater benefits, particularly when the costs of achieving compliance vary across production lines, facilities, or firms. ABT can be allowed on a plant-wide, firm-wide, or region-wide basis rather than vent by vent, provided this does not produce unacceptable local air quality outcomes (such as "hot spots" from local pollution concentration).

Informational Measures Rather than Regulation

If intervention is contemplated to address a market failure that arises from inadequate or asymmetric information, informational remedies will often be preferred. Measures to improve the availability of information include government establishment of a standardized testing and rating system (the use of which could be mandatory or voluntary), mandatory disclosure requirements (e.g., by advertising, labeling, or enclosures), and government provision of information (e.g., by government publications, telephone hotlines, or public interest broadcast announcements). A regulatory measure to improve the availability of information, particularly about the concealed characteristics of products, provides consumers a greater choice than a mandatory product standard or ban.

Specific informational measures should be evaluated in terms of their benefits and costs. Some effects of informational measures are easily overlooked. The costs of a mandatory disclosure requirement for a consumer product will include not only the cost of gathering and communicating the required information, but also the loss of net benefits of any information displaced by the mandated information. The other costs also may include the effect of providing information that is ignored or misinterpreted, and inefficiencies arising from the incentive that mandatory disclosure may give to overinvest in a particular characteristic of a product or service.

Where information on the benefits and costs of alternative informational measures is insufficient to provide a clear choice between them, you should consider the least intrusive informational alternative sufficient to accomplish the regulatory objective. To correct an informational market failure it may be sufficient for government to establish a standardized testing and rating system without mandating its use, because competing firms that score well according to the system should thereby have an incentive to publicize the fact.

D. Analytical Approaches

Both benefit-cost analysis (BCA) and cost-effectiveness analysis (CEA) provide a systematic framework for identifying and evaluating the likely outcomes of alternative regulatory choices. A major rulemaking should be supported by both types of analysis wherever possible. Specifically, you should prepare a CEA for all major rulemakings for which the primary benefits are improved public health and safety to the extent that a valid effectiveness measure can be developed to represent expected health and safety outcomes. You should also perform a BCA for major health and safety rulemakings to the extent that valid monetary values can be assigned to the primary expected health and safety outcomes. In undertaking these analyses, it is important to keep in mind the larger objective of analytical consistency in estimating benefits and costs across regulations and agencies, subject to statutory limitations. Failure to maintain such consistency may prevent achievement of the most risk reduction for a given level of resource expenditure. For all other major rulemakings, you should carry out a BCA. If some of the primary benefit categories cannot be expressed in monetary units, you should also conduct a CEA. In unusual cases where no quantified information on benefits, costs and effectiveness can be produced, the regulatory analysis should present a qualitative discussion of the issues and evidence.

Benefit-Cost Analysis

A distinctive feature of BCA is that both benefits and costs are expressed in monetary units, which allows you to evaluate different regulatory options with a variety of attributes using a common measure.[4] By measuring incremental benefits and costs of successively more stringent regulatory alternatives, you can identify the alternative that maximizes net benefits.

The size of net benefits, the absolute difference between the projected benefits and costs, indicates whether one policy is more efficient than another. The ratio of benefits to costs is not a meaningful indicator of net benefits and should not be used for that purpose. It is well known that considering such ratios alone can yield misleading results.

Even when a benefit or cost cannot be expressed in monetary units, you should still try to measure it in terms of its physical units. If it is not possible to measure the physical units, you should still describe the benefit or cost qualitatively. For more information on describing qualitative information, see the section "*Developing Benefit and Cost Estimates.*"

When important benefits and costs cannot be expressed in monetary units, BCA is less useful, and it can even be misleading, because the calculation of net benefits in such cases does not provide a full evaluation of all relevant benefits and costs.

You should exercise professional judgment in identifying the importance of non-quantified factors and assess as best you can how they might change the ranking of alternatives based on estimated net benefits. If the non-quantified benefits and costs are likely to be important, you should recommend which of the non-quantified factors are of sufficient importance to justify consideration in the regulatory decision. This discussion should also include a clear explanation that support designating these non-quantified factors as important. In this case, you should also consider conducting a threshold analysis to help decision makers and other users of the analysis to understand the potential significance of these factors to the overall analysis.

Cost-Effectiveness Analysis[5]

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[4] Mishan EJ (1994), *Cost-Benefit Analysis*, fourth edition, Routledge, New York.

[5] For a full discussion of CEA, see Gold, ML, Siegel, JE, Russell, LB, and Weinstein, MC (1996), *Cost Effectiveness in Health and Medicine: The Report of the Panel on Cost-Effectiveness in Health and Medicine*, Oxford University Press, New York.

Cost-effectiveness analysis can provide a rigorous way to identify options that achieve the most effective use of the resources available without requiring monetization of all of relevant benefits or costs. Generally, cost-effectiveness analysis is designed to compare a set of regulatory actions with the same primary outcome (e.g., an increase in the acres of wetlands protected) or multiple outcomes that can be integrated into a single numerical index (e.g., units of health improvement).

Cost-effectiveness results based on averages need to be treated with great care. They suffer from the same drawbacks as benefit-cost ratios. The alternative that exhibits the smallest cost-effectiveness ratio may not be the best option, just as the alternative with the highest benefit-cost ratio is not always the one that maximizes net benefits. Incremental cost-effectiveness analysis (discussed below) can help to avoid mistakes that can occur when policy choices are based on average cost-effectiveness.

CEA can also be misleading when the "effectiveness" measure does not appropriately weight the consequences of the alternatives. For example, when effectiveness is measured in tons of reduced pollutant emissions, cost-effectiveness estimates will be misleading unless the reduced emissions of diverse pollutants result in the same health and environmental benefits.

When you have identified a range of alternatives (e.g., different levels of stringency), you should determine the cost-effectiveness of each option compared with the baseline as well as its incremental cost-effectiveness compared with successively more stringent requirements. Ideally, your CEA would present an array of cost-effectiveness estimates that would allow comparison across different alternatives. However, analyzing all possible combinations is not practical when there are many options (including possible interaction effects). In these cases, you should use your judgment to choose reasonable alternatives for careful consideration.

When constructing and comparing incremental cost-effectiveness ratios, you should be careful to determine whether the various alternatives are mutually exclusive or whether they can be combined. If they can be combined, you should consider which might be favored under different regulatory budget constraints (implicit or explicit). You should also make sure that inferior alternatives identified by the principles of strong and weak dominance are eliminated from consideration.[6]

The value of CEA is enhanced when there is consistency in the analysis across a diverse set of possible regulatory actions. To achieve consistency, you need to carefully construct the two key components of any CEA: the cost and the "effectiveness" or performance measures for the alternative policy options.

With regard to measuring costs, you should be sure to include all the relevant costs to society – whether public or private. Rulemakings may also yield cost savings (e.g., energy savings associated with new technologies). The numerator in the cost-effectiveness ratio should reflect net costs, defined as the gross cost incurred to comply with the requirements (sometimes

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[6] Gold ML, Siegel JE, Russell LB, and Weinstein MC (1996), *Cost Effectiveness in Health and Medicine: The Report of the Panel on Cost-Effectiveness in Health and Medicine*, Oxford University Press, New York, pp. 284-285.

called “total” costs) minus any cost savings. You should be careful to avoid double-counting effects in both the numerator and the denominator of the cost-effectiveness ratios. For example, it would be incorrect to reduce gross costs by an estimated monetary value on life extension if life-years are already used as the effectiveness measure in the denominator.

In constructing measures of “effectiveness”, final outcomes, such as lives saved or life-years saved, are preferred to measures of intermediate outputs, such as tons of pollution reduced, crashes avoided, or cases of disease avoided. Where the quality of the measured unit varies (e.g., acres of wetlands vary substantially in terms of their ecological benefits), it is important that the measure capture the variability in the value of the selected “outcome” measure. You should provide an explanation of your choice of effectiveness measure.

Where regulation may yield several different beneficial outcomes, a cost-effectiveness comparison becomes more difficult to interpret because there is more than one measure of effectiveness to incorporate in the analysis. To arrive at a single measure you will need to weight the value of disparate benefit categories, but this computation raises some of the same difficulties you will encounter in BCA. If you can assign a reasonable monetary value to all of the regulation’s different benefits, then you should do so. But in this case, you will be doing BCA, not CEA.

When you can estimate the monetary value of *some* but not all of the ancillary benefits of a regulation, but cannot assign a monetary value to the primary measure of effectiveness, you should subtract the monetary estimate of the ancillary benefits from the gross cost estimate to yield an estimated net cost. (This net cost estimate for the rule may turn out to be negative – that is, the monetized benefits exceed the cost of the rule.) If you are unable to estimate the value of some of the ancillary benefits, the cost-effectiveness ratio will be overstated, and this should be acknowledged in your analysis. CEA does not yield an unambiguous choice when there are benefits or costs that have not been incorporated in the net-cost estimates. You also may use CEA to compare regulatory alternatives in cases where the statute specifies the level of benefits to be achieved.

The Effectiveness Metric for Public Health and Safety Rulemakings

When CEA is applied to public health and safety rulemakings, one or more measures of effectiveness must be selected that permits comparison of regulatory alternatives. Agencies currently use a variety of effectiveness measures.

There are relatively simple measures such as the number of lives saved, cases of cancer reduced, and cases of paraplegia prevented. Sometimes these measures account only for mortality information, such as the number of lives saved and the number of years of life saved. There are also more comprehensive, integrated measures of effectiveness such as the number of "equivalent lives" (ELs) saved and the number of "quality-adjusted life years" (QALYs) saved.

The main advantage of the integrated measures of effectiveness is that they account for a rule's impact on morbidity (nonfatal illness, injury, impairment and quality of life) as well as premature death. The inclusion of morbidity effects is important because (a) some illnesses (e.g., asthma) cause more instances of pain and suffering than they do premature death, (b) some population groups are known to experience elevated rates of morbidity (e.g, the elderly and the poor) and thus have a strong interest in morbidity measurement[7], and (c) some regulatory alternatives may be more effective at preventing morbidity than premature death (e.g., some advanced airbag designs may diminish the nonfatal injuries caused by airbag inflation without changing the frequency of fatal injury prevented by airbags).

However, the main drawback of these integrated measures is that they must meet some restrictive assumptions to represent a valid measure of individual preferences.[8] For example, a QALY measure implicitly assumes that the fraction of remaining lifespan an individual would give up for an improvement in health-related quality of life does not depend on the remaining lifespan. Thus, if an individual is willing to give up 10 years of life among 50 remaining years for a given health improvement, he or she would also be willing to give up 1 year of life among 5 remaining years. To the extent that individual preferences deviate from these assumptions, analytic results from CEA using QALYs could differ from analytic results based on willingness-to-pay-measures.[9] Though willingness to pay is generally the preferred economic method for evaluating preferences, the CEA method, as applied in medicine and health, does not evaluate health changes using individual willingness to pay. When performing CEA, you should consider using at least one integrated measure of effectiveness when a rule creates a significant impact on both mortality and morbidity.

When CEA is performed in specific rulemaking contexts, you should be prepared to make appropriate adjustments to ensure fair treatment of all segments of the population. Fairness is important in the choice and execution of effectiveness measures. For example, if QALYs are used to evaluate a lifesaving rule aimed at a population that happens to experience a high rate of disability (i.e., where the rule is not designed to affect the disability), the number of life years saved should not necessarily be diminished simply because the rule saves the lives of people with life-shortening disabilities. Both analytic simplicity and fairness suggest that the estimated number of life years saved for the disabled population should be based on average life expectancy information for the relevant age cohorts. More generally, when numeric adjustments are made for life expectancy or quality of life, analysts should prefer use of population averages rather than information derived from subgroups dominated by a particular demographic or income group.

OMB does not require agencies to use any specific measure of effectiveness. In fact, OMB encourages agencies to report results with multiple measures of effectiveness that offer different insights and perspectives. The regulatory analysis should explain which measures were selected and why, and how they were implemented.

The analytic discretion provided in choice of effectiveness measure will create some inconsistency in how agencies evaluate the same injuries and diseases, and it will be difficult for

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[7] Russell LB and Sisk JE (2000), “Modeling Age Differences in Cost Effectiveness Analysis”, *International Journal of Technology Assessment in Health Care*, 16(4), 1158-1167.

[8] Pliskin JS, Shepard DS, and Weinstein MC (1980), "Utility Functions for Life Years and Health Status," *Operations Research*, 28(1), 206-224.

[9] Hammitt JK (2002), "QALYs Versus WTP," *Risk Analysis*, 22(5), pp. 985-1002.

OMB and the public to draw meaningful comparisons between rulemakings that employ different effectiveness measures. As a result, agencies should use their web site to provide OMB and the public with the underlying data, including mortality and morbidity data, the age distribution of the affected populations, and the severity and duration of disease conditions and trauma, so that OMB and the public can construct apples-to-apples comparisons between rulemakings that employ different measures.

There are sensitive technical and ethical issues associated with choosing one or more of these integrated measures for use throughout the Federal government. The Institute of Medicine (IOM) may assemble a panel of specialists in cost-effectiveness analysis and bioethics to evaluate the advantages and disadvantages of these different measures and other measures that have been suggested in the academic literature. OMB believes that the IOM guidance will provide Federal agencies and OMB useful insight into how to improve the measurement of effectiveness of public health and safety regulations.

Distributional Effects

Those who bear the costs of a regulation and those who enjoy its benefits often are not the same people. The term “distributional effect” refers to the impact of a regulatory action across the population and economy, divided up in various ways (e.g., income groups, race, sex, industrial sector, geography). Benefits and costs of a regulation may also be distributed unevenly over time, perhaps spanning several generations. Distributional effects may arise through ”transfer payments” that stem from a regulatory action as well. For example, the revenue collected through a fee, surcharge in excess of the cost of services provided, or tax is a transfer payment.

Your regulatory analysis should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers can properly consider them along with the effects on economic efficiency. Executive Order 12866 authorizes this approach. Where distributive effects are thought to be important, the effects of various regulatory alternatives should be described quantitatively to the extent possible, including the magnitude, likelihood, and severity of impacts on particular groups. You should be alert for situations in which regulatory alternatives result in significant changes in treatment or outcomes for different groups. Effects on the distribution of income that are transmitted through changes in market prices can be important, albeit sometimes difficult to assess. Your analysis should also present information on the streams of benefits and costs over time in order to provide a basis for assessing intertemporal distributional consequences, particularly where intergenerational effects are concerned.

E. Identifying and Measuring Benefits and Costs

This Section provides guidelines for your preparation of the benefit and cost estimates required by Executive Order 12866 and the “Regulatory Right-to-Know Act.” The discussions in previous sections will help you identify a workable number of alternatives for consideration in your analysis and an appropriate analytical approach to use.

General Issues

1. Scope of Analysis

Your analysis should focus on benefits and costs that accrue to citizens and residents of the United States. Where you choose to evaluate a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately. The time frame for your analysis should cover a period long enough to encompass all the important benefits and costs likely to result from the rule.

2. Developing a Baseline

You need to measure the benefits and costs of a rule against a baseline. This baseline should be the best assessment of the way the world would look absent the proposed action. The choice of an appropriate baseline may require consideration of a wide range of potential factors, including:

- evolution of the market,
- changes in external factors affecting expected benefits and costs,
- changes in regulations promulgated by the agency or other government entities, and
- the degree of compliance by regulated entities with other regulations.

It may be reasonable to forecast that the world absent the regulation will resemble the present. If this is the case, however, your baseline should reflect the future effect of current government programs and policies. For review of an existing regulation, a baseline assuming "no change" in the regulatory program generally provides an appropriate basis for evaluating regulatory alternatives. When more than one baseline is reasonable and the choice of baseline will significantly affect estimated benefits and costs, you should consider measuring benefits and costs against alternative baselines. In doing so you can analyze the effects on benefits and costs of making different assumptions about other agencies' regulations, or the degree of compliance with your own existing rules. In all cases, you must evaluate benefits and costs against the same baseline. You should also discuss the reasonableness of the baselines used in the sensitivity analyses. For each baseline you use, you should identify the key uncertainties in your forecast.

EPA's 1998 final PCB disposal rule provides a good example of using different baselines. EPA used several alternative baselines, each reflecting a different interpretation of existing regulatory requirements. In particular, one baseline reflected a literal interpretation of EPA's 1979 rule and another the actual implementation of that rule in the year immediately preceding the 1998 revision. The use of multiple baselines illustrated the substantial effect changes in EPA's implementation policy could have on the cost of a regulatory program. In the years after EPA adopted the 1979 PCB disposal rule, changes in EPA policy -- especially allowing the disposal of automobile "shredder fluff" in municipal landfills -- reduced the cost of the program by more than $500 million per year.

In some cases, substantial portions of a rule may simply restate statutory requirements that would be self-implementing, even in the absence of the regulatory action. In these cases, you should use a pre-statute baseline. If you are able to separate out those areas where the agency has discretion, you may also use a post-statute baseline to evaluate the discretionary elements of the action.

3. Evaluation of Alternatives

You should describe the alternatives available to you and the reasons for choosing one alternative over another. As noted previously, alternatives that rely on incentives and offer increased flexibility are often more cost-effective than more prescriptive approaches. For instance, user fees and information dissemination may be good alternatives to direct command-and-control regulation. Within a command-and-control regulatory program, performance-based standards generally offer advantages over standards specifying design, behavior, or manner of compliance.

You should carefully consider all appropriate alternatives for the key attributes or provisions of the rule. The previous discussion outlines examples of appropriate alternatives. Where there is a "continuum" of alternatives for a standard (such as the level of stringency), you generally should analyze at least three options: the preferred option; a more stringent option that achieves additional benefits (and presumably costs more) beyond those realized by the preferred option; and a less stringent option that costs less (and presumably generates fewer benefits) than the preferred option.

You should choose reasonable alternatives deserving careful consideration. In some cases, a regulatory program will focus on an option that is near or at the limit of technical feasibility. In this case, the analysis would not need to examine a more stringent option. For each of the options analyzed, you should compare the anticipated benefits to the corresponding costs.

It is not adequate simply to report a comparison of the agency's preferred option to the chosen baseline. Whenever you report the benefits and costs of alternative options, you should present both total and incremental benefits and costs. You should present incremental benefits and costs as differences from the corresponding estimates associated with the next less-stringent alternative.[10] It is important to emphasize that incremental effects are simply differences between successively more stringent alternatives. Results involving a comparison to a "next best" alternative may be especially useful.

In some cases, you may decide to analyze a wide array of options. In 1998, DOE analyzed a large number of options in setting new energy efficiency standards for refrigerators and freezers and produced a rich amount of information on their relative effects. This analysis -- examining more than 20 alternative performance standards for one class of refrigerators with top-mounted freezers -- enabled DOE to select an option that produced $200 more in estimated net benefits per refrigerator than the least attractive option.

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[10] For the least stringent alternative, you should estimate the incremental benefits and costs relative to the baseline. Thus, for this alternative, the incremental effects would be the same as the corresponding totals. For each alternative that is more stringent than the least stringent alternative, you should estimate the incremental benefits and costs relative to the closest less-stringent alternative.

You should analyze the benefits and costs of different regulatory provisions separately when a rule includes a number of distinct provisions. If the existence of one provision affects the benefits or costs arising from another provision, the analysis becomes more complicated, but the need to examine provisions separately remains. In this case, you should evaluate each specific provision by determining the net benefits of the proposed regulation with and without it.

Analyzing all possible combinations of provisions is impractical if the number is large and interaction effects are widespread. You need to use judgment to select the most significant or relevant provisions for such analysis. You are expected to document all of the alternatives that were considered in a list or table and which were selected for emphasis in the main analysis.

You should also discuss the statutory requirements that affect the selection of regulatory approaches. If legal constraints prevent the selection of a regulatory action that best satisfies the philosophy and principles of Executive Order 12866, you should identify these constraints and estimate their opportunity cost. Such information may be useful to Congress under the Regulatory Right-to-Know Act.

4. Transparency and Reproducibility of Results

Because of its influential nature and its special role in the rulemaking process, it is appropriate to set minimum quality standards for regulatory analysis. You should provide documentation that the analysis is based on the best reasonably obtainable scientific, technical, and economic information available. To achieve this, you should rely on peer-reviewed literature, where available, and provide the source for all original information.

A good analysis should be transparent and your results must be reproducible. You should clearly set out the basic assumptions, methods, and data underlying the analysis and discuss the uncertainties associated with the estimates. A qualified third party reading the analysis should be able to understand the basic elements of your analysis and the way in which you developed your estimates.

To provide greater access to your analysis, you should generally post it, with all the supporting documents, on the internet so the public can review the findings. You should also disclose the use of outside consultants, their qualifications, and history of contracts and employment with the agency (e.g., in a preface to the RIA). Where other compelling interests (such as privacy, intellectual property, trade secrets, etc.) prevent the public release of data or key elements of the analysis, you should apply especially rigorous robustness checks to analytic results and document the analytical checks used.

Finally, you should assure compliance with the Information Quality Guidelines for your agency and OMB's "Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies" ("data quality guidelines") http://www.whitehouse.gov/omb/fedreg/reproducible.html.

Developing Benefit and Cost Estimates

1. Some General Considerations

The analysis document should discuss the expected benefits and costs of the selected regulatory option and any reasonable alternatives. How is the proposed action expected to provide the anticipated benefits and costs? What are the monetized values of the potential real incremental benefits and costs to society? To present your results, you should:

- include separate schedules of the monetized benefits and costs that show the type and timing of benefits and costs, and express the estimates in this table in constant, undiscounted dollars (for more on discounting see "*Discount Rates*" below);
- list the benefits and costs you can quantify, but cannot monetize, including their timing;
- describe benefits and costs you cannot quantify; and
- identify or cross-reference the data or studies on which you base the benefit and cost estimates.

When benefit and cost estimates are uncertain (for more on this see "*Treatment of Uncertainty*" below), you should report benefit and cost estimates (including benefits of risk reductions) that reflect the full probability distribution of potential consequences. Where possible, present probability distributions of benefits and costs and include the upper and lower bound estimates as complements to central tendency and other estimates.

If fundamental scientific disagreement or lack of knowledge prevents construction of a scientifically defensible probability distribution, you should describe benefits or costs under plausible scenarios and characterize the evidence and assumptions underlying each alternative scenario.

2. The Key Concepts Needed to Estimate Benefits and Costs

"Opportunity cost" is the appropriate concept for valuing both benefits and costs. The principle of "willingness-to-pay" (WTP) captures the notion of opportunity cost by measuring what individuals are willing to forgo to enjoy a particular benefit. In general, economists tend to view WTP as the most appropriate measure of opportunity cost, but an individual's "willingness-to-accept" (WTA) compensation for not receiving the improvement can also provide a valid measure of opportunity cost.

WTP and WTA are comparable measures under special circumstances. WTP and WTA measures may be comparable in the following situations: if a regulation affects a price change rather than a quantity change; the change being evaluated is small; there are reasonably close substitutes available; and the income effect is small.[11] However, empirical evidence from experimental economics and psychology shows that even when income/wealth effects are "small", the measured differences between WTP and WTA can be large.[12] WTP is generally

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[11] See Hanemann WM (1991), *American Economic Review*, 81(3), 635-647.

[12] See Kahneman D, Knetsch JL, and Thaler RH (1991), "Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias," *Journal of Economic Perspectives* 3(1), 192-206.

considered to be more readily measurable. Adoption of WTP as the measure of value implies that individual preferences of the affected population should be a guiding factor in the regulatory analysis.

Market prices provide rich data for estimating benefits and costs based on willingness-to-pay if the goods and services affected by the regulation are traded in well-functioning competitive markets. The opportunity cost of an alternative includes the value of the benefits forgone as a result of choosing that alternative. The opportunity cost of banning a product -- a drug, food additive, or hazardous chemical -- is the forgone net benefit (i.e., lost consumer and producer surplus[13]) of that product, taking into account the mitigating effects of potential substitutes.

The use of any resource has an opportunity cost regardless of whether the resource is already owned or has to be purchased. That opportunity cost is equal to the net benefit the resource would have provided in the absence of the requirement. For example, if regulation of an industrial plant affects the use of additional land or buildings within the existing plant boundary, the cost analysis should include the opportunity cost of using the additional land or facilities.

To the extent possible, you should monetize any such forgone benefits and add them to the other costs of that alternative. You should also try to monetize any cost savings as a result of an alternative and either add it to the benefits or subtract it from the costs of that alternative. However, you should not assume that the "avoided" costs of not doing another regulatory alternative represent the benefits of a regulatory action where there is no direct, necessary relationship between the two. You should also be careful when the costs avoided are attributable to an existing regulation. Even when there is a direct relationship between the two regulatory actions, the use of avoided costs is problematic because the existing regulation may not maximize net benefits and thus may itself be questionable policy. (See the section, "Direct Use of Market Data," for more detail.)

Estimating benefits and costs when market prices are hard to measure or markets do not exist is more difficult. In these cases, you need to develop appropriate proxies that simulate market exchange. Estimates of willingness-to-pay based on revealed preference methods can be quite useful. As one example, analysts sometimes use "hedonic price equations" based on multiple regression analysis of market behavior to simulate market prices for the commodity of interest. The hedonic technique allows analysts to develop an estimate of the price for specific attributes associated with a product. For instance, a house is a product characterized by a variety of attributes including the number of rooms, total floor area, and type of heating and cooling. If there are enough data on transactions in the housing market, it is possible to develop an estimate of the implicit price for specific attributes, such as the implicit price of an additional bathroom or for central air conditioning. This technique can be extended, as well, to develop an estimate for

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[13] Consumer surplus is the difference between what a consumer pays for a unit of a good and the maximum amount the consumer would be willing to pay for that unit. It is measured by the area between the price and the demand curve for that unit. Producer surplus is the difference between the amount a producer is paid for a unit of a good and the minimum amount the producer would accept to supply that unit. It is measured by the area between the price and the supply curve for that unit.

the implicit price of public goods that are not directly traded in markets. An analyst can develop implicit price estimates for public goods like air quality and access to public parks by assessing the effects of these goods on the housing market. Going through the analytical process of deriving benefit estimates by simulating markets may also suggest alternative regulatory strategies that create such markets.

You need to guard against double-counting, since some attributes are embedded in other broader measures. To illustrate, when a regulation improves the quality of the environment in a community, the value of real estate in the community generally rises to reflect the greater attractiveness of living in a better environment. Simply adding the increase in property values to the estimated value of improved public health would be double counting if the increase in property values reflects the improvement in public health. To avoid this problem you should separate the embedded effects on the value of property arising from improved public health. At the same time, an analysis that fails to incorporate the consequence of land use changes when accounting for costs will not capture the full effects of regulation.

3. Revealed Preference Methods

Revealed preference methods develop estimates of the value of goods and services -- or attributes of those goods and services -- based on actual market decisions by consumers, workers and other market participants. If the market participant is well informed and confronted with a real choice, it may be feasible to determine accurately and precisely the monetary value needed for a rulemaking. There is a large and well-developed literature on revealed preference in the peer-reviewed, applied economics literature.

Although these methods are well grounded in economic theory, they are sometimes difficult to implement given the complexity of market transactions and the paucity of relevant data. When designing or evaluating a revealed preference study, the following principles should be considered:

- the market should be competitive. If the market isn’t competitive (e.g., monopoly, oligopoly), then you should consider making adjustments such that the price reflects the true value to society (often called the “shadow price”);
- the market should not exhibit a significant information gap or asymmetric information problem. If the market suffers from information problems, then you should discuss the divergence of the price from the underlying shadow price and consider possible adjustments to reflect the underlying shadow price;
- the market should not exhibit an externality. In this case, you should discuss the divergence of the price from the underlying shadow price and consider possible adjustments to reflect the underlying shadow price;
- the specific market participants being studied should be representative of the target populations to be affected by the rulemaking under consideration;
- a valid research design and framework for analysis should be adopted. Examples include using data and/or model specifications that include the markets for substitute and complementary goods and services and using reasonably unrestricted functional forms. When specifying substitute and complementary goods, the analysis should preferably be

based on data about the range of alternatives perceived by market participants. If such data are not available, you should adopt plausible assumptions and describe the limitations of the analysis.

- the statistical and econometric models employed should be appropriate for the application and the resulting estimates should be robust in response to plausible changes in model specification and estimation technique; and
- the results should be consistent with economic theory.

You should also determine whether there are multiple revealed-preference studies of the same good or service and whether anything can be learned by comparing the methods, data and findings from different studies. Professional judgment is required to determine whether a particular study is of sufficient quality to justify use in regulatory analysis. When studies are used in regulatory analysis despite their technical weaknesses (e.g., due to the absence of other evidence), the regulatory analysis should discuss any biases or uncertainties that are likely to arise due to those weaknesses. If a study has major weaknesses, the study should not be used in regulatory analysis.

a. Direct Uses of Market Data

Economists ordinarily consider market prices as the most accurate measure of the marginal value of goods and services to society. In some instances, however, market prices may not reflect the true value of goods and services due to market imperfections or government intervention. If a regulation involves changes to goods or services where the market price is not a good measure of the value to society, you should use an estimate that reflects the shadow price. Suppose a particular air pollutant damages crops. One of the benefits of controlling that pollutant is the value of the crop yield increase as a result of the controls. That value is typically measured by the price of the crop. However, if the price is held above the market price by a government program that affects supply, a value estimate based on this price may not reflect the true benefits of controlling the pollutant. In this case, you should calculate the value to society of the increase in crop yields by estimating the shadow price, which reflects the value to society of the marginal use of the crop. If the marginal use is for exports, you should use the world price. If the marginal use is to add to very large surplus stockpiles, you should use the value of the last units released from storage minus storage cost. If stockpiles are large and growing, the shadow price may be low or even negative.

Other goods whose market prices may not reflect their true value include those whose production or consumption results in substantial (1) positive or negative external effects or (2) transfer payments. For example, the observed market price of gasoline may not reflect marginal social value due to the inclusion of taxes, other government interventions, and negative externalities (e.g., pollution). This shadow price may also be needed for goods whose market price is substantially affected by existing regulations that do not maximize net benefits.

b. Indirect Uses of Market Data

Many goods or attributes of goods that are affected by regulation--such as preserving environmental or cultural amenities--are not traded directly in markets. The value for these goods or attributes arise both from use and non-use. Estimation of these values is difficult because of the absence of an organized market. However, overlooking or ignoring these values in your regulatory analysis may significantly understate the benefits and/or costs of regulatory action.

"Use values" arise where an individual derives satisfaction from using the resource, either now or in the future. Use values are associated with activities such as swimming, hunting, and hiking where the individual makes use of the natural environment.

"Non-use values" arise where an individual places value on a resource, good or service even though the individual will not use the resource, now or in the future. Non-use value includes bequest and existence values.

General altruism for the health and welfare of others is a closely related concept but may not be strictly considered a "non-use" value.[14] A general concern for the welfare of others should supplement benefits and costs equally; hence, it is not necessary to measure the size of general altruism in regulatory analysis. If there is evidence of selective altruism, it needs to be considered specifically in both benefits and costs.

Some goods and services are indirectly traded in markets, which means that their value is reflected in the prices of related goods and services that are directly traded in markets. Their use values are typically estimated through revealed preference methods. Examples include estimates of the values of environmental amenities derived from travel-cost studies, and hedonic price models that measure differences or changes in the value of real estate. It is important that you utilize revealed preference models that adhere to economic criteria that are consistent with utility maximizing behavior. Also, you should take particular care in designing protocols for reliably estimating the values of these attributes.

4. Stated Preference Methods

Stated Preference Methods (SPM) have been developed and used in the peer-reviewed literature to estimate both "use" and "non-use" values of goods and services. They have also been widely used in regulatory analyses by Federal agencies, in part, because these methods can be creatively employed to address a wide variety of goods and services that are not easy to study through revealed preference methods.

The distinguishing feature of these methods is that hypothetical questions about use or non-use values are posed to survey respondents in order to obtain willingness-to-pay estimates relevant to benefit or cost estimation. Some examples of SPM include contingent valuation, conjoint analysis and risk-tradeoff analysis. The surveys used to obtain the health-utility values used in CEA are similar to stated-preference surveys but do not entail monetary measurement of value. Nevertheless, the principles governing quality stated-preference research, with some obvious exceptions involving monetization, are also relevant in designing quality health-utility research.

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[14] See McConnell KE (1997), *Journal of Environmental Economics and Management*, *32*, 22-37.

When you are designing or evaluating a stated-preference study, the following principles should be considered:

- the good or service being evaluated should be explained to the respondent in a clear, complete and objective fashion, and the survey instrument should be pre-tested;
- willingness-to-pay questions should be designed to focus the respondent on the reality of budgetary limitations and alerted to the availability of substitute goods and alternative expenditure options;
- the survey instrument should be designed to probe beyond general attitudes (e.g., a "warm glow" effect for a particular use or non-use value) and focus on the magnitude of the respondent's economic valuation;
- the analytic results should be consistent with economic theory using both "internal" (within respondent) and "external" (between respondent) scope tests such as the willingness to pay is larger (smaller) when more (less) of a good is provided;
- the subjects being interviewed should be selected/sampled in a statistically appropriate manner. The sample frame should adequately cover the target population. The sample should be drawn using probability methods in order to generalize the results to the target population;
- response rates should be as high as reasonably possible. Best survey practices should be followed to achieve high response rates. Low response rates increase the potential for bias and raise concerns about the generalizability of the results. If response rates are not adequate, you should conduct an analysis of non-response bias or further study. Caution should be used in assessing the representativeness of the sample based solely on demographic profiles. Statistical adjustments to reduce non-response bias should be undertaken whenever feasible and appropriate;
- the mode of administration of surveys (in-person, phone, mail, computer, internet or multiple modes) should be appropriate in light of the nature of the questions being posed to respondents and the length and complexity of the instrument;
- documentation should be provided about the target population, the sampling frame used and its coverage of the target population, the design of the sample including any stratification or clustering, the cumulative response rate (including response rate at each stage of selection if applicable); the item non-response rate for critical questions; the exact wording and sequence of questions and other information provided to respondents; and the training of interviewers and techniques they employed (as appropriate);
- the statistical and econometric methods used to analyze the collected data should be transparent, well suited for the analysis, and applied with rigor and care.

Professional judgment is necessary to apply these criteria to one or more studies, and thus there is no mechanical formula that can be used to determine whether a particular study is of sufficient quality to justify use in regulatory analysis. When studies are used despite having weaknesses on one or more of these criteria, those weaknesses should be acknowledged in the regulatory analysis, including any resulting biases or uncertainties that are likely to result. If a study has too many weaknesses with unknown consequences for the quality of the data, the study should not be used.

The challenge in designing quality stated-preference studies is arguably greater for non-use values and unfamiliar use values than for familiar goods or services that are traded (directly or indirectly) in market transactions. The good being valued may have little meaning to respondents, and respondents may be forming their valuations for the first time in response to the questions posed. Since these values are effectively constructed by the respondent during the elicitation, the instrument and mode of administration should be rigorously pre-tested to make sure that responses are not simply an artifact of specific features of instrument design and/or mode of administration.

Since SPM generate data from respondents in a hypothetical setting, often on complex and unfamiliar goods, special care is demanded in the design and execution of surveys, analysis of the results, and characterization of the uncertainties. A stated-preference study may be the only way to obtain quantitative information about non-use values, though a number based on a poor quality study is not necessarily superior to no number at all. Non-use values that are not quantified should be presented as an "intangible" benefit or cost.

If both revealed-preference and stated-preference studies that are directly applicable to regulatory analysis are available, you should consider both kinds of evidence and compare the findings. If the results diverge significantly, you should compare the overall size and quality of the two bodies of evidence. Other things equal, you should prefer revealed preference data over stated preference data because revealed preference data are based on actual decisions, where market participants enjoy or suffer the consequences of their decisions. This is not generally the case for respondents in stated preference surveys, where respondents may not have sufficient incentives to offer thoughtful responses that are more consistent with their preferences or may be inclined to bias their responses for one reason or another.

5. Benefit-Transfer Methods

It is often preferable to collect original data on revealed preference or stated preference to support regulatory analysis. Yet conducting an original study may not be feasible due to the time and expense involved. One alternative to conducting an original study is the use of "benefit transfer" methods. (The transfer may involve cost determination as well). The practice of "benefit transfer" began with transferring existing estimates obtained from indirect market and stated preference studies to new contexts (i.e., the context posed by the rulemaking). The principles that guide transferring estimates from indirect market and stated preference studies should apply to direct market studies as well.

Although benefit-transfer can provide a quick, low-cost approach for obtaining desired monetary values, the methods are often associated with uncertainties and potential biases of unknown magnitude. It should therefore be treated as a last-resort option and not used without explicit justification.

In conducting benefit transfer, the first step is to specify the value to be estimated for the rulemaking. You should identify the relevant measure of the policy change at this initial stage. For instance, you can derive the relevant willingness-to-pay measure by specifying an indirect utility function. This identification allows you to "zero in" on key aspects of the benefit transfer.

The next step is to identify appropriate studies to conduct benefit transfer. In selecting transfer studies for either point transfers or function transfers, you should base your choices on the following criteria:

- The selected studies should be based on adequate data, sound and defensible empirical methods and techniques.
- The selected studies should document parameter estimates of the valuation function.
- The study context and policy context should have similar populations (e.g., demographic characteristics). The market size (e.g., target population) between the study site and the policy site should be similar. For example, a study valuing water quality improvement in Rhode Island should not be used to value policy that will affect water quality throughout the United States.
- The good, and the magnitude of change in that good, should be similar in the study and policy contexts.
- The relevant characteristics of the study and the policy contexts should be similar. For example, the effects examined in the original study should be "reversible" or "irreversible" to a degree that is similar to the regulatory actions under consideration.
- The distribution of property rights should be similar so that the analysis uses the same welfare measure. If the property rights in the study context support the use of WTA measures while the rights in the rulemaking context support the use of WTP measures, benefit transfer is not appropriate.
- The availability of substitutes across study and policy contexts should be similar.

If you can choose between transferring a function or a point estimate, you should transfer the entire demand function (referred to as benefit function transfer) rather than adopting a single point estimate (referred to as benefit point transfer).[15]

Finally, you should not use benefit transfer in estimating benefits if:

- resources are unique or have unique attributes. For example, if a policy change affects snowmobile use in Yellowstone National Park, then a study valuing snowmobile use in the state of Michigan should not be used to value changes in snowmobile use in the Yellowstone National Park.
- If the study examines a resource that is unique or has unique attributes, you should not transfer benefit estimates or benefit functions to value a different resource and vice versa. For example, if a study values visibility improvements at the Grand Canyon, these results should not be used to value visibility improvements in urban areas.
- There are significant problems with applying an *"ex ante"* valuation estimate to an *"ex post"* policy context. If a policy yields a significant change in the attributes of the good, you should not use the study estimates to value the change using a benefit transfer approach.
- You also should not use a value developed from a study involving, small marginal

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[15] See Loomis JB (1992), *Water Resources Research*, *28*(3), 701-705 and Kirchoff, S, Colby, BG, and LaFrance, JT (1997), *Journal of Environmental Economics and Management*, *33*, 75-93.

changes in a policy context involving large changes in the quantity of the good.

Clearly, all of these criteria are difficult to meet. However, you should attempt to satisfy as many as possible when choosing studies from the existing economic literature. Professional judgment is required in determining whether a particular transfer is too speculative to use in regulatory analysis.

6. Ancillary Benefits and Countervailing Risks

Your analysis should look beyond the direct benefits and direct costs of your rulemaking and consider any important ancillary benefits and countervailing risks. An ancillary benefit is a favorable impact of the rule that is typically unrelated or secondary to the statutory purpose of the rulemaking (e.g., reduced refinery emissions due to more stringent fuel economy standards for light trucks) while a countervailing risk is an adverse economic, health, safety, or environmental consequence that occurs due to a rule and is not already accounted for in the direct cost of the rule (e.g., adverse safety impacts from more stringent fuel-economy standards for light trucks).

You should begin by considering and perhaps listing the possible ancillary benefits and countervailing risks. However, highly speculative or minor consequences may not be worth further formal analysis. Analytic priority should be given to those ancillary benefits and countervailing risks that are important enough to potentially change the rank ordering of the main alternatives in the analysis. In some cases the mere consideration of these secondary effects may help in the generation of a superior regulatory alternative with strong ancillary benefits and fewer countervailing risks. For instance, a recent study suggested that weight-based, fuel-economy standards could achieve energy savings with fewer safety risks and employment losses than would occur under the current regulatory structure.

Like other benefits and costs, an effort should be made to quantify and monetize ancillary benefits and countervailing risks. If monetization is not feasible, quantification should be attempted through use of informative physical units. If both monetization and quantification are not feasible, then these issues should be presented as non-quantified benefits and costs. The same standards of information and analysis quality that apply to direct benefits and costs should be applied to ancillary benefits and countervailing risks.

One way to combine ancillary benefits and countervailing risks is to evaluate these effects separately and then put both of these effects on the benefits side, not on the cost side. Although it is theoretically appropriate to include disbenefits on the cost side, legal and programmatic considerations generally support subtracting the disbenefits from direct benefits.

7. Methods for Treating Non-Monetized Benefits and Costs

Sound quantitative estimates of benefits and costs, where feasible, are preferable to qualitative descriptions of benefits and costs because they help decision makers understand the magnitudes of the effects of alternative actions. However, some important benefits and costs (e.g., privacy protection) may be inherently too difficult to quantify or monetize given current data and methods. You should carry out a careful evaluation of non-quantified benefits and costs. Some authorities[16] refer to these non-monetized and non-quantified effects as "intangible".

a. Benefits and Costs that are Difficult to Monetize

You should monetize quantitative estimates whenever possible. Use sound and defensible values or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible. If monetization is impossible, explain why and present all available quantitative information. For example, if you can quantify but cannot monetize increases in water quality and fish populations resulting from water quality regulation, you can describe benefits in terms of stream miles of improved water quality for boaters and increases in game fish populations for anglers. You should describe the timing and likelihood of such effects and avoid double-counting of benefits when estimates of monetized and physical effects are mixed in the same analysis.

b. Benefits and Costs that are Difficult to Quantify

If you are not able to quantify the effects, you should present any relevant quantitative information along with a description of the unquantified effects, such as ecological gains, improvements in quality of life, and aesthetic beauty. You should provide a discussion of the strengths and limitations of the qualitative information. This should include information on the key reason(s) why they cannot be quantified. In one instance, you may know with certainty the magnitude of a risk to which a substantial, but unknown, number of individuals are exposed. In another instance, the existence of a risk may be based on highly speculative assumptions, and the magnitude of the risk may be unknown.

For cases in which the unquantified benefits or costs affect a policy choice, you should provide a clear explanation of the rationale behind the choice. Such an explanation could include detailed information on the nature, timing, likelihood, location, and distribution of the unquantified benefits and costs. Also, please include a summary table that lists all the unquantified benefits and costs, and use your professional judgment to highlight (e.g., with categories or rank ordering) those that you believe are most important (e.g., by considering factors such as the degree of certainty, expected magnitude, and reversibility of effects).

While the focus is often placed on difficult to quantify benefits of regulatory action, some costs are difficult to quantify as well. Certain permitting requirements (e.g., EPA's New Source Review program) restrict the decisions of production facilities to shift to new products and adopt innovative methods of production. While these programs may impose substantial costs on the economy, it is very difficult to quantify and monetize these effects. Similarly, regulations that establish emission standards for recreational vehicles, like motor bikes, may adversely affect the performance of the vehicles in terms of driveability and 0 to 60 miles per hour acceleration. Again, the cost associated with the loss of these attributes may be difficult to quantify and monetize. They need to be analyzed qualitatively.

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[16] Mishan EJ (1994), *Cost-Benefit Analysis*, fourth edition, Routledge, New York.

8. Monetizing Health and Safety Benefits and Costs

We expect you to provide a benefit-cost analysis of major health and safety rulemakings in addition to a CEA. The BCA provides additional insight because (a) it provides some indication of what the public is willing to pay for improvements in health and safety and (b) it offers additional information on preferences for health using a different research design than is used in CEA. Since the health-preference methods used to support CEA and BCA have some different strengths and drawbacks, it is important that you provide decision makers with both perspectives.

In monetizing health benefits, a WTP measure is the conceptually appropriate measure as compared to other alternatives (e.g., cost of illness or lifetime earnings), in part because it attempts to capture pain and suffering and other quality-of-life effects. Using the WTP measure for health and safety allows you to directly compare your results to the other benefits and costs in your analysis, which will typically be based on WTP.

If well-conducted revealed-preference studies of relevant health and safety risks are available, you should consider using them in developing your monetary estimates. If appropriate revealed-preference data are not available, you should use valid and relevant data from stated-preference studies. You will need to use your professional judgment when you are faced with limited information on revealed preference studies and substantial information based on stated preference studies.

A key advantage of stated-preference and health-utility methods compared to revealed preference methods is that they can be tailored to address the ranges of probabilities, types of health risks and specific populations affected by your rule. In many rulemakings there will be no relevant information from revealed-preference studies. In this situation you should consider commissioning a stated-preference study or using values from published stated-preference studies. For the reasons discussed previously, you should be cautious about using values from stated-preference studies and describe in the analysis the drawbacks of this approach.

a. Nonfatal Health and Safety Risks

With regard to nonfatal health and safety risks, there is enormous diversity in the nature and severity of impaired health states. A traumatic injury that can be treated effectively in the emergency room without hospitalization or long-term care is different from a traumatic injury resulting in paraplegia. Severity differences are also important in evaluation of chronic diseases. A severe bout of bronchitis, though perhaps less frequent, is far more painful and debilitating than the more frequent bouts of mild bronchitis. The duration of an impaired health state, which can range from a day or two to several years or even a lifetime (e.g., birth defects inducing mental retardation), need to be considered carefully. Information on both the severity and duration of an impaired health state is necessary before the task of monetization can be performed.

When monetizing nonfatal health effects, it is important to consider two components: (1) the private demand for prevention of the nonfatal health effect, to be represented by the preferences of the target population at risk, and (2) the net financial externalities associated with poor health such as net changes in public medical costs and any net changes in economic production that are not experienced by the target population. Revealed-preference or stated-preference studies are necessary to estimate the private demand; health economics data from published sources can typically be used to estimate the financial externalities caused by changes in health status. If you use literature values to monetize nonfatal health and safety risks, it is important to make sure that the values you have selected are appropriate for the severity and duration of health effects to be addressed by your rule.

If data are not available to support monetization, you might consider an alternative approach that makes use of health-utility studies. Although the economics literature on the monetary valuation of impaired health states is growing, there is a much larger clinical literature on how patients, providers and community residents value diverse health states. This literature typically measures health utilities based on the standard gamble, the time tradeoff or the rating scale methods. This health utility information may be combined with known monetary values for well-defined health states to estimate monetary values for a wide range of health states of different severity and duration. If you use this approach, you should be careful to acknowledge your assumptions and the limitations of your estimates.

b. Fatality Risks

Since agencies often design health and safety regulation to reduce risks to life, evaluation of these benefits can be the key part of the analysis. A good analysis must present these benefits clearly and show their importance. Agencies may choose to monetize these benefits. The willingness-to-pay approach is the best methodology to use if reductions in fatality risk are monetized.

Some describe the monetized value of small changes in fatality risk as the "value of statistical life" (VSL) or, less precisely, the "value of a life." The latter phrase can be misleading because it suggests erroneously that the monetization exercise tries to place a “value” on individual lives. You should make clear that these terms refer to the measurement of willingness to pay for reductions in only small risks of premature death. They have no application to an identifiable individual or to very large reductions in individual risks. They do not suggest that any individual’s life can be expressed in monetary terms. Their sole purpose is to help describe better the likely benefits of a regulatory action.

Confusion about the term "statistical life" is also widespread. This term refers to the sum of risk reductions expected in a population. For example, if the annual risk of death is reduced by one in a million for each of two million people, that is said to represent two "statistical lives" extended per year (2 million people x 1/1,000,000 = 2). If the annual risk of death is reduced by one in 10 million for each of 20 million people, that also represents two statistical lives extended.

The adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economic and public policy analysis community. A considerable body of academic literature is available on this subject. This literature involves either explicit or implicit valuation of fatality risks, and generally involves the use of estimates of

VSL from studies on wage compensation for occupational hazards (which generally are in the range of 10^{-4} annually), on consumer product purchase and use decisions, or from an emerging literature using stated preference approaches. A substantial majority of the resulting estimates of VSL vary from roughly $1 million to $10 million per statistical life.[17]

There is a continuing debate within the economic and public policy analysis community on the merits of using a single VSL for all situations versus adjusting the VSL estimates to reflect the specific rule context. A variety of factors have been identified, including whether the mortality risk involves sudden death, the fear of cancer, and the extent to which the risk is voluntarily incurred.[18] The consensus of EPA's recent Science Advisory Board (SAB) review of this issue was that the available literature does not support adjustments of VSL for most of these factors. The panel did conclude that it was appropriate to adjust VSL to reflect changes in income and any time lag in the occurrence of adverse health effects.

The age of the affected population has also been identified as an important factor in the theoretical literature. However, the empirical evidence on age and VSL is mixed. In light of the continuing questions over the effect of age on VSL estimates, you should not use an age-adjustment factor in an analysis using VSL estimates.[19]

Another way that has been used to express reductions in fatality risks is to use the life expectancy method, the "value of statistical life-years (VSLY) extended." If a regulation protects individuals whose average remaining life expectancy is 40 years, a risk reduction of one fatality is expressed as "40 life-years extended." Those who favor this alternative approach emphasize that the value of a statistical life is not a single number relevant for all situations. In particular, when there are significant differences between the effect on life expectancy for the population affected by a particular health risk and the populations studied in the labor market studies, they prefer to adopt a VSLY approach to reflect those differences. You should consider providing estimates of both VSL and VSLY, while recognizing the developing state of knowledge in this area.

Longevity may be only one of a number of relevant considerations pertaining to the rule. You should keep in mind that regulations with greater numbers of life-years extended are not necessarily better than regulations with fewer numbers of life-years extended. In any event, when you present estimates based on the VSLY method, you should adopt a larger VSLY estimate for senior citizens because senior citizens face larger overall health risks from all causes and they may have accumulated savings to spend on their health and safety.[20]

The valuation of fatality risk reduction is an evolving area in both results and methodology. Hence, you should utilize valuation methods that you consider appropriate for the

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[17] See Viscusi WK and Aldy JE, *Journal of Risk and Uncertainty* (forthcoming) and Mrozek JR and Taylor LO (2002), *Journal of Policy Analysis and Management*, *21*(2), 253-270.

[18] Distinctions between "voluntary" and "involuntary" should be treated with care. Risks are best considered to fall within a continuum from "voluntary" to "involuntary" with very few risks at either end of this range. These terms are also related to differences in the cost of avoiding risks.

[19] Graham JD (2003), Memorandum to the President's Management Council, Benefit-Cost Methods and Lifesaving Rules. This memorandum can be found at http://www.whitehouse.gov/omb/inforeg/pmc_benefit_cost_memo.pdf

[20] Office of Information and Regulatory Affairs, OMB, Memorandum to the President's Management Council, ibid.

regulatory circumstances. Since the literature-based VSL estimates may not be entirely appropriate for the risk being evaluated (e.g., the use of occupational risk premia to value reductions in risks from environmental hazards), you should explain your selection of estimates and any adjustments of the estimates to reflect the nature of the risk being evaluated. You should present estimates based on alternative approaches, and if you monetize mortality risk reduction, you should do so on a consistent basis to the extent feasible. You should clearly indicate the methodology used and document your choice of a particular methodology. You should explain any significant deviations from the prevailing state of knowledge. If you use different methodologies in different rules, you should clearly disclose the fact and explain your choices.

c. Valuation of Reductions in Health and Safety Risks to Children

The valuation of health outcomes for children and infants poses special challenges. It is rarely feasible to measure a child's willingness to pay for health improvement and an adult's concern for his or her own health is not necessarily relevant to valuation of child health. For example, the wage premiums demanded by workers to accept hazardous jobs are not readily transferred to rules that accomplish health gains for children.

There are a few studies that examine parental willingness to pay to invest in health and safety for their children. Some of these studies suggest that parents may value children's health more strongly than their own health. Although this parental perspective is a promising research strategy, it may need to be expanded to include a societal interest in child health and safety.

Where the primary objective of a rule is to reduce the risk of injury, disease or mortality among children, you should conduct a cost-effectiveness analysis of the rule. You may also develop a benefit-cost analysis to the extent that valid monetary values can be assigned to the primary expected health outcomes. For rules where health gains are expected among both children and adults and you decide to perform a benefit-cost analysis, the monetary values for children should be at least as large as the values for adults (for the same probabilities and outcomes) unless there is specific and compelling evidence to suggest otherwise.[21]

Discount Rates

Benefits and costs do not always take place in the same time period. When they do not, it is incorrect simply to add all of the expected net benefits or costs without taking account of when the actually occur. If benefits or costs are delayed or otherwise separated in time from each other, the difference in timing should be reflected in your analysis.

As a first step, you should present the annual time stream of benefits and costs expected to result from the rule, clearly identifying when the benefits and costs are expected to occur. The beginning point for your stream of estimates should be the year in which the final rule will begin to have effects, even if that is expected to be some time in the future. The ending point should be far enough in the future to encompass all the significant benefits and costs likely to result from the rule.

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[21] For more information, see Dockins C., Jenkins RR, Owens N, Simon NB, and Wiggins LB (2002), *Risk Analysis*, 22(2), 335-346.

In presenting the stream of benefits and costs, it is important to measure them in constant dollars to avoid the misleading effects of inflation in your estimates. If the benefits and costs are initially measured in prices reflecting expected future inflation, you can convert them to constant dollars by dividing through by an appropriate inflation index, one that corresponds to the inflation rate underlying the initial estimates of benefits or costs.

1. The Rationale for Discounting

Once these preliminaries are out of the way, you can begin to adjust your estimates for differences in timing. (This is a separate calculation from the adjustment needed to remove the effects of future inflation.) Benefits or costs that occur sooner are generally more valuable. The main rationales for the discounting of future impacts are:

(a) Resources that are invested will normally earn a positive return, so current consumption is more expensive than future consumption, since you are giving up that expected return on investment when you consume today.
(b) Postponed benefits also have a cost because people generally prefer present to future consumption. They are said to have positive time preference.
(c) Also, if consumption continues to increase over time, as it has for most of U.S. history, an increment of consumption will be less valuable in the future than it would be today, because the principle of diminishing marginal utility implies that as total consumption increases, the value of a marginal unit of consumption tends to decline.

There is wide agreement with point (a). Capital investment is productive, but that point is not sufficient by itself to explain positive interest rates and observed saving behavior. To understand these phenomena, points (b) and (c) are also necessary. If people are really indifferent between consumption now and later, then they should be willing to forgo current consumption in order to consume an equal or slightly greater amount in the future. That would cause saving rates and investment to rise until interest rates were driven to zero and capital was no longer productive. As long as we observe positive interest rates and saving rates below 100 percent, people must be placing a higher value on current consumption than on future consumption.

To reflect this preference, a discount factor should be used to adjust the estimated benefits and costs for differences in timing. The further in the future the benefits and costs are expected to occur, the more they should be discounted. The discount factor can be calculated given a discount rate. The formula is 1/ (1+ the discount rate)^t where "t" measures the number of years in the future that the benefits or costs are expected to occur. Benefits or costs that have been adjusted in this way are called "discounted present values" or simply "present values". When, and only when, the estimated benefits and costs have been discounted, they can be added to determine the overall value of net benefits.

2. Real Discount Rates of 3 Percent and 7 Percent

OMB's basic guidance on the discount rate is provided in OMB Circular A-94 (http://www.whitehouse.gov/omb/circulars/index.html). This Circular points out that the analytically preferred method of handling temporal differences between benefits and costs is to adjust all the benefits and costs to reflect their value in equivalent units of consumption and to discount them at the rate consumers and savers would normally use in discounting future consumption benefits. This is sometimes called the "shadow price" approach to discounting because doing such calculations requires you to value benefits and costs using shadow prices, especially for capital goods, to correct for market distortions. These shadow prices are not well established for the United States. Furthermore, the distribution of impacts from regulations on capital and consumption are not always well known. Consequently, any agency that wishes to tackle this challenging analytical task should check with OMB before proceeding.

As a default position, OMB Circular A-94 states that a real discount rate of 7 percent should be used as a base-case for regulatory analysis. The 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital. It approximates the opportunity cost of capital, and it is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector. OMB revised Circular A-94 in 1992 after extensive internal review and public comment. In a recent analysis, OMB found that the average rate of return to capital remains near the 7 percent rate estimated in 1992. Circular A-94 also recommends using other discount rates to show the sensitivity of the estimates to the discount rate assumption.

Economic distortions, including taxes on capital, create a divergence between the rate of return that savers earn and the private rate of return to capital. This divergence persists despite the tendency for capital to flow to where it can earn the highest rate of return. Although market forces will push after-tax rates of return in different sectors of the economy toward equality, that process will not equate pre-tax rates of return when there are differences in the tax treatment of investment. Corporate capital, in particular, pays an additional layer of taxation, the corporate income tax, which requires it to earn a higher pre-tax rate of return in order to provide investors with similar after-tax rates of return compared with non-corporate investments. The pre-tax rates of return better measure society's gains from investment. Since the rates of return on capital are higher in some sectors of the economy than others, the government needs to be sensitive to possible impacts of regulatory policy on capital allocation.

The effects of regulation do not always fall exclusively or primarily on the allocation of capital. When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate. The alternative most often used is sometimes called the "social rate of time preference." This simply means the rate at which "society" discounts future consumption flows to their present value. If we take the rate that the average saver uses to discount future consumption as our measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a fair approximation. Over the last thirty years, this rate has averaged around 3 percent in real terms on a pre-tax basis. For example, the yield on 10-year Treasury notes has averaged 8.1 percent since

1973 while the average annual rate of change in the CPI over this period has been 5.0 percent, implying a real 10-year rate of 3.1 percent.

For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent. An example of this approach is EPA's analysis of its 1998 rule setting both effluent limits for wastewater discharges and air toxic emission limits for pulp and paper mills. In this analysis, EPA developed its present-value estimates using real discount rates of 3 and 7 percent applied to benefit and cost streams that extended forward for 30 years. You should present a similar analysis in your own work.

In some instances, if there is reason to expect that the regulation will cause resources to be reallocated away from private investment in the corporate sector, then the opportunity cost may lie outside the range of 3 to 7 percent. For example, the average real rate of return on corporate capital in the United States was approximately 10 percent in the 1990s, returning to the same level observed in the 1950s and 1960s. If you are uncertain about the nature of the opportunity cost, then you should present benefit and cost estimates using a higher discount rate as a further sensitivity analysis as well as using the 3 and 7 percent rates.

3. Time Preference for Health-Related Benefits and Costs

When future benefits or costs are health-related, some have questioned whether discounting is appropriate, since the rationale for discounting money may not appear to apply to health. It is true that lives saved today cannot be invested in a bank to save more lives in the future. But the resources that would have been used to save those lives can be invested to earn a higher payoff in future lives saved. People have been observed to prefer health gains that occur immediately to identical health gains that occur in the future. Also, if future health gains are not discounted while future costs are, then the following perverse result occurs: an attractive investment today in future health improvement can always be made more attractive by delaying the investment. For such reasons, there is a professional consensus that future health effects, including both benefits and costs, should be discounted at the same rate. This consensus applies to both BCA and CEA.

A common challenge in health-related analysis is to quantify the time lag between when a rule takes effect and when the resulting physical improvements in health status will be observed in the target population. In such situations, you must carefully consider the timing of health benefits before performing present-value calculations. It is not reasonable to assume that all of the benefits of reducing chronic diseases such as cancer and cardiovascular disease will occur immediately when the rule takes effect. For rules addressing traumatic injury, this lag period may be short. For chronic diseases it may take years or even decades for a rule to induce its full beneficial effects in the target population.

When a delay period between exposure to a toxin and increased probability of disease is likely (a so-called latency period), a lag between exposure reduction and reduced probability of disease is also likely. This latter period has sometimes been referred to as a "cessation lag," and it may or may not be of the same duration as the latency period. As a general matter, cessation lags will only apply to populations with at least some high-level exposure (e.g., before the rule takes effect). For populations with no such prior exposure, such as those born after the rule takes effect, only the latency period will be relevant.

Ideally, your exposure-risk model would allow calculation of reduced risk for each year following exposure cessation, accounting for total cumulative exposure and age at the time of exposure reduction. The present-value benefits estimate could then reflect an appropriate discount factor for each year's risk reduction. Recent analyses of the cancer benefits stemming from reduction in public exposure to radon in drinking water have adopted this approach. They were supported by formal risk-assessment models that allowed estimates of the timing of lung cancer incidence and mortality to vary in response to different radon exposure levels.[22]

In many cases, you will not have the benefit of such detailed risk assessment modeling. You will need to use your professional judgment as to the average cessation lag for the chronic diseases affected by your rule. In situations where information exists on latency but not on cessation lags, it may be reasonable to use latency as a proxy for the cessation lag, unless there is reason to believe that the two are different. When the average lag time between exposures and disease is unknown, a range of plausible alternative values for the time lag should be used in your analysis.

4. Intergenerational Discounting

Special ethical considerations arise when comparing benefits and costs across generations. Although most people demonstrate time preference in their own consumption behavior, it may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. Future citizens who are affected by such choices cannot take part in making them, and today's society must act with some consideration of their interest.

One way to do this would be to follow the same discounting techniques described above and supplement the analysis with an explicit discussion of the intergenerational concerns (how future generations will be affected by the regulatory decision). Policymakers would be provided with this additional information without changing the general approach to discounting.

Using the same discount rate across generations has the advantage of preventing time-inconsistency problems. For example, if one uses a lower discount rate for future generations, then the evaluation of a rule that has short-term costs and long-term benefits would become more favorable merely by waiting a year to do the analysis. Further, using the same discount rate across generations is attractive from an ethical standpoint. If one expects future generations to be better off, then giving them the advantage of a lower discount rate would in effect transfer resources from poorer people today to richer people tomorrow.

Some believe, however, that it is ethically impermissible to discount the utility of future generations. That is, government should treat all generations equally. Even under this approach,

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[22] Committee on Risk Assessment of Exposure to Radon in Drinking Water, Board on Radiation Effects Research, Commission on Life Sciences (1996), *Risk Assessment of Radon in Drinking Water*, National Research Council, National Academy Press, Washington, DC.

it would still be correct to discount future costs and consumption benefits generally (perhaps at a lower rate than for intragenerational analysis), due to the expectation that future generations will be wealthier and thus will value a marginal dollar of benefits or costs by less than those alive today. Therefore, it is appropriate to discount future benefits and costs relative to current benefits and costs, even if the welfare of future generations is not being discounted. Estimates of the appropriate discount rate appropriate in this case, from the 1990s, ranged from 1 to 3 percent per annum.[23]

A second reason for discounting the benefits and costs accruing to future generations at a lower rate is increased uncertainty about the appropriate value of the discount rate, the longer the horizon for the analysis. Private market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist. As explained by Martin Weitzman[24], in the limit for the deep future, the properly averaged certainty-equivalent discount factor (i.e., $1/[1+r]^t$) corresponds to the minimum discount rate having any substantial positive probability. From today's perspective, the only relevant limiting scenario is the one with the lowest discount rate – all of the other states at the far-distant time are relatively much less important because their expected present value is so severely reduced by the power of compounding at a higher rate.

If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.

5. Time Preference for Non-Monetized Benefits and Costs

Differences in timing should be considered even for benefits and costs that are not expressed in monetary units, including health benefits. The timing differences can be handled through discounting. EPA estimated cost-effectiveness in its 1998 rule, "Control of Emissions from Nonroad Diesel Engines," by discounting both the monetary costs and the non-monetized emission reduction benefits over the expected useful life of the engines at the 7 percent real rate recommended in OMB Circular A-94.

Alternatively, it may be possible in some cases to avoid discounting non-monetized benefits. If the expected flow of benefits begins as soon as the cost is incurred and is expected to be constant over time, then annualizing the cost stream is sufficient, and further discounting of benefits is unnecessary. Such an analysis might produce an estimate of the annualized cost per ton of reduced emissions of a pollutant.

6. The Internal Rate of Return

The internal rate of return is the discount rate that sets the net present value of the discounted benefits and costs equal to zero. The internal rate of return does not generally

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[23] Portney PR and Weyant JP, eds. (1999), *Discounting and Intergenerational Equity*, Resources for the Future, Washington, DC.

[24] Weitzman ML In Portney PR and Weyant JP, eds. (1999), *Discounting and Intergenerational Equity*, Resources for the Future, Washington, DC.

provide an acceptable decision criterion, and regulations with the highest internal rate of return are not necessarily the most beneficial. Nevertheless, it does provide useful information and for many it will offer a meaningful indication of regulation's impact. You should consider including the internal rate of return implied by your regulatory analysis along with other information about discounted net present values.

Other Key Considerations

1. Other Benefit and Cost Considerations

You should include these effects in your analysis and provide estimates of their monetary values when they are significant:

- Private-sector compliance costs and savings;
- Government administrative costs and savings;
- Gains or losses in consumers' or producers' surpluses;
- Discomfort or inconvenience costs and benefits; and
- Gains or losses of time in work, leisure and/or commuting/travel settings.

Estimates of benefits and costs should be based on credible changes in technology over time. For example, retrospective studies may provide evidence that “learning” will likely reduce the cost of regulation in future years. The weight you give to a study of past rates of cost savings resulting from innovation (including “learning curve” effects) should depend on both its timeliness and direct relevance to the processes affected by the regulatory alternative under consideration. In addition, you should take into account cost-saving innovations that result from a shift to regulatory performance standards and incentive-based policies. On the other hand, significant costs may result from a slowing in the rate of innovation or of adoption of new technology due to delays in the regulatory approval process or the setting of more stringent standards for new facilities than existing ones. In some cases agencies are limited under statute to consider only technologies that have been demonstrated to be feasible. In these situations, it may be useful to estimate costs and cost savings assuming a wider range of technical possibilities.

When characterizing technology changes over time, you should assess the likely technology changes that would have occurred in the absence of the regulatory action (technology baseline). Technologies change over time in both reasonably functioning markets and imperfect markets. If you assume that technology will remain unchanged in the absence of regulation when technology changes are likely, then your analysis will over-state both the benefits and costs attributable to the regulation.

Occasionally, cost savings or other forms of benefits accrue to parties affected by a rule who also bear its costs. For example, a requirement that engine manufacturers reduce emissions from engines may lead to technologies that improve fuel economy. These fuel savings will normally accrue to the engine purchasers, who also bear the costs of the technologies. There is no apparent market failure with regard to the market value of fuel saved because one would expect that consumers would be willing to pay for increased fuel economy that exceeded the cost of providing it. When these cost savings are substantial, and particularly when you estimate them to be greater than the cost associated with achieving them, you should examine and discuss why market forces would not accomplish these gains in the absence of regulation. As a general matter, any direct costs that are averted as a result of a regulatory action should be monetized wherever possible and either added to the benefits or subtracted from the costs of that alternative.

2. The Difference between Costs (or Benefits) and Transfer Payments

Distinguishing between real costs and transfer payments is an important, but sometimes difficult, problem in cost estimation. Benefit and cost estimates should reflect real resource use. Transfer payments are monetary payments from one group to another that do not affect total resources available to society. A regulation that restricts the supply of a good, causing its price to rise, produces a transfer from buyers to sellers. The net reduction in the total surplus (consumer plus producer) is a real cost to society, but the transfer from buyers to sellers resulting from a higher price is not a real cost since the net reduction automatically accounts for the transfer from buyers to sellers. However, transfers from the United States to other nations should be included as costs, and transfers from other nations to the United States as benefits, as long as the analysis is conducted from the United States perspective.

You should not include transfers in the estimates of the benefits and costs of a regulation. Instead, address them in a separate discussion of the regulation's distributional effects. Examples of transfer payments include the following:

- Scarcity rents and monopoly profits
- Insurance payments
- Indirect taxes and subsidies

Treatment of Uncertainty

The precise consequences (benefits and costs) of regulatory options are not always known for certain, but the probability of their occurrence can often be developed. The important uncertainties connected with your regulatory decisions need to be analyzed and presented as part of the overall regulatory analysis. You should begin your analysis of uncertainty at the earliest possible stage in developing your analysis. You should consider both the statistical variability of key elements underlying the estimates of benefits and costs (for example, the expected change in the distribution of automobile accidents that might result from a change in automobile safety standards) and the incomplete knowledge about the relevant relationships (for example, the uncertain knowledge of how some economic activities might affect future climate change).[25] By assessing the sources of uncertainty and the way in which benefit and cost estimates may be affected under plausible assumptions, you can shape your analysis to inform decision makers and the public about the effects and the uncertainties of alternative regulatory actions.

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[25] In some contexts, the word "variability" is used as a synonym for statistical variation that can be described by a theoretically valid distribution function, whereas "uncertainty" refers to a more fundamental lack of knowledge. Throughout this discussion, we use the term "uncertainty" to refer to both concepts.

The treatment of uncertainty must be guided by the same principles of full disclosure and transparency that apply to other elements of your regulatory analysis. Your analysis should be credible, objective, realistic, and scientifically balanced.[26] Any data and models that you use to analyze uncertainty should be fully identified. You should also discuss the quality of the available data used. Inferences and assumptions used in your analysis should be identified, and your analytical choices should be explicitly evaluated and adequately justified. In your presentation, you should delineate the strengths of your analysis along with any uncertainties about its conclusions. Your presentation should also explain how your analytical choices have affected your results.

In some cases, the level of scientific uncertainty may be so large that you can only present discrete alternative scenarios without assessing the relative likelihood of each scenario quantitatively. For instance, in assessing the potential outcomes of an environmental effect, there may be a limited number of scientific studies with strongly divergent results. In such cases, you might present results from a range of plausible scenarios, together with any available information that might help in qualitatively determining which scenario is most likely to occur.

When uncertainty has significant effects on the final conclusion about net benefits, your agency should consider additional research prior to rulemaking. The costs of being wrong may outweigh the benefits of a faster decision. This is true especially for cases with irreversible or large upfront investments. If your agency decides to proceed with rulemaking, you should explain why the costs of developing additional information—including any harm from delay in public protection—exceed the value of that information.

For example, when the uncertainty is due to a lack of data, you might consider deferring the decision, as an explicit regulatory alternative, pending further study to obtain sufficient data.[27] Delaying a decision will also have costs, as will further efforts at data gathering and analysis. You will need to weigh the benefits of delay against these costs in making your decision. Formal tools for assessing the value of additional information are now well developed in the applied decision sciences and can be used to help resolve this type of complex regulatory question.

"Real options" methods have also formalized the valuation of the added flexibility inherent in delaying a decision. As long as taking time will lower uncertainty, either passively or actively through an investment in information gathering, and some costs are irreversible, such as the potential costs of a sunk investment, a benefit can be assigned to the option to delay a decision. That benefit should be considered a cost of taking immediate action versus the alternative of delaying that action pending more information. However, the burdens of delay—including any harm to public health, safety, and the environment—need to be analyzed carefully.

1. Quantitative Analysis of Uncertainty

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[26] When disseminating information, agencies should follow their own information quality guidelines, issued in conformance with the OMB government-wide guidelines (67 FR 8452, February 22, 2002).

[27] Clemen RT (1996), *Making Hard Decisions: An Introduction to Decision Analysis*, second edition, Duxbury Press, Pacific Grove.

Examples of quantitative analysis, broadly defined, would include formal estimates of the probabilities of environmental damage to soil or water, the possible loss of habitat, or risks to endangered species as well as probabilities of harm to human health and safety. There are also uncertainties associated with estimates of economic benefits and costs, such as the cost savings associated with increased energy efficiency. Thus, your analysis should include two fundamental components: a quantitative analysis characterizing the probabilities of the relevant outcomes and an assignment of economic value to the projected outcomes. It is essential that both parts be conceptually consistent. In particular, the quantitative analysis should be conducted in a way that permits it to be applied within a more general analytical framework, such as benefit-cost analysis. Similarly, the general framework needs to be flexible enough to incorporate the quantitative analysis without oversimplifying the results. For example, you should address explicitly the implications for benefits and costs of any probability distributions developed in your analysis.

As with other elements of regulatory analysis, you will need to balance thoroughness with the practical limits on your analytical capabilities. Your analysis does not have to be exhaustive, nor is it necessary to evaluate each alternative at every step. Attention should be devoted to first resolving or studying the uncertainties that have the largest potential effect on decision making. Many times these will be the largest sources of uncertainties. In the absence of adequate data, you will need to make assumptions. These should be clearly identified and consistent with the relevant science. Your analysis should provide sufficient information for decision makers to grasp the degree of scientific uncertainty and the robustness of estimated probabilities, benefits, and costs to changes in key assumptions.

For major rules involving annual economic effects of $1 billion or more, you should present a formal quantitative analysis of the relevant uncertainties about benefits and costs. In other words, you should try to provide some estimate of the probability distribution of regulatory benefits and costs. In summarizing the probability distributions, you should provide some estimates of the central tendency (e.g., mean and median) along with any other information you think will be useful such as ranges, variances, specified low-end and high-end percentile estimates, and other characteristics of the distribution.

Your estimates cannot be more precise than their most uncertain component. Thus, your analysis should report estimates in a way that reflects the degree of uncertainty and not create a false sense of precision. Worst-case or conservative analyses are not usually adequate because they do not convey the complete probability distribution of outcomes, and they do not permit calculation of an expected value of net benefits. In many health and safety rules, economists conducting benefit-cost analyses must rely on formal risk assessments that address a variety of risk management questions such as the baseline risk for the affected population, the safe level of exposure or, the amount of risk to be reduced by various interventions. Because the answers to some of these questions are directly used in benefits analyses, the risk assessment methodology must allow for the determination of expected benefits in order to be comparable to expected costs. This means that conservative assumptions and defaults (whether motivated by science policy or by precautionary instincts), will be incompatible with benefit analyses as they will result in benefit estimates that exceed the expected value. Whenever it is possible to characterize quantitatively the probability distributions, some estimates of expected value (e.g., mean and median) must be provided in addition to ranges, variances, specified low-end and high-end percentile estimates, and other characteristics of the distribution.

Whenever possible, you should use appropriate statistical techniques to determine a probability distribution of the relevant outcomes. For rules that exceed the $1 billion annual threshold, a formal quantitative analysis of uncertainty is required. For rules with annual benefits and/or costs in the range from 100 million to $1 billion, you should seek to use more rigorous approaches with higher consequence rules. This is especially the case where net benefits are close to zero. More rigorous uncertainty analysis may not be necessary for rules in this category if simpler techniques are sufficient to show robustness. You may consider the following analytical approaches that entail increasing levels of complexity:

- Disclose qualitatively the main uncertainties in each important input to the calculation of benefits and costs. These disclosures should address the uncertainties in the data as well as in the analytical results. However, major rules above the $1 billion annual threshold require a formal treatment.
- Use a numerical sensitivity analysis to examine how the results of your analysis vary with plausible changes in assumptions, choices of input data, and alternative analytical approaches. Sensitivity analysis is especially valuable when the information is lacking to carry out a formal probabilistic simulation. Sensitivity analysis can be used to find "switch points" -- critical parameter values at which estimated net benefits change sign or the low cost alternative switches. Sensitivity analysis usually proceeds by changing one variable or assumption at a time, but it can also be done by varying a combination of variables simultaneously to learn more about the robustness of your results to widespread changes. Again, however, major rules above the $1 billion annual threshold require a formal treatment.
- Apply a formal probabilistic analysis of the relevant uncertainties – possibly using simulation models and/or expert judgment as revealed, for example, through Delphi methods.[28] Such a formal analytical approach is appropriate for complex rules where there are large, multiple uncertainties whose analysis raises technical challenges, or where the effects cascade; it is required for rules that exceed the $1 billion annual threshold. For example, in the analysis of regulations addressing air pollution, there is uncertainty about the effects of the rule on future emissions, uncertainty about how the change in emissions will affect air quality, uncertainty about how changes in air quality will affect health, and finally uncertainty about the economic and social value of the change in health outcomes. In formal probabilistic assessments, expert solicitation is a useful way to fill key gaps in your ability to assess uncertainty.[29] In general, experts can be used to quantify the probability distributions of key parameters and relationships. These solicitations, combined with other sources of data, can be combined in Monte Carlo simulations to derive a probability distribution of benefits and costs. You should

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[28] The purpose of Delphi methods is to generate suitable information for decision making by eliciting expect judgment. The elicitation is conducted through a survey process which eliminates the interactions between experts. See Morgan MG and Henrion M (1990), *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Riskand Policy Analysis*, Cambridge University Press.

[29] Cooke RM (1991), *Experts in Uncertainty: Opinion and Subjective Probability in Science*, Oxford University Press.

pay attention to correlated inputs. Often times, the standard defaults in Monte Carlo and other similar simulation packages assume independence across distributions. Failing to correctly account for correlated distributions of inputs can cause the resultant output uncertainty intervals to be too large, although in many cases the overall effect is ambiguous. You should make a special effort to portray the probabilistic results—in graphs and/or tables—clearly and meaningfully.

New methods may become available in the future. This document is not intended to discourage or inhibit their use, but rather to encourage and stimulate their development.

2. Economic Values of Uncertain Outcomes

In developing benefit and cost estimates, you may find that there are probability distributions of values as well for each of the outcomes. Where this is the case, you will need to combine these probability distributions to provide estimated benefits and costs.

Where there is a distribution of outcomes, you will often find it useful to emphasize summary statistics or figures that can be readily understood and compared to achieve the broadest public understanding of your findings. It is a common practice to compare the "best estimates" of both benefits and costs with those of competing alternatives. These "best estimates" are usually the average or the expected value of benefits and costs. Emphasis on these expected values is appropriate as long as society is "risk neutral" with respect to the regulatory alternatives. While this may not always be the case, you should in general assume "risk neutrality" in your analysis. If you adopt a different assumption on risk preference, you should explain your reasons for doing so.

3. Alternative Assumptions

If benefit or cost estimates depend heavily on certain assumptions, you should make those assumptions explicit and carry out sensitivity analyses using plausible alternative assumptions. If the value of net benefits changes from positive to negative (or vice versa) or if the relative ranking of regulatory options changes with alternative plausible assumptions, you should conduct further analysis to determine which of the alternative assumptions is more appropriate. Because different estimation methods may have hidden assumptions, you should analyze estimation methods carefully to make any hidden assumptions explicit.

F. Specialized Analytical Requirements

In preparing analytical support for your rulemaking, you should be aware that there are a number of analytic requirements imposed by law and Executive Order. In addition to the regulatory analysis requirements of Executive Order 12866, you should also consider whether your rule will need specialized analysis of any of the following issues.

Impact on Small Businesses and Other Small Entities

Under the Regulatory Flexibility Act (5 U.S.C. chapter 6), agencies must prepare a proposed and final "regulatory flexibility analysis" (RFA) if the rulemaking could "have a significant impact on a substantial number of small entities." You should consider posting your RFA on the internet so the public can review your findings.

Your agency should have guidelines on how to prepare an RFA and you are encouraged to consult with the Chief Counsel for Advocacy of the Small Business Administration on expectations concerning what is an adequate RFA. Executive Order 13272 (67 FR 53461, August 16, 2002) requires you to notify the Chief Counsel for Advocacy of any draft rules that might have a significant economic impact on a substantial number of small entities. Executive Order 13272 also directs agencies to give every appropriate consideration to any comments provided by the Advocacy Office. Under SBREFA, EPA and OSHA are required to consult with small business prior to developing a proposed rule that would have a significant effect on small businesses. OMB encourages other agencies to do so as well.

Analysis of Unfunded Mandates

Under the Unfunded Mandates Act (2 U.S.C. 1532), you must prepare a written statement about benefits and costs prior to issuing a proposed or final rule (for which your agency published a proposed rule) that may result in aggregate expenditure by State, local, and tribal governments, or by the private sector, of $100,000,000 or more in any one year (adjusted annually for inflation). Your analytical requirements under Executive Order 12866 are similar to the analytical requirements under this Act, and thus the same analysis may permit you to comply with both analytical requirements.

Information Collection, Paperwork, and Recordkeeping Burdens

Under the Paperwork Reduction Act (44 U.S.C. chapter 35), you will need to consider whether your rulemaking (or other actions) will create any additional information collection, paperwork or recordkeeping burdens. These burdens are permissible only if you can justify the practical utility of the information for the implementation of your rule. OMB approval will be required of any new requirements for a collection of information imposed on 10 or more persons and a valid OMB control number must be obtained for any covered paperwork. Your agency's CIO should be able to assist you in complying with the Paperwork Reduction Act.

Information Quality Guidelines

Under the Information Quality Law, agency guidelines, in conformance with the OMB government-wide guidelines (67 FR 8452, February 22, 2002), have established basic quality performance goals for all information disseminated by agencies, including information disseminated in support of proposed and final rules. The data and analysis that you use to support your rule must meet these agency and OMB quality standards. Your agency's CIO should be able to assist you in assessing information quality. The Statistical and Science Policy

Branch of OMB's Office of Information and Regulatory Affairs can provide you assistance. This circular defines OMB's minimum quality standards for regulatory analysis.

Environmental Impact Statements

The National Environmental Policy Act (42 U.S.C. 4321-4347) and related statutes and executive orders require agencies to consider the environmental impacts of agency decisions, including rulemakings. An environmental impact statement must be prepared for "major Federal actions significantly affecting the quality of the human environment." You must complete NEPA documentation before issuing a final rule. The White House Council on Environmental Quality has issued regulations (40 C.F.R. 1500-1508) and associated guidance for implementation of NEPA, available through CEQ's website (http://www.whitehouse/gov/ceq/).

Impacts on Children

Under Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks," each agency must, with respect to its rules, "to the extent permitted by law and appropriate, and consistent with the agency's mission," "address disproportionate risks to children that result from environmental health risks or safety risks." For any substantive rulemaking action that "is likely to result in" an economically significant rule that concerns "an environmental health risk or safety risk that an agency has reason to believe may disproportionately affect children," the agency must provide OMB/OIRA "an evaluation of the environmental health or safety effects of the planned regulation on children," as well as "an explanation of why the planned regulation is preferable to other potentially and reasonably feasible alternatives considered by the agency."

Energy Impacts

Under Executive Order 13211 (66 FR 28355, May 22, 2001), agencies are required to prepare and submit to OMB a Statement of Energy Effects for significant energy actions, to the extent permitted by law. This Statement is to include a detailed statement of "any adverse effects on energy supply, distribution, or use (including a shortfall in supply, price increases, and increased use of foreign supplies)" for the action and reasonable alternatives and their effects. You need to publish the Statement or a summary in the related NPRM and final rule. For further guidance, see OMB Memorandum 01-27 ("Guidance on Implementing Executive Order 13211", July 13, 2001), available on OMB's website.

G. Accounting Statement

You need to provide an accounting statement with tables reporting benefit and cost estimates for each major final rule for your agency. You should use the guidance outlined above to report these estimates. We have included a suggested format for your consideration.

Categories of Benefits and Costs

To the extent feasible, you should quantify all potential incremental benefits and costs. You should report benefit and cost estimates within the following three categories: monetized quantified, but not monetized; and qualitative, but not quantified or monetized.

These categories are mutually exclusive and exhaustive. Throughout the process of listing preliminary estimates of benefits and costs, agencies should avoid double-counting. This problem may arise if more than one way exists to express the same change in social welfare.

Quantifying and Monetizing Benefits and Costs

You should develop quantitative estimates and convert them to dollar amounts if possible. In many cases, quantified estimates are readily convertible, with a little effort, into dollar equivalents.

Qualitative Benefits and Costs

You should categorize or rank the qualitative effects in terms of their importance (e.g., certainty, likely magnitude, and reversibility). You should distinguish the effects that are likely to be significant enough to warrant serious consideration by decision makers from those that are likely to be minor.

Treatment of Benefits and Costs over Time

You should present undiscounted streams of benefit and cost estimates (monetized and net) for each year of the analytic time horizon. You should present annualized benefits and costs using real discount rates of 3 and 7 percent. The stream of annualized estimates should begin in the year in which the final rule will begin to have effects, even if the rule does not take effect immediately. Please report all monetized effects in 2001 dollars. You should convert dollars expressed in different years to 2001 dollars using the GDP deflator.

Treatment of Risk and Uncertainty

You should provide expected-value estimates as well as distributions about the estimates, where such information exists. When you provide only upper and lower bounds (in addition to best estimates), you should, if possible, use the 95 and 5 percent confidence bounds. Although we encourage you to develop estimates that capture the distribution of plausible outcomes for a particular alternative, detailed reporting of such distributions is not required, but should be available upon request.

The principles of full disclosure and transparency apply to the treatment of uncertainty. Where there is significant uncertainty and the resulting inferences and/or assumptions have a critical effect on the benefit and cost estimates, you should describe the benefits and costs under plausible alternative assumptions. You may add footnotes to the table as needed to provide documentation and references, or to express important warnings.

In a previous section, we identified some of the issues associated with developing estimates of the value of reductions in premature mortality risk. Based on this discussion, you should present alternative primary estimates where you use different estimates for valuing reductions in premature mortality risk.

Precision of Estimates

Reported estimates should reflect, to the extent feasible, the precision in the analysis. For example, an estimate of $220 million implies rounding to the nearest $10 million and thus a precision of +/-$5 million; similarly, an estimate of $222 million implies rounding to the nearest $1 million and thus, a precision of +/-$0.5 million.

Separate Reporting of Transfers

You should report transfers separately and avoid the misclassification of transfer payments as benefits or costs. Transfers occur when wealth or income is redistributed without any direct change in aggregate social welfare. To the extent that regulatory outputs reflect transfers rather than net welfare gains to society, you should identify them as transfers rather than benefits or costs. You should also distinguish transfers caused by Federal budget actions -- such as those stemming from a rule affecting Social Security payments -- from those that involve transfers between non-governmental parties -- such as monopoly rents a rule may confer on a private party. You should use as many categories as necessary to describe the major redistributive effects of a regulatory action. If transfers have significant efficiency effects in addition to distributional effects, you should report them.

Effects on State, Local, and Tribal Governments, Small Business, Wages and Economic Growth

You need to identity the portions of benefits, costs, and transfers received by State, local, and tribal governments. To the extent feasible, you also should identify the effects of the rule or program on small businesses, wages, and economic growth.[30] Note that rules with annual costs that are less than one billion dollars are likely to have a minimal effect on economic growth.

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[30] The Regulatory Flexibility Act (5 U.S.C. 603(c), 604).

OMB #: **Agency/Program Office:**
Rule Title:
RIN#: **Date:**

Category	*Primary Estimate*	*Minimum Estimate*	*Maximum Estimate*	*Source Citation (RIA, preamble, etc.)*
BENEFITS				
monetized benefits				
Annualized quantified, but unmonetized, benefits				
(unquantified) benefits				
COSTS				
Annualized monetized costs				
Annualized quantified, but unmonetized, costs				
Qualitative (unquantified) costs				
TRANSFERS				
Annualized monetized transfers: "on budget"				
from whom to whom?				
Annualized monetized transfers: "off-budget"				
From whom to whom?				
Category	*Effects*			*Source Citation (RIA, preamble, etc.)*
Effects on State, local, and/or tribal governments				
Effects on small businesses				
Effects on wages				
Effects on growth				

H. Effective Date

The effective date of this Circular is January 1, 2004 for regulatory analyses received by OMB in support of proposed rules, and January 1, 2005 for regulatory analyses received by OMB in support of final rules. In other words, this Circular applies to the regulatory analyses for draft proposed rules that are formally submitted to OIRA after December 31, 2003, and for draft final rules that are formally submitted to OIRA after December 31, 2004. (However, if the draft proposed rule is subject to the Circular, then the draft final rule will also be subject to the Circular, even if it is submitted prior to January 1, 2005.) To the extent practicable, agencies should comply earlier than these effective dates. Agencies may, on a case-by-case basis, seek a waiver from OMB if these effective dates are impractical.

Regulatory Impact Analysis: Frequently Asked Questions (FAQs)

February 7, 2011

With this document, the Office of Information and Regulatory Affairs (OIRA) is providing answers to frequently asked questions about the regulatory impact analysis that is required by Executive Order 12866 and OMB Circular A-4.[1] In addition, President Obama signed Executive Order 13563, "Improving Regulation and Regulatory Review," on January 18, 2011; that Executive Order incorporates the requirements of Executive Order 12866 and specifically directs agencies "to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible."

The purpose of this document is to offer answers to questions often asked with respect to regulatory impact analysis; nothing said here is meant to alter existing requirements in any way. For more complete guidance, please consult Executive 13563, Executive Order 12866, and Circular A-4.

1. When do I need to provide a regulatory impact analysis, and what is the definition of "economically significant"?

Executive Order 12866 provides that agencies must submit a regulatory impact analysis for those regulatory actions that are "significant" within the meaning of Section 3(f)(1) – or what Circular A-4 describes as "economically significant."[2] A regulatory action is economically significant if it is anticipated (1) to "[h]ave [1] an annual effect on the economy of $100 million or more" or (2) to "adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities."

The $100 million threshold applies to the impact of the proposed or final regulation in *any one year,* and it includes *benefits, costs, or transfers*. (The word "or" is important: $100 million in annual benefits, *or* costs, *or* transfers is sufficient; $50 million in benefits and $49 million in costs, for example, is not.)

The second criterion – whether the rule would "adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities" – requires careful consideration of the phrase "adversely affect in a material way." There are no hard-and-fast rules here. Suppose, for example, that a regulation (1) would impose $98 million in first-year costs for pollution control equipment, with lower annual costs thereafter, (2) would disproportionately and adversely affect a small sector of the economy, and (3) would threaten to create significant job loss. This rule would be considered economically significant.

The $100 million threshold is identical to the monetary threshold for determining whether a rule is “major” under the Congressional Review Act (CRA). Under that Act, a “major rule” is one that “has resulted in or is likely to result in . . . an annual effect on the economy of $100,000,000 or more.”[3] For both Executive Order 12866 and the CRA, the $100 million threshold is not adjusted for inflation (unlike the expenditure threshold contained in the Unfunded Mandates Reform Act[4]). Under the Congressional Review Act, a rule also qualifies as “major” if it has resulted in or is likely to result in “a major increase in costs or prices for consumers, individual industries, Federal, State, or local government agencies, or geographic regions” or “significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic and export markets.”[5]

2. How should my regulatory impact analysis be presented to the public?

To inform the public of the expected consequences of regulations, agencies should present their analysis in plain language. To promote transparency and public participation, they should provide a clear executive summary of their central conclusions.[6] They should clearly and prominently include a standardized accounting statement, and are particularly encouraged to do so in the preamble and executive summary.[7] That statement should include one or more tables summarizing their assessment of costs, benefits, and transfers, at both 3% and 7% discount rates.[8] Consistent with the Executive Order 13563 and Executive Order 12866, OMB recommends that the tables provide a transparent statement of both quantitative and qualitative benefits and costs of the proposed or planned action as well as of reasonable alternatives.[9] In addition to providing a clear table of aggregate costs and benefits, agencies are strongly encouraged to provide one or more separate tables disaggregating and showing the components of those figures.[10]

In comparing benefits to costs, agencies should emphasize net benefits rather than ratios. As Circular A-4 states, “[t]he size of net benefits, the absolute difference between the projected benefits and costs, indicates whether one policy is more efficient than another. The ratio of benefits to costs is not a meaningful indicator of net benefits and should not be used for that purpose. It is well known that considering such ratios alone can yield misleading results.”[11]

3. Can something other than a “market failure” be identified as the “need” for the regulation?

Yes. Executive Order 13563 states, “Where appropriate and permitted by law, each agency may consider (and discuss qualitatively) values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts.” Circular A-4 states that “you should try to explain whether the action is intended to address a significant market failure *or* to meet some other compelling public need such as improving governmental processes or promoting intangible values such as distributional fairness or privacy.”[12] The word “or” is once again significant: if a market failure does not exist but there is a compelling public need for regulation, then the agency should clearly identify the problem that it intends to address and explain and assess the significance of that problem.[13]

4. Even if I have identified a market failure or other need for regulation, should I still consider alternatives to Federal regulation?

Yes. In taking into account a range of alternatives, you should begin by asking whether to regulate at all. Even where a market failure clearly exists, there may be alternatives to Federal regulation, including antitrust enforcement, consumer-initiated litigation in the product liability system, and administrative compensation systems.[14]

You should also consider the option of deferring to regulation at the State or local level. To be sure, problems that affect interstate commerce or spill across State lines may best be addressed by Federal regulation. But more localized problems may be more efficiently addressed locally.[15] In such situations, deferring to state and local regulation can encourage regulatory experimentation and innovation while also fostering learning and competition to establish the best regulatory policies.[16]

There are often questions about the proper relationship among Federal, state, and local requirements. Where Federal regulation is warranted, you should avoid imposing conflicting or duplicative requirements wherever possible. Executive Order 13563 states, “Some sectors and industries face a significant number of regulatory requirements, some of which may be redundant, inconsistent, or overlapping. Greater coordination across agencies could reduce these requirements, thus reducing costs and simplifying and harmonizing rules. In developing regulatory actions and identifying appropriate approaches, each agency shall attempt to promote such coordination, simplification, and harmonization.”

While some problems are best handled at the state level, others can be handled through simultaneous regulation from different levels of government. In some cases, however, the increased compliance costs required for firms to meet different State and local regulations may exceed any benefits stemming from the diversity of State and local regulation.[17] With close reference to statutory requirements and governing legal principles, you should consider when and whether it is appropriate to retain State and local regulation.

5. After determining that Federal regulation is the best way to proceed, how do I identify and provide an adequate analysis of “potentially effective and reasonably feasible alternatives” as required by Executive Order 12866 ?

Executive Order 12866 requires an “assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation” and “an explanation why the planned regulatory action is preferable to the identified potential alternatives.”[18] You should ordinarily consider analyzing at least three options: the preferred option; a more stringent option; and a less stringent one.[19]

In some cases, the relevant alternatives might not line up on a continuum of stringency, but might involve different approaches, with distinct advantages and disadvantages. If, for example, an agency is considering banning the sale of a potentially unsafe product, it might consider instead requiring disclosure of health risks to the public. Executive Order 13563 states, "Where relevant, feasible, and consistent with regulatory objectives, and to the extent permitted by law, agencies shall identify and consider regulatory approaches that reduce burdens and maintain flexibility and freedom of choice for the public." Warnings, appropriate default rules, and disclosure requirements are examples.

In considering which alternatives to discuss, you should explore which approaches are feasible and plausible ways of meeting the regulatory objective. When the preferred option includes a number of distinct provisions, the benefits and costs of different regulatory provisions should be analyzed separately in order to facilitate consideration of the full range of potential alternatives.[20]

6. What is the appropriate time horizon for estimating costs and benefits?

Executive Order 13563 directs agencies "to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible." When choosing the appropriate time horizon for estimating costs and benefits, agencies should consider how long the regulation being analyzed is likely to have resulting effects. The time horizon begins when the regulatory action is implemented and ends when those effects are expected to cease.[21] Ideally, analysis should include all future costs and benefits. Here as elsewhere, however, a "rule of reason" is appropriate, and the agency should consider for how long it can reasonably predict the future and limit its analysis to this time period. Thus, if a regulation has no predetermined sunset provision, the agency will need to choose the endpoint of its analysis on the basis of a judgment about the foreseeable future. For rules that require large up-front capital investments, the life of the capital is also an option. For most agencies, a standard time period of analysis is 10 to 20 years, and rarely exceeds 50 years.

7. What is a baseline and how do I identify it?

The baseline is the best assessment of how the world would look in the absence of the proposed action during the relevant time horizon. Specifically, the baseline should incorporate the agency's best forecast for how the world will change (if at all) during the identified time horizon, with particular attention to factors such as the evolution of relevant markets; population or economic growth; possible behavioral changes, learning, and adaptation by relevant members of the public; technological changes and advances; and changes in regulations promulgated by the agency or other government entities. Identifying this baseline is necessary to allow assessment of the relative benefits and costs attributable to the proposed action.[22]

For review of an existing regulation or one that simply restates statutory requirements that are self-implementing, a pre-statute baseline, assuming "no change," is appropriate.[23]

Multiple baselines could be appropriate when more than one baseline is reasonable – perhaps because another agency's existing regulation could be implemented in different ways – and the choice would significantly affect estimated benefits and costs.[24]

8. When should I conduct an uncertainty analysis? A sensitivity analysis?

Regulatory analysis requires predictions about the future. What the future holds, both in the baseline and under the regulatory alternative under consideration, is rarely certain. The important uncertainties connected with the regulatory decision should be analyzed and presented as part of the regulatory impact analysis.[25] It is common practice for an agency's uncertainty analysis to present a central "best estimate," which reflects the expected value of the benefits and costs of the rule, as well as a description of the ranges of plausible values for benefits, costs, and net benefits. This description informs the decision-makers and the public of the degree of uncertainty associated with the regulatory decision.[26]

In general, you should also include a "sensitivity analysis" that shows how results of your analysis vary with plausible changes in assumptions, choices of input data, and alternative analytical approaches.[27] The level of detail in the analysis can vary with the expected effects of the rule; you should use more rigorous analytical approaches, and more comprehensive sensitivity analysis, for rules with especially large consequences. For rules that exceed the $1 billion annual threshold, Circular A-4 states that "a formal quantitative analysis of uncertainty is required."

9. What is the difference between a transfer and a cost?

Costs affect the total resources available to society. Transfer payments are monetary payments from one group to another that do not affect total resources.[28] The agency should not include transfer payments in its estimates of the benefits and costs of a regulation. Instead, it should address them in a separate discussion of the distributional effects of the regulation.[29] Distinguishing between real costs and transfer payments is an important, but sometimes difficult, problem in cost estimation.

Examples of costs include:

- Expenditures, including goods and services, required to comply with the regulation
- Reductions in consumer and producer well-being resulting from regulation-induced price or quantity changes
- Increases in premature death, illness, or disability (e.g., in the case where a regulation that would reduce certain safety risks would have the consequence of increasing other safety risks).

Examples of transfers include:

- Fees to government agencies for goods or services already provided by the agency (that is, monetary transfers from feepayers to the government—because the goods and services are already counted as government costs, including them as private costs would entail double counting)
- Increases in sales tax revenue as a result of increases in sales (that is, monetary transfers from consumers to government)
- Payments by the Federal government for goods or services provided by the private sector (that is, monetary transfers by the government to service providers, such as reimbursements by the Medicare program)
- Reductions in sales by one business that are matched by increases in sales by another (that is, transfers in economic activity from one business to another)
- Reductions in resources for some consumers that are matched by increases for others (that is, transfers of resources among consumers)[30]

10. <u>Why must I present the estimates using both 3% and 7% discount rates</u>?

The 7 percent rate is a recent estimate of the average before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital in the private sector.[31] The effects of regulation, however, do not always fall exclusively or primarily on the allocation of capital. When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate. The alternative most often used is sometimes called the "social rate of time preference," which simply means the rate at which "society" discounts future consumption flows to their present value. If we use the rate that the average saver uses to discount future consumption as our measure, then the real rate of return on long-term government debt provides a fair approximation. Historically, this rate has averaged around 3 percent in real terms on a pre-tax basis.[32]

Special considerations arise when comparing benefits and costs across generations. If the regulatory action will have important intergenerational benefits or costs, the agency should consider a sensitivity analysis, using a lower but positive discount rate, in addition to calculating net benefits using discount rates of 3 percent and 7 percent.[33]

11. <u>How do I value time</u>?

Some regulations require people to spend time on certain activities to comply with their provisions – as, for example, through paperwork or monitoring. The costs of such requirements should be described both in terms of hours and to the extent feasible, in terms of monetary equivalents. In order to value the cost of time, agencies should consider what those people would be doing with their time if they did not need to comply with the regulations.[34] The resulting figures, like all other costs and benefits, should be annualized (see below). As a general rule, workers' hourly wages can be used as a proxy for the value of the time that they could have spent doing other work. If the regulation requires paperwork, it may be appropriate to value the relevant time at the hourly wage for the workers asked to complete the required tasks. If specific expertise is needed to complete those tasks, the average wages of workers with that expertise should be used. If, for example, the regulation will require software changes by computer programmers, it would be appropriate to use the wages of computer programmers.

In some cases, regulations will result in time savings for individuals, and such savings should be described both in terms of hours saved and to the extent feasible, in terms of monetary equivalents. Monetized estimates should include a measure of the value of that time calculated in the same way as costs. If the time saved is not work, it is appropriate to try to estimate people's willingness to pay for the improvement. This estimate attempts to measure what individuals would be willing to pay to enjoy the particular benefit of time saved for the relevant activity.[35]

Sometimes regulations do not save time, but do lead to improvements in the quality of time spent on an activity. An example would be a regulation that requires airlines to provide adequate food and potable water to passengers within two hours of being delayed in an aircraft grounded on the tarmac. The regulation would not shorten people's waiting time, but would improve the quality of that waiting time. In this case, it is appropriate to try to estimate people's willingness to pay for the improvement. Studies or surveys of individuals in similar circumstances may be available to use as a reference point for estimates.

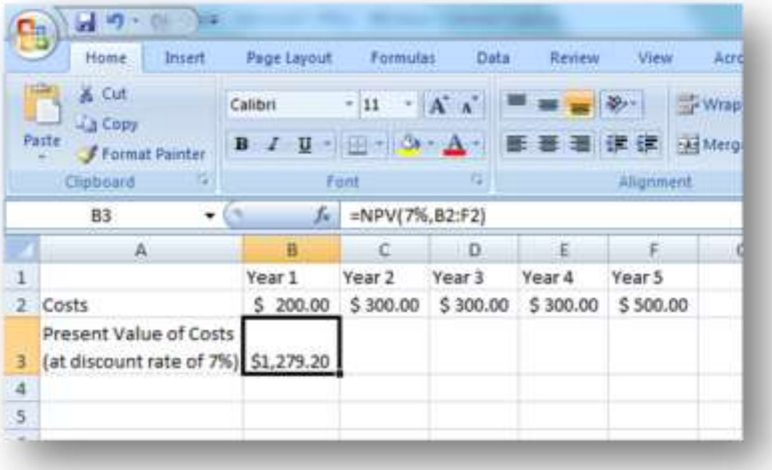
12. <u>How do I annualize?</u>

As part of a regulatory analysis, agencies are asked to provide estimates of the annualized costs and benefits of a regulation.[36] Under this requirement, agencies should take a stream of future benefits and costs of the rule and estimate its approximate yearly costs and benefits. The first step in the annualization of costs is to find the present value of the stream of future costs. To find that value, each year's expected costs should be discounted back to the present using the following formula:

$$Present\ Value\ of\ Year\ T's\ Costs = \frac{C_t}{(1+i)^t}$$

where C_t is the cost t years in the future and i is the discount rate.

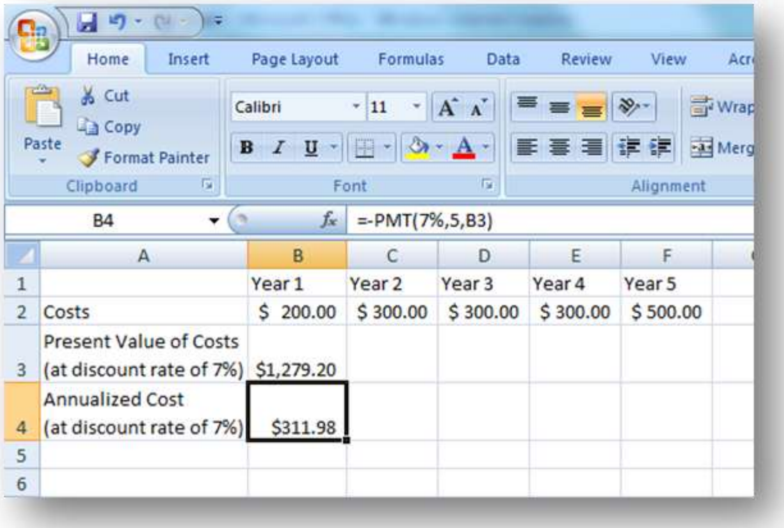
Then, each year's discounted costs should be added together to find the present value of costs. If you are using an Excel spreadsheet, you can use the NPV (Net Present Value) function to calculate the present value of costs from a set of future costs, as follows:



B3 =NPV(7%,B2:F2)

	A	B	C	D	E	F
1		Year 1	Year 2	Year 3	Year 4	Year 5
2	Costs	$ 200.00	$ 300.00	$ 300.00	$ 300.00	$ 500.00
3	Present Value of Costs (at discount rate of 7%)	$1,279.20				
4						
5						

The next step is to compute an annualized cost from this present value. This step is akin to spreading the costs equally over each period, taking account of the discount rate. If you are using Excel, an easy way to compute this amount is to use the PMT function, which calculates the annualized amount needed over a number of years to equal a given present value at a particular discount rate. The formula returns a negative number, so the result should be multiplied by -1 to obtain the annualized cost.



B4 =-PMT(7%,5,B3)

	A	B	C	D	E	F
1		Year 1	Year 2	Year 3	Year 4	Year 5
2	Costs	$ 200.00	$ 300.00	$ 300.00	$ 300.00	$ 500.00
3	Present Value of Costs (at discount rate of 7%)	$1,279.20				
4	Annualized Cost (at discount rate of 7%)	$311.98				
5						
6						

Annualized benefits can be computed from a stream of expected future benefits using the same method.

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[1] Executive Order 12866 is available at: http://www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866.pdf. Circular A-4 is available at: http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf.

[2] Executive Order 12866 refers to "those matters identified as, or determined by the Administrator of OIRA to be, a significant regulatory action within the scope of section 3(f)(1)." Circular A-4 states that "Executive Order 12866 requires agencies to conduct a regulatory analysis for economically significant regulatory actions as defined by Section 3(f)(1)." (P. 1).

[3] 5 U.S.C. § 804(2).

[4] Under the Unfunded Mandates Reform Act, each agency must prepare a benefit-cost analysis "before promulgating any general notice of proposed rulemaking that is likely to result in promulgation of any rule" that "includes any Federal mandate that may result in the expenditure by State, local, and tribal governments, in the aggregate, or by the private sector, of $100,000,000 or more (adjusted annually for inflation) in any 1 year." 2 U.S.C. §1532. For such rules, with limited exceptions, the "agency shall identify and consider a reasonable number of regulatory alternatives and from those alternatives select the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule, for (1) State, local, and tribal governments, in the case of a rule containing a Federal intergovernmental mandate; and (2) the private sector, in the case of a rule containing a Federal private sector mandate." 2 U.S.C. §1535.

[5] *Id.* See also "Guidance for Implementing the Congressional Review Act," M-99-13, available at http://www.whitehouse.gov/sites/default/files/omb/assets/memoranda_2010/m99-13.pdf. Note that these alternative tests for a "major rule" under the CRA are not the same as the second criterion under Executive Order 12866 (to "adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities"); by contrast, the CRA's language is drawn from Executive Order 12291, which was revoked in 1993. See Executive Order 12291, §1(b), available at http://www.archives.gov/federal-register/codification/executive-order/12291.html; Executive Order 12866, §11 ("Executive Order Nos. 12291 and 12498; all amendments to those Executive orders; all guidelines issued under those orders; and any exemptions from those orders heretofore granted for any category of rule are revoked.").

[6] Circular A-4 states: "Your analysis should . . . have an executive summary." (P. 3).

[7] Circular A-4 states that "[y]our analysis should . . . have an executive summary, including a standardized accounting statement." (P. 3). It also states that "[y]ou need to provide an accounting statement with tables reporting benefit and cost estimate for each major final rule for your agency." (P. 44). See also OMB's "2010 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," available at http://www.whitehouse.gov/sites/default/files/omb/legislative/reports/2010_Benefit_Cost_Report.pdf. This report states that:

> For all economically significant regulatory actions, we recommend that agencies should clearly and prominently present, in the preamble and in the executive summary of the regulatory impact analysis, one or more tables summarizing the assessment of costs and benefits required under Executive Order 12866 Section 6(a)(3)(C)(i)-(iii). The tables should provide a transparent statement of both quantitative and qualitative benefits and costs of the proposed or planned action as well as of reasonable alternatives. The tables should include all relevant information that can be quantified and monetized, along with relevant information that can be described only in qualitative terms . . . . To the extent feasible in light of the nature of the issue and the relevant data, all benefits and costs should be quantified and monetized. To communicate any uncertainties, we recommend that the table should offer a range of values, in addition to best estimates, and it should clearly indicate impacts that cannot be quantified or monetized. If nonquantifiable variables are involved, they should be clearly identified. Agencies should attempt, to the extent feasible, not merely to identify such variables but also to signify their importance.
> (P. 51).

[8] Under the heading of "Accounting Statement," Circular A-4 states that "[y]ou should present undiscounted streams of benefit and cost estimates (monetized and net) for each year of the analytic time horizon. You should present annualized benefits and costs using real discount rates of 3 and 7 percent." (P. 45).

[9] Circular A-4 states: "The analysis document should discuss the expected benefits and costs of the selected regulatory option and any reasonable alternatives . . . . To present your results, you should: include separate schedules of the monetized benefits and costs that show the type and timing of benefits and costs, and express the estimates in this table in constant, undiscounted dollars . . . ; list the benefits and costs you can quantify, but cannot

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monetize, including their timing; describe benefits and costs you cannot quantify; and identify or cross-reference the data or studies on which you base the benefit and cost estimates." (P. 18).

[10] See OMB's "2010 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," available at http://www.whitehouse.gov/sites/default/files/omb/legislative/reports/2010_Benefit_Cost_Report.pdf. It states that "[i]t will often be useful to accompany a simple, clear table of aggregated costs and benefits with a separate table offering disaggregated figures, showing the components of the aggregate figures." (P. 51).

[11] See p. 10 of Circular A-4.

[12] See p. 4 of Circular A-4.

[13] Executive Order 12866 states that "Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American people." Circular A-4 states that "you should try to explain whether the action is intended to address a significant market failure or to meet some other compelling public need such as improving governmental processes or promoting intangible values such as distributional fairness or privacy." (P. 4).

[14] Circular A-4 states: "Even where a market failure exists, you should consider other means of dealing with the failure before turning to Federal regulation. Alternatives to Federal regulation include antitrust enforcement, consumer-initiated litigation in the product liability system, or administrative compensation systems. In assessing whether Federal regulation is the best solution, you should also consider the possibility of regulation at the State or local level. In some cases, the nature of the market failure may itself suggest the most appropriate level of governmental level of regulation." (P. 5)

[15] Circular A-4 states: "In assessing whether Federal regulation is the best solution, you should also consider the possibility of regulation at the State or local level. In some cases, the nature of the market failure may itself suggest the most appropriate governmental level of regulation. For example, problems that spill across State lines (such as acid rain whose precursors are transported widely in the atmosphere) are probably best addressed by Federal regulation. More localized problems, including those that are common to many areas, may be more efficiently addressed locally." (P. 6).

[16] Circular A-4 states: "The advantages of leaving regulatory issues to State and local authorities can be substantial. If public values and preferences differ by region, those differences can be reflected in varying State and local regulatory policies. Moreover, States and localities can serve as a testing ground for experimentation with alternative regulatory policies. One State can learn from another's experience while local jurisdictions may compete with each other to establish the best regulatory policies. You should examine the proper extent of State and local discretion in your rulemaking context." (P. 6).

[17] Circular A-4 states: "Where Federal regulation is clearly appropriate to address interstate commerce issues, you should try to examine whether it would be more efficient to retain or reduce State and local regulation. The local benefits of State regulation may not justify the national costs of a fragmented regulatory system. For example, the increased compliance costs for firms to meet different State and local regulations may exceed any advantages associated with the diversity of State and local regulation. Your analysis should consider the possibility of reducing as well as expanding State and local rulemaking." (P. 6).

[18] See Section 6(a)(3)(C) of Executive Order 12866.

[19] Circular A-4 states: "In general, both the benefits and costs associated with a regulation will increase with the level of stringency (although marginal costs generally increase with stringency, whereas marginal benefits may decrease). You should study alternative levels of stringency to understand more fully the relationship between stringency and the size and distribution of benefits and costs among different groups." (P. 8).

[20] Circular A-4 states that when "consider[ing] alternative regulatory approaches," there "must be some balance between thoroughness and the practical limits on your analytical capacity. With this qualification in mind, you should nevertheless explore modifications of some or all of a regulation's attributes or provisions to identify appropriate alternatives." (P. 7).

[21] Circular A-4 states: "You should present undiscounted streams of benefit and cost estimates (monetized and net) for each year of the analytic time horizon." (P. 45). A-4 also provides that "you should present the annual time stream of benefits and costs expected to result from the rule, clearly identifying when the benefits and costs are expected to occur. The beginning point for your stream of estimates should be the year in which the final rule will begin to have effects, even if that is expected to be some time in the future. The ending point should be far enough in the future to encompass all the significant benefits and costs likely to result from the rule." (P. 31).

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[22] Circular A-4 states that "[y]ou need to measure the benefits and costs of a rule against a baseline. This baseline should be the best assessment of the way the world would look absent the proposed action. The choice of an appropriate baseline may require consideration of a wide range of potential factors, including: evolution of the market, changes in external factors affecting expected benefits and costs, changes in regulations promulgated by the agency or other government entities, and the degree of compliance by regulated entities with other regulations." (P. 15).

[23] Circular A-4 states: "It may be reasonable to forecast that the world absent the regulation will resemble the present. If this is the case, however, your baseline should reflect the future effect of current government programs and policies. For review of an existing regulation, a baseline assuming 'no change' in the regulatory program generally provides an appropriate basis for evaluating regulatory alternatives. . . . In some cases, substantial portions of a rule may simply restate statutory requirements that would be self-implementing, even in the absence of the regulatory action. In these cases, you should use a pre-statute baseline." (PP. 15-16).

[24] Circular A-4 states: "When more than one baseline is reasonable and the choice of baseline will significantly affect estimated benefits and costs, you should consider measuring benefits and costs against alternative baselines. In doing so you can analyze the effects on benefits and costs of making different assumptions about other agencies' regulations, or the degree of compliance with your own existing rules. In all cases, you must evaluate benefits and costs against the same baseline." (P. 15).

[25] Circular A-4 states that the "important uncertainties connected with your regulatory decisions need to be analyzed and presented as part of the overall regulatory analysis." (P. 38).

[26] Circular A-4 states: "Where there is a distribution of outcomes, you will often find it useful to emphasize summary statistics or figures that can be readily understood and compared to achieve the broadest public understanding of your findings. It is a common practice to compare the 'best estimate' of both benefits and costs with those of competing alternatives. These 'best estimates' are usually the average or the expected value of benefits and costs." (P. 48).

[27] Circular A-4 states: "Use a numerical sensitivity analysis to examine how the results of your analysis vary with plausible changes in assumptions, choices of input data, and alternative analytical approaches." (P. 41).

[28] This general statement does not take into account the potential inefficiencies that may arise from taxation (other than lump-sum taxation). Transfer payments could affect total resources available to society because of the marginal cost of public funds.

[29] Circular A-4 states: "You should report transfers, separately and avoid and misclassification of transfer payments as benefits or costs. Transfers occur when wealth or income is redistributed without any direct change in aggregate social welfare." (P. 46).

[30] Circular A-4 states: "A regulation that restricts the supply of a good, causing its price to rise, produces a transfer from buyers to sellers. The net reduction in the total surplus (consumer plus producer) is a real cost to society, but the transfer from buyers to sellers resulting from a higher price is not a real cost since the net reduction automatically accounts for the transfer from buyers to sellers." (P. 38).

[31] Circular A-4 states: "The 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital. It approximates the opportunity cost of capital, and it is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector." (P. 33).

[32] Circular A-4 provides: "The effects of regulation do not always fall exclusively or primarily on the allocation of capital. When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate. The alternative most often used is sometimes called the 'social rate of time preference.' This simply means the rate at which 'society' discounts future consumption flows to their present value. If we take the rate that the average saver uses to discount future consumption as our measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a fair approximation. Over the last thirty years, this rate has averaged around 3 percent in real terms on a pre-tax basis." (P. 33).

[33] Circular A-4 offers a brief relevant background on economic and ethical issues and states: "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." (P. 36).

[34] Circular A-4 states: "You should include [other benefit and cost considerations] in your analysis and provide estimates of their monetary values when they are significant: [p]rivate-sector compliance costs and savings; [g]overnment administrative costs and savings; [g]ains or losses in consumers' or producers' surpluses; [d]iscomfort

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or inconvenience costs and benefits; and [g]ains or losses of time in work, leisure and/or commuting/travel settings." (P. 37).

[35] According to Circular A-4, "[o]pportunity cost is the appropriate concept for valuing both benefits and costs. The principle of 'willingness-to-pay' (WTP) captures the notion of opportunity cost by measuring what individuals are willing to forgo to enjoy a particular benefit." (P. 18). Circular A-4 adds: "In general, economists tend to view WTP as the most appropriate measure of opportunity cost, but an individual's 'willingness-to-accept' (WTA) compensation for not receiving the improvement can also provide a valid measure of opportunity cost." Hence it may be valid for agencies to consider use of WTA. See pp. 18-19 of Circular A-4 for a general discussion of the concept of "willingness to pay."

[36] Circular A-4 states: "As a first step, you should present the annual time stream of benefits and costs expected to result from the rule, clearly identifying when the benefits and costs are expected to occur . . . . Benefits and costs that occur sooner are generally more valuable . . . . To reflect this preference, a discount factor should be used to adjust the estimated benefits and costs for differences in timing. The further in the future the benefits and costs are expected to occur, the more they should be discounted. The discount factor can be calculated given a discount rate." (PP. 31-32). It also states that "[y]ou should present annualized benefits and costs . . ." (P. 45).

Health and Ecological Criteria Division
Office of Science and Technology
Office of Water
United States Environmental Protection Agency
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ARSENIC AND FISH CONSUMPTION

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ARSENIC AND FISH CONSUMPTION

Health and Ecological Effects Division
Office of Science and Technology
Office of Water

ABSTRACT

This report summarizes available data on human intake of inorganic arsenic by consumption of fish and shellfish and arsenic in drinking water. It estimates total exposure to inorganic arsenic from these vehicles under a variety of exposure scenarios.

Much of the arsenic in fish and shellfish is present in the form of organic compounds rather than as inorganic arsenic. For this report, EPA utilized published data on the concentrations of total arsenic and inorganic arsenic in a variety of fish and shellfish species. These data along with data from the U.S. Department of Agriculture Food Consumption Survey on fish/shellfish intake of consumers and non consumers were used to generate estimates for the inorganic arsenic intake for several exposure scenarios. The scenario for the group with the highest potential exposure (90 μg/day) was individuals consuming a diet high in fish and shellfish and having a preference for shellfish. An scenario for the average fish consumer estimated an intake of 4 μg/day and the scenario for the general consumer with only occasional fish/shellfish intake estimated an intake of 0.6 μg/inorganic arsenic per day. Scenarios for consumer groups with other fish/shellfish consumption patterns were evaluated as well.

The evaluation of inorganic arsenic exposure from fish and shellfish provides support for utilizing the existing MCL of 50 ppb for arsenic as an ambient water criterion in some areas until EPA updates its risk assessment for arsenic and revises the MCL. The exposure evaluation also illustrates a need for site specific criterion when high consumption of fish and shellfish is coupled with arsenic contamination of drinking water. Toxicity concern related to the arsenic in marine fish and shellfish is mitigated by the fact that it is largely present as arsenobetaine, a metabolically stable compound that is rapidly excreted. Additional studies of the forms of organic arsenic in fresh water species are needed.

1.0 INTRODUCTION

The U.S. Environmental Protection Agency's (EPA) guidance for arsenic under the Safe Drinking Water Act and the Clean Water Act are different. EPA's drinking water standard, or maximum contaminant level (MCL) for arsenic is 50 ppb and was developed by the Public Health Service in the 1940's. The Ambient Water Quality Criterion under the Clean Water Act is 0.018 ppb based on an estimated one in a million cancer risk (EPA, 1980). EPA has recognized that there is considerable uncertainty in the cancer risk value and is presently in the process of developing a new risk analysis in order to propose a new MCL. Under legislative requirements, the EPA will issue a proposal for an arsenic MCL in the year 2000. Until that time the 50 ppb will remain in effect for public potable water sources.

The question has been raised as to whether the 50 ppb MCL for arsenic in drinking water can also serve as an Ambient Water Quality Criterion for arsenic until the risk assessment revision is complete and whether fish/shellfish consumption from the same waters adds significantly to the inorganic arsenic exposure. According to the Clean Water Act Criteria Document for arsenic (EPA, 1980), trivalent and pentavalent, inorganic, arsenic compounds are the most toxic species. This document accepts that premise and updates the Criteria Document in terms of the forms of arsenic in fish and shellfish.

The following report examines the available quantitative data on arsenic in fish and shellfish as well as its speciation (inorganic vs. organic). Estimates are made for human exposures to inorganic arsenic from fish/shellfish and drinking water under several exposure scenarios that apply to the average and high end of the distribution curve for fish/shellfish consumption. An exposure assessment for the average consumer within the general population (which includes nonconsumers) is also presented. The document is a technical summary of the available data on the arsenic in fish and shellfish as well as an exposure evaluation for inorganic arsenic.

2.0 ARSENIC IN FISH

The quantitative data on arsenic concentrations and speciation in fish are limited but are generally consistent with the hypothesis that most and sometimes all of the arsenic in fish is organic rather than inorganic. The available analytical data on arsenic in fish are presented below. The data are grouped by the source of the fish and the type of arsenic. All data are reported in terms of wet mass. The following presents data on total arsenic in marine species and then freshwater species followed by inorganic arsenic for marine species and then freshwater species.

Total Arsenic in Marine and Estuarine Species. Ballin et al. (1994) analyzed samples of 13 species of marine fish for total arsenic. Average concentrations ranged from 0.6 to 37 ppm. Only two of 20 samples had values greater than 10 ppm, one of three plaice samples and a catfish sample. In cases where samples for a given species originated from different source waters, there was considerable variability in total arsenic concentration. Total arsenic concentrations from three different herring samples ranged from 0.7 to 4 ppm; there was also variability among the results for 5 samples from the same fish. The two species with the highest average levels of total arsenic were plaice from Fladenground (32 ppm; standard deviation 14) and catfish from Gr. Fisherbank (37 ppm; standard deviation 28).

In another study, Lawrence et al. (1986) obtained samples of fish muscle from different areas in Canada. Both Atlantic and Pacific fish species were evaluated. The average total arsenic concentrations for replicate samples ranged from 1.1 ppm (herring) to 13.2 ppm (sole) for Atlantic species and 0.31 (salmon) to 7.4 ppm (cod) for Pacific Species. A total of 6 Atlantic species and 5 Pacific species were evaluated. Slight differences were apparent in the Atlantic versus Pacific samples of the same species. For example the sole sample from the Atlantic had **13.2 ppm while that from the Pacific had 5.2 ppm and the cod sample from the Atlantic had 5.2 ppm while that from the Pacific had 7.4 ppm. Based on the sample variability observed by Ballin et al. (1994), these differences are most likely a reflection of variability in samples rather than differences that result because of the arsenic in the source water. Additional support for this conclusion is provided by analysis of a sample of sole purchased locally in Ottawa which had only 0.10 ppm total arsenic, a value far lower than that for either the Atlantic or Pacific samples. The low value for this sample may represent loss during storage and shipping. Le et al. (1994) found that up to 48% of the total arsenic could be released in defrost liquid.**

In order to evaluate microwave assisted distillation with atomic absorption spectrometry as a method for determining inorganic arsenic, Lopes et al. (1994) analyzed commercially purchased canned or frozen samples of anchovies, tuna, sardines, hake and sole for total as well as inorganic arsenic. Total arsenic concentrations ranged from 0.82 ppm (tuna) to 7.76 ppm (sole)

In a report developed for Region 10 of the U.S. EPA, Chew (1996) **summarized data from the published literature on the concentrations of total arsenic and inorganic arsenic in fish and shellfish. The data apply primarily to samples from Japan and all but one sample came from the** Pacific Ocean. Total average arsenic concentrations ranged from values less than 1 to 10 ppm for fish with two outliers: skate (64 ppm) and stingray (17 ppm).

Total Arsenic in Fresh Water Species. Ballin et al. (1994) examined the total arsenic in fresh water fish from rivers in Northern Germany, the River Elbe or from a fish hatchery. Seven species were examined; the average total arsenic concentrations were lower than those for marine fish and ranged from the detection limit to 1.5 ppm. The highest concentration was present in rainbow trout specimens from a fish hatchery and the lowest concentration was found in perch from a river in Northern Germany. The trout sample was the only one with a concentration of greater than 0.1 ppm.

The lower levels of total arsenic in fresh water fish are substantiated by analysis of the muscle tissue of several species collected in Ontario and Alberta, Canada (Lawrence et al., 1986). Concentrations ranged from 0.007 ppm (yellow perch) to 0.24 ppm (striped perch). Nine replicate samples were analyzed. Among the 23 samples of fresh water fish analyzed by Ballin et al (1994) and Lawrence et al. (1986), the total arsenic was less than 0.3 ppm for 22.

Inorganic Arsenic in Marine and Estuarine Species. In the data summarized by Chew (1996), average inorganic arsenic concentrations ranged from the detection limit to 0.2 ppm. The species with the highest average percentage of arsenic as inorganic arsenic were shark (9.5%), sturgeon (6.9%) and sucker (8.5%). In all other cases the percent of inorganic arsenic was less than 4 %. The two species with the highest average concentrations of total arsenic (skate, stingray) had none of their arsenic present as inorganic arsenic and the species with the highest concentrations of inorganic arsenic (shark, sturgeon, sucker) had low average total arsenic concentrations (2.1, 0.6 and 0.2 ppm respectively). In the study by Lopez et al. (1994), the percent inorganic arsenic in the 5 fish samples analyzed was less than 5% in all samples when analyzed by microwave-assisted distillation and atomic absorption spectrometry.

Ballin et al. (1994) did not analyze the fish for either inorganic arsenic or total organic arsenic. They did analyze the tissues for arsenobetaine and phospholipid arsenic, the major organic forms of arsenic in fish. In marine fish, the arsenobetaine accounted for 96% to 100% of the total arsenic and the phospholipid arsenic for 0.17 to 4.12 % of the total. Assuming, no other organic arsenic forms were present in the fish examined, the maximum amount of inorganic arsenic present was 2%.

Lawrence et al. (1986) analyzed 11 replicate samples of fish muscle for arsenobetaine and arsenocholine using purification by high performance liquid chromatography (HPLC) and identification with atomic absorption spectrometry and fast atom bombardment mass spectrometry. In addition to arsenobetaine and arsenocholine, the method was able to identify two unknown organic compounds containing arsenic. In all fish samples except salmon, the only compound identified was arsenobetaine which accounted for 78 to 88% of the total arsenic. In salmon an unidentified form of organic arsenic was present in addition to arsenobetaine. The arsenobetaine was 41% of the total arsenic and the unknown compound was 42 % of the total arsenic.

Caution must be used in evaluating the Lawrence et al. (1986) data because the percent recovery from samples spiked with arsenobetaine was 80 to 84% quite similar to the percent of arsenic reported to be present as arsenobetaine in most samples. Thus, this method could under report the amount of arsenic present as organic arsenic because of recovery problems. The authors point out that when the results are corrected for recovery they indicate that arsenobetaine accounted for "essentially all of the arsenic present in the marine samples analyzed". It must also be remembered that Lawrence et al. (1986) did not analyze the samples for phospholipid containing arsenic which Ballin et al. (1994) demonstrated to be present in marine fish tissues.

Inorganic Arsenic in Fresh Water Species. In analysis of 9 replicate samples of fresh water fish, Lawrence et al. (1986) did not identify either arsenobetaine or arsenocholine. An unknown organoarsenic compound was present in all samples. This compound accounted for 71 to 85% of the total arsenic. Caution must be used in evaluating these data since it was not possible to quantify the recovery for the unidentified compound. The same unknown compound was present in all fresh fish samples whether they were from Manitoba or Alberta. Elution of the unidentified compound from the HPLC column indicated that it was more hydrophilic than arsenobetaine.

3.0 ARSENIC IN SHELLFISH

Total Arsenic. Total arsenic concentrations in shellfish tend to be higher than those for finfish. In the data summarized by Chew (1996), average total arsenic concentrations for shellfish ranged from 0.2 to 126 ppm. The highest concentrations were seen in two mollusk samples. However, mollusk values were highly variable among the 20 samples tested (range: 1-126 ppm; Chew, 1996). In the study by Ballin et al. (1994), the total arsenic in 4 species of shellfish ranged from 2.6 to 21 ppm; the highest concentration was found in lobster. The average value from pooled samples of blue mussels (40 samples) was 2.6 ppm (Ballin et al., 1994). Lawrence et al. (1986) found the total arsenic in replicate lobster, scallop and shrimp samples to be 5.2 ppm, 0.68 ppm and 20.8 ppm respectively. The concentrations of total arsenic in a samples of lobster purchased commercially in Ottawa was 4.7 ppm and in a shrimp sample was 7.2 ppm. Lopez et al. (1994) found values of 4.01 ppm, 0.34 ppm and 2.95 ppm for commercially purchased samples of cockles, prawns, and mussels respectively.

Inorganic Arsenic. The average amount of arsenic present as inorganic arsenic in shellfish was less than 3% in all cases but one among the data summarized by Chew (1996). In the case of *Barnea dilatata*, the one exception, 98% of the arsenic was inorganic but the total arsenic was low (0.2 ppm) making the net exposure to inorganic arsenic low despite the high percentage present. Lopez et al. (1994) found the inorganic arsenic to account for 8% of the total in cockles and 11% in muscles. The amount of inorganic arsenic in the prawns was below the limit of detection (0.023 ppm).

The data by Ballin et al. (1994) are of minimal value for deriving an estimate of the inorganic arsenic in shellfish because samples were not analyzed for inorganic arsenic and the authors felt that two organic forms of arsenic monitored (arsenobetaine and phospholipid arsenic) did not account for all of the organic arsenic.

Ballin et al. (1994) evaluated shrimp, lobster, mussels and oysters for their arsenobetaine and arsenic containing phospholipids. Oysters and blue mussels had the lowest concentrations of arsenobetaine plus phospholipid arsenic (30 and 40%). The authors hypothesized that water soluble arsenocholine, the metabolic precursor to arsenobetaine, accounted for most of the difference between the arsenobetaine and total arsenic concentrations rather than inorganic arsenic. Oysters and muscles had a fair amount of their arsenic present in the fat soluble phospholipid phase (10 to 20%) suggesting that some arsenocholine had been incorporated in the choline-containing phospholipids or sphingolipids.

In shrimp, Ballin et al. (1994) found that 87% of the arsenic was present as arsenobetaine and 4% as phospholipid arsenic while Lawrence et al.(1986) found that 76% was present as arsenobetaine and 15% as arsenocholine. In lobster, 59% of the arsenic was present as arsenobetaine and 2 % as phospholipid arsenic according to Ballin et al. (1994) and Lawrence et al. (1886) found 87% as arsenobetaine and none as arsenocholine. As discussed above, one cannot infer from these data that the remaining arsenic is present in inorganic compounds. Le et al. (1994) found arsenobetaine to be the primary organic arsenic compound in shrimp and prawns.

Table I summarizes the data on total, organic and inorganic concentrations of arsenic in fish and shellfish. The organic arsenic data are extrapolated from either the total arsenic and inorganic arsenic data (Chew, 1996) or the total arsenic plus the arsenobetaine, arsenocholine and/or phospholipid arsenic data (Ballin et al., 1994; Lawrence et al., 1986). In general, the data support the conclusion, that, in fish, less than 10% of the total arsenic is inorganic (Chew, 1996). Indeed, it was 4% or less for all fish species other than shark, sturgeon and sucker evaluated by Chew (1996); a total of 40 species were evaluated.

Table 1
Arsenic in Fish and Shellfish

Genus	Total Arsenic ppm.	Inorganic Arsenic ppm	Organic Arsenic ppm or %.	Reference
Fish	0.6-37	ND	>98%	Ballin et al., 1994
	0.1-64	DL-0.12	0.1-64 ppm	Chew, 1996
	1.1-13.2	NA	78-88 %	Lawrence et al., 1986
	0.82-7.76	<0.023-<5	NA	Lopez et al., 1994
Shellfish	2.6-21	ND	NA	Ballin et al., 1994
	0.2-126	DL-0.6	<.01-126 ppm	Chew, 1996
	0.68-20.8	NA	87-91%	Lawrence et al., 1986
	0.34-2.95	<0.023-11	NA	Lopez et al., 1994

Weights expressed as ppm wet weight
ND = Not Determined
NA = Not Applicable
DL = Detection Limit

4.0 SPECIATION OF ORGANIC ARSENIC IN FISH AND SHELLFISH

The predominant organic arsenic compounds in marine fish and shellfish are arsenobetaine and arsenocholine (Ballin et al., 1994). Some of the arsenocholine is found in tissue phospholipids. The amount of arsenobetaine exceeds the arsenocholine (Chew, 1996). In both compounds, arsenic has replaced the nitrogen of the natural metabolite (choline; betaine). Arsenic is incorporated into the betaine molecule by microorganisms, phytoplankton, zooplankton and algae (Ballin et al., 1994). The fish obtain arsenobetaine from their food supply. The principle organic form of arsenic in freshwater fish is neither arsenobetaine or arsenocholine according to data collected by Lawrence wt al. (1986). A single compound was isolated from all samples and accounted at least 70 to 85% of all the arsenic present if recovery was complete. The composition of this compound was not identified but it appeared to be more hydrophilic than arsenobetaine.

Betaine is formed metabolically from choline through oxidation and becomes an excretory nitrogen metabolite. Betaine excretions vary between species. In addition, betaine can serve as a methyl donor in biological systems, becoming N,N-dimethyl glycine (Montgomery, 1990). Betaine acts as an osmolyte in marine species (Neufield and Wright, 1996) and as a chemosensory agent (Knutsen, 1992). A study of feeding behavior in North Sea turbot and Dover sole suggest that betaine is one of a number of water-soluble, nitrogen-containing compounds that stimulate feeding behavior in fish larvae and may help to attract the larvae to the plankton layer (Knutsen, 1992). Betaine is probably released to water in plankton-rich areas producing an betaine-enriched microenvironment.

Arsenobetaine is metabolically inert in mammalian systems. Almost all of the radiolabeled arsenic in arsenobetaine administered orally or intravenously to rats, mice or guinea pig was excreted in three days (Vahter et al., 1983; Yamauchi et al. 1986). In rats and mice, more than 99% of the excreted label was found in the urine as arsenobetaine. In comparable studies using arsenocholine, there was greater label retention with 70-80% excreted in three days (Marafante et al., 1984). Extracts from mouse urine showed that more than 90% of the water soluble arsenic excreted was present as arsenobetaine. It can be assumed that some of the retained arsenocholine is incorporated in membranes as phosphatidyl choline compounds or in lipoprotein complexes and, thus, will have little tendency to bioaccumulate as inorganic arsenic.

Small amounts of methylarsonic acid and dimethylarsinic acid have been identified in fish and shellfish (Buchet et al., 1994; Chew 1996). Chew (1996) reported data from a study of fish at the ASARCO Tacoma Smelter Site in Washington state. The amount of methylarsonic acid in striped sea perch was 0.02 ppb and that in rock sole was 0.002 ppb. The dimethylarsinic acid in these two species was 0.02 ppb and $\leq$ 6.6 ppb, respectively. In mussels there was 0.02 ppb for both the methylarsonic and dimethylarsinic acid. The total arsenic concentration was only available for the rock sole and the total arsenic data were not internally consistent with the speciation data. Therefore, it is difficult to evaluate the significance of these results. Buchet et al. (1994) found that the recovery of methylarsonic acid and dimethylarsinic acid varied with the extraction technique and between samples for the same fish.

The data available on the speciation of arsenic in fish and shellfish mitigate some of the concerns generally associated with arsenic exposure. In most cases, more than 95% of the arsenic is present as organic rather than inorganic compounds (Chew, 1996). The most prevalent of the organic species, especially in marine fish, is arsenobetaine (Ballin et al., 1994; Lawrence et al. 1986), a compound with minimal tissue retention in the animals species studied and a compound that is excreted without metabolic alteration. The compound present in the next highest concentration is arsenocholine. The arsenocholine is estimated to be less than 1% of the total arsenic (Edmonds and Francesconi, 1993). Most of the arsenocholine is converted to arsenobetaine and excreted. A small portion may become incorporated in phospholipids and retained; another small amount may be converted to trimethylarsine oxide (Chew, 1996).

Arsenobetaine and arsenocholine and the unidentified organic arsenic compound in freshwater fish are hydrophilic and have little tendency to bioaccumulate in edible fish tissues. They are unlikely to be present in adipose deposits due to their hydrophilic nature although some arsenocholine may be present in membrane phospholipids. Organic arsenicals, especially arsenobetaine, appear to be significantly less toxic than inorganic arsenic species (Edmonds and Francesconi, 1993). Each of these factors diminishes human health concerns related to exposure to organic arsenic compounds in fish and shellfish. Additional support for a conclusion that the organic arsenic compounds from fish and shellfish do not bioconcentrate is provided by data showing that samples of human milk from 88 mothers from the Faroe Islands did not show elevated arsenic in their transition milk despite consumption of diets rich in seafoods (Grandjean et al., 1995).

5.0 ESTIMATED ARSENIC IN FISH AND SHELLFISH FROM WATER CONTAINING 50 PPB ARSENIC

5.1 EPA Bioconcentration Factors for Arsenic

The EPA bioconcentration factor for total arsenic in a fish and shellfish is 44 (EPA, 1980, 1984). It applies to bioconcentration from a mixture of fish and shellfish (roughly 10-15% shellfish). The arsenic concentration by shellfish exceeds that for fish by nearly two orders of magnitude (EPA, 1980). The shellfish value (350) came from a 112 day test of a saltwater oyster species exposed to trivalent arsenic while the bioconcentration factor for bluegill was 4 after a 28 day exposure (EPA, 1980).

The EPA bioconcentration factors were derived from laboratory studies where the water was spiked with trivalent inorganic arsenic. Thus, they may not be representative of what happens in a natural ecosystem where inorganic arsenic is processed through a number of trophic levels before it reaches the fish or shellfish.

The data presented in Sections 2.0 and 3.0 of this report do not include any information on the amount of arsenic in the source waters from which samples were obtained. Thus, it is not possible to evaluate the bioaccumulation that lead to the tissue levels of arsenic measured in the fish or shellfish. In general, the average total arsenic in clean costal and ocean waters is low, about 1 to 3 ug/L. Levels are much higher in estuary systems receiving arsenic discharges (Neff, 1997). The arsenic concentration for most lakes and rivers is less than 5 ug/L (Crecelius, 1997).

A comparison of the amounts of total arsenic in some of the fish and shellfish samples collected from the marine environment with normal background levels of inorganic arsenic in the water, suggests that, for at least the marine environment, arsenic accumulated to a greater extent than suggested by laboratory bioconcentration factor of 4 measured for a freshwater species in a laboratory study. The data on the accumulation of arsenic in fresh water species is conceptually closer to laboratory bioconcentration factors.

5.2 Estimated Total Arsenic

For this report, concentrations of total and inorganic arsenic in edible tissues from fish and shellfish are estimated using the EPA bioconcentration factor for arsenic and the arsenic concentration in ambient water. Deficiencies in the bioconcentration factor are part of the uncertainty for the analysis.

In cases where the fish and shellfish come from water containing 50 ppb arsenic, the estimated total arsenic concentration in edible tissues is 2.2 mg/kg or 2.2 ppm when calculated using the EPA bioconcentration factor.

$$50\ \mu g/L \times 44\ L/kg(BCF) \times 1\ mg/1000\ \mu g = 2.2\ mg/kg \text{ total arsenic}$$

This estimate is within the range observed for fish and shellfish in the most recent USFDA Total Diet Study (0.75 ppm for fish sticks to 2.8 for cod/haddock; MacIntosh, 1997; personal communications). In the data for fish collected by Chew (1996), 70% of the samples had total arsenic concentrations below 2.2 ppm. In the studies by Ballin et al. (1994 and Lawrence et al. (1986) over 60% of the combined marine and fresh water fish data set fell below this value. Because nothing is known concerning the arsenic concentrations in the source water for the field sample data presented by Ballin et al. (1994), Chew (1996) Lawrence et al. (1986) or Lopez et al. (1994), the comparison of the calculated concentration for fish and shellfish with the field data merely supports the calculated value as plausible.

5.3 Estimated Inorganic Arsenic

The maximum inorganic arsenic in fish and shellfish used for this estimate is 4% as discussed in Sections 2.0 and 3.0 above. The median inorganic arsenic value for the fish and shellfish data reported by Chew (1996) is 0.4 %. No inorganic arsenic was detected in 23 of 42 fish samples

and 18 of 50 shellfish samples. Therefore, the median value reflects the higher inorganic arsenic concentrations found in shellfish and is a conservative value.

Using a 4% maximum inorganic arsenic value for a mixed fish and shellfish diet, 2.2 ppm total arsenic in fish/shellfish is equivalent to 0.09 ppm inorganic arsenic.

$$2.2 \text{ mg/kg As}_{\text{total}} \times 4 \text{ g As}_{\text{inorganic}}/100 \text{ g As}_{\text{total}} = 0.09 \text{ mg/kg As}_{\text{inorganic}}$$

Using 0.4% as the median inorganic arsenic concentration for a mixed fish and shellfish diet, 2.2 ppm total arsenic in fish/shellfish is equivalent to 0.01 ppm inorganic arsenic.

$$2.2 \text{ mg/kg As}_{\text{total}} \times 0.4 \text{ g As}_{\text{inorganic}}/100 \text{ g As}_{\text{total}} = 0.01 \text{ mg/kg As}_{\text{inorganic}}$$

6.0 ESTIMATED INORGANIC ARSENIC EXPOSURE FROM FISH/SHELLFISH CONSUMPTION

Inorganic arsenic exposure estimates for high and average fish and shellfish consumers can be derived using the inorganic arsenic concentrations estimates above and information on population fish/shellfish consumption. The following exposure scenarios are presented for this report based on available data.

High fish/high arsenic - The 99.9th percentile fish/shellfish consumer and the estimated maximum inorganic arsenic concentration for a mixed fish/shellfish diet (4%). This group eats the maximum amount of fish and shellfish on a daily basis and consistently chooses species that have the higher percentages of inorganic arsenic.

High fish/average arsenic -The 99.9th percentile fish/shellfish consumer and the median inorganic arsenic concentration (0.4%). This group eats the maximum amount of fish and shellfish on a daily basis and chooses species with a variety of inorganic arsenic concentrations over a range from low to high.

Average fish/high arsenic - The 50th percentile fish/shellfish consumer and the estimated maximum inorganic arsenic concentration for a mixed fish /shellfish diet. This group has a diet that includes fish and/or shellfish frequently but is not totally dependant on fish/shellfish as a dietary protein source. The group preferences tend towards the fish/shellfish species that have the higher concentrations of inorganic arsenic.

Average fish/ average arsenic - The 50th percentile fish/shellfish consumer and the median inorganic arsenic concentration. This group has a diet that includes fish and/or shellfish frequently but is not totally dependant on fish/shellfish as a dietary protein source.
The group preferences include a variety of fish and shellfish species with inorganic arsenic concentrations that range from low to high.

The fish consumption values used for these calculation were derived from the 1989-1991 dietary records from the USDA Continuing Survey of Food Intake (USEPA, 1995). The USDA food consumption survey collects data on three consecutive days of food intake. Data for one day is provided through a 24-hour recall interview and data for two days through food intake records kept by the respondent. Fish-consumers were segregated from all respondents based on their consumption of fish at least once during the three day survey period. The population data used for the exposure estimates described above apply only to the fish-consuming population rather than the entire population Therefore the data may represent a rather skewed distribution. For the purpose of defining a exposure on the high end of the distribution curve the data are appropriate and useful.

The 99.9th percentile value for females (461 g/day) is used to simulate the eating habits of subsistence fishers such as the Eskimos and other native Indian tribes that consume a diet that is very high in fish and shellfish. This is the highest intake value reported. The 99.9th percentile value or maximum reported value is more than 4 times the 95th percentile value (USEPA, 1995). The 50th percentile value from the USDA data for males was used for the exposure estimate rather than that for females because it is a higher value.

Eskimo's and other native Indian tribes in Alaska have the highest consumption of fish and shellfish within the United States (Wolfe, 1996). In one study of 351 Eskimos, Indians and Aleuts, average fish and shellfish consumption was 109 g/day (Nobmann et al., 1992). This intake lies between the 75th and 95th percentiles of fish consumers in the country as a whole (EPA, 1995). Wolfe (1996) found that the average intake of wild foods by the subsistence populations in Alaska was slightly greater than one pound of wild food per day with 61% of this total contributed by fish and shellfish. In some areas the average consumption of wild foods was two pounds per day. In studies of the Tulalip and Squaxin Island tribes of Puget Sound the mean fish/shellfish consumption for a 70 Kg adult was 71 g/day and the 95% percentile value was 226 g/day (Toy et al., 1995). In a study of the Native Tribes of the Columbia River Basin, the mean value for the adult fish consuming population was 63 g/day and the 99th percentile value was 389 g/day (CRITFC, 1994). These data support the fish/shellfish intake values used for the exposure estimates.

Two addition exposure estimates are also included in this report. These groups are identified as follows:

High fish (shellfish preference)/high arsenic -The 99.9% fish/shellfish consumer who is also at the 99% for shellfish consumption (125 g/day). These individuals consume a high percent of their fish/shellfish in the form of shellfish and select species with the high concentrations of inorganic arsenic.

General population/high arsenic - The average person who consumes fish or shellfish only occasionally but selects species with the high concentrations of inorganic arsenic.

The first of the added groups cover subsistence users of fish and shellfish who have a greater than average intake of shellfish. The arsenic exposure for this group includes separate calculations for the arsenic in fish and shellfish using a fish bioconcentration factor of 4 for fish and a factor of 350 for shellfish (USEPA, 1980, 1985). The 99th percentile shellfish consumption from the USDA data (125 g/day) was used for the shellfish portion of the diet and the difference between the 99.9th percentile fish/shellfish value (461 g/day) and the shellfish value was used for fish consumption (336 g/day).

The first five exposure scenarios defined above apply to those individuals who routinely consume fish and/or shellfish as a dietary protein source. However, most of the general population consumes fish and shellfish only occasionally, and some individuals never eat fish or shellfish. Thus, the general population has a lower exposure averaged over time. The EPA uses a daily fish intake of 6.5 g/day to represent these individuals (EPA, 1989). This is a normalized concentration which recognizes that, on the days that fish and/or shellfish are consumed, the intake will be higher than 6.5 grams but there will also be many days in the course of a year that there is no consumption of either fish or shellfish. This group is identified as "General Population " in subsequent tables. As a worst case, the higher inorganic arsenic concentration was used for the general population arsenic exposure calculation. Individuals who consume fish or shellfish only occasionally tend to have a few species they favor (e.g. tuna, shrimp) and the species of preference may be among the higher arsenic species.

Inorganic arsenic exposures from fish and shellfish under the different exposure scenarios listed above are summarized in Table 2. The fish/shellfish consumption values apply to total fish/shellfish consumption and include marine, estuarine and freshwater species. They are calculated using the following equation:

$$2.2 \text{ mg As}_{\text{total}}/\text{ kg fish/shellfish} \times \text{fish/shellfish intake (kg/day)} \times \text{mg As}_{\text{inorganic}}/100 \text{ mg As}_{\text{total}} = \text{mg As}_{\text{inorganic}}/\text{day}$$

Units have been adjusted so that the inorganic arsenic concentrations are expressed in μg/ day in Table 2. The USEPA limitation on arsenic in marine waters is 36 ppb (USEPA, 1992). Therefore, the estimates based on all fish and shellfish being from waters containing 50 ppb is an overestimate in situations where a mixture of marine, estuarine and freshwater species are consumed.

Table 2
Inorganic Arsenic Exposure from Fish and Shellfish Consumption

Consumer Category	Inorganic Arsenic %	Fish/Shellfish Consumption g/day	Inorganic Arsenic Exposure μg/day
High Fish - High Arsenic	4	461*	41
High Fish - Average Arsenic	0.4	461*	4
Average Fish - High Arsenic	4	42 *	4
Average Fish -Average Arsenic	0.4	42*	0.4
High Fish (shellfish preference)- High Arsenic	4	125 (shellfish) 336 (fish)	87.5 shellfish 2.7 fish 90 total
General Population	4	6.5**	0.6

* 1989-1991 data from the USDA Continuing Survey of Food Intake (USEPA, 1995)

** 1973-1974 data from the National Purchase Dairy Survey (USEPA, 1989)

Other dietary components can have an impact on the net inorganic arsenic exposure for the for all consumer groups. Macintosh et al. (1996) found that other foods in the Total Diet Study such as chicken and rice contributed to the total arsenic exposure. The form of arsenic in food may also contribute to the effect of a given food material on the total body arsenic load.

7.0 INORGANIC ARSENIC EXPOSURE FROM FISH, SHELLFISH AND POTABLE WATER

The data on inorganic arsenic from fish and shellfish from Table 2 can be combined with data on arsenic concentrations in potable water to obtain a profile for net inorganic arsenic exposures in the population groups characterized above. The high estimate for the arsenic concentration in potable water is 20 ppb and the average estimate is 5 ppb. These values were obtained from a study of arsenic in potable water sources conducted by the University of Colorado at Boulder and Malcolm Pirnie, Inc. (1997). Water consumption is estimated as 2 liters/day.

In the University of Colorado at Boulder/ Malcolm Pirnie Study (1997), 88 % or more of the ground water samples analyzed in the Western United States in three separate surveys had concentrations of 20 ppb or less. Concentrations were 5 ppb or less in more than 50% of the ground water systems evaluated. The highest arsenic concentration from ground water sources were in the Western region. None of the surface water systems surveyed in the Western United States contained greater than 5 ppb arsenic. In one survey, there were a few surface water systems in the North Central region of the country that exceeded 20 ppb arsenic (12%). Most arsenic in potable water is inorganic and ground water sources contain higher arsenic concentrations than surface water sources. The highest arsenic concentrations in the country are concentrated on the west coast.

Table 3 presents the estimates for net exposure to inorganic arsenic when the estimates from fish and shellfish consumption are combined with the data on the average and high concentrations of arsenic in Public Water supplies across the country. The value used as the high arsenic concentrations is 20 ppb based on survey data rather than the Arsenic MCL and is exceeded by only about 10% of Public Water Systems. Each of the exposure estimates for inorganic arsenic intakes from fish, shellfish and water is less than the exposure that results from ingesting 2 L of water containing the 50 ppb arsenic except for the High fish/shellfish preference scenarios.

Table 3
Total Inorganic Arsenic Exposures Fish/Shellfish and Water
for High and Average Fish Consuming Populations

Consumer Category	Fish/shellfish* μg/day	Water** μg/day	Total μg/day
High Fish - High Arsenic	41	40	81
	41	10	51
High Fish - Average Arsenic	4	40	44
	4	10	14
Average Fish - High Arsenic	4	40	44
	4	10	14
Average Fish - Average Arsenic	0.40	40	40
	0.40	10	10
High Fish (Shellfish Preference)- High Arsenic	90	40	130
	90	10	100
General Population	0.6	40	41
	0.6	10	11

* Based on a maximum 4% of the total arsenic being inorganic arsenic in an mixed fish/shellfish diet

** Water consumption is estimated as 2 liters/ day.

There are some regions in the western part of the country where arsenic levels in potable water from public systems are equal to the MCL and other private systems where the arsenic may exceed the MCL. For Public Water Systems where the potable water concentration is equal to the MCL, fish and shellfish consumption by the general populations does not increase the risk from arsenic exposure since it represents a less than a 1 μg (1%) increase in the net arsenic exposure. However, for regions where high levels of arsenic in the potable water are accompanied by high levels of fish and shellfish consumption the net increase in inorganic arsenic exposure would be greater and site-specific criteria can be developed for surface waters and for fish consumption.

In developing site-specific criteria the state should characterize the size and location of the population of concern and determine their fish/shellfish and water intake rate. The fish and shellfish consumption should consider the species and dietary intake per species. Actual total arsenic and inorganic arsenic values for the species consumed and actual concentrations in drinking water should be used in the exposure calculations wherever possible. Other sources of arsenic exposure should also be considered and quantified.

8.0 UNCERTAINTY

There are a number of uncertainties in the preceding exposure assessment for inorganic arsenic from fish and shellfish originating from water containing 50 ppb arsenic. The exposure estimates assume a mixed fish and shellfish diet in which average inorganic arsenic concentration is no greater than 4% of the total arsenic. This would not apply to any diet with high consumption of shark, sturgeon and sucker. However, these species are not used by the Eskimo and other northern Indian tribes that serve as an example of a 99.9 percentile fish/shellfish-consuming population. Species that constitute the fish component of the diet for Eskimo's and other northern Indians are salmon, halibut, herring, whitefish, sheefish, blackfish and cod (Wolfe, 1996).

The exposure assessments for all but the High Fish (Shellfish Preference) group are also based on a bioconcentration factor that applies to a mixed fish/shellfish diet. It does not apply to a diet that is heavily weighted towards shellfish, particularly mollusks. In the Eskimo and other northern Indian tribes, shellfish is a maximum of 9% of the diet (Wolfe, 1996) a value that is representative of the fish/shellfish biconcentration factor used for the inorganic arsenic exposure calculations. However, shellfish consumption for the Tulalip tribe of Washington State is about 60% of the fish/shellfish intake (Toy et al., 1996). Thus, the inorganic arsenic exposure estimates presented above would not apply to this group.

There is also some uncertainty in the bioconcentration factor since it results from laboratory studies in which the water was spiked with inorganic arsenic. The values obtained may not be representative of natural ecosystems where arsenic can passes through various trophic levels before entry into fish tissues. The data suggest that bioaccumulation through the food chain is more complex in marine species than in fresh water species.

There is some uncertainty in the toxicological assessment for organic arsenic compounds. To the extent that most of the organic arsenic species in the fish are trimethylated species such as arsenobetaine, arsenocholine and trimethylarsine oxide, toxicokinetic data support the conclusion that there is little, if any interaction of the arsenic metabolite with other biomolecules. Thus, the toxicity of these compounds is low. However, in cases where dimethylarsinic acid is found in fish/shellfish species, low toxicity cannot be assumed because there are some data that suggest that dimethylarsinic acid is a tumor promotor (Chew, 1996). If dimethylarsinic acid is a promotor, it could become a risk factor for carcinogenicity. A weight-of -evidence determination for the promoting properties of dimethylarsinic acid has not been established. Lack of data on the nature of the organoarsenic compound or compounds present in freshwater fish contributes additional uncertainty in cases where most fish consumed are freshwater species.

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Mann, Laurie

From: Mann, Laurie
Sent: Monday, August 03, 2015 2:49 PM
To: MacIntyre, Mark
Cc: Croxton, Dave; Nickel, Brian
Subject: PCB response to Don

Mark,
Here's our response (reviewed by Dave C, Brian & me)

Don,
We want to make sure there is common understanding regarding the sources of PCBs in the Spokane River. Based on information in the email you sent us, we think that you may have misunderstood the information that was provided to you by members of the Task Force, and we believe that EPA and the Task Force have the same general understanding of the origins of the PCB contamination:

1) There is a mix of past (legacy) and present sources of PCBs contributing to the current PCB impairments in the Spokane river. Many contaminant pathways, like air deposition, contain a mix of legacy PCBs and new, inadvertently generated PCBs.
2) We believe that the relatively high levels of PCBs seen today in the Spokane River are likely the result of legacy contamination from industrial use of PCBs prior to the ban on PCB manufacturing in 1979. Today, those historic sources continue to contribute PCBs to the river through a variety of pathways including PCB contamination in soils (traveling to the river via stormwater and groundwater), building materials (traveling to the river via air deposition and stormwater) and lake and river sediment.
3) One reason we believe that newer consumer products with inadvertently-generated PCBs are a small fraction of the problem is that the PCB impairments in the Spokane River are unusually high relative to other parts of the State. If consumer products were the primary source of PCB contamination in the Spokane River, we would expect to see high levels of PCB contamination throughout Washington – and we don't.
4) The point source dischargers to the Spokane River (excluding stormwater) contribute between 8 and 33% of the loading in the River (varying with river flow). The remainder of the PCB loading comes from a variety of sources, including groundwater, stormwater, air deposition, tributaries, and unidentified sources in Idaho. Inadvertently-generated PCBs likely contribute loading to some of these pathways, especially air deposition, stormwater, and wastewater.

EPA is concerned about all of these potential sources, past and present, and strongly supports the work of the Task Force to further delineate the sources of PCB loading in the Spokane watershed.

If you have any further questions, please feel free to contact us. EPA's response to the remainder of your questions are included below:

> Question #1
>
> Why, when production of PCBs is banned in this country, does the EPA still allow a certain percentage of PCBs to occur in products sold here?
>
> While EPA's PCB regulations generally ban the manufacture (defined to include import as well) of PCBs, an exception is made for inadvertently generated PCBs that are unintentional impurities of many common commercial chemical or

manufacturing processes. EPA's regulations impose an annual average of 25 ppm and a 50 ppm maximum on the concentration of inadvertently generated PCBs manufactured or imported into the United States (see definition of "excluded manufacturing process, 40 CFR §761.3). Imported products and products produced domestically are regulated in the same manner. EPA has concluded that allowing such inadvertent generation has important economic benefits and does not pose an unreasonable risk to human health or the environment (see 49 FR 28172).

Question #2

Does the EPA have a short or long term plan to modify that policy?

Revising current regulations to reduce inadvertently generated PCBs presents both policy and scientific challenges. EPA currently has no plans to modify its policy regarding regulations of inadvertently generated PCBs.

Currently, EPA is considering restricting and/or eliminating many of the remaining authorized uses of higher-concentration liquid PCBs (see "Polychlorinated Biphenyls: Reassessment of Use Authorizations", April 10, 2010; 75 FR 17645). These remaining uses are the largest reservoir of commercial mixtures (Aroclors) that contain the dioxin-like PCBs. While restricting such uses would not address inadvertently generated non-dioxin-like PCBs, EPA believes this effort would help to reduce potential exposure and risk from remaining dioxin-like PCB uses. EPA is in the process of evaluating options for revising current PCB regulations, it has not made any proposed or final decisions.

In addition to potential rulemakings, another activity that may help to address inadvertently generated PCBs in products is EPA's Green Chemistry Program. EPA has provided funding to Washington State Department of Ecology to establish a Green Chemistry Center and is a member of the Advisory Board for the Center. The Green Chemistry Center plans to host a workshop later this year on PCBs inadvertently produced in inks and pigments, perhaps leading to improvements in the production and use of PCB-free inks and pigments.

From: Don Fels [redacted]
Sent: Monday, July 27, 2015 4:43 PM
To: MacIntyre, Mark
Subject: Re: Spokane River

hi Mark- I am writing a two part piece on the PCBs in the Spokane River for crosscut.com. I have interviewed many of the stakeholders there, most of whom have committed a great deal of time to serve

on the Task Force trying to find solutions to the problem of PCBs getting in the tissue of fish in the river. All have told me that they began their work years ago thinking that the issue was legacy polluters who left PCBs in the soil that drains into the river, or who flushed the pollutants into the river directly. But those point sources only account for 8% of the PCBs in the Spokane River. The rest are coming in from common everyday use, that are buried in products used by us all. The EPA allows a certain percentage of PCBs to occur in such products. Why is that when production of PCBs is banned in this country? And does the EPA have a short/long term plan to modify that policy? I would greatly appreciate speaking with someone who can answer my questions.
thanks,
Don Fels

On Mon, Jul 27, 2015 at 12:29 PM, MacIntyre, Mark <Macintyre.Mark@epa.gov> wrote:

> Hey Don! Mark MacIntyre @ EPA….Can you give me a call about your Spokane River Story?
>
> Thanks!
>
> MM
>
> ***Mark A. MacIntyre***
> ***Senior Communications Officer***
> ***U.S. Environmental Protection Agency - Region 10***
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[Letter to leaders of federally-recognized tribes, signed by Kenneth J. Kopocis, August 11, 2015]

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

OFFICE OF WATER

Dear Honorable Leader:

The U.S. Environmental Protection Agency is initiating consultation and coordination with federally recognized Indian tribes to consider a potential rulemaking that would establish baseline water quality standards under the Clean Water Act for waters on Indian reservations that currently do not have EPA-approved WQS in place to protect water quality. The EPA's goal is to address the existing gaps in CWA protection of reservation waters where there are no existing EPA-approved WQS. Standards would establish baseline human health and environmental goals as the basis for the CWA protection. This potential rulemaking effort adds to a growing list of initiatives the EPA is undertaking that recognize the importance of tribal waters, tribal sovereignty, and the need to better protect the water resources that tribes rely on.

The potential benefits to tribes and the environment of establishing baseline WQS through a federal rulemaking are significant. WQS define the goals for the quality of reservation waters and serve as the foundation of the water quality-based pollution control program mandated by the CWA to protect human health, recreation, wildlife, aquatic life, and other uses. WQS are the cornerstone to prevent future degradation of waters, and improve water quality in impaired waters, by providing a basis to assess the health of water bodies and impose limits in permits to control pollution discharges, including upstream discharges.

The EPA strongly supports and will continue to encourage eligible tribes to obtain Treatment in a Similar Manner as a State under the CWA in order for tribes to establish their own WQS for approval by the EPA and to administer their own WQS program. The EPA recognizes, however, that not all tribes may seek TAS and some tribes may continue to experience challenges to establishing their own WQS. Out of over 300 tribes with Indian reservations, only 40 have EPA-approved tribal WQS in place. This means those tribal waters without WQS may not have the full suite of protections afforded under the CWA.

Establishing baseline WQS for Indian reservations through a federal rulemaking could ensure a baseline level of protection for tribal waters and a step in supporting tribal interests in protecting their water quality and use of reservation waters. In addition, baseline WQS could provide more protections now than currently exist to address concerns about waters flowing into the reservation from adjacent jurisdictions, until such time that the tribe establishes its own customized WQS and obtains the EPA's approval to make them effective under the CWA.

Working as government-to-government partners with tribes, the EPA seeks to explore this potential effort to establish baseline WQS for Indian reservations, and solicits feedback from tribes on factors to consider to ensure the EPA crafts an effective federal rulemaking that reflects tribes' interests in protecting reservation waters under the CWA. This effort is consistent with the EPA's responsibilities under the CWA and the goals of the EPA's 1984 Indian Policy. Some tribal leaders may recall that between 1999 and 2003, the EPA developed a draft rulemaking of federal WQS for those waters in Indian country that did not have EPA-approved WQS. The EPA is interested in building on elements of that earlier effort to ensure a baseline level of protection exists for reservation waters.

Enclosed is a consultation and coordination plan that includes a description of the action under consultation and the process the EPA intends to follow, including a timeline for the consultation and coordination period, and information on how you can provide input on this action. The EPA's consultation information is also available on EPA's Tribal Portal (http://www.epa.gov/tribal/consultation).

This consultation and coordination process will be conducted in accordance with the *EPA Policy on Consultation and Coordination with Indian Tribes* (http://www.epa.gov/tribal/consultation). The EPA invites you and your designated representative(s) to participate in this process. The EPA's anticipated timeline for the consultation and coordination period is expected to extend from the date of this letter to November 6, 2015.

If you have any questions, please contact Danielle Anderson (anderson.danielle@epa.gov) of my staff. We look forward to hearing from you on this important matter.

Sincerely,

Kenneth J. Kopocis
Deputy Assistant Administrator

Enclosure

Consultation Plan
For Considering a Baseline Water Quality Standards Proposed Rule

August 2015

Background Information

The EPA is exploring a federal rulemaking to establish baseline Water Quality Standards (WQS) for waters on Indian reservations that do not have Clean Water Act (CWA) WQS in place. This adds to a growing list of initiatives that the EPA is undertaking to better protect tribal water quality and uses. For example, the EPA proposed an action to streamline the TAS process for tribes on August 7 (see http://water.epa.gov/scitech/swguidance/standards/wqslibrary/tribal.cfm), and is planning to propose a process later this year for tribes to apply for the section 303(d) program for listing impaired waters and developing total maximum daily loads (TMDLs) (see http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/policy.cfm).

This baseline WQS action is focused on establishing baseline federal WQS for Indian reservations that are not currently covered by EPA-approved WQS. Such WQS could be used in water quality permitting decisions that impact reservation waters, including permits directly upstream from reservation waters. At any time, tribes, with assistance from the EPA, could still seek to obtain TAS authority (under CWA section 518) to adopt and administer their own tribal-specific WQS for EPA approval. Tribe-adopted, EPA-approved WQS would supersede any baseline WQS established by this potential rulemaking.

The EPA is considering including a combination of CWA 101(a)(2) designated uses, numeric criteria, narrative “free from” criteria, and general WQS provisions in the baseline WQS. The EPA may also consider providing some very limited regional adjustments for consistency with other federal actions. However, the EPA recognizes that fully customized standards are best achieved by a tribe with TAS that develops its own WQS for approval by the EPA. Tribe-adopted, EPA-approved WQS best reflect tribal-specific circumstances and uses that are not feasible for national baseline WQS. Nonetheless, baseline WQS could be developed to be fully protective of water quality, and may be critical for those tribes that may never seek TAS or adopt their own WQS. This rulemaking could impact the EPA’s direct implementation of the CWA on Indian reservations including facilitating the use of approved WQS in EPA-issued permits, providing water quality certifications, and other protective actions.

Tribal leaders may recall that in 1999-2003, the EPA initiated the process of promulgating federal WQS for Indian reservations that did not have EPA-approved WQS. The EPA is interested in your feedback on how we might build on elements of that earlier effort to better ensure Indian reservations have EPA-approved WQS and the full slate of protections under the CWA.

Potential Benefits for Tribes

The potential benefits of establishing baseline WQS through a federal rulemaking are significant given that WQS define the goals for a waterbody and serve as the foundation of the water quality-based pollution control program mandated by the CWA to protect human health, recreation, wildlife, aquatic life, and other uses.

In this potential rulemaking, the EPA would be providing a set of WQS that the EPA, states, and tribes would use on a consistent basis for water quality management decisions where there are currently no EPA-approved WQS in place. The benefits of having federal WQS in place for reservation waters where no EPA-approved WQS exist include:

- Facilitating tribal participation with states and the federal government to inform water quality management decisions impacting those waters on the reservation;
- Establishing goals for the quality of reservation waters that are recognized under the CWA;
- Providing a basis for enforceable National Pollutant Discharge Elimination System (NPDES) permits to require controls beyond basic technology-based controls. (Water discharges allowed by NPDES permits must meet WQS set under the CWA for those receiving waters);
- Providing a mechanism to control discharges through other federal licenses and permits (CWA section 401 certification); and
- Protecting reservation water quality from upstream discharges flowing into reservation waters from other jurisdictions.

Areas for Consultation and Coordination

Consistent with the EPA's Policy on Consultation and Coordination with Tribes, the EPA seeks to consult and coordinate with federally recognized tribes to solicit feedback on all aspects of this potential rulemaking, including input on how best to structure and develop baseline WQS for Indian reservations which currently do not have EPA-approved WQS. The EPA is particularly interested in hearing from tribes on the following questions:

Questions relating to tribes' interests in protecting water quality:

(1) What would an effective federal rulemaking look like to you and your tribe?

(2) What water quality protection issues (or issues specifically related to WQS) are you and your tribe facing that should be considered in this potential rulemaking?

   a. Concerns for reservation water quality and degradation of water quality?
   b. Concerns for upstream sources of water pollution?
   c. Concerns for neighboring state WQS?
   d. Concerns for water uses relating to equity, safety, drinking water, treaty rights, or economic interests?

(3) Do tribes have examples of situations they are facing regarding water quality that could help inform, or that should be addressed, by this potential rulemaking?

Questions relating to the EPA's CWA implementation responsibilities:

(4) What approaches in a potential rulemaking should the EPA consider to implement CWA WQS on reservations and be most effective for you and your tribe?

(5) Do you have any concerns about this action? Are there any sensitivities or unintended consequences that the EPA should consider before moving forward on this action?

(6) If the EPA provided baseline standards, would this change your tribe's interest in pursuing TAS?

   a. Would your tribe be more likely to pursue TAS? If yes, would your tribe be interested in using baseline standards as a starting point to develop more specific standards for reservation waters?
   b. Would your tribe be more likely **not** to pursue TAS?
   c. No effect?

Tribes may submit written consultation comments by email or mail to:

Danielle Anderson, anderson.danielle@epa.gov
USEPA Headquarters
William Jefferson Clinton Building
1200 Pennsylvania Avenue, N.W.
Mail Code: 4305T
Washington, DC 20460

Tribal Consultation and Coordination Process and Time Frame

Consultation and coordination with tribes on a proposed rulemaking will occur according to the table below. If the EPA decides to move forward with a proposed rulemaking, tribes will have the opportunity to further consult with the EPA once the rule is proposed. In addition, tribes may provide input as part of the public comment period that immediately follows the publication of a proposed rule.

The table on the next page describes the process and timeline for consultation and coordination on this action. Tribes may access this letter through the Tribal Consultation Opportunities Tracking System (TCOTS), located at: http://tcots.epa.gov/oita/TConsultation.nsf/TC?OpenView.

Tribal Consultation and Coordination Process and Timeline	
Date	**Event**
Date of this letter through November 6, 2015.	Consultation and coordination period
August 17-20, 2015	Information presentation and discussion at the Tribal Lands and Environment Forum, Minneapolis, MN EPA's Office of Water will participate in this conference, and is available for consultation discussions during the conference. For more information, see http://www7.nau.edu/itep/main/Conferences/confr_tlef/. Session: USEPA Major Initiatives Discussion with Senior USEPA Staff, Tuesday, August 18, 10:30 a.m. to 12:00 p.m.
September 9-11, 2015	Information presentation and discussion at the Region 10 Region Tribal Operations Committee meeting. EPA's Office of Water will participate in this conference by telephone. Details will be announced via TCOTS and email, "Time-Sensitive U.S. EPA Office of Water Information and Tribal Participation Opportunities"
September 23, 2015 Time: 2:00 – 4:00 p.m. EDT	Tribes-only information, coordination and consultation webinar* Details will be announced via TCOTS and email, "Time-Sensitive U.S. EPA Office of Water Information and Tribal Participation Opportunities"
October 18, 2015 Time: Afternoon	72nd Annual Meeting, National Congress of American Indians, San Diego, CA. Session details to be determined. EPA officials will participate in this conference, and will be available for consultation discussions during the conference. For more information, see http://www.ncai.org/events/2015/10/18/72nd-annual-convention-and-marketplace.
October 26, 2015	Information presentation and discussion at the Region 9 Region Tribal Operations Committee meeting in Reno, NV. EPA's Office of Water will participate in the accompanying Annual Tribal/EPA conference, and is available for consultation discussions during the conference. Details will be announced via TCOTS and email, "Time-Sensitive U.S. EPA Office of Water Information and Tribal Participation Opportunities"

*The webinar will include two segments: The first segment will be used to coordinate and share information, and provide an opportunity for input and questions on the proposal. The second segment will provide an opportunity for consultation comments from tribal consultation officials.

Contact information for all events:

Danielle Anderson, anderson.danielle@epa.gov
EPA Office of Water
(202) 564-1631

For additional information regarding the prior federal core WQS rulemaking effort for Indian Country, please visit:
http://water.epa.gov/scitech/swguidance/standards/wqsregs.cfm

EPA has additional resources available that explain the Clean Water Act and Water Quality Standards, please visit:
http://www2.epa.gov/laws-regulations/summary-clean-water-act
http://water.epa.gov/scitech/swguidance/standards/

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Acquisition of Polychlorinated Biphenyls (PCBs) By Pacific Chinook Salmon: An Exploration of Various Exposure Scenarios

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(Submitted 31 October 2011; Returned for Revision 2 December 2011; Accepted 3 January 2012)

ABSTRACT

In 2011, as part of an update to its state water quality standards (WQS) for protection of human health, the State of Oregon adopted a fish consumption rate of 175 g/day for freshwater and estuarine finfish and shellfish, including anadromous species. WQS for the protection of human health whose derivation is based in part on anadromous fish, create the expectation that implementation of these WQS will lead to lower contaminant levels in returning adult fish. Whether this expectation can be met is likely a function of where and when such fish are exposed. Various exposure scenarios have been advanced to explain acquisition of bioaccumulative contaminants by Pacific salmonids. This study examined 16 different scenarios with bioenergetics and toxicokinetic models to identify those where WQS might be effective in reducing polychlorinated biphenyls (PCBs)—a representative bioaccumulative contaminant—in returning adult Fall chinook salmon, a representative salmonid. Model estimates of tissue concentrations and body burdens in juveniles and adults were corroborated with observations reported in the literature. Model results suggest that WQS may effect limited ($<$ approximately 2 $\times$) reductions in PCB levels in adults who were resident in a confined marine water body or who transited a highly contaminated estuary as out-migrating juveniles. In all other scenarios examined, WQS would have little effect on PCB levels in returning adults. Although the results of any modeling study must be interpreted with caution and are not necessarily applicable to all salmonid species, they do suggest that the ability of WQS to meet the expectation of reducing contaminant loadings in anadromous species is limited. Integr Environ Assess Manag 2012;8:553–562. © 2012 SETAC

Keywords: Anadromous fish Pacific salmonids Chinook Water quality standards PCBs

INTRODUCTION

In 2011, as part of the update of its state water quality standards (WQS) for protection of human health (USEPA 2000), the State of Oregon adopted a fish consumption rate (FCR) of 175 g/day for freshwater and estuarine finfish and shellfish. This value is the highest among all US states and 10 times higher than the US Environmental Protection Agency's (USEPA) national default FCR of 17.5 g/day for the general population (Matzke and Wigal 2011; USEPA 2000). Fish consumption surveys among 4 Native American tribes in the Columbia River basin demonstrated that they consume fish, primarily anadromous, at higher rates than the general population. When Oregon's WQS for organic chemicals and trace metals were calculated using the national FCR, these criteria likely afforded less protection to such high-end consumers of fish and shellfish. Raising the FCR was assumed to offer added protection to populations, such as Native Americans, that consume greater quantities of fish or shellfish on a regular basis and also to specific subpopulations, such as children and women of childbearing age, who may be more susceptible to any chemical contaminants in fish and shellfish. One aspect of increasing the FCR was deciding whether to include consumption of anadromous fish, such as salmon, in the total ingestion rate. USEPA typically does not include salmon in ingestion rate estimates ''…on the assumption that adult salmon spend most of their lives in the open ocean and take up bioaccumulative and persistent contaminants almost exclusively via the food chain in that environment.'' (USEPA 2007). Nonetheless, as a matter of policy, these species were ultimately included in the data sets used to derive the Oregon FCR because they are of special interest and concern to Northwest Native American tribes (Matzke and Wigal 2011).

Water quality standards for protection of human health that are more stringent, because they are based in part on anadromous fish consumption data, create the expectation that their implementation will lead to lower contaminant levels in such fish. If exposure occurs in waters within the State's jurisdiction (''waters of the state''), then more stringent WQS generated by a higher FCR may reduce both contaminant loads in anadromous fish and risk to humans from subsequent consumption of these fish. This benefit of lower risk, and thus increased availability for consumption, would partially offset regulatory costs associated with what are significantly more stringent WQS. If, however, anadromous species are primarily contaminated in waters beyond the State's jurisdiction (e.g., in the open ocean), then more stringent WQS may simply impose economic and legal costs on the State's economy without the offsetting benefits of reductions in contaminant loads and associated risk. Thus the decision to include anadromous fish in a FCR calculation should be informed by some knowledge of where and when anadromous fish are most likely to be exposed to, and uptake, the majority of their contaminant burden.

All Supplemental Data may be found in the online version of this article.

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Conceptually, contaminant concentration and body burden are a function of where and for how long the specific life stage of a fish and a contaminant are colocated relative to one another in the environment. Because of their anadromous life history, Pacific salmonids occupy 3 distinct habitat types during their lifetimes, each of which may present a different opportunity for exposure to a contaminant: a) freshwater habitats, where eggs hatch and fry develop, b) estuary habitats, where smolts enter marine waters to feed and reside for some time during migration to c) ocean habitats, where the fish spend the majority of their lives. An exposure scenario is defined by where a fish is in space (exposure location), the time it spends in each location (exposure duration), and the contaminant concentration in prey at that location (exposure concentration). A number of exposure scenarios have been advanced, in both the published literature and in anecdotal accounts, to explain the circumstances under which Pacific Northwest salmonids may acquire a contaminant load. Frequently discussed scenarios have contaminant uptake occurring when: a) juveniles are reared in a hatchery (Johnson et al. 2009), b) juveniles (fry, subyearling, yearling) are out-migrating through fresh or estuarine waters (Johnson, Ylitalo, Sloan, et al. 2007; Johnson, Ylitalo, Arkoosh, et al. 2007), particularly if they transit areas with known contamination (Meador et al. 2010), c) adults are in near-shore marine waters (Missildine et al. 2005; O'Neill and West 2009; O'Neill et al. 1998), d) adults are in the open ocean (Cullon et al. 2009; Ewald et al. 1998; Krümmel et al. 2003, 2005; Rice and Moles 2006), e) adults partake of a final ''feeding frenzy'' in marine waters just before entering freshwater to spawn (anecdotal), or f) adults migrate upriver to spawn (anecdotal). Note that scenario (f) differs from one where exposure is to a contaminant body burden, acquired elsewhere, that is mobilized during spawning (Debruyn et al. 2004). Because the FCR is only relevant to calculation of WQS for protection of human health, this study focused on where fish could acquire tissue residues that could pose a health risk if consumed by humans. It did not address either the protection of aquatic life or the effect of contaminant burdens on the health of anadromous fish, important issues that have been studied by others (Arkoosh et al. 1998; Spromberg and Meador 2005).

The primary objective of this study was to corroborate model estimates of contaminant tissue concentrations and body burdens for specific exposure scenarios with those observed in returning adult Pacific salmonids. Model corroboration considered both the magnitude and lifetime trajectories of both contaminant concentrations and body burdens. A scenario (or scenarios) corroborated by observations might be one that offers a possible explanation for the genesis of those observations. A secondary objective of this study was to identify exposure scenarios within which implementation of a WQS inclusive of anadromous fish might reasonably be expected to reduce contaminant levels in such fish. Because life histories of these anadromous fish are complex and varied, it did not seem possible to test the absolute plausibility of an exposure scenario for all combinations of salmon species, types, evolutionarily significant units (i.e., a population of organisms that is considered distinct for purposes of conservation), or individuals. It did appear feasible, however, to identify a plausible scenario (or scenarios) based on corroboration between scenario-specific model estimates and observed tissue concentrations and body burdens in a representative species of salmonid. Bioenergetics and toxicokinetic (bioaccumulation) models were used to estimate contaminant concentrations and body burdens at locations (spatial dimension) typically occupied by juvenile and adult life stages (temporal dimension) of an idealized individual salmonid.

METHODS

Overview

Figure 1 illustrates the conceptual approach to this study. For each simulated day {d} postemergence, a bioenergetics model was used to estimate the mass of invertebrate and vertebrate prey consumed by a fish on that day, for a total lifetime of 2040 d (≈5.5 y). This is likely an overestimate of lifespan, as most Fall chinook return at 3–4 y of age. The model runs for 2040 d to show the potential trajectory of bioaccumulation should a fish live for its theoretical maximum lifespan. Concurrently, the spatial location {y} of the fish on day {d} was estimated based on an individual's idealized life history. The contaminant concentration in prey was quantified at specific locations based on observed levels. A toxicokinetic (bioaccumulation) model was then used to combine estimates of contaminant concentrations in prey with estimates of prey consumption rates to make an estimate of contaminant levels (as both concentration and body burden) in a fish on day {d} at location {y} (Drouillard et al. 2009). Model estimates of tissue concentrations were then compared with those reported in the literature to assess the explanatory power of various exposure scenarios.

Representative salmonid

Pacific salmon have evolved many diverse strategies for juvenile migration, estuarine rearing, and adult migration and spawning (Allen and Hassler 1986; Groot and Margolis 1991; Healy 1991; Quinn 2004). Life histories of anadromous salmonids do, however, have some common traits. Adult fish spawn in freshwater streams, usually in late summer or fall. Their large yolky eggs are buried in the substrate, where embryonic development occurs. Juveniles emerge from the substrate the following spring as fry and are dependent on external food sources on emerging. Species life histories diverge at this point, with some species migrating to the estuary and others delaying their migration for months or years. After passing through the estuary, the fish carry out most of the growth in the ocean, spending, depending on the species and stock, between 1 and 6 years there. Adults then return to their natal streams or lakes to spawn and die shortly thereafter.

Fall chinook salmon (*Oncorhynchus tshawytscha*) were selected as the representative salmonid species because it is highly valued commercially, likely represents an important exposure pathway in the diet of peoples with subsistence lifestyles and high salmon consumption rates, is spiritually and culturally prized among certain Native American tribes, and is known to accumulate contaminants (Carlson and Hites 2005). With chinook, 2 distinct ''types'' have evolved. A ''stream-type'' (or Spring) is found most commonly in headwater streams of large river systems. This type has a longer freshwater residency and carries out extensive offshore migrations in the central North Pacific ocean before returning

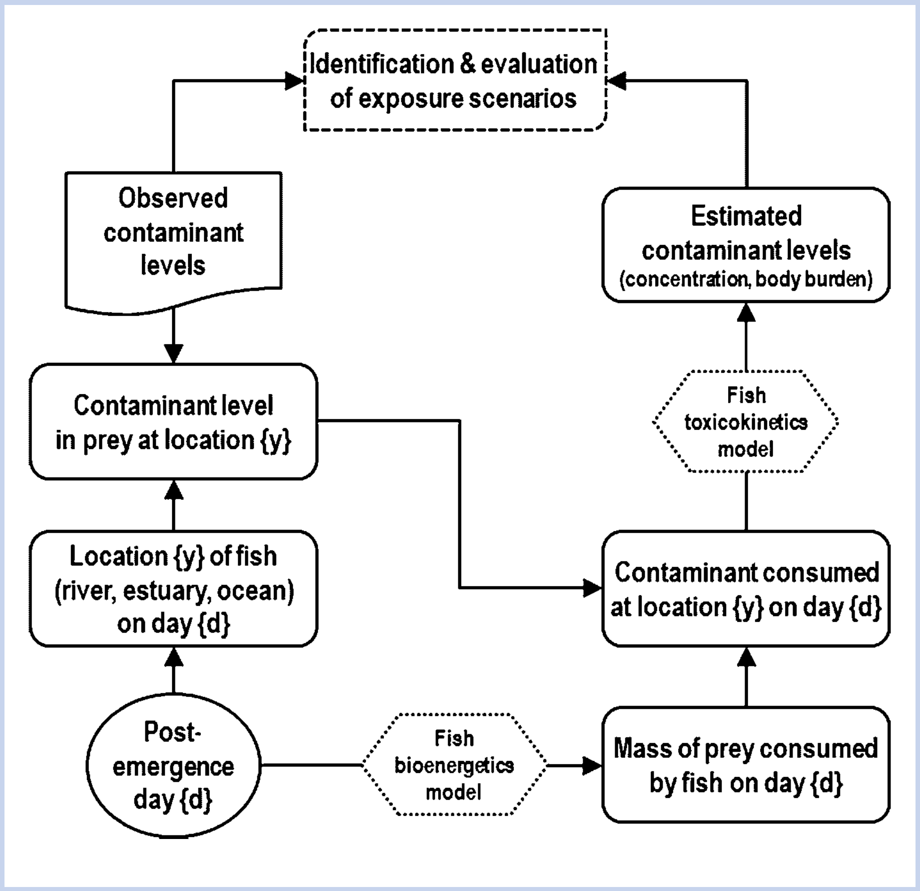

Figure 1. Conceptual model for conduct of this study.

to its natal streams in the spring or summer months. Juveniles migrate as yearlings after overwintering in the river environment. Stream-type juveniles are much more dependent on freshwater stream ecosystems because of their extended residence in these areas, but they spend little time in estuaries before moving to the ocean. They typically spend their first year at sea in near-shore waters before moving into the Gulf of Alaska and Northern Pacific Ocean for 2–4 years. An ''ocean-type'' (or Fall) is found commonly in coastal streams. Juveniles typically migrate to sea within the first 3 months of life, but timing of migration is quite variable (Reimers and Loeffel 1967). Some disperse to estuaries as fry immediately after emergence, some spend additional time in freshwater before entering the estuary, and some rapidly transit the estuary after short or long periods of residence in freshwater. Ocean-type spend more time in estuaries as juveniles than any other Pacific salmon but variation in timing and duration of estuarine residence is considerable (Hering 2009). After entering ocean waters, they tend to migrate along the coast, spend their ocean life in coastal waters (≈5–8 km offshore), and return to their natal streams or rivers principally as summer and fall runs. After 1–6 years in marine waters, both types return to their natal waters to spawn, the difference being that the ocean-type spawns almost immediately after reaching their natal stream whereas the stream-type typically spends several months in freshwater before spawning. Chinook from Alaska are almost entirely stream-type, whereas those from northern British Columbia are mixed stream- and ocean-types, and those further south in Puget Sound and Oregon waters are predominantly ocean-type (Healy 1991).

Representative contaminant

Polychlorinated biphenyls (PCBs) were selected as the representative persistent, bioaccumulative, and toxic (PBT) contaminant because their physicochemical behavior is well characterized, they have been detected in fresh and marine waters, in the tissues of various salmonid species, and in the tissues of salmonid invertebrate and vertebrate prey (Carlson and Hites 2005; O'Neill and West 2009). Empirical data on PCB concentrations in fresh and marine waters, in chinook salmon, and in their dietary items at various life stages, were drawn from the literature and are summarized in Table S1 (Supplemental Data). These data, although extensive and of good quality, nonetheless had some limitations. Ready comparisons between studies were challenged by PCB concentrations, particularly total concentrations, being reported as differing summations of various aroclors or congeners. Studies did not always report both wet weight and lipid-normalized concentrations, or data needed to convert from one to the other. Body burden estimates, an important adjunct to concentration measurements, were also rarely reported. There were also few measurements of PCB concentrations in adult fish caught at sea at known locations and apparently none of PCBs levels in the stomach contents of such fish. Many studies did not report ancillary data, such as type of salmon (Fall or Spring), weight, length, age, or lipid content, that would have been useful for comparative purposes.

A metaanalysis of the observations listed in Table S1 (Supplemental Data) suggested groups based on sampling location and tissue concentration. Wild fish in headwater (1st–3rd order) streams, including fish in headwater reaches of Puget Sound rivers and large rivers discharging to the ocean, and hatchery fish formed distinct groups, with wild fish in headwater streams having the lowest reported prey and tissue concentrations of all groups. Three groups were evident for Puget Sound: fish collected in the Sound itself, fish collected from contaminated estuaries, and fish taken from presumably un- or less contaminated, estuaries. Fish entering the ocean directly (i.e., not through Puget Sound) from large rivers and those that entered directly from small rivers formed 2 additional groups. Fish caught in the open ocean (e.g., Gulf of Alaska) or in coastal waters outside of Puget Sound (e.g., Johnstone Strait) formed a final group.

From the perspective of observed mean tissue concentrations in returning adults, fish could be placed, seemingly without regard to their type or exposure experience as out-migrating juveniles, into 1 of 3 concentration ranges: 1) a higher ''Sound'' range (mean tissue concentrations from 35 to 90 μg/kg, w/w) for returning adults whose natal river discharged into Puget Sound, 2) a middle ''Large River'' range (mean tissue concentrations from 10 to 40 μg/kg, w/w) for returning adults whose natal river discharged directly to the ocean from a watershed with significant urban land use and other anthropogenic impacts (e.g., Columbia River, Fraser River), or 3) a lower ''Ocean'' range (mean tissue concentrations from 10 to 20 μg/kg, w/w) for returning adults whose natal river also discharged directly to the ocean but from a watershed with few anthropogenic impacts (e.g., Salmon River, OR). This low range also included adults caught in the open waters of the North Pacific, Gulf of Alaska, or Bering Sea on the assumption that their natal rivers were also lightly impacted. Data for returning adults were sufficient to identify 2 ranges based on observed mean body burdens: a high range (200–400 μg/fish, w/w) for adults caught within Puget Sound and in the Duwamish, Deschutes, and Lower Fraser Rivers and a low range (30–100 μg/fish, w/w) for fish caught in the North Pacific Ocean, Gulf of Alaska, or Bering Sea. The differences between these high and low ranges for concentration (6–7-fold) and burden (7–10-fold) may be explained in part by the hydrology of Puget Sound, which is a deep, fjord-like estuary with a narrow connection to oceanic waters through the Strait of Juan de Fuca and shallow sills at Admiralty Inlet. These hydrological features tend to isolate its waters from less contaminated open ocean waters, reduce summer flushing time relative to that of the Strait of Georgia, and allow for contaminants to become entrained within it (Friebertshauser and Duxbury 1972; O'Neill and West 2009; Thomson 1994). This hydrology, combined with considerable urbanization on its surrounding lands, and the presence of several federal Superfund sites, may make the Sound a unique upper bound case for PCB contamination in Pacific Northwest coastal waters. These 5 ranges were used for corroboration purposes, in that a potentially explanatory exposure scenario would be one that placed its model estimates for both tissue concentration and body burden within either the higher or lower ranges observed in returning adult salmon.

Exposure Scenarios

Locations. In general, anadromous fish may be exposed to a contaminant while out-migrating as a juveniles through freshwater or estuarine environments, as adults in the marine environment, or in all 3 environments at different times. Within this general context, measurements summarized in Table S1 (Supplemental Data) were used to identify 16 specific exposure scenarios (Table 1). Because of the known ubiquity of PCBs in aquatic environments, a constant dissolved phased PCB concentration of 10 pg/L in both fresh and marine waters was assumed for all scenarios (Iwata et al. 1993). Seven scenarios (Scenarios 1–8) assumed that exposure occurred via water and prey consumption in only 1 specific location. Scenario 1 had exposure occurring only when wild juveniles out-migrate through river reaches with few, if any, significant anthropogenic impacts (e.g., Salmon River, OR), whereas Scenario 2 assumed exposure only when fish were reared on contaminated food in hatcheries. Exposures in estuaries within Puget Sound could occur when transiting (Scenario 3) a contaminated estuary (e.g., Duwamish Waterway) or another estuary that connects with the Sound (Scenario 4). Estuaries that enter open marine waters directly could be those for large rivers (Scenario 5) with urbanization in their watersheds (e.g., Columbia River, Fraser River), or small rivers (Scenario 6) with little urbanization in their watersheds (e.g., coastal rivers in Washington, Oregon, or Alaska). Exposures could also take place only in Puget Sound (Scenario 7) or only in unconfined coastal or the open marine waters (e.g., Gulf of Alaska) (Scenario 8). Although exposure in just 1 location is possible (e.g., only when transiting a contaminated estuary), fish have the potential, particularly with globally ubiquitous contaminants like PCBs, to be exposed in multiple locations. Eight scenarios (Scenarios 9–16) allowed for combined exposures via water and prey in multiple locations (Table 1). For example, Scenario 15 assumes that an out-migrating wild juvenile (Scenario 1) enters the open ocean (+ Scenario 8) through the estuary of a small river (+ Scenario 6), whereas Scenario 10 assumes that a hatchery-raised fish (Scenario 2) takes up residency in Puget Sound (+ Scenario 7) after entering it through an estuary with known contamination (+ Scenario 4). Although there is no empirical evidence to suggest that Pacific salmon indulge in a prespawning ''feeding frenzy'' (Higgs et al. 1995), the effect of any such behavior was evaluated by assuming that the consumption rate increased by 10 times for 30 days before the start of the spawning migration. Because Pacific salmon cease feeding during the spawning migration (Higgs et al. 1995), the only uptake of a contaminants during this portion of a salmon's life cycle would be from water via the gills.

Duration. Chinook in Puget Sound and Oregon waters are predominantly Fall or ocean-type (Healy 1991). Fall chinook may spend approximately 60–210 d postemergence in freshwater and approximately 10 and 90 d in an estuary. For this study, an idealized Fall chinook was assumed to have an exposure duration in freshwater for 130 d postemergence (median of the freshwater range), then in an estuary environment for 50 d (median of the estuary range), and the remaining 1860 d in the marine environment (Table 1), for a total lifetime of 2040 d (≈5.5 y). Median values were selected to explore what happens to a ''typical'' individual. Here the

Table 1. Summary of exposure scenarios, durations, and concentrations in Fall chinook

Scenario[a]	Exposure location	Exposure duration[c]	Exposure concentration (C_D, μg/kg, w/w)[b]	
			Juveniles[d]	Adults[d]
1	Freshwater: Wild (upstream of most anthropogenic stressors)	130	5 (5–23)	—
2	Freshwater: Hatchery	130	12 (10–14)	—
3	Estuary: Contaminated (Puget Sound)	50	450 (57–760)	—
4	Estuary: Other (Puget Sound)	50	34 (22–59)	—
5	Estuary: Large river	50	62 (20–115)	—
6	Estuary: Small river	50	10	—
7	Ocean: Puget Sound	1860	—	28[e]
8	Ocean: Open water	1860	—	6[e]
9 (1 + 3 + 7)	Wild > contaminated > Sound	Fall chinook resident in Puget Sound		
10 (2 + 3 + 7)	Hatchery > contaminated > Sound			
11 (1 + 4 + 7)	Wild > other > Sound			
12 (2 + 4 + 7)	Hatchery > other > Sound			
13 (1 + 5 + 8)	Wild > urban > Ocean	Fall chinook outside Puget Sound		
14 (2 + 5 + 8)	Hatchery > urban > Ocean			
15 (1 + 6 + 8)	Wild > non-urban >Ocean			
16 (2 + 6 + 8)	Hatchery > non-urban > Ocean			

[a] All scenarios assume a constant dissolved phase PCB concentration of 10 pg/L.

[b] Concentration as grand mean of means in Table 1 (minimum–maximum range of means).

[c] Days postemergence.

[d] Concentration in stomach contents.

[e] PCB concentration in Pacific herring, assuming contaminated herring is 20% of total adult diet.

marine environment was either Puget Sound or the open ocean. A lifetime of this length is expected to overestimate exposure, as returns typically occur within 3–4 years of entering the marine environment.

PCB concentrations in prey. A key input to the toxicokinetic model is the PCB concentration in salmonid invertebrate and vertebrate prey (C_D), which is typically the PCB concentration in salmonid stomach contents. Each individual exposure scenario was assigned a different representative value for C_D, based on available dietary data as detailed in Table S1 (Supplemental Data) and summarized in Table 1. Its value in all scenarios was a point estimate representing a grand mean. For wild juveniles (Scenario 1), C_D was that for fish from the Salmon River (Oregon). For hatchery juveniles (Scenario 2), C_D was the mean PCB concentration in feed from various Oregon, Washington, Columbia River, and Columbia Basin fish hatcheries, exclusive of concentrations measured before 2000, as these appeared unusually high relative to more recent measurements. The C_D point estimate for a contaminated estuary (Scenario 3) was the mean of data from the Commencement Bay and Duwamish Waterway Superfund sites. That for a large river estuary (Scenario 5) was the mean of data from uncontaminated rivers entering Puget Sound, plus those for the lower Columbia and Fraser Rivers. All of these watersheds include urban lands subject to a variety of anthropogenic stressors, including chemical stressors. The Lower Columbia River, for example, is likely impacted at its confluence with the Willamette River by the Portland metropolitan area (Johnson, Ylitalo, Sloan, et al. 2007; Johnson, Ylitalo, Arkoosh, et al. 2007) and the Fraser River in Canada by its passage through the Vancouver (BC) metropolitan area. For a small river estuary (Scenario 6), C_D was the mean in the diet of fish in small, coastal rivers whose estuaries enter the ocean directly, without an intervening sound. Because of a paucity of data on PCB concentrations in adult stomach contents, the C_D for adults, in both Puget Sound (Scenario 7) and the open ocean (Scenario 8), was inferred from measured PCB concentrations in Pacific herring (*Clupea pallasi*), prey comprising 20%–60% of an adult's diet (Healy 1991; West et al. 2008).

Bioenergetic Model (Daily Consumption Rate)

As out-migrating juveniles in freshwater, wild chinook salmon typically feed on pelagic, drifting, and epibenthic larval and adult insects. In estuaries, their diet shifts toward pelagic zooplankton, epibenthic amphipods, and, as they grow larger, small fishes. In the marine environment, the diet of adult chinook is largely comprised of larval and juvenile fishes (principally Pacific herring [*Clupea*]), pelagic amphipods, and crab megalopa (Healey 1991; Schabetsberger et al. 2003). The Wisconsin bioenergetics model 3.0 (Hanson et al. 1997; Madenjian et al. 2004) was used, unmodified, to estimate the feeding rate (G_D), fecal egestion rate (G_F), and body weight (W) for juvenile (J) and adult (A) chinook salmon cohorts for each day of a 2040 d lifetime. The model's default values for chinook salmon were used to parameterize its physiological variables (Hanson et al. 1997; Stewart and Ibarra 1991). These included the allometric parameters for dependence of consumption and respiration on body mass, the most sensitive variables (i.e., those with the greatest influence on model predictions). Values for user-specified variables were: weight range (J: 0.1–80 g, A: 80–15 000 g), indigestible fraction of prey (J, A: 20%), prey energy content (J: 2000 J/g, A: 4000 J/g, wet body mass; energy densities of typical prey items (Hanson et al. 1997: see Appendix B), prey dietary fraction (1, unitless; because all prey had the same energy content and digestibility), predator energy content (4000 J/g, wet body mass), and water temperature (10° C, midpoint of optimal growth range [Allen and Haster 1986]).

Toxicokinetic Model (Contaminant Uptake and Retention)

Uptake from prey items and elimination via feces are the major pathways by which fish accumulate and eliminate persistent hydrophobic ($\log K_{OW} \approx 6$) organic contaminants such as PCBs (Qiao et al. 2000). Uptake of such contaminants from water via the gills is of less importance due to their generally low concentrations (pg/L) in fresh or marine waters (Gobas and Mackay 1987; Iwata et al. 1993). A mass balance contaminant accumulation model was implemented in STELLA^{TM} (Isee Systems) using variables and algorithms developed by Arnot and Gobas (2003, 2004) and Gobas and Arnot (2010). The 2 most sensitive variables in this model are $\log K_{OW}$ (that was a fixed value) and the concentration of a contaminant in prey items (C_D). Values for C_D (Table 1), as well as the day or days on which a fish is exposed, were varied to match the exposure scenario being evaluated. Table S2 (Supplemental Data) summarizes model variables and equations; relationships for these are shown in Figure S1 (Supplemental Data). This model provided estimates of tissue concentration and body burden resulting for uptake of PCBs from both surface water (via gill exchange) and prey (via consumption) for all, or any portion, of a fish's lifespan. Both estimates were necessary because for non- or poorly metabolized contaminants (such as PCBs) in a fast-growing species, decreases in concentration due mainly to growth dilution may be misinterpreted as reductions in burden (i.e., as a loss of contaminant mass). Burden is a better indicator of the difficult-to-reverse consequences of long term exposure to a recalcitrant contaminant.

RESULTS AND DISCUSSION

Scenarios

Observed and model estimated tissue concentrations are listed in Table 2; body burdens in Table 3. Scenario-specific model results, in relation to ranges observed in returning adults after 3–4 years in seawater, are shown in Figure 2 for concentrations and Figure 3 for body burdens. Trajectories through time of tissue concentrations, again in relation to observed ranges, are shown in Figures S2–S8 (Supplemental Material).

Individual scenarios. Exposures only in upstream freshwater habitats (Scenario 1 [Figure S2]) or only in a hatchery (Scenario 2 [Figure S2]), or only while transiting uncontaminated estuaries (Scenarios 4 and 6 [Figure S3]) all failed to produce estimates for returning adult fish within any of the observed concentration ranges. With the unusually high dietary concentrations reported before 1993 set aside, hatchery fish exposed to contaminated food (Scenario 2) would be indistinguishable from those exposed only in the open ocean (Scenario 8 [Figure S4]), which suggests that hatcheries may be an unlikely sole source of PCB loads in returning adults. Exposure only in Puget Sound (Scenario 7 [Figure S4]) or only in the open ocean (Scenario 8) was sufficient to generate concentrations and burdens within the Sound and Ocean ranges, respectively, for fish with 3–4 years in seawater and also at end-of-life (Figures 2 and 3). Exposure only in a large river estuary (Scenario 5 [Figure S3]) yielded

Table 2. Comparison of observed and modeled tissue concentrations (μg/kg, w/w)[a]

	Out-migrating juveniles		Returning adults
Scenario	**River at 130 d**	**Estuary at 180 d**	**3–4 y[b]**
1	8 5 (4–8)[c]	6	2
2	18 24 (10–50)[c]	15	3
3	0.4	196 197 (24–725)[c]	38 49 (35–57)[d]
4	0.4	15 45 (40–50)[c]	3 51 (37–83)[d]
5	0.4	27 57 (49–70)[c]	6 34 (11–47)[d]
6	0.4	8 17 (4–46)	2 12 (7–19)
7	0.4	0.4	65 67 (40–86)[d]
8	0.4	0.4	14 11 (9–14)[d]
9	8 5 (4–8)[c]	202 197 (24–725)[c]	103 67 (40–86)[d]
10	18 24 (10–50)[c]	211 197 (24–725)[c]	104 67 (40–86)[d]
11	8 5 (4–8)[c]	21 45 (40–50)[c]	69 67 (40–86)[d]
12	18 24 (10–50)[c]	30 45 (40–50)[c]	70 67 (40–86)[d]
13	6 5 (4–8)[c]	32 57 (49–70)[c]	20 11 (9–14)[d]
14	18 24 (10–50)[c]	42 57 (49–70)[c]	22 11 (9–14)[d]
15	8 5 (4–8)[c]	11 17 (4–46)[c]	16 11 (9–14)[d]
16	18 24 (10–50)[c]	19 17 (4–46)[c]	18 11 (9–14)[d]

[a] Single and upper values are model estimates; lower values are observed concentrations.

[b] Three to four winters in seawater, as average of postemergence Days 1145–1510.

[c] Observed tissue concentration, grand mean (range of means).

[d] Observed tissue concentration, grand mean (range of means), age of fish not specified.

Table 3. Comparison of observed and model estimated body burdens (μg/fish, w/w)

	Out-migrating juveniles		Returning adults
Scenario	**River at 130 d**	**Estuary at 180 d**	**3–4 y[k]**
1	0.2	0.4	9
	0.2[g]	0.4[a]	
2	1	1 2.0 (1.5)[f]	18
3	0.01	12	212
		2.1 (9.2)[d]	350 (800)[e]
		4.8 (0.8)[h]	218–333[i]
4	0.01	1	19
5	0.01	2	32
6	0.01	0.5	11
7	0.01	0.02	372
			260–340[b]
			280–390[c]
8	0.01	0.02	82
			29–98[j]
9	0.2	12	587
10	0.5	12	596
11	0.2	1	394
12	0.5	2	403
13	0.2	2	116
14	0.5	2	126
15	0.2	1	93
16	1	1	102

[a] Estimated value in 10 g out-migrating smolts (O'Neill and West 2009).

[b] Puget Sound adult chinook after 1–2 winters in saltwater (O'Neill and West 2009).

[c] Puget Sound adult chinook after 3–4 winters in saltwater (O'Neill and West 2009).

[d] Out-migrating smolts in the Duwamish River, mean (95th percentile) (O'Neill and West 2009).

[e] Adults returning to the Duwamish River, mean (95th percentile) (O'Neill and West 2009).

[f] Out-migrating hatchery fish in 1989, 1993, and 2000, mean (1 SD) (Meador et al. 2002).

[g] Out-migrating wild juveniles collected in 2000 in the Duwamish River upstream of major urban impacts, mean (Meador et al. 2002).

[h] Out-migrating juveniles collected in 1989, 1993, 2000 in the Duwamish River estuary, mean (1 SD) (Meador et al. 2002).

[i] Adults returning to the Lower Fraser River (BC) and Duwamish and Deschutes Rivers (WA) (Cullon et al. 2009).

[j] Adults collected in the Gulf of Alaska and North Pacific Ocean (Carlson and Hites 2005; Easton et al. 2002), in Johnstone Strait (Cullon et al. 2009), and off Vancouver Island (BC) (Ikonomou et al. 2007).

[k] 3 to 4 winters in seawater, as average of post-emergence days 1145 to 1510.

concentration estimates just below, but burden estimates at, the lower range, whereas short, intense exposures not unlike those achieved by passage through an estuary containing an in-water contaminated site (Scenario 3 [Figure S3]) generated concentration and burden estimates at the higher range. An estuary fed by a large river flowing through areas impacted by anthropogenic chemical stressors (e.g., the Columbia River at its confluence with the Willamette River is affected by the urban areas of Portland [OR] and Vancouver [WA], as well as a large in-water Superfund site) could produce such exposures.

Scenario 3, a single large exposure when out-migrant juveniles transit a contaminated estuary, produced tissue and burden estimates at the lower bound of those observed in 3–4-year-old adults (Figures 2 and 3). Tissue concentrations slowly declined but body burdens were recalcitrant, indicating that even a relatively brief (≤50 d) exposure to elevated prey concentrations may have lasting consequences in terms of increased PCB burdens carried by adults. Average and adjusted average contaminant concentrations in adults taken from Puget Sound after 1–4 years in salt water (O'Neill and West 2009) were compared to model estimated concentrations. Scenario 3 provided the closest approximation to these observations in terms of both magnitude of, and rate of decline in, concentration (Figure S9). Colloquially, a juvenile transiting a contaminated location appears to ''jump-start'' acquisition of a body burden of highly bioaccumulative contaminants such as PCBs. Scenario 7 did not suggest declines in tissue concentrations, suggesting that apparent declines, particularly in burdens, result from samples composed of individual fish with differing exposure experiences.

Absent a short, intense exposure to chemical stressors (e.g., Scenarios 3 and 5), simple residence in, or extended transit through, contaminated marine waters may be sufficient to generate the majority of the observed loads. The degree of loading may be a function of the extent of the time spent is residence or transit. Thus exposures before entering marine waters that do not involve intense exposures are unlikely to be the principal source of PCB loads observed in returning adults. This finding of a dominant role for exposure in open marine waters is consistent with reports by others (O'Neill and West 2009) and with the USEPA rationale for not including anadromous fish in exposure estimates (USEPA 2007).

Multiple scenarios. Exposure upstream, then in a contaminated estuary, then in Puget Sound (Scenarios 9 and 10 [Figure S5]), approximately doubled concentration and burden estimates over those for the Sound (Scenario 7) alone. Conversely, exposures upstream, then in an uncontaminated Puget Sound estuary, then in Puget Sound (Scenarios 11 and 12 [Figure S6]) did not produce concentration and burden estimates different than those in the Sound (Scenario 7) alone. This emphasizes the role played by short but intense exposures associated with a contaminated estuary. Exposure upstream, then in an large river estuary, then in open marine waters (Scenarios 13 and 14 [Figure S7]), also approximately doubled concentration and burden estimates over those for the open ocean (Scenario 8) alone. An initial spike in concentration (Figure S7) due to the large river estuary was subsequently ameliorated by a longer exposure to less contaminated prey in the open ocean, causing concen-

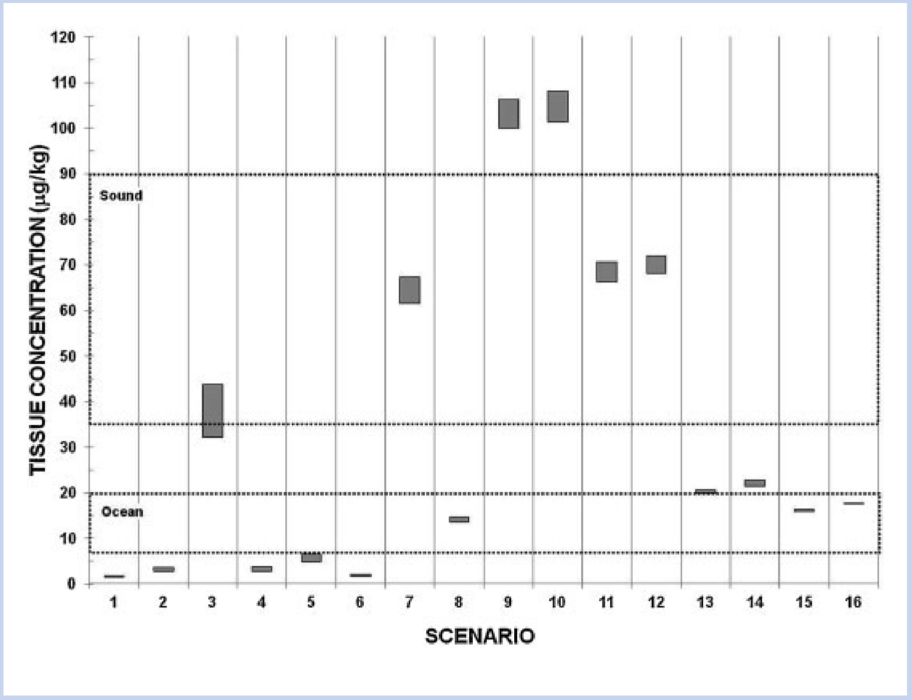

Figure 2. Comparison of tissue concentration estimates (µg/kg, w/w) by scenario (vertical bars) to observed tissue concentration ranges (boxes with dotted line borders) in adult fish at 3–4 y in marine waters.

tration and burden estimates to settle into the large river range between the Sound and Ocean ranges. However, exposures upstream, then in a small river estuary, then in the open ocean (Scenarios 15 and 16 [Figure S8]) did not produce concentration and burden estimates different than those in the open ocean (Scenario 8) alone.

Miscellaneous scenarios. Uptake from water was a small and comparatively inconsequential source of PCB concentrations and burdens, indicating that observed adult burdens could not be obtained only during the upstream spawning migration in freshwater. However, the ubiquity and persistence of legacy PCBs (and other legacy chemicals with similar

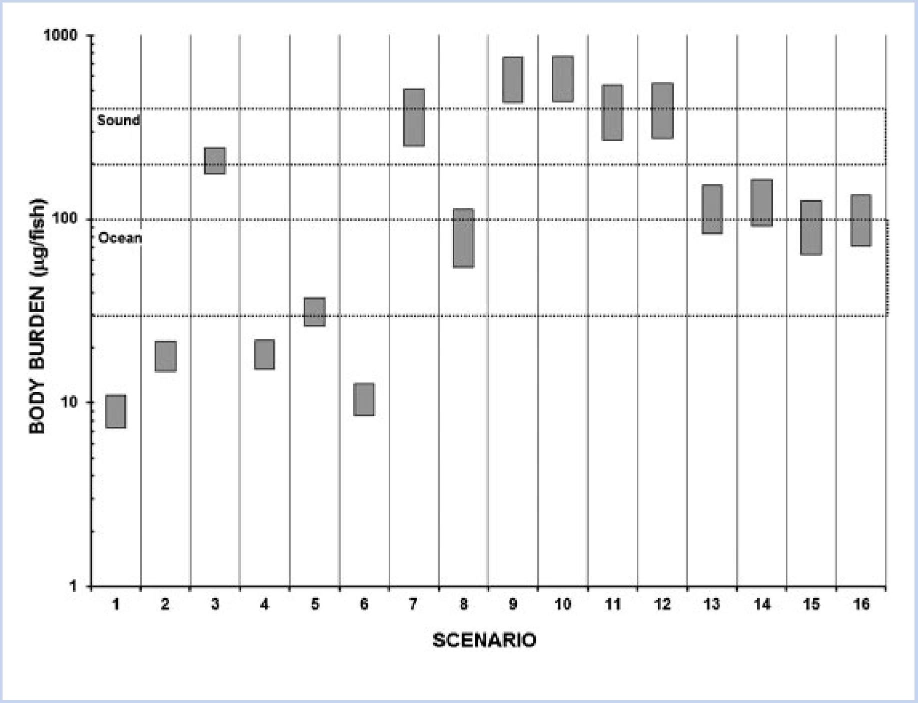

Figure 3. Comparison of body burden estimates (µg/fish) by scenario (vertical bars) to observed body burden concentration ranges (boxes with dotted line borders) in adult fish at 3–4 y in marine waters.

physicochemical properties) virtually guarantees that any fish, whether anadromous or resident, will have some small PCB burden (CTUIR 2007; Henny et al. 2003). The ''feeding frenzy'' scenario (a 10-fold increase in the consumption rate in the 30 d before the start of spawning) had no discernible effect on either concentrations or burdens estimated for any scenario. It is thus highly unlikely that an adult fish could acquire concentrations or burdens on the order of observed levels simply by sharply increasing its feeding near the end of its life.

Implications for WQS

This study focused on 1 type (Fall) of 1 species (chinook) of salmonid and on 1 PBT contaminant (PCBs), corroborated by a metaanalysis of available data on tissue concentrations and body burdens of that contaminant collected in the Pacific Northwest and Alaska by a number of researchers. It applied these data to models that are well established and whose behavior, including sensitive inputs, is well understood. However, these species, data, and models all embed uncertainties of various types, not all of which are readily identifiable or quantifiable. As a result, the results of this (or any) modeling study must be interpreted with caution; however, it may still provide insights into the efficacy of WQS for reducing contaminant loads in Fall chinook salmon. Note, however, that the specific applicability of these results to other salmonid species was not determined here. At a minimum, these results may be useful for dispelling assertions about exposure scenarios that are physiologically improbable and whose pursuit is unlikely to result in protective outcomes.

Results suggest that using WQS as waterbody target concentrations may yield only small ($\leq 2\times$) reductions in PCB levels (or of other ubiquitous legacy contaminants with similar PBT properties) in returning adult Fall chinook salmon because the majority of uptake likely occurs while adults are in marine waters beyond the state's jurisdiction. WQS would also have little effect on hatchery fish whose PCB load stems from consumption of contaminated feed (Scenario 2). Scenario 8 results suggest, as have others (O'Neill and West 2009), that PCB loads in fish either resident outside of Puget Sound or not in contact with a contaminated estuary likely stem primarily from exposure in open marine waters. Because states do not have jurisdiction over the open ocean, implementation of WQS will not occur in such waters.

Puget Sound is unique marine water body in that it is both poorly flushed and subject to contaminant loading from surrounding urban landscapes, which have been shown to be disproportionate contributors of chemical stressors (Black et al. 2000; Paul and Meyer 2001). It is also host to several major in-water contaminated sites, where WQS are currently being used to guide remediation efforts. Although addressing these sites is likely to eliminate excesses in concentrations and burdens (e.g., Scenarios 9 and 10), doing so is unlikely to result in large reductions in bioaccumulative contaminants in anadromous fish. Because of the known relationship between urban land use and chemical stressors (Black et al. 2000), use of WQS in controlling or reducing contaminants from nonpoint sources (e.g., runoff from impervious surfaces, nonpermitted stormwater flows, runoff of air deposition [Hope 2008]) will also be required (McCarthy et al. 2008). Because permitted and properly managed point sources (e.g., industrial, wastewater treatment, permitted stormwater) are no longer significant contributors of PCBs to watersheds, use of WQS to regulate such sources would not reduce chemical loadings throughout the Sound. Although implementation of WQS for all waters entering the Sound may, over time, yield lower contaminant levels within the Sound, there are likely to be practical limits on the affect WQS can have on globally distributed legacy contaminants such as PCBs.

Including anadromous fish in the FCR used for developing WQS for protection of human health creates the expectation that implementation of this WQS will significantly reduce bioaccumulative contaminants (e.g., PCBs, PBDEs, dioxins/furans) in such fish. Based on these model results, meeting WQS may lead to small reductions ($\leq 2\times$) only for returning Fall chinook salmon adults that were resident in a confined water body (e.g., Puget Sound) or who transited a highly contaminated estuary (e.g., Duwamish Waterway) as outmigrating juveniles. Otherwise, it may be unrealistic to expect attainment of WQS to result in reduced contaminant burdens in species who receive these burdens as adults in unconfined coastal or open marine waters. Where attainment of WQS can be physically linked to reductions in contaminant loads, benefits will typically out-weigh costs associated with its attainment. Conversely, any physical disconnects between attainment of WQS and expected reductions in contaminant loads creates a situation with costs but few, if any, off-setting benefits. Such a cost-benefit disparity can frustrate those seeking the protection of WQS and those legally required to implement controls designed to attain it.

SUPPLEMENTAL DATA

Supporting Tables S1–S9.

Supporting Figure S1.

Supporting Figure S2.

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ES&T
FEATURES

Cancer risk management

A review of 132 federal regulatory decisions

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Various federal agencies are responsible for promulgating regulations and standards to protect the public from exposure to environmental carcinogens. Although many factors are considered in the decision to regulate a carcinogen, one important issue concerns the probability that individuals in an exposed population will develop cancer.

What has not been clear, however, is the level of cancer risk that triggers regulation, or whether there is consistency within and between agencies in arriving at the risk decisions that underpin regulatory action. We have retrospectively reviewed the use of cancer risk estimates in prevailing federal standards and in withdrawn regulatory initiatives to determine whether any simple patterns emerge to correlate risk level with regulatory action. Our results show that there are definite patterns and a surprising degree of consistency in the federal regulatory process.

The sources of the data reviewed are notices of proposed or final regulations found in the *Federal Register* and in published and unpublished regulatory support documents, all of which are in the public domain. Three measures of risk are considered: *Individual risk* is measured as an upper-limit estimate of the probability that the most highly exposed individual in a population will develop cancer as a result of a lifetime of exposure. The *size of the population* exposed to the hazards is considered. Finally, *population risk* is measured as an upper-limit estimate of the number of additional incidences of cancer in the exposed population. Federal agencies compute population risks (as measured by the number of cancer deaths per year) by one of two methods: by multiplying maximum individual risk by population size or by accounting for variations in individual exposure levels and adding up the resulting figures for an entire population. Almost one-third of the population risk estimates reviewed here were calculated using the first method, although the second method is preferable.

Knowledge of two additional terms, de manifestis and de minimis, is important to understanding the patterns that emerge from the data. *De manifestis* risk, literally a risk of obvious or evident concern, has its roots in the legal definition of an "obvious risk"; one that is instantly recognized by a person of ordinary intelligence. *De minimis* risk has been used for a number of years by regulators to define an acceptable level of risk that is below regulatory concern. This term stems from the legal principle, *de minimis non curat lex;* "the law does not concern itself with trifles."

Table 1 lists 132 regulatory decisions for which at least one of these measures of risk was estimated prior to regulation of the substance in question. The methods used by federal agencies for estimating individual risk are generally considered to overestimate risk; they assume maximum exposure and a linear no-threshold dose–response function. For example, the population risk estimate for saccharin (Number 100 in Table 1) is listed as 1200 cancer deaths annually, although the Food and Drug Administration (FDA) states that this is an upper-limit risk estimate and the actual risk is between zero and 1200.

The published maximum risk estimates have been taken at face value; any errors in the estimates or interagency differences in the approach to risk analysis are not considered impor-

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TABLE 1
Preregulatory risk levels for chemical carcinogen exposures

Chemical decision	Agency	Individual lifetime risk (per 10^6)	Exposed population size (millions)	Annual cancer cases	Reference
Public					
Acrylonitrile					
1. Food	F	0.01	220	0.01	49-FR-36635
2. Air	E1	380	220	0.5	50-FR-24312
Aflatoxins					
3. Corn	F	70	34	90	FDA Docket No. 78N-0048
4. Peanuts	F	3	220	35	
5. *Aluminum tris*	E2	0.003	—	—	48-FR-50532
6. *Amblen*	E2	0.001	—	—	46-FR-17229
Amitraz					
7. Apples^a	E2	0.2	220	6	44-FR-2678
8. Pears	E2	0.2	220	8	44-FR-2678
Arsenic					
9. Primary lead smelters	E1	0.7–10	—	0.006–0.1	48-FR-33112
10. Primary zinc smelters	E1	0.1–2	—	0.005–0.008	48-FR-33112
11. Zinc oxide plants	E1	20–300	—	0.002–0.02	48-FR-33112
12. Chemical manufacturers	E1	4–60	—	0.0008–0.1	48-FR-33112
13. Secondary lead smelters^a	E1	21–340	—	0.04–6	48-FR-33112
14. High copper smelters^a	E1	2300–36,000	0.37	1–18	48-FR-33112
15. Low copper smelters^a	E1	430–6900	0.65	2	48-FR-33112
16. Glass manufacturers^a	E1	64–1000	4.2	0.07–1	48-FR-33112
17. *Asbestos*^{a}	E4	1–7	—	—	51-FR-3738
18. *Benomyl*	E2	0.7	—	—	47-FR-46747
Benzene					
19. Maleic anhydride plants	E1	8	10	0.03	49-FR-8386
20. Ethylbenzene styrene plants	E1	14	2.5	0.06	49-FR-8386
21. Storage vessels	E1	4	85	0.04	49-FR-8386
22. Coke byproduct^a	E1	640	20	2	49-FR-23522
23. Fugitive emissions^a	E1	20	30	0.5	49-FR-23498
24. Equipment leaks^a	E1	50	—	0.1	49-FR-23498
25. Paint strippers^a	C	40	—	—	43-FR-21838
26. *Butadiene*^{b}	E1	7600–30,000	52	18.5	50-FR-41466
27. *C.I. Vat Orange #1*	F	0.000003	—	—	50-FR-20405
28. *Carbon tetrachloride*^{b}	E1	700	230	70	50-FR-32621
29. *Chloroallyldiethiocarbamate*	E2	0.2	—	—	46-FR-27973
Chlorobenzilate					
30. U.S. population^a	E2	0.3	210	6	44-FR-9548
31. Florida population^a	E2	0.7	8	0.8	44-FR-9548
Chloroform^b					
32. Water	E1	9	—	2	50-FR-39626
33. Waste	E1	2	—	0.5	50-FR-39626
34. *Chlorinated benzenes*	E1	0.2–1	6.5	0.0005–0.007	50-FR-32626
35. *Chlorothalonil*	E2	2	—	—	49-FR-45853
36. *Chromium*^{b}	E1	1200–16,000	220	290	50-FR-24317
37. *Cinnamyl anthranilate*^{a}	F	0.1	—	—	47-FR-22545
38. *Coke oven emissions*^{a}	E1	350–3600	0.12	2–6	41-FR-46742
39. *Cypermethrin*	E2	0.1	—	—	50-FR-1112
40. *Cyromazine*	E2	0.1	—	—	49-FR-18120
41. *Diallate*^{a}	E2	10	—	—	PD #4, 1982
1,2-Dibromo-3-chloropropane					
42. Peanuts^a	E2	60	220	1900	44-FR-65151
43. Vegetable^a	E2	60	220	1900	44-FR-65151
Dimethylnitrosamine					
44. Baby bottles^a	F	0.004	—	—	FDA Docket No. 83D-0414
45. Paper, paperboard	F	0.0006	—	—	50-FR-4643
46. *1,4-Dioxane*	F	0.0000004	—	—	50-FR-36872
Epichlorohydrin					
47. Air	E1	1	220	0.001	50-FR-24575
48. Dimethylamine	F	0.0000002	—	—	49-FR-13016
49. Polyamide	F	0.001	—	—	49-FR-13021
50. *Ethalfluralin*	E2	0.4	—	—	49-FR-511
51. *Ethylene bisdithiocarbamates*	E2	50	220	—	47-FR-47669
Ethylene dibromide					
Soil fumigant					
52a. Food^a	E2	1	230	36	48-FR-46228
52b. Water^a	E2	8	230	25	PD #4, 1983
53. Stored grain fumigant	E2	100	—	—	PD #4, 1983
54. Spot grain fumigant^a	E2	24	230	790	49-FR-4452
55. Quarantine fumigant^a	E2	30	230	330	48-FR-46228
56. *Ethylene oxide*^{b}	E1	200	—	60	50-FR-40286
Formaldehyde					
57. High school teachers	E4	3	0.038	0.02	49-FR-21870
58. High school students	E4	0.03	3.8	0.01	49-FR-21870
59. College teachers	E4	7	0.1	0.1	49-FR-21870
60. College students	E4	0.3	2.9	0.1	49-FR-21870
61. Medical students	E4	40.3	40.075	40.005	449-FR-21870
62. Dental students	E4	40.3	40.0215	40.001	449-FR-21870
63. Nursing students	E4	0.3	0.245	0.01	49-FR-21870
64. Mobile homes^b	E4	13	4.2	8	49-FR-21870
65. Homes (non-urea-formaldehyde foam insulation)	E4	10	100	160	49-FR-21870
66. Rural air	E4	0.3	58	2	49-FR-21870
67. Urban air	E4	3	160	80	49-FR-21870
68. Particle board	E4	20	—	0.01	49-FR-21870
69. Homes (urea-formaldehyde foam insulation)	E4	5	1.8	1.3	49-FR-21870
70. Urea-formaldehyde insulation^a	C	9–30	1.8	23	46-FR-11188

Chemical decision	Agency	Individual lifetime risk (per 10^6)	Exposed population size (millions)	Annual cancer cases	Reference
FD&C Yellow #5 (total)	—	0.04	—	—	50-FR-35774
71. 4-Aminoazobenzene	F	0.00005–0.001	—	—	50-FR-35774
72. 4-Aminobiphenyl	F	0.01	—	—	50-FR-35774
73. Aniline	F	0.000004	—	—	50-FR-35774
74. Azobenzene	F	0.00002	—	—	50-FR-35774
75. Benzidine	F	0.03	—	—	50-FR-35774
76. 1,3-Diphenyltriazene	F	0.0004	—	—	50-FR-35774
Gasoline products					
77. Bulk terminals[a]	E2	200–400	—	1–2	49-FR-31706
78. Service stations[a]	E2	4.4–7.2	—	3–6	49-FR-31706
79. Self-serve[a]	E2	6–9	—	20–30	49-FR-31706
80. *Lead acetate*	F	0.02	—	—	45-FR-72112
Lindane					
81. Ornamental uses	E2	0.8	0.08	—	45-FR-45362
82. Dog dips[a]	E2	0.4	15	—	PD #4, 1980
83. Shelf paper	E2	2	11	—	PD #4, 1980
84. *Methoxychlor*	E2	0.005	—	—	45-FR-49117
Methylene chloride					
85. Decaffeinated coffee	F	0.1	3.7	0.05	50-FR-51551
86. Aerosol cosmetics[a]	F	10	—	—	50-FR-51551
87. Air[b]	E1	10	—	—	50-FR-42037
88. *4,4′-Methylenedianiline*	E4	0.1–2	0.03	—	48-FR-42898
89. *Methylenebis (o-chloroaniline)*	E4	0.3	0.03	—	48-FR-22954
90. *Metolachlor*	E2	0.1	—	—	47-FR-23932
91. *Oryzalin*	E2	0.06–0.5	—	—	49-FR-45854
92. *2,2′-Oxammidobis*	F	0.007	—	—	48-FR-37616
93. *Oxyfluorfen* (perchloroethylene) diet	E2	0.1	—	—	47-FR-27118
94. *Pentachlorophenol*[a]	E2	100	0.02	—	49-FR-28666
95. *Polycyclic organic matter*	E1	7–20	220	200	49-FR-31680
Radionuclides					
96. Department of Energy facilities	E5	70	64	0.07	50-FR-5190
97. Nuclear Regulatory Commission, non-DOE facilities	E5	2	—	0.001	50-FR-5190
98. Elemental phosphorus	E5	100	3	0.06	50-FR-5190
99. Radon-222 uranium mill tailings[a]	E5	1000	—	3–6	51-FR-6382
100. *Saccharin*	F	40	220	600–1200	42-FR-19996
Tetrachlorodibenzo-p-dioxin					
101. Local[a]	E2	20	0.0009	0.02	48-FR-48434
102. General[a]	E2	0.2	220	7.5	48-FR-48434
p-Toluidine					
103. D&C Green #5, #6	F	0.003	—	—	47-FR-24278
104. Diet	F	0.007	—	—	47-FR-14138
105. Contact lenses	F	0.00001	—	—	48-FR-13020
106. D&C Red #6, #7	F	0.002	—	—	47-FR-57681
107. *Trichloroethylene*[b]	E1	9	—	4	50-FR-52442
108. *Trifluralin*	E2	0.05	—	—	PD #4, 1985 (OTS, 1982)[c]
109. *Trihalomethanes*[a]	E3	40	230	340	47-FR-9796
Vinyl chloride					
110. Ethylene dichloride–vinyl chloride monomer plants[a]	E1	260	5	0.6	50-FR-1182
111. Polyvinyl chloride plants[a]	E1	900	5	16	50-FR-1182
112. Food (polymers)	F	0.01	—	—	51-FR-4173
113. *Vinylidene chloride*	E1	80	—	0.07	50-FR-32632
Occupational					
Amitraz					
114. Pears	E2	10	0.005	0.004	44-FR-2678
115. Apples[a]	E2	10	0.005	0.002	44-FR-2678
116. *Arsenic*[a]	O	200–300	—	380	48-FR-1864
Asbestos					
117. 20 Fibers/cm^3[a]	O	17,000	0.4	180	49-FR-14120
118. 2 Fibers/cm^3[a]	O	6400	0.4	90	49-FR-14120
119. *Benzene*[a]	O	4400-15,200	0.05	44–150	50-FR-50512
120. *Chlorobenzilate*	E2	140	0.07	0.01	44-FR-9548
1,2-Dibromo-3-chloropropane					
121. Citrus[a]	E2	9300	—	0.05	Final PD, 1979
122. Cotton[a]	E2	10	—	0.001	44-FR-65151
123. Peaches[a]	E2	360	—	0.6	44-FR-65151
124. Pineapple	E2	9	—	0.001	49-FR-1556
125. Soybeans[a]	E2	9	—	0.01	44-FR-65151
Ethylene dibromide					
126. OSHA[a]	O	7000–11,000	0.0006	1.5	48-FR-45958
127. Soil fumigant[a]	E2	3500	0.014	0.7	48-FR-46228
Spot grain fumigant					
128. Millworkers[a]	E2	2000	0.016	5	49-FR-4452
129. Applicators[a]	E2	10,000	0.006	9	PD #4, 1984
130. Quarantine fumigant[a]	E2	30,000	—	0.5	PD #4, 1984
131. *Ethylene oxide*[a]	O	6300–11,000	0.07	70	49-FR-25734
Tetrachlorodibenzo-p-dioxin					
132. Rights-of-way brush[a]	E2	350	0.086	0.1	48-FR-48434

[a] Agency acted to reduce risk.
[b] No regulatory decision has been made.
[c] Office of Toxic Substances, EPA.

Agency key
C = Consumer Product Safety Commission
E = Environmental Protection Agency
E1 = Office of Air Quality Planning and Standards
E2 = Office of Pesticide Programs
E3 = Office of Drinking Water
E4 = Office of Toxic Substances
E5 = Office of Radiation Programs
F = Food and Drug Administration
O = Occupational Safety and Health Administration

Source key
FR = Federal Register
PD = Position Document

FIGURE 1

Preregulatory levels of maximum individual lifetime risk reviewed by federal agencies

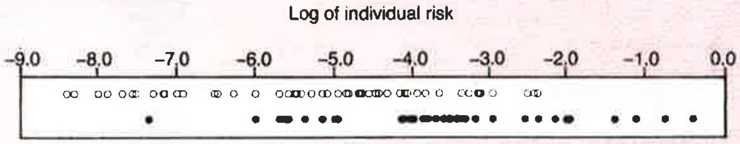


Figure Key: ○ = Agencies did not act to reduce public risk; ● = agencies acted to reduce public risk; ☐ and ■ = action taken or not taken, respectively, for occupational risk; + = no regulatory decision has been made.

tant for our analysis. All that matters is that when the regulatory decision was made, risk managers were presented with these estimates as the best available upper-bound estimates.

Categories of risk

Figure 1 presents preregulatory levels of maximum individual risk for regulatory decisions involving public exposure to chemical carcinogens. Two patterns are apparent. First, every chemical with an individual risk above 4×10^{-3} (four chances in 1000 that a chronically exposed individual will develop cancer) was regulated. Second, except for one FDA decision (Number 44 in Table 1), no action was taken to reduce individual lifetime risk levels that were below 1×10^{-6}.

The Delaney Clause of the Federal Food, Drug and Cosmetic Act Food Additives Amendment of 1958 states: "No additive shall be deemed safe if it is found to induce cancer when ingested by man or animal." Despite this, in all 11 decisions made between 1980 and 1985 involving indirect carcinogenic food additives, FDA set standards but did not require existing risk levels to be reduced. FDA has recently argued that the Delaney Clause permits use of carcinogenic food additives with cancer risks below 1×10^{-6}; a decision that is being challenged in court. Our analysis shows that FDA's reasoning is consistent with historical practice.

Figure 2 presents 58 cases in which estimates of both individual risk and population size were available at the time a regulatory decision was made. Estimated exposed populations ranged from 9700 to 230 million, the latter for the total U.S. population. There does not appear to be a strong correlation between the size of the population exposed and the likelihood of regulation. This conclusion is contrary to that reached by Milvey, who stated that the de minimis risk level is a function of the size of the population at risk (*1*). To further investigate this question, we review estimates of individual and population risk.

Figure 3 presents decisions for which individual and population risk estimates were available at the time of regulation. Three categories of risk can be identified. De manifestis risks are those that are so high that agencies almost always acted to reduce them, and de minimis risks are so low that agencies almost never acted to reduce them (*2*). The risks falling into the area between these extremes were regulated in some cases but not in others.

Figure 4 shows 19 occupational decisions that have been added to Figure 3 to provide data on small populations at high individual risk; no other data exist for these cases. It is assumed that decisions to regulate occupational exposures can be used to aid in defining de manifestis and de minimis risk levels because public exposures to carcinogenic substances should be regulated at least as stringently as occupational exposures are.

Line A of Figure 4 defines the de manifestis level; above this line, federal agencies always acted to reduce risk. For exposures resulting in a small-population risk, the de manifestis level is approximately 4×10^{-3}. As population risk approaches 250 cancer deaths (which could only occur in a population the size of the entire United States) the de manifestis level drops to about 3×10^{-4}. Line B shows the de minimis level. Below this line, no action has ever been taken to reduce risk. Line B indicates that for small-population effects, regulatory action was never taken for individual risk levels below 10^{-4}. For effects resulting from exposures to the entire U.S. population, the level of acceptable risk drops to 10^{-6}. Line C is the area beyond which no data can fall. Figure 4 is essentially an analysis of the Reagan administration's regulatory decisions; only six decisions in Figure 4 occurred before 1980.

Figure 4 raises two questions. First, what justification is given by regulatory

FIGURE 2

Effect of individual risk vs. population size on chemical carcinogen regulations

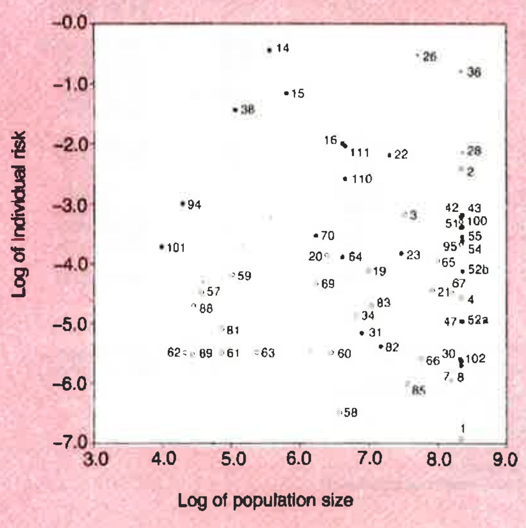


FIGURE 3

Effect of individual vs. population risk on chemical carcinogen regulation

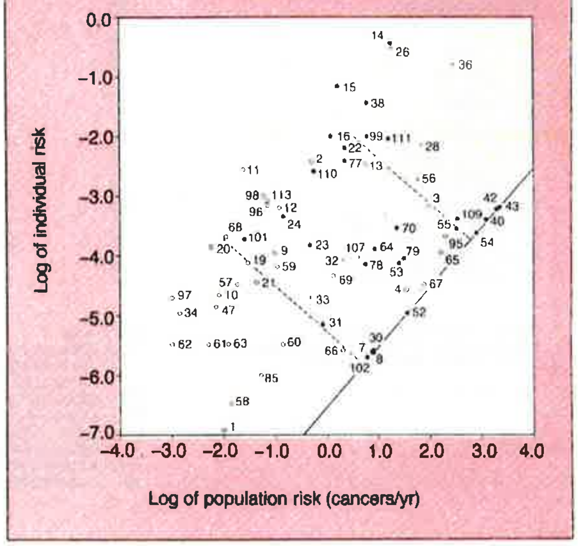


FIGURE 4
Effect of individual vs. population risk on chemical carcinogen regulation

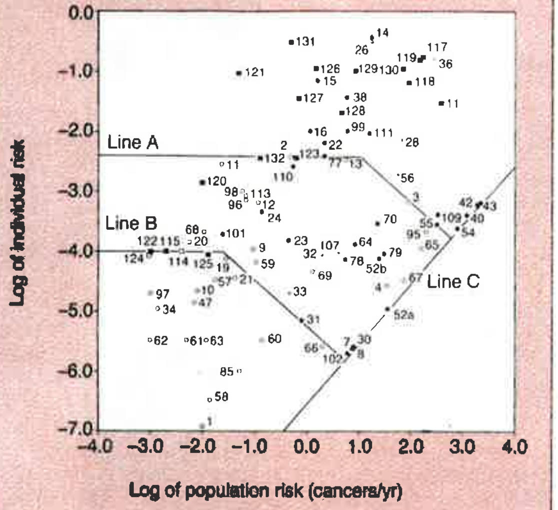
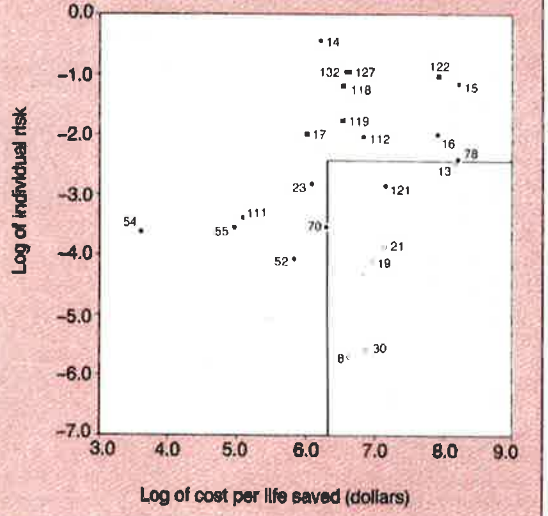


FIGURE 5
Effect of cost on the regulation of chemical carcinogens



agencies for not regulating chemicals in the de minimis category of risk? Second, what justification is given for regulatory decisions involving chemicals in the region between the de manifestis and de minimis levels? The primary answer given by federal agencies to the first question, as defined in Figure 4, is insignificant population risk. Table 2 shows those regulatory decisions that cited insufficient risk as the reason not to regulate. EPA's most explicit statement on the use of population effects in setting acceptable levels of risk is found in its decision on radionuclide standards (Table 1, Numbers 96–99).

In declining to regulate natural radionuclide emissions from elemental phosphorus plants (with an individual risk of 1×10^{-3}), the EPA decision states, "If risk to the most exposed individuals were the only criterion for judgment, this relatively high risk might well have led to a decision to regulate. However, this risk must be weighted against both the low aggregate risk [0.06 cancer deaths per year] and against other factors," such as cost (*3*).

Only two decisions in the de minimis region of Figure 4 consider factors other than small-population risk. Arsenic emissions from zinc smelters and benzene emissions from storage vessels are regulated by Section 112 of the Clean Air Act, the enforcement of which is heavily influenced by available technology. At the time of regulation, these two sources were already controlled with the best available technology (BAT), and further regulation could have resulted in shutdown of the industry (*4, 5*).

Analysis of regulatory decisions involving chemicals in the region between the de manifestis and de minimis levels indicates that cost effectiveness is the primary determinant of regulation. Figure 5 shows the cost effectiveness (cost per life saved) of regulating exposures to 23 chemicals vs. their preregulatory individual lifetime risk. Substances with individual risks above the de manifestis level were regulated regardless of cost.

In the region between the de manifestis and de minimis levels, substances with risk reduction costs of less than \$2 million per life saved were regulated; substances that cost more were not regulated. This conclusion is based on limited data, but it is consistent with EPA guidance suggesting that regulation is warranted if the cost per life saved does not exceed \$1.5 million (*6*).

The two major factors that influence the magnitude of cost, and by extension the decision to regulate, are the availability of substitutes (for example, decisions 8 and 30) and whether emissions currently are controlled by BAT (for example, decisions 9–13 and 19–21).

In reviewing the regulatory decisions of the past decade, two trends are apparent. First, there is an increased use of quantitative risk analysis, which extrapolates animal data to humans. Between 1976 and 1980, quantitative risk analysis was used in regulatory decisions involving only eight chemicals; from 1981 to 1985 the number of decisions increased to 53. Second, there are indications that the definition of de minimis is changing.

Prior to 1980, it was generally agreed that the de minimis risk was 10^{-6} per lifetime risk, regardless of population. Figure 4 indicates that for small-population risks, the de minimis risk is now considered to be a 10^{-4} lifetime risk. However, every decision in the de minimis region of Figure 4 was made after 1983.

Regulatory guidelines

The Environmental Protection Agency has specifically requested assistance in developing a quantitative rule for incorporating population risk into the decision-making process (*7*). EPA has suggested a de minimis individual lifetime risk level of 10^{-5} to 10^{-4} for small populations and 10^{-7} to 10^{-6} for large populations. Although no such explicit standard has been developed, we can see that there are simple rules that can be used to guide regulatory decisions. These guidelines incorporate individual risk, population risk, and cost effectiveness into a single framework, even though it is recognized that no absolute rules are possible.

Guideline 1. There is a de manifestis individual lifetime risk level that is a function of population risk, as shown in Line A of Figure 4. Above this level, regulatory action should be taken to reduce risk.

Guideline 2. There is a de minimis individual lifetime risk level that is a function of population risk, as shown in Line B of Figure 4. Below this line, regulatory action generally need not be taken.

Guideline 3. In the region between the de manifestis and de minimis levels, regulatory action should be taken if the

TABLE 2
Decisions citing insignificant population risk as the reason not to regulate

Chemical	Individual risk	Population risk (cancer/yr)	Agency comments
Arsenic			
Zinc oxide	3×10^{-3}	0.02	*Total cancer incidence, even on a national basis, is likely to be small compared to the incidence associated with smoking and diet.*
Secondary lead smelters	3×10^{-3}	6	
Primary lead smelters	1×10^{-4}	0.1	
Chemical manufacturing	6×10^{-4}	0.1	
Zinc smelters	2×10^{-5}	0.008	
Radionuclides			
Elemental phosphorus	1×10^{-3}	0.06	*This risk [10^{-3} individual risk] must be weighed against both the low aggregate risk and against other factors.*
Vinylidene chloride	8×10^{-4}	0.07	*Magnitude of the public health risk is small.*
Radionuclides			
Department of Energy facilities	7×10^{-4}	0.07	*[Population impact] insufficient to warrant regulation.*
Nuclear Regulatory Commission, non-DOE	2×10^{-5}	0.001	
Formaldehyde			
Teachers	7×10^{-5}	0.1	*[Population risk below one cancer risk per year, which is] insignificant risk of widespread harm.*
Students	3×10^{-6}	0.001–0.1	
Chlorinated benzenes	1×10^{-5}	0.007	*Health risk is not sufficient to warrant regulation.*
Epichlorohydrin	1×10^{-5}	0.001	*Relatively low aggregate risk.*

cost is below $2 million per life saved.

These guidelines have significant implications, for example, concerning remedial action at hazardous-waste sites. Most such sites pose risk to only a limited geographic area, where population risks presumably are small. Past regulatory actions by EPA indicate that 10^{-4} would be the de minimis risk level for these areas.

Perhaps the most surprising aspect of our study is the consistency found among federal agencies' methods in the use of cancer risk estimates for regulatory decisions. With the possible exception of FDA decisions concerning de minimis risks, the history of federal decision making indicates that all agencies are fairly consistent in their implicit definitions of de manifestis and de minimis levels of risk. If the above three guidelines were adopted explicitly, consistency with past decisions would be maintained and the process of regulatory decision making would be simplified considerably.

Acknowledgment

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(1) Milvey, P. *Risk Anal.* **1986,** *6,* 69–79.
(2) Byrd, D. M.; Lave L. B. In *De Minimis Risk;* Whipple, C. G., Ed.; Plenum: New York, in press.
(3) *Fed Regist.* **1983,** *49,* 43906.
(4) *Fed Regist.* **1982,** *48,* 33112.
(5) *Fed Regist.* **1983,** *49,* 8386.
(6) "Guidelines for Performing Regulation Impact Analysis," EPA 230/01-84-0003; EPA: Washington, D.C., 1983.
(7) *Fed Regist.* **1985,** *51,* 1602.

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Regulatory Impact Analysis: A Primer

With this document, the Office of Information and Regulatory Affairs is providing a primer to assist agencies in developing regulatory impact analyses (RIAs), as required for economically significant rules by Executive Order 13563, Executive Order 12866, and OMB Circular A-4.[1]

In accordance with those requirements, agencies should include the information described below in their RIAs. This primer is limited to the requirements of Executive Order 13563,[2] Executive Order 12866,[3] and Circular A-4[4]; it does not address requirements imposed by other authorities, such as the National Environmental Policy Act, the Regulatory Flexibility Act, the Unfunded Mandates Reform Act, the Paperwork Reduction Act, and various Executive Orders that require analysis. Executive Order 13563, Executive Order 12866, and Circular A-4, as well as those other authorities, should be consulted for further information.

The purpose of this primer is to offer a summary of the requirements of OMB Circular A-4. The primer is not meant to be a substitute for the more detailed description in that Circular. Nothing in this primer is intended to alter existing requirements or policy.

Contents

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[1] Agencies may also find "Regulatory Impact Analysis: Frequently Asked Questions" (http://www.whitehouse.gov/sites/default/files/omb/circulars/a004/a-4_FAQ.pdf) and "Agency Checklist: Regulatory Impact Analysis" (http://www.whitehouse.gov/sites/default/files/omb/inforeg/regpol/RIA_Checklist.pdf), helpful as well.

[2] Available at: http://www.reginfo.gov/public/jsp/Utilities/EO_13563.pdf

[3] Available at: http://www.reginfo.gov/public/jsp/Utilities/EO_12866.pdf

[4] Available at: http://www.whitehouse.gov/sites/default/files/omb/assets/omb/circulars/a004/a-4.pdf

A. Introduction

Executive Orders 13563 and 12866 require agencies to provide to the public and to OMB a careful and transparent analysis of the anticipated consequences of economically significant regulatory actions. This analysis includes an assessment and (to the extent feasible) a quantification and monetization of benefits and costs anticipated to result from the proposed action and from alternative regulatory actions. Executive Order 13563 specifically requires agencies "to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible."

The purpose of the RIA is to inform agency decisions in advance of regulatory actions and to ensure that regulatory choices are made after appropriate consideration of the likely consequences. To the extent permitted by law, agencies should proceed only on the basis of a reasoned determination that the benefits justify the costs (recognizing that some benefits and costs are difficult to quantify). Regulatory analysis also has an important democratic function; it promotes accountability and transparency and is a central part of open government.

Important goals of regulatory analysis are (1) to establish whether federal regulation is necessary and justified to achieve a social goal and (2) to clarify how to design regulations in the most efficient, least burdensome, and most cost-effective manner. To that end, Executive Orders 13563 and 12866 require agencies to consider a range of regulatory alternatives, including the option of not regulating, and to design their regulations in the most cost-effective manner to achieve the regulatory objective. Agencies should select the alternative that maximizes net benefits, while also taking into consideration distributive impacts and qualitative benefits and costs, unless a statute requires another approach.

B. Key Elements of a Regulatory Impact Analysis

An RIA should include the following three basic elements:

A statement of the need for the regulatory action: An analysis should begin with a clear explanation of the need for the regulatory action, including a description of the problem that the agency seeks to address. Agencies should explain whether the action is intended to address a market failure or to promote some other goal, such as improving governmental processes, protecting privacy, or combating discrimination. If the action is compelled by statute or judicial directive, agencies should describe the specific authority and the extent of discretion permitted.

A clear identification of a range of regulatory approaches: If an agency has decided that Federal regulation is appropriate, it should identify and include in its RIA a range of alternative regulatory approaches, including the option of not regulating. Alternatives to Federal regulation include State or local regulation, voluntary action on the part of the private sector, antitrust enforcement, consumer-initiated litigation in the product liability system, and administrative compensation systems. Where relevant, agencies should consider flexible approaches that reduce burdens and maintain freedom of choice, such as warnings, appropriate default rules, and disclosure requirements. To the extent feasible, agencies should specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt.

An estimate of the benefits and costs—both quantitative and qualitative—of the proposed regulatory action and its alternatives: After identifying a set of potential regulatory approaches, the agency should conduct a benefit-cost analysis that estimates the benefits and costs associated with each alternative approach. The benefits and costs should be quantified and monetized to the extent possible, and presented in both physical units (e.g., number of illnesses avoided) and monetary terms. When quantification of a particular benefit or cost is not possible, it should be described qualitatively. The analysis of these alternatives may also consider, where relevant and appropriate, values such as equity, human dignity, fairness, potential distributive impacts, privacy, and personal freedom.

The agency's analysis should be based on the best available scientific, technical, and economic information. To achieve this goal, the agency should generally rely on peer-reviewed literature, where available, and provide the source for all original information. In cases of particular complexity or novelty, the agency should consider subjecting its analytic models to peer review.[5] In cases in which there is no reliable data or research on relevant issues, the agency should consider developing the necessary data and research. In addition, the agency should comply with the Information Quality Guidelines for the agency and with OMB's "Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies."[6] Executive Order 13563 also provides that "[c]onsistent with the President's Memorandum for the Heads of Executive Departments and Agencies, 'Scientific Integrity' (March 9, 2009), and its implementing guidance, each agency shall ensure the objectivity of any scientific and technological information and processes used to support the agency's regulatory actions."

The agency should clearly document all of the assumptions and methods used in the analysis, discuss the uncertainties associates with estimates, and publicly provide the supporting data and underlying analysis (if possible on the Internet; see Executive Order 13563, section 2 (b)), so that a qualified third party reading the analysis could understand and reproduce the analysis. Regulatory analysis should also include a clear, plain language executive summary, including a table, that summarizes the benefit and cost estimates for each regulatory action and alternative under consideration, including the qualitative and non-monetized benefits and costs.[7]

C. Preparing a Regulatory Impact Analysis

This section provides a step-by-step guide to preparing an RIA. The three key elements discussed in the previous section are important; this section focuses primarily on the benefit and

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[5] For additional discussion, see OMB's "Final Information Quality Bulletin for Peer Review", available at: http://www.whitehouse.gov/sites/default/files/omb/assets/omb/fedreg/2005/011405_peer.pdf

[6] Available at http://www.whitehouse.gov/omb/fedreg_reproducible/

[7] For additional discussion, see 2010 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities, page 51. Available at: http://www.whitehouse.gov/sites/default/files/omb/legislative/reports/2010_Benefit_Cost_Report.pdf

cost assessment of regulatory alternatives required by Executive Order 13563, Executive Order 12866, and Circular A-4.

Benefit -cost analysis (BCA) provides a systematic framework for evaluating the likely outcomes of alternative regulatory choices. It allows agencies to evaluate different regulatory options with a variety of attributes using a common measure – a monetary unit. When important benefits and costs cannot be expressed in monetary units or quantified in any manner, the BCA can provide useful information about the relative merits of regulatory alternatives, but the "net benefits" estimate, viewed in isolation, may be incomplete and misleading.

To provide a complete RIA, agencies should follow these steps:

- Describe the need for the regulatory action
- Define the baseline
- Set the timeframe of analysis
- Identify a range of regulatory alternatives
- Identify the consequences of regulatory alternatives
- Quantify and monetize the benefits and costs
- Discount future benefits and costs
- Evaluate non-quantified and non-monetized benefits and costs
- Characterize uncertainty in benefits, costs, and net benefits

Below we provide additional information for each of these steps.

Step 1: Describe the need for the regulatory action

As discussed in the previous section, an analysis should begin with a reasonably detailed description of the need for the regulatory action and should include an explanation of how the regulatory action will meet that need. The RIA should explain whether the action is intended to address a significant market failure (e.g., externality, market power, and inadequate or asymmetric information) or to meet some other compelling public need such as improving governmental processes or promoting values such as privacy or human dignity. If the regulation is designed to correct a significant market failure, the RIA should describe the failure both qualitatively and (where feasible) quantitatively. If a regulation is required by statute or judicial directive, the RIA should clearly explain the specific authority, extent of agency discretion, and permissible regulatory instruments.

Step 2: Define the Baseline

The baseline represents the agency's best assessment of what the world would be like absent the action. To specify the baseline, the agency may need to consider a wide range of factors and should incorporate the agency's best forecast of how the world will change in the future, with particular attention to factors that affect the expected benefits and costs of the rule. For example, population growth, economic growth, and the evolution of the relevant markets should all be taken into account. For regulations that largely restate statutory requirements, the analysis should use a pre-statutory baseline. For analyses supporting modifications to an existing regulation, a baseline assuming no change in the regulatory program generally provides an appropriate basis for evaluating regulatory alternatives.

The analysis should focus on benefits and costs that accrue to citizens and residents of the United States. Where the agency chooses to evaluate a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately.

Step 3: Set the Time Horizon of Analysis

When choosing the appropriate time horizon for estimating benefits and costs, agencies should consider how long the regulation being analyzed is likely to have economic effects. The time frame for the analysis should cover a period long enough to encompass all the important benefits and costs likely to result from the rule. However, the agency should also consider for how long it can reasonably predict the future and should limit its analysis to that time period. Thus, if a regulation has no predetermined sunset provision, the agency will need to choose the endpoint of its analysis based on the foreseeable future or the agency's ability to forecast reliably. For rules that require large up-front capital investments, the life of the capital is also an option.

Step 4: Identify a Range of Regulatory Alternatives

The agency should consider a range of potentially effective and reasonably feasible regulatory alternatives. The relevant alternatives might involve different approaches, with distinct advantages and disadvantages. In considering which alternatives to discuss, an agency should reasonably explore which approaches are feasible and plausible ways of meeting the regulatory objective. An agency should give particular attention to identifying and assessing flexible regulatory approaches, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public.

Consistent with Executive Order 13563, section 4, an agency might consider flexible approaches that maintain freedom of choice. If, for example, an agency is considering banning the sale of a potentially unsafe product, it might consider instead requiring disclosure of health risks to the public. Once an agency identifies the least burdensome tool for achieving its regulatory objective, measuring the incremental benefits and costs of successively more stringent regulatory alternatives will allow an agency to identify the alternative that maximizes net benefits.

Agencies should consider any of the following, alone or in combination, to develop regulatory alternatives:

- *Deferral to state or local regulation.* Agencies should consider the option of deferring to regulation at the State or local level. To be sure, problems that affect interstate commerce or spill across State lines may best be addressed by Federal regulation. But more localized problems may be more efficiently addressed locally. In such situations, deferring to state and local regulation can encourage regulatory experimentation and innovation while also fostering learning and competition to establish the best regulatory policies.

- *Market-oriented approaches rather than direct controls.* Agencies should consider market-oriented regulatory approaches that use economic incentives to achieve regulatory goals and that afford entities greater flexibility in compliance. Such approaches include fees, penalties, subsidies, marketable permits or offsets, changes in liability rules or property rights, and required bonds, insurance, or warranties. In the domain of environmental protection, for example, emissions trading may deserve careful consideration as an approach that might achieve the same gain at a significantly lower cost.
- *Performance standards rather than design standards.* Performance standards express requirements in terms of outcomes, for example requiring achievement of a particular emissions level. By contrast, design standards specify the means to achieve those outcomes, for example requiring installation of a particular emissions control technology. Because they allow firms to have the flexibility to choose the most cost-effective methods for achieving the regulatory goal, and create an incentive for innovative solutions, performance standards are generally preferred to design standards.
- *Informational Measures.* If intervention is contemplated to address a market failure that arises from inadequate or asymmetric information or poor information processing, informational remedies will often be preferred. To the extent feasible, specific informational measures should be evaluated with reference to their benefits and costs.
- *Default rules rather than mandates.* Agencies should consider whether default rules are a better instrument than mandates for achieving regulatory objectives. If, for example, there is significant heterogeneity in the relevant population, a default rule may be preferable to a mandate because it allows people to act in ways that are suited to their own situations.
- *Enforcement Methods.* Alternative monitoring (e.g., Federal, State, or local authorities) and reporting methods (e.g., on-site inspections, periodic reporting, and noncompliance penalties) may vary in their benefits and costs.
- *Stringency.* Typically both the benefits and costs associated with a regulation will increase with the level of stringency. Agencies should study alternative levels of stringency to determine the level that maximizes net benefits.
- *Compliance dates.* The timing of a regulation can have an important effect on its net benefits. Agencies should consider various possible compliance dates, because (for example) a later date might, in some circumstances, promote predictability and significantly reduce compliance costs without greatly reducing benefits.
- *Requirements based on firm size.* If the expected costs or the expected benefits of compliance vary based on firm size, different requirements for large and small firms, based on these estimated differences, may be appropriate. Greater flexibility for small business, in the form of delayed compliance dates or partial or total exemptions, is worth careful consideration. At the same time, agencies should consider whether such differences in regulatory treatment provide one group of firms with a competitive advantage over others, create artificial incentives to keep firm sizes small (and thus deter hiring), or lead to foregone benefits that exceed the cost savings to exempted firms.

- *Requirements based on geographic regions.* Where there are significant regional variations in benefits and/or costs, agencies should consider setting different requirements for different regions to maximize net benefits.

At a minimum, agencies should compare, with their preferred option, a more stringent and less stringent alternative, and assess the benefits and costs of the three possibilities, with careful consideration of which achieves the greatest net benefits. And when the preferred option includes a number of distinct provisions, the benefits and costs of different regulatory provisions should be analyzed separately in order to facilitate consideration of the full range of potential alternatives.

Step 5: Identify the Consequences of Regulatory Alternatives

Benefits and costs. Agencies should identify the potential benefits and costs for each alternative and its timing. It may be useful to identify the benefits and costs in the following manner:

- Benefits and costs that can be monetized, and their timing;
- Benefits and costs that can be quantified, but not monetized, and their timing;
- Benefits and costs that cannot be quantified.

In addition to the direct benefits and costs of each alternative, the list should include any important ancillary benefits and countervailing risks. An ancillary benefit is a favorable impact of the alternative under consideration that is typically unrelated or secondary to the purpose of the action (e.g., reduced refinery emissions due to more stringent fuel economy standards for light trucks). A countervailing risk is an adverse economic, health, safety, or environmental consequence that results from a regulatory action and is not already accounted for in the direct cost of the action (e.g., adverse safety impacts from more stringent fuel-economy standards for light trucks). As with other benefits and costs, an effort should be made to quantify and monetize both ancillary benefits and countervailing risks.

Distributional effects. Those who bear the costs of a regulation and those who enjoy its benefits often are not the same people. The term "distributional effect" refers to the impact of a regulatory action across the population and economy, divided up in various ways (e.g., income groups, race, sex, industrial sector, geography).

The regulatory analysis should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers can properly consider them along with the effects on economic efficiency (i.e., net benefits). Executive Order 13563 and Executive 12866 authorize this approach. Where distributive effects are thought to be important, the effects of various regulatory alternatives should be described quantitatively to the extent possible, including the magnitude, likelihood, and severity of impacts on particular groups.

Examples of distributional effects that could potentially be quantified include:

- Health benefits that accrue principally to low-income groups
- Regulatory costs that are imposed principally on low-income groups
- Reductions in sales by one business that are matched by increases in sales by another (transfer in economic activity from one business to another)
- Reductions in well-being for some consumers that are matched by increases for others (transfer of well-being among consumers)

Transfer payments. Distributional effects may arise through "transfer payments" that stem from a regulatory action as well. Transfer payments are monetary payments from one group to another that do not affect total resources available to society. For example, transfers payments include revenue collected through a fee, a surcharge in excess of the cost of services provided, and a tax.

Distinguishing between real costs and transfer payments is an important, but sometimes difficult, problem in cost estimation. A stylized example may help to clarify. Consider a regulation that taxes an air pollutant that is harmful to human health and is a by-product of some manufacturing process. In response to the tax, firms modify their manufacturing process to reduce (but not eliminate) the pollutant. The benefits of the regulation are reductions in premature death, illness, and disability resulting from the decreased emission of the regulated pollutant, as well as benefits to ecosystems, improvements in visibility, and so on. The cost of the regulation is equal to the cost to firms of modifying their production process (e.g., purchasing abatement technology). The taxes paid on the pollutant by the firm to the government are a transfer and have no effect on the net benefits of the regulation.

Examples of costs include:

- Goods and services required to comply with the regulation
- Reductions in consumer and producer well-being due to regulation-induced price or quantity changes
- Increases in premature death, illness, or disability (e.g., in the case where a regulatory proposal that would reduce certain safety and/or health risks would also have the consequence of increasing other safety and/or health risks).

Examples of transfer payments include:

- Changes in sales tax revenue due to changes in sales (monetary transfers from consumers to government)
- Payment by the Federal government for goods or services provided by the private sector (monetary transfers to the government to service providers, such as reimbursements by the Medicare program)
- Fees to government agencies for goods or services provided by the agency (monetary transfers from fee payers to the government—the goods and services are already counted as government costs and including them as private costs would entail double counting)

Step 6: Quantify and Monetize the Benefits and Costs

The agency should use the best reasonably obtainable scientific, technical, economic, and other information to quantify the likely benefits and costs of each regulatory alternative. Presenting benefits and costs in physical units in addition to monetary units will improve the transparency of the analysis. For example, the benefits of a regulation that reduces emissions of air pollution might be quantified in terms of the number of premature deaths avoided each year; the number of prevented nonfatal illnesses and hospitalizations; the number of prevented lost work or school days; improvements in visibility in specific regions; and improvements in ecosystem health as measured by specific indicators (e.g. lake acidification). Some costs – such as countervailing risks – may also be quantified in similar terms before they are turned into monetary equivalents.

As discussed in greater detail below, the agency should, to the extent feasible, estimate the monetary value of the benefits and costs of each regulatory alternative considered. Both benefits and costs are measured by the value that individuals place on the change resulting from a particular regulatory alternative. This value is typically and most easily measured in terms of the amount of money the individual would pay ("willingness to pay" (WTP)) or require as compensation ("willingness to accept" (WTA)), so that the individual is indifferent between the current state of the world (baseline), on the one hand, and the consequences of the regulatory alternative along with the monetary payment, on the other hand.

To the extent possible, agencies should estimate people's valuations of benefits and costs using revealed preference studies based on actual behavior. Revealed preference methods develop estimates of the value of goods and services — or attributes of those goods and services — based on actual market decisions by consumers, workers, and other market participants. If the market participant is well-informed and confronted with a real choice, and properly processes information, it may be feasible to determine accurately and precisely the monetary value of the changes associated with an alternative.

If the goods or attributes of goods that are affected by regulation — such as preserving environmental or cultural amenities — are not traded in markets, it may be difficult to use revealed preference methods. In such cases, the value of the goods or attributes may arise both from use and non-use. "Use values" arise where an individual derives satisfaction from using the resource, either now or in the future, for example by living in or moving to a neighborhood with clean air or water. "Non-use values" arise where an individual places value on a resource, good, or service even though the individual will not use the resource, now or in the future, for example by valuing wildlife in remote areas.

In the absence of an organized market, it is difficult to estimate use and non-use values. When studies are designed to elicit such values either though indirect market studies or stated preference methods, agencies should pay careful attention to characterization of the uncertainties. However, overlooking or ignoring these values may significantly understate the benefits and/or costs of regulatory action.

Agencies should include the following effects, where relevant, in their analysis and provide estimates of their monetary values:

- Private-sector compliance costs and savings;
- Government administrative costs and savings;
- Gains or losses in consumers' or producers' surpluses;
- Discomfort or inconvenience benefits and costs; and
- Gains or losses of time in work, leisure, and/or commuting/travel settings.

To improve the transparency of the analysis, monetary values of distinct benefits and costs should be presented separately, in addition to being summed and presented as total benefits and total costs.

Considerations in monetizing health and safety effects

In monetizing health and safety benefits, the agency should use the WTP measure (or, if appropriate, the WTA measure), rather than other alternatives (e.g., avoided cost of illness or avoided lost earnings). This is because WTP/WTA attempts to capture pain and suffering and other quality-of-life effects.

When monetizing nonfatal health effects, the agency should consider two factors: (1) the private demand for prevention of the nonfatal health effect, to be represented by the preferences of the target population at risk and (2) the net financial externalities associated with poor health, such as net changes in public medical costs and any net changes in economic production that are not experienced by the target population. Revealed-preference or stated-preference studies are necessary to estimate the private demand; health economics data from published sources can typically be used to estimate the financial externalities caused by changes in health status. If an agency uses literature values to monetize nonfatal health and safety risks, it is important to make sure that the values selected are appropriate for the severity and duration of health effects to be addressed by the alternative under consideration.

Since agencies often design health and safety regulation to reduce risks to life, evaluation of the benefits of reducing fatality risks can be the key part of the analysis. The goal of this analysis is to monetize the value of small changes in fatality risk – a measurement of WTP for reductions in only small risks of premature death. This concept is commonly referred to as the "value of statistical life" (VSL).[8] A considerable body of academic literature is available on this subject. Current agency practice provides a VSL ranging from roughly $5 million to $9 million per statistical life.

Another approach to express reductions in fatality risks is to use the life expectancy method, the "value of statistical life-years (VSLY) extended." If a regulation protects individuals whose average remaining life expectancy is 40 years, a risk reduction of one fatality is expressed as "40

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[8] The term "value of life" is sometimes used to describe this concept. However, this term can be misleading because it suggests, erroneously, that the monetization exercise tries to place a "value" on individual lives. Use of VSL should not suggest that the value of any individual's life can be expressed in monetary terms. The sole purpose is to help estimate the likely benefits of a regulatory action that reduces the risks that people face.

life-years extended." Those who favor this alternative approach emphasize that the value of a statistical life is not a single number relevant for all situations. In particular, when there are significant differences between the effect on life expectancy for the population affected by a particular health risk and the populations studied in the labor market studies, they prefer to adopt a VSLY approach to reflect those differences. It is appropriate to consider providing estimates of both VSL and VSLY, while recognizing the developing state of knowledge in this area.

Step 7: Discount Future Benefits and Costs

The benefits and costs of a regulatory action typically take place in the future. Moreover, benefits and costs may not be distributed across time in the same manner. For example, a common challenge in evaluating alternatives that have health-related consequences is to quantify the time lag between when an action would take effect and when the resulting change in health status will be observed.

To provide an accurate assessment of benefits and costs that occur at different points in time or over different time horizons, an agency should use discounting. Agencies should provide benefit and cost estimates using both 3 percent and 7 percent annual discount rates expressed as a present value as well as annualized. These are "real" interest rates that should be used to discount benefits and costs measured in constant dollars. Unlike typical market interest rates, real rates exclude the expected rate of future price inflation.

The 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy, based on historical data. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital. It approximates the opportunity cost of capital, and it is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector.

The 3 percent discount rate is based on a recognition that the effects of regulation do not always fall exclusively or primarily on the allocation of capital. When regulation primarily and directly affects private consumption, a lower discount rate is appropriate. The alternative most often used is sometimes called the "social rate of time preference." This term simply means the rate at which "society" discounts future consumption flows to their present value. If one assumes the rate that the average saver uses to discount future consumption is a measure of the social rate of time preference, the real rate of return on long-term government debt may provide a fair approximation. Over the last thirty years, this rate has averaged around 3 percent in real annual terms on a pre-tax basis.

Special considerations arise when comparing benefits and costs across generations. Although most people demonstrate time preference in their own consumption behavior, it may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. Future citizens who are affected by such choices cannot take part in making them, and today's society must act with due consideration of their interests. Many people have argued for a principle of intergenerational neutrality, which would mean that those in the present generation would not treat those in later generations as worthy of less concern. Discounting the welfare of future generations at 7 percent or even 3 percent could create serious ethical problems.

An additional reason for discounting the benefits and costs accruing to future generations at a lower rate is the longer the horizon for the analysis, the greater the uncertainty about the appropriate value of the discount rate. Private market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist. As several economists (including Martin Weitzman[9]) have explained, for the very distant future, the properly averaged discount factor corresponds to the minimum discount rate having any substantial positive probability.

At the same time, some economists have cautioned that using a zero discount rate could raise intractable analytical problems. They have argued that with zero discounting, even a small improvement in welfare, if permanent, would justify imposing any cost on current generations since the benefits would be infinite.

If the regulatory action will have important intergenerational benefits or costs, the agency might consider a sensitivity analysis using a lower but positive discount rate, ranging from 1 to 3 percent, in addition to calculating net benefits using discount rates of 3 percent and 7 percent.

Step 8: Evaluate Non-quantified and Non-monetized Benefits and Costs

Sound quantitative estimates of benefits and costs, where feasible, are preferable to qualitative descriptions of benefits and costs because they help decision-makers to understand the magnitudes of the effects of alternative actions and compare across different types of consequences. However, some important benefits and costs (e.g., protection of human dignity, equity, or privacy, see Executive Order 13563, section 1(c)) may be difficult or impossible to quantify or monetize given current data and methods. Agencies should carry out a careful evaluation of non-quantifiable and non-monetized benefits and costs.

Benefits and costs that are difficult to monetize. If monetization is not possible, the agency should explain why and present all available quantitative information. For example, an agency may not be able to monetize a benefit in terms of privacy or dignity, but it may be able to quantify the number of beneficiaries. Alternatively, an agency may be able to quantify, but not to monetize, increases in water quality and fish populations resulting from water quality regulation. If so, the agency should attempt to describe benefits in terms of (for example) stream miles of improved water quality for boaters and increases in game fish populations for anglers. When estimates of monetized effects and quantified physical effects are mixed in the same analysis, the agency should describe the timing and likelihood of such effects, and should avoid double-counting of effects.

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[9] Weitzman ML In Portney PR and Weyant JP, eds. (1999), *Discounting and Intergenerational Equity*, Resources for the Future, Washington, DC.

Benefits and costs that are difficult to quantify. If the agency cannot quantify a benefit or cost, the agency should explain why and present any available quantitative information. For example, the agency may not be able to quantify the number of individuals exposed to a risk but may be able to quantify the magnitude of the risk to those who are exposed. The agency should also provide a detailed qualitative description of any unquantified effects, such as ecological gains, improvements in quality of life, and aesthetic beauty. The agency should provide a discussion of the strengths and limitations of the qualitative information.

When the unquantified benefits or costs affect a policy choice, the agency should provide a clear explanation of the rationale behind the choice. Such an explanation could include detailed information on the nature, timing, likelihood, location, and distribution of the unquantified benefits and costs. The agency should include a summary table that lists all significant unquantified benefits and costs, highlighting (e.g., with categories or rank ordering) those that the agency believes are most important (e.g., by considering factors such as the degree of certainty, expected magnitude, and reversibility of effects).

Breakeven analysis. When quantification and monetization are not possible, many agencies have found it both useful and informative to engage in threshold or "breakeven" analysis. This approach answers the question, "How large would the value of the non-quantified benefits have to be for the rule to yield positive net benefits?" Suppose, for example, that a regulation that protects water quality costs $105 million annually, and that it also has significant effects in reducing pollution in rivers and streams. It is clear that the benefits of the regulation would exceed its costs if and only if those effects could reasonably be valued at $105 million or more. Once the nature and extent of the water quality benefits are understood, it might well be easy to see whether or not the benefits plausibly exceed the costs – and if the question is difficult, at least it would be clear why it is difficult. Breakeven analysis is an important tool, and it can provide insights when quantification is speculative or impossible.[10]

Cost-effectiveness analysis. Cost-effectiveness analysis (CEA) can provide a helpful way to identify options that achieve the most effective use of the available resources (without requiring monetization of all of the relevant benefits and costs). Generally, cost-effectiveness analysis is designed to compare a set of regulatory actions with the same primary outcome (e.g., an increase in the acres of wetlands protected) or multiple outcomes that can be integrated into a single numerical index (e.g., units of health improvement). This approach provides useful information about relative performance of regulatory alternatives (i.e., best 'bang for the buck'). At the same time, a comparison of monetized benefits and costs is necessary to determine which alternative maximizes net benefits.

When CEA is applied to public health and safety rulemakings, a measure of effectiveness must be selected that permits comparison of regulatory alternatives. Agencies currently use a variety of effectiveness measures. There are relatively simple measures such as the number of lives saved, cases of cancer reduced, or cases of paraplegia prevented. Sometimes these measures

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[10] For additional discussion, see *2011 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*, page 66-67. Available at: http://www.whitehouse.gov/sites/default/files/omb/inforeg/2011_cb/2011_cba_report.pdf

account only for mortality information, such as the number of lives saved and the number of years of life saved. There are also more comprehensive, integrated measures of effectiveness such as the number of "equivalent lives" (ELs) saved and the number of "quality-adjusted life years" (QALYs) saved. While OMB does not require agencies to use any specific measure of effectiveness, an Institute of Medicine report recommends that agencies use QALYs for all health and safety issues.[11] In any event, the regulatory analysis should explain why a measure was selected and how it was implemented.

Step 9: Characterize uncertainty in benefits, costs, and net benefits

Regulatory analysis requires forecasts about the future. What the future holds, both in the baseline and under the regulatory alternative under consideration, is typically not known for certain. The important uncertainties connected with the regulatory decision should be analyzed and presented as part of the overall regulatory analysis. The goal of the agency's uncertainty analysis is to present both a central "best estimate," which reflects the expected value of the benefits and costs of the rule, as well as a description of the ranges of plausible values for benefits, costs, and net benefits, which informs decision-makers and the public of the degree of uncertainty associated with the regulatory decision.

In developing an uncertainty analysis, agencies should follow these steps:

> *Specify potential scenarios*. As a first step, the agency should specify a set of plausible, mutually exclusive *scenarios* for both the baseline and for each regulatory alternative. Each scenario represents a complete description of a state of the world, including its evolution through time, that could arise. The goal is to specify scenarios that cover the full range of how the benefits and costs of the rule might vary. Typically this is done by specifying the set of factors that affect the benefits and costs of the regulatory alternatives.
>
> *Calculate the benefits and costs associated with each scenario.* Once the set of plausible scenarios has been specified, the agency can calculate the benefits and costs associated with each scenario. At this stage, the agency has all of the information it needs to conduct a *sensitivity analysis*. A sensitivity analysis examines how the benefits and costs of the rule change with key uncertain variables.
>
> *Construct a range of values.* When the agency cannot specify probabilities for the relevant scenarios, the agency should develop a central scenario for the baseline and for each regulatory alternative that reflects the agency's *best estimate* of the likely consequences of each regulatory alternative. The agency should use the benefits and costs of these best estimates to approximate the expected value of the benefits and costs of each regulatory alternative to use in its regulatory decision-making. The agency should also characterize ranges of *plausible* benefits, costs, and net benefits of each regulatory alternative. The goal is not to characterize the full range of *possible* outcomes, which

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[11] IOM (2006). Valuing Health for Regulatory Cost-Effectiveness Analysis. The National Academies Press, Washington, DC.

> may turn out to be extremely large, but rather the range of *plausible* outcomes as in a confidence interval. The agency must use its judgment on the range of scenarios that such ranges should reflect. At a minimum, the range should include a "high" and a "low" scenario that provide plausible upper and lower bounds.

The approach to constructing a range outlined above should be thought of as the minimal analysis that agencies should conduct. When feasible, agencies should also:

> *Assign probabilities and calculate expected values*. Having specified the set of plausible scenarios, the benefits and costs associated with each scenario, and the probabilities of each scenario, the agency should calculate expected values of the benefits and costs for each regulatory alternative. In these cases, where probability distributions can be assigned to each scenario, the agency should conduct a formal uncertainty analysis in which it characterizes the distributions of benefits, costs, and net benefits.

Circular A-4 requires formal quantitative analysis of uncertainty for rules that exceed the $1 billion annual threshold in benefits or costs.

D. Summarizing the Regulatory Analysis

Regulatory analysis should include a clear, plain language executive summary. The summary should include one or more tables that summarize the benefit and cost estimates for each regulatory action and alternative under consideration as well as the qualitative and non-monetized benefits and costs.[12] The summary should include:

- *Alternative regulatory approaches.* At a minimum, one or more tables should generally be used to report the benefits and costs of both the agency's preferred option and at least one alternative that is less stringent (i.e., lower cost) and one alternative that is more stringent (i.e., higher cost). For each of the regulatory alternatives, the agency should calculate benefits and costs relative to a common baseline.

- *Categories of benefits and costs.* The agency should categorize the benefits and costs into three mutually exclusive and exhaustive categories: (1) quantified and monetized; (2) quantified but not monetized; and (3) neither quantified nor monetized. The agency should not include any benefit or cost in more than one of these categories. For example, if the agency has monetized fatalities averted by an alternative, it should report the dollar value as part of the quantified and monetized benefits, and should avoid double-counting the number of "lives saved" in the quantified but not monetized benefits category. (Of

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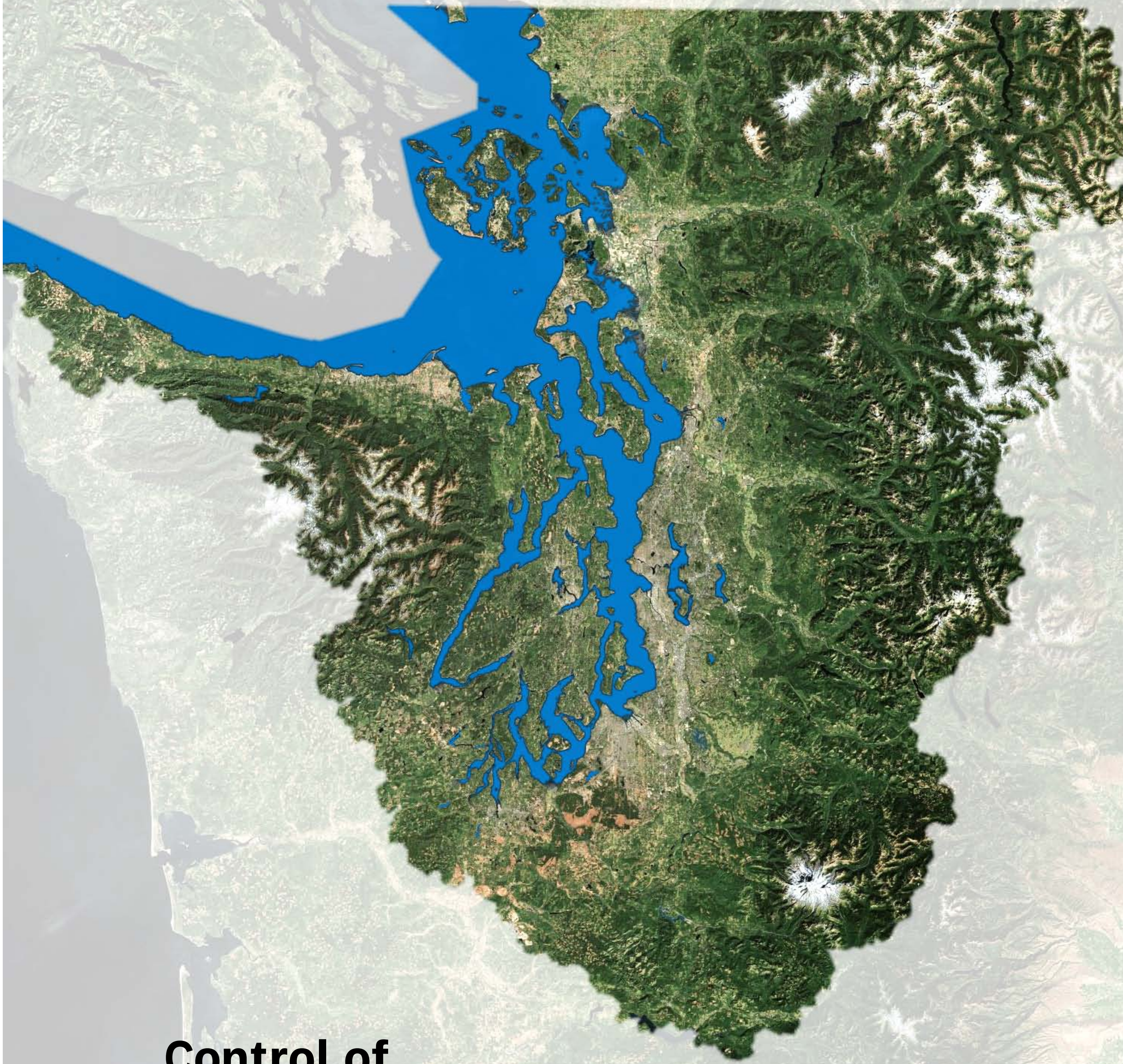
[12] Circular A-4 states: "…you should present a summary of the benefit and cost estimates for each alternative, including the qualitative and non-monetized factors affected by the rule, so that readers can evaluate them." (P.3) In addition, it states: "Your analysis should also have an executive summary, including a standardized accounting statement." (P. 3). It further states, "You need to provide an accounting statement with tables reporting benefit and cost estimates for each major final rule for your agency." (P. 44). Circular A-4 includes an example of a format for agency consideration.

course, the agency may also choose to report the monetized benefits in physical units, but should do so in a way that clearly avoids double-counting).

- *Separate reporting of distributional effects, including transfers.* The agency should report distributional effects, including transfers, separately and avoid the misclassification of transfer payments as benefits or costs.

- *Rank qualitative impacts.* The agency should categorize or rank the qualitative effects in terms of their importance (e.g., certainty, likely magnitude, and reversibility). The agency should distinguish the effects that are likely to be significant enough to warrant serious consideration by decision-makers from those that are likely to be minor.

- *Transparency.* The agency should add notes to the bottom of the tables that enable readers to interpret the information in the tables correctly. For example, when there is significant uncertainty to estimates, a caveat describing the nature of the uncertainty should be provided in the notes.



Control of Toxic Chemicals in Puget Sound

Characterization of Toxic Chemicals in Puget Sound and Major Tributaries, 2009-10

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Control of Toxic Chemicals in Puget Sound

Characterization of Toxic Chemicals in Puget Sound and Major Tributaries, 2009-10

by

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Olympia, Washington 98504-7710

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Abstract

The Washington State Department of Ecology (Ecology) is conducting a series of technical studies that will inform strategies to control sources of toxic chemicals to Puget Sound. The studies come under the umbrella of the Puget Sound Toxics Loading Analysis (PSTLA). Phases 1 and 2 of the PSTLA developed loading estimates for toxic chemicals and used computer model simulations to predict outcomes of control actions. Ongoing Phase 3 studies are intended to reduce uncertainties associated with chemical loadings and model predictions.

For the present study, Ecology collected seasonal water samples at seven ambient marine sites throughout Puget Sound and its ocean boundary waters, and from the mouths of the five largest rivers flowing into Puget Sound. Samples were analyzed for a wide range of inorganic and organic chemicals of concern.

Many chemicals were seldom or never detected in marine water samples, but concentrations of metals and polychlorinated biphenyls (PCBs) were similar to previously reported values. Concentrations of organic carbon, copper, and PCBs were higher in outgoing Puget Sound waters than in incoming ocean waters. The opposite was true for cadmium. Ocean exchange estimates indicated that most target chemicals of concern appear to be exported from Puget Sound to the ocean.

River water samples contained measurable concentrations of conventional parameters, nutrients, metals, and some organic compounds. Concentrations were generally within ranges previously reported. Petroleum-related compounds, semivolatile organic compounds (BNAs), polycyclic aromatic hydrocarbons (PAHs), and chlorinated pesticides were seldom detected. Daily loads calculated for many chemicals can be compared to estimated loads from other studies and model simulations.

Suspended particulate matter (SPM) was also collected from deep marine waters and river waters, and samples were analyzed for a suite of chemicals similar to those analyzed for water samples. Results from the Hood Canal and South Puget Sound basins were used to estimate loss rates of toxic chemicals from the water column via sedimentation. Toxic chemicals such as PAHs were more often detected in river SPM than in river water.

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The authors of this report thank the following people for contributions to this study:

- Members of the Puget Sound Toxics Loading Analysis Steering Committee
- Washington State Department of Ecology staff:
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    - Jeff Westerlund

Executive Summary

Introduction

The Washington State Department of Ecology (Ecology) is working in collaboration with the Puget Sound Partnership and other state and federal agencies on a multi-phase Puget Sound Toxics Loading Analysis (PSTLA). The purpose of the PSTLA is to quantify various sources of toxic contaminants entering Puget Sound and to better understand the behavior and fate of the contaminants within the ecosystem. Results of the PSTLA will form part of the technical basis for a comprehensive strategy to reduce and control toxic chemical releases to Puget Sound.

In Phase 1 of the PSTLA, existing data were used to estimate loadings of toxic chemicals released to Puget Sound via surface runoff, atmospheric deposition, permitted wastewater discharges, combined sewer overflows, and direct spills (Hart Crowser et al., 2007). Phase 2 of the analysis refined land-use classifications and roadway loadings to improve toxic chemical loading estimates for the entire Puget Sound basin (EnviroVision et al., 2008). Overall estimates of surface runoff loading were later recalculated (Herrera, 2010a).

Ecology expanded numerical modeling begun in Phase 2 to provide insights into the relative importance of various loading pathways. The resulting Puget Sound Toxics Box Model (Pelletier and Mohamedali, 2009) allowed managers to investigate the response of contaminant concentrations in the water, sediment, and biota of Puget Sound to various source-control strategies. Initial modeling exercises were performed for polychlorinated biphenyls (PCBs) due to the relative abundance of existing PCB data. Future modeling efforts will examine fate and transport of other toxic contaminants, including polybrominated diphenyl ethers (PBDEs).

Data Gaps

A review of readily available data collected since 1995 on selected toxic chemicals in Puget Sound and the Straits of Juan de Fuca and Georgia (Serdar, 2008) identified significant gaps and limitations in the existing data. With few exceptions, the available data were deemed inadequate for providing representative concentrations for Box Model input and analyses. Phase 2 simulations using the Box Model also indicated more data would improve the accuracy of predictions. The greatest sources of uncertainty for Box Model predictions were:

- Limited data from which to choose input values representing toxic chemical loading from surface runoff.
- Limited data on concentrations of toxic chemicals likely to be exchanged between Puget Sound and ocean boundary waters [1] (*ocean exchange*).

The authors of the modeling study recommended that Phase 3 studies should fill these data gaps and thereby address uncertainties.

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[1] For purposes of this study, ocean boundary waters are defined as the sampling locations in the Straits of Juan de Fuca and Georgia that, although they do not reflect true oceanic waters, represent conditions at the ocean boundary used in the Box Model (external to Puget Sound proper).

Study Purpose

The present 2009-10 study was designed to collect data that would improve input values to the Puget Sound Toxics Box Model, thereby reducing uncertainty in model predictions. These data could also be used to calibrate the model. Specific objectives of the study were:

- Measure concentrations of target toxic chemicals and other water quality parameters in samples representing ocean boundary waters likely to enter and marine waters likely to exit the modeled portion of Puget Sound.
    - Whole water samples collected from the deep layer near the main ocean boundary (Strait of Juan de Fuca and Haro Strait).
    - Whole water samples collected from the surface layer of the four primary Puget Sound basins (Whidbey, Main, Hood Canal, and South Sound).
- Measure concentrations of target toxic chemicals and other water quality parameters in the five rivers having the greatest annual discharges to Puget Sound (Skagit, Snohomish, Nooksack, Stillaguamish, and Puyallup).
- Identify sources of variability in concentrations of target toxic chemicals and other water quality parameters.
- Determine concentrations of toxic chemicals associated with suspended particulate matter (SPM) in marine and river waters.

Study Findings

Marine Water and SPM

Major findings from the marine sampling portion of the 2009-10 study include:

- Suspended solids, organic carbon, metals, PCBs, and PBDEs in samples collected from the surface and deep layers of the marine water column were routinely detected but consistently low. Semivolatile organic compounds (BNAs) and chlorinated pesticides were rarely detected and polycyclic aromatic hydrocarbons (PAHs) were never detected in marine water samples.
- The range of total PCB concentrations measured for ambient marine waters was 6.1-75 pg/L (mean = 26.3 pg/L). The mean concentration in ocean boundary waters (20.4 pg/L) was significantly less than the mean for Puget Sound marine waters (30.7 pg/L). Both values were lower than the mean concentration previously reported for the Strait of Georgia (42 pg/l; Dangerfield et al., 2007).
- Total PCB concentrations in the deep marine waters were significantly higher than those in the surface waters. This was true for the ocean boundary waters and Puget Sound (Figure ES-1). A significant positive relationship between total PCBs and total suspended solids (TSS) suggested that sedimentation plays a key role in the fate of PCBs in the Sound.

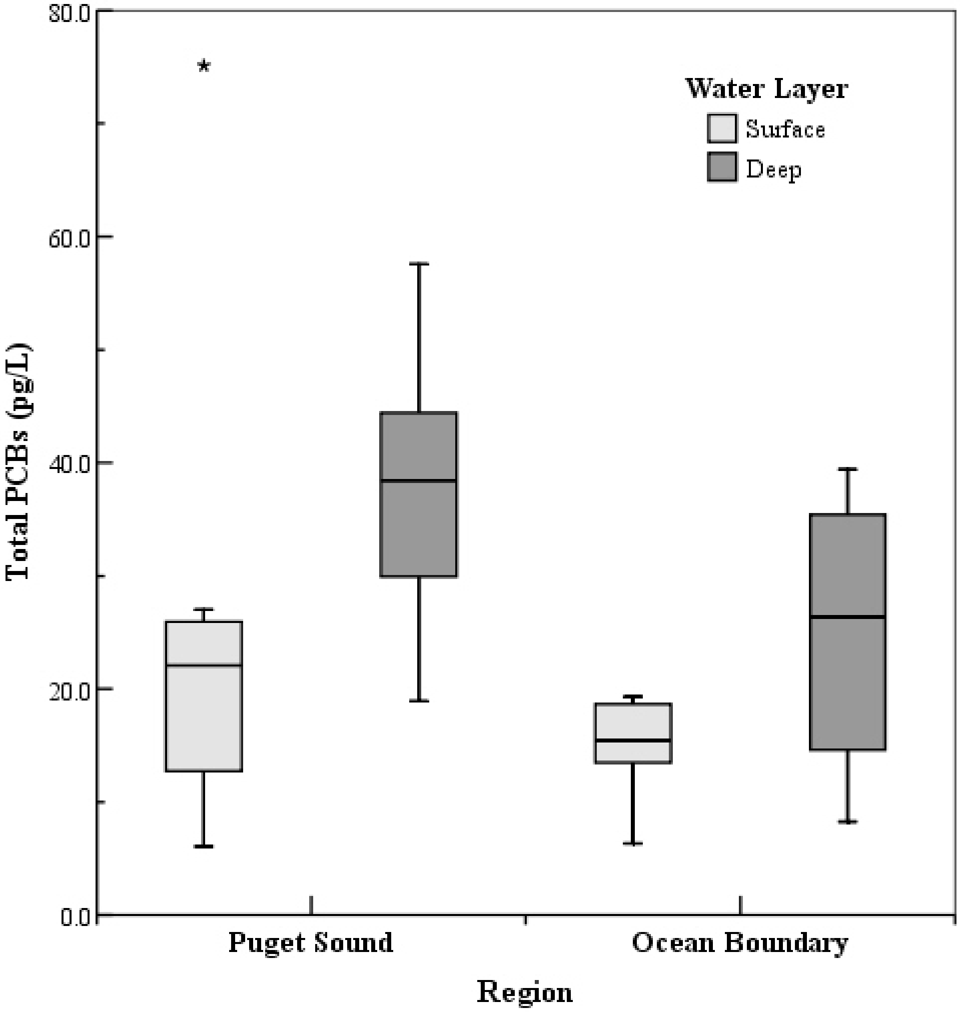

Figure ES-1. Total PCB concentrations in surface and deep marine waters.

- The range of detected total PBDE concentrations in marine waters (51 - 18,700 pg/L) was much wider than the range of total PCB concentrations. Total PBDEs concentrations were often 10 times higher in the present study than concentrations reported by Canadian researchers (Dangerfield et al., 2007). No evidence suggested the higher concentrations were due to sample contamination. Sources of high PBDE concentrations were not identified.
- Organic carbon concentrations in marine water samples resembled concentrations previously reported for the Strait of Georgia (Johannessen et al., 2008), but were substantially lower than marine water concentration records in Ecology's EIM database.
- Calculations of chemical exchange between Puget Sound and ocean waters, based on present study results, indicated most toxic chemicals are probably being exported out of Puget Sound. A notable exception was cadmium, which appeared to be imported into Puget Sound. This was due to incoming ocean waters having significantly higher concentrations than surface waters flowing out of the Sound to the ocean. The direction of net exchange for total PCBs and total PBDEs between the ocean and Puget Sound could not be estimated from the data collected.

- Samples of SPM collected from sediment traps deployed in Hood Canal and South Puget Sound (Case+Carr Inlets) contained similar concentrations of organic carbon, metals, and PBDEs. PCB concentrations in Case+Carr Inlet SPM were more than three times greater than those in Hood Canal.

River Water and SPM

Major findings from the river sampling portion of the study include:

- Concentrations of total suspended solids (TSS), organic carbon, nutrients, hardness, and metals were within the ranges reported from previous studies by Ecology and other monitoring programs (Inkpen and Embry, 1998; Wise et al., 2007).
- River water samples seldom contained detectable concentrations of petroleum-related compounds (oil and grease, TPH-D, and TPH-G), BNAs, PAHs, or chlorinated pesticides. River SPM collected by centrifugation in December 2009 and January 2010 contained detectable concentrations of many individual PAH compounds.
- The average concentration of total PCBs measured in surface water from the five rivers was 16.3 pg/L. The range of concentrations measured was 2.6 - 59 pg/L. This range is somewhat lower than the range reported by King County for the Green/Duwamish Rivers (83 - 814 pg/L; Willston, 2009) that flow through a more urban and industrial watershed.
- PBDEs were detected in less than half of the river water samples. Total PBDE concentrations were highly variable ranging from 10.9 - 265 pg/L, with an average of 55.6 pg/L.
- Total PAH concentrations in SPM (excluding retene) ranged from 32 - 210 μg/Kg, with an average of 120 μg/Kg. Concentrations of individual PAHs were <20 μg/Kg, except for retene which averaged 230 μg/Kg.
- Few other organic compounds (BNAs, TPH-D, chlorinated pesticides) were detected in SPM.
- Estimated daily loading of total PCBs from all five rivers ranged from 0.015 - 0.57 g/day.
- Estimated daily loading of total PBDEs from all five rivers ranged from 0.017 - 4.22 g/day.

Notable relationships between parameters include the following:

- TSS concentrations were significantly correlated with, and explained between 63% and 86% of the variability in, concentrations of total phosphorus and total metals.
- Organic carbon, total nitrogen, and nitrate+nitrite concentrations were significantly lower during July than during the other two sampling periods.
- Congeners belonging to the more polar PCB homolog groups (those with fewer chlorine atoms) were significantly correlated with many parameters in the dissolved phase (ortho-phosphate and dissolved metals). Congeners in the more hydrophobic PCB homologs (those with more chlorine atoms) were significantly correlated with TSS, total organic carbon (TOC), and parameters often found in particulate form (total nitrogen and total phosphorus).

Recommendations

Based on the findings of the present study, the following recommendations are made:

- Future sampling should focus on the collection and analysis of particulate samples to improve the detection frequency of hydrophobic compounds.
- More intensive water column sampling should be conducted near the ocean boundaries to Puget Sound proper (Admiralty Inlet sill and Deception Pass). Samples should be analyzed for a reduced suite of chemicals, with priority given to chemicals exhibiting high variability in the present study (e.g., PBDEs). This would improve current estimates of ocean exchange.
- Depth-integrated water sampling of large rivers should be conducted with focus on increased sampling frequency, a reduced suite of chemicals, and improved detection limits for organic contaminants. More frequent sampling during all phases of runoff-related events is needed to understand seasonal and other temporal patterns. This would facilitate a better characterization of loading during baseflow conditions and runoff-related events.
- Standard operating procedures (SOPs) for the collection and analysis of seawater samples for dissolved (DOC) and particulate organic carbon (POC) should be revised. For example, all equipment used for sample collection and processing should be made exclusively of glass or lined with Teflon.

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Introduction

Puget Sound Toxics Loading Analysis

The State of Washington enacted legislation in 2007 to protect and restore the Puget Sound ecosystem by 2020. The Puget Sound Partnership, while developing the Puget Sound Action Agenda, identified the control of toxic chemical releases as a high priority.

To inform a comprehensive strategy to reduce and control toxic releases, the Washington State Department of Ecology (Ecology) and others [2] undertook a multi-year Puget Sound Toxics Loading Analysis (PSTLA). The PSTLA was intended to quantify various sources of toxic contaminants entering Puget Sound and to better understand the behavior and fate of the contaminants within the ecosystem. Results of the PSTLA will form the technical basis for a toxics control strategy.

Phase 1 of the PSTLA used existing data to estimate loadings of toxic chemicals to Puget Sound via surface runoff, atmospheric deposition, permitted wastewater discharges, combined sewer overflows, and direct spills (Hart Crowser et al., 2007). Phase 2 improved watershed loading estimates for the entire Puget Sound basin by using revised land-use classifications and incorporating roadway loadings (EnviroVision et al., 2008; Herrera, 2010a). Modeling efforts were also expanded to provide insights about the relative importance of various loading pathways. The resulting Puget Sound Toxics Box Model [3] (Pelletier and Mohamedali, 2009) was composed of three parts:

1. Water circulation and transport box model (Appendix B, Figure B-1).
2. Contaminant fate and transport mass balance model.
3. Food web transfer bioaccumulation model.

The Box Model was initially used to predict how concentrations of polychlorinated biphenyls (PCBs) in the water, sediment, and biota of Puget Sound might respond to various source-control strategies. In doing so, the model identified substantial uncertainties and data gaps.

Data Gaps and Recommended Actions

The greatest source of uncertainty about Box Model predictions was the input values used to represent toxic chemical loading to Puget Sound from surface runoff (river loading). Another major source of uncertainty was the limited information available on concentrations and loads of toxic chemicals exchanged between the ocean and Puget Sound (Serdar, 2008). The authors of the modeling study recommended Phase 3 investigations to address these uncertainties. These included the following targeted efforts:

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[2] The Puget Sound Partnership, U.S. Environmental Protection Agency (EPA), and other federal, state, and local agencies.

[3] Hereafter, this report often refers to the Puget Sound Toxics Box Model simply as the Box Model.

- **Major tributaries.** Estimates of toxic chemical loadings from surface runoff should be improved by monitoring concentrations of toxic chemicals in rivers, streams, and discharges from publically-owned water treatment facilities (POTWs), especially in relation to land uses and flow regimes (baseflow or storm runoff).
- **Ocean boundary waters.** Estimates of toxic chemicals transported from ocean boundary waters into Puget Sound should be improved because they may:
    - Be similar in magnitude to toxics loadings from major land uses in Puget Sound watersheds.
    - Influence concentrations of toxics observed in Puget Sound and its biota.
- **Puget Sound water column.** Toxic chemical concentrations in major Puget Sound basins, and how they partition between suspended particulate matter (SPM) and water (dissolved), should be measured because they are important determinants of biological uptake.

Goals and Objectives

The principal goal of the present 2009-10 study was to provide concentration data for various toxic chemicals that could be used to address these data gaps. Specific objectives listed in the Quality Assurance (QA) Project Plan (Coots and Osterberg, 2009) included:

- Collect samples representing seawater entering and leaving the modeled portion of Puget Sound, especially:
    - Samples collected from the deep layer of ocean boundary waters (Strait of Juan de Fuca and Haro Strait) [4].
    - Samples collected from the surface layer of four Puget Sound basins (Main, Whidbey, South Sound, and Hood Canal) [5].
- Measure concentrations of the following parameters in seawater samples collected from above *and* below any density gradient (pycnocline) in ocean boundary waters and the four major Puget Sound basins:
    - Total suspended solids (TSS).
    - Total and dissolved organic carbon (TOC and DOC).
    - Total and dissolved fractions of five metals (arsenic, cadmium, copper, lead, and zinc).
    - Semivolatile organic compounds (BNAs).
    - Polycyclic aromatic hydrocarbons (PAHs).
    - Chlorinated pesticides.
    - Polychlorinated biphenyl (PCB) and polybrominated diphenyl ether (PBDE) congeners.

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[4] Samples collected from the western end of the Strait of Juan de Fuca would be less representative of seawater entering Puget Sound.

[5] Samples collected from surface layer waters of the Straits of Juan de Fuca and Georgia could include toxic chemicals originating outside of Puget Sound and therefore be less representative of leaving Puget Sound.

- Measure concentrations of the same chemicals of concern *plus* the following parameters in the five rivers with the greatest annual discharges to Puget Sound (Skagit, Snohomish, Nooksack, Stillaguamish, and Puyallup):
    - Hardness.
    - Nutrients (total nitrogen [TN], nitrate+nitrite nitrogen, ammonia nitrogen, total phosphorus [TP], and ortho-phosphate).
    - Petroleum-related compounds.
        - Oil and grease.
        - Diesel and gasoline fractions of petroleum hydrocarbons (TPH-D and TPH-G).
- Identify variability in concentrations of target toxic chemicals and other water quality parameters.
- Determine concentrations of toxic chemicals associated with SPM in marine and river waters.

Outcomes

Results of the present study include the following:

- Concentration ranges for target chemicals in ocean boundary waters and the major Puget Sound basins.
- Estimates of chemical exchange between ocean boundary waters and Puget Sound.
- Concentration ranges for target chemicals near the mouths of five major rivers discharging to Puget Sound.
- Estimates of daily chemical loads from the same rivers to Puget Sound.
- Some indications of spatial and temporal variability in chemical concentrations in the marine water column and near the river mouths.

Study results also provide data for calibrating the existing Puget Sound Toxics Box Model and using it to predict the transport and fate of other toxic chemicals. Consequently, the study contributes to developing a control strategy for toxic chemicals entering Puget Sound.

Study Design

The QA Project Plan (Coots and Osterberg, 2009) described the study design in detail. The following section summarizes the major project elements:

Ocean Exchange of Toxic Chemicals

Ecology collected samples from ocean boundary waters (Strait of Juan de Fuca and Haro Strait) and major Puget Sound basins (Whidbey, Main, South Sound, and Hood Canal) to determine water column concentrations of a suite of chemicals of concern (Figure 1). At each location, samples were collected from two depths representing the surface and deep layers simulated by the Box Model (Table 1). Temporal variability was addressed by sampling the water layers over three seasons. Ecology used the results to estimate the annual mass transport of target chemicals into and out of Puget Sound at the main ocean boundaries (Admiralty Inlet and Deception Pass).

River Loading of Toxic Chemicals

Ecology sampled the five rivers with the greatest mean annual flow near their mouths but upstream of any likely intrusion of marine (salt) water (Figure 1). Each river was sampled on three occasions intended to represent:

- Summer baseflows.
- Fall runoff or storm-related flows.
- Winter baseflows.

Water samples collected using depth-integrated methods were analyzed for the same toxic chemicals as marine waters, plus nutrients and hardness. Surface grab samples were also collected and analyzed for petroleum-related compounds. Instantaneous loads were calculated using measured concentrations of the various parameters and the mean daily flows.

Toxic Chemicals Associated with Particulates

Ecology measured concentrations of toxic chemicals associated with SPM in samples collected during the winter season from the marine water column and from near the five river mouths. Sediment traps were deployed at five locations to collect SPM from the marine water column (Figure 1). Centrifuges were used to concentrate SPM pumped from each river at nearly the same time that whole water samples were collected.

Sampling Methods

Marine Water Column

Ecology chose the marine water column sampling sites shown in Figure 1 to represent ambient conditions in the four major Puget Sound basins and near the main ocean boundaries (Admiralty Inlet and Deception Pass). Sites were established at the deepest location near the centroid of each basin. Two sites in the Strait of Juan de Fuca and one in Haro Strait were chosen to represent boundary waters. All sampling sites were located away from river mouths and nearshore influences. The geographic coordinates for each sampling site are listed in Table 1.

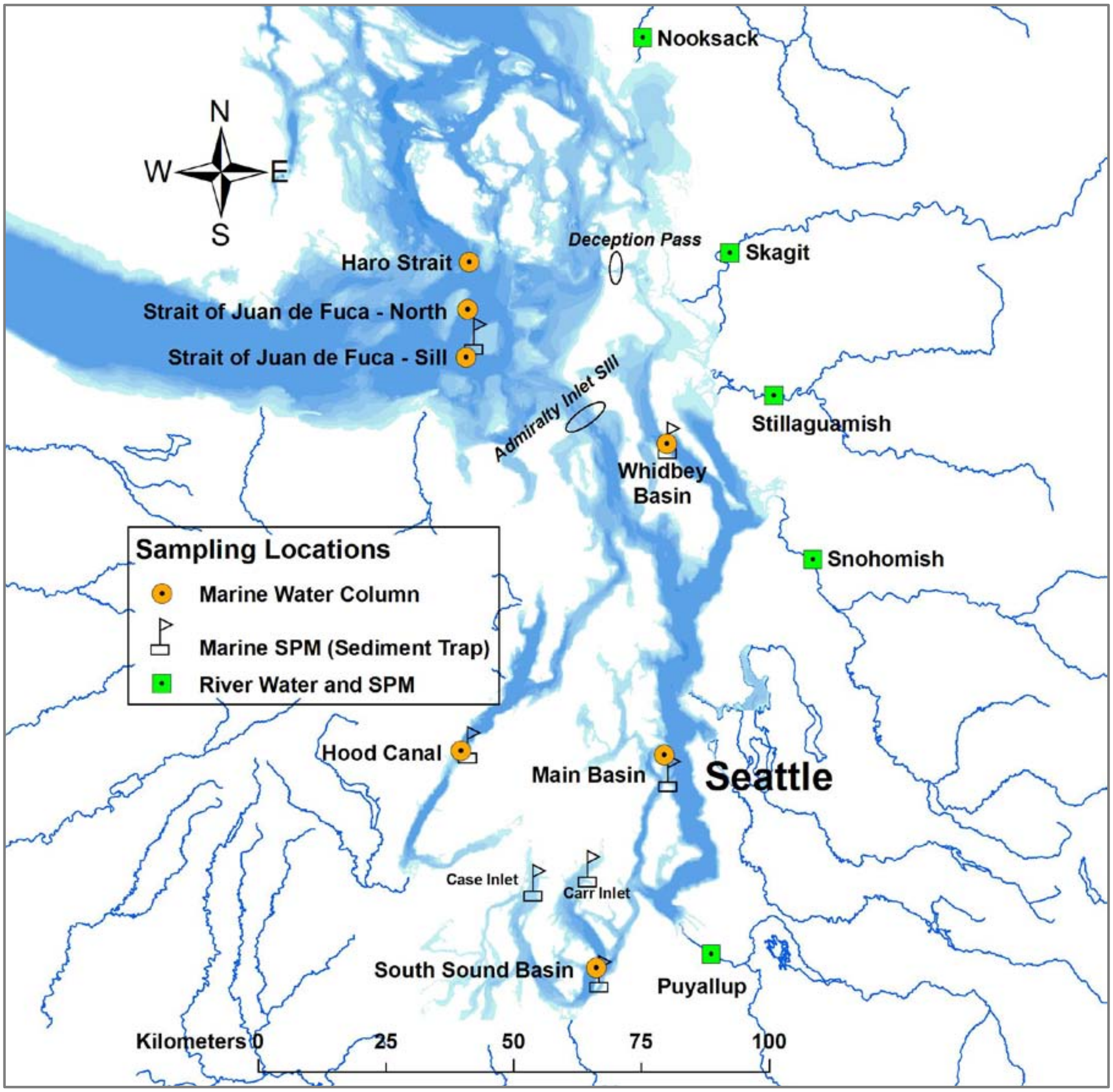

Figure 1. Marine water column and river sampling locations.

Puget Sound Toxics Box Model marine boundaries are shown in italics. Also shown are locations where sediment traps were deployed in Carr and Case Inlets during 2008 (see Results).

Table 1. Marine water column sampling site information.

Coordinates are listed for each sampling site chosen to represent Puget Sound Toxics Box Model regions. Also listed are depths used by the Box Model to divide surface from deep water layers.

Sampling Site ID	Latitude	Longitude	Box Model Region	Depth (meters) Dividing Water Layers
	(Decimal degrees; NAD83)			
Hood	47.5589	-123.0048	Hood Canal South	13
South Sound	47.1847	-122.6378	Puget Sound South	30
Main	47.5616	-122.4759	Puget Sound Main	50
Whidbey	48.1083	-122.4900	Whidbey Basin	9
SJdF at Sill	48.2500	-123.0250	Boundary Conditions	50
SJdF North	48.3333			
Haro Strait	48.4167			

SJdF = Strait of Juan de Fuca.

The circulation and transport component of the Puget Sound Toxics Box Model (Pelletier and Mohamedali, 2009; Babson et al., 2006) divided each basin vertically into surface and deep water column layers, as shown in Table 1. To provide chemical concentration data for model input and calibration, water samples were collected from within the surface and deep layers at the seven sampling locations. To assess the seasonal variability of water column concentrations, each site was sampled on three occasions (July 2009, October 2009, and January 2010).

The platform for marine sampling activities was the research vessel (R.V.) *Skookum*, an aluminum hull vessel with no antifouling coat. The *Skookum* was positioned by GPS within 100 feet of target coordinates, and the engine was off for at least five minutes prior to sampling. All sampling activities were conducted on the windward side to minimize contamination from shipboard sources.

Prior to sampling the water column at each site, a Conductivity/Temperature/Depth profiler (CTD; Model SBE25, Sea-Bird Electronics, Inc.) was deployed to measure temperature, salinity, and density throughout the water column. CTD deployments were conducted according to manufacturer protocols (Sea-Bird, 2009a and 2009b). Density profiles were assessed in the field to evaluate whether the water column was stratified (i.e., a less dense surface layer overlying a more dense deep water layer) and to accordingly select water sampling depths as follows:

- If density stratification was present, sampling depths targeted the approximate middle of the observed surface and deep layers.
- Absent stratification, sample collection targeted depths at the approximate middle of Box Model-defined surface and deep layers (Table 1).

Actual sampling depths are documented in Appendix B (Tables B-1 and B2; Figures B-2 through B-8). CTD data were later post-processed using recommended protocols, standard oceanographic equations, and manufacturer software (Sea-Bird, 2009c and 2010).

Water column samples were collected using a pair of 10-liter, Teflon-coated GO-FLO discrete samplers (General Oceanics, Inc.; Figure 2). Mounted on a non-metallic Vectran rope, the two samplers were deployed simultaneously to collect 20 liters from a targeted depth. Collection of samples from the deep layer preceded surface layer sampling at all locations. To prevent contamination of water samples expected to contain very low concentrations of target chemicals, strict protocols were employed for GO-FLO deployment and sample decanting. These protocols were based on EPA *clean hands / dirty hands* techniques (EPA, 1996), and are documented in Appendix C.

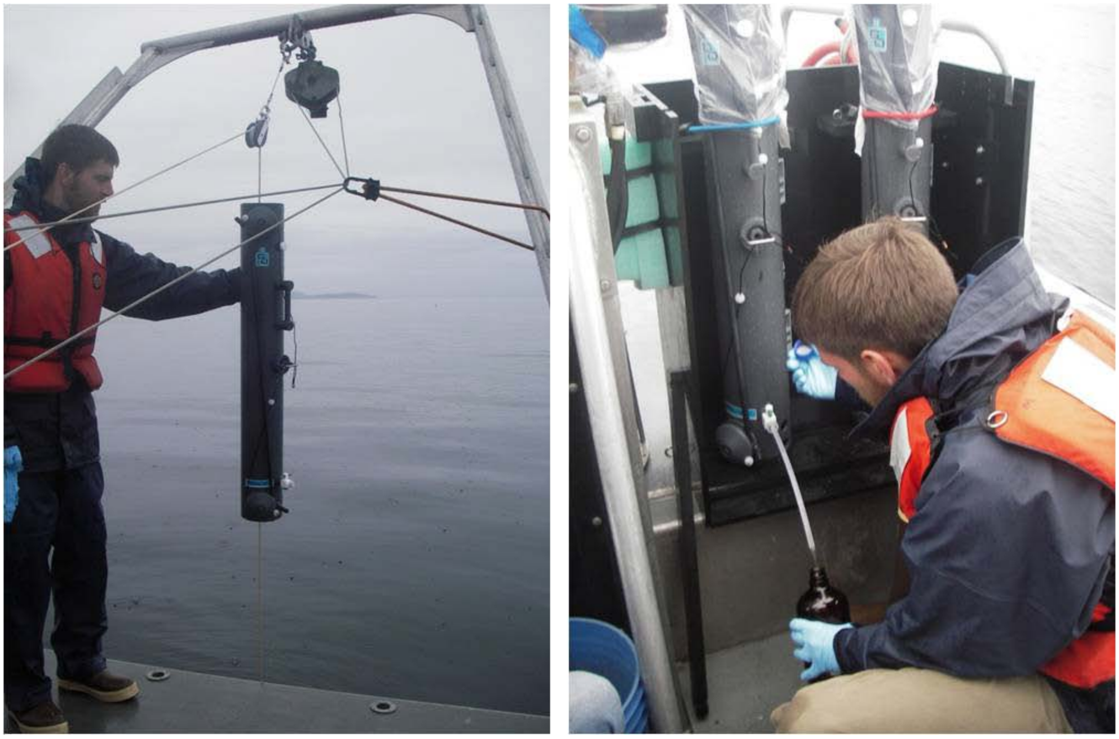

Figure 2. Collecting samples from the marine water column using GO-FLO samplers.

After retrieval, sample water was drained from the GO-FLO samplers through clean Teflon tubing to pre-rinse and then fill certified, pre-cleaned containers. Subsamples were filled in the following order: TSS, particulate organic carbon (POC) and DOC, PCB congeners, PBDE congeners, chlorinated pesticides, PAHs, BNAs, and total and dissolved metals. The volume, container, preservation, and holding times for each of these analytes are listed in Appendix C (Table C-1). Atmospheric exposure of the sample water during a typical bottle fill was minimal, occurring over a distance of approximately one inch (between the end of the Teflon tubing and the receiving bottle) for only 5 to 30 seconds.

Notable modifications to subsampling protocols from those presented in the QA Project Plan included:

- Salinity was not measured to confirm sample collection depth.
- A portable glove box was not used for transferring water to sample bottles (to eliminate exposure of samples to ambient air) because deck space was limited.

No seawater samples were collected for analysis of organic carbon during the first sampling event (July 2009) because previously available methods (Stutes and Bos, 2007) were inadequate for the purposes of this study. New field protocols were developed based on SOPs used by the University of Maryland's Horn Point Environmental laboratory (Lane et al., 2000) and others (Johannessen et al., 2008). The new procedures used an all-glass filtration apparatus and 0.7-µm pore-size glass fiber filters, with the filters and filtrate analyzed for POC and DOC, respectively (see Appendix C for details). Sampling for organic carbon resumed in October 2009 and was conducted at all locations and depths during the final two sampling events.

Various field quality control (QC) samples were also collected during each seasonal sampling. Results were used to assess environmental variability, replicability of sampling and analytical methods, and the potential for sample contamination by sampling equipment and procedures. Appendix D describes the purpose of each type of field QA sample and a description of how it was created in the field. Appendix D also presents field QA data and discusses how these data influenced interpretation of water column sample results.

Marine SPM

Ecology collected samples of SPM settling through the marine water column using moored sediment traps. A total of five moorings were deployed, each equipped with multiple traps. Sampling targeted the four Puget Sound basins where water column sampling was conducted, as well as a single location in the Strait of Juan de Fuca to collect SPM from the ocean boundary waters. All moorings were anchored in water no deeper than 50 meters and located as near as possible to water sampling stations (Figure 1).

Sediment trap moorings were deployed during October 2009. At sites where water column stratification was observed, traps were positioned to collect SPM from both the surface and deep water layers (two traps within each layer). At sites where the water column was completely mixed at the time of deployment, multiple traps were mounted within a single mid-depth zone. The configuration of each site's mooring is presented in Appendix B (Figure B-9).

Individual sediment traps consisted of paired straight-sided glass collection cylinders, each 50 cm tall by 10 cm diameter (5H:1W; 78.5 cm^2 opening area). A schematic of the construction details of the traps and their moorings is presented in the QA Project Plan (Coots and Osterberg, 2009), and further discussion can be found in Norton (2001 and 1996). At deployment, collection cylinders were filled with two liters of high salinity water (4% NaCl) and sodium azide (2% NaN_3) as a preservative to reduce microbial degradation of the samples.

Traps were intended to be deployed for a period of two to three months, collecting SPM between the fall and winter water column samplings. However, efforts to recover the traps during January and February 2010 were mostly unsuccessful, with moorings having either failed or drifted down slope too far to locate. Only the mooring in the Hood Canal was located; unfortunately, it had been disturbed and most of the collection cylinders were damaged. The SPM collected by the deepest (40 meters) sediment trap from the Hood Canal was intact and visibly undisturbed, and was deemed usable.

Upon retrieval, overlying water was removed from the two Hood Canal cylinders using a peristaltic pump. The salinity of the water immediately above the SPM in each cylinder was measured with a refractometer to verify that preservative remained. The SPM from the two cylinders was slurried, combined in a glass sample jar, and allowed to settle overnight. It was then concentrated by laboratory centrifugation (2000 rpm for at least 10 minutes), homogenized, and weighed. Total dry mass was estimated from the measured wet mass and approximate percent solids. Based on the estimated dry mass, chemical analyses were prioritized and subsamples were apportioned into certified, pre-cleaned glass sample containers for each analysis.

The Hood Canal trap yielded enough SPM to analyze a subset of the planned suite of parameters, including percent solids, TOC, five metals, PCB congeners, and PBDE congeners. To supplement these analytical results, archived sediment trap material from a recent Ecology study was also analyzed. The archived SPM had been collected by mid-water column sediment traps (identical to those employed in the present 2009-10 study) moored at sites in the Case and Carr Inlets (Figure 1) between March and June 2008 (Norton, 2009). Archived SPM from the Case and Carr traps was thawed [6], combined, and homogenized. Subsamples were distributed into sample jars for analysis of percent solids, metals, and PCB and PBDE congeners.

River Water

Ecology sampled five rivers contributing the greatest annual discharge to Puget Sound from bridges located beyond the normal upper extent of saline water intrusion. All bridges were near U.S. Geological Survey (USGS) or Ecology gaging stations (Figure 1 and Table 2). Additional details about sampling sites and sampling activities are presented in Appendix B (Table B-3 and Figures B-11 to B-15).

Sampling occurred at times intended to capture three river conditions:

- Baseflows during the dry season (July).
- Flows related to “first fall flush” or storm-related runoff (October).
- Baseflows during the wet season (December/January).

Depth-integrated samples were collected using Teflon one-liter sample bottles fit with Teflon nozzles sized for expected current velocities. Bottles and nozzles were pre-cleaned to priority pollutant standards using laboratory soap, tap water, 10% nitric acid, de-ionized water, acetone, and hexane. Similar cleaning procedures are described elsewhere (PSEP, 1997; Ecology, 2006 and 2008).

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[6] Particulate material from Case and Carr Inlet traps had been frozen and stored in glass jars for approximately 18 months.

Table 2. Sampling locations near mouths of the five largest rivers discharging to Puget Sound.

River Name	Watershed Area [1] (km^2)	Annual Flow (Period of Record)		Sampling Location (Decimal degrees, NAD 1983)		Location Description	River Mile (RM)	Nearest Gaging Station
		cfs	cms	Latitude	Longitude			
Skagit	8,010	16,530 (69 yrs)	468	48.4450	-122.3354	Old Hwy 99 Mt. Vernon	15.7	USGS 12200500
Snohomish	4,440	9,810 (38 yrs)	278	47.9107	-122.0987	Avenue D Snohomish	12.7	Ecology 07A090 [2]
Nooksack	2,050	3,925 (38 yrs)	111	48.8189	-122.5801	Slater Road So. of Ferndale	3.4	Ecology 01A050 [3]
Stillaguamish	1,440	3,860 (38 yrs)	109	48.1969	-122.2104	I-5, west of Arlington	11.1	Ecology 05A070
Puyallup	2,460	3,310 (92 yrs)	94	47.2140	-122.3415	66th Avenue Puyallup	5.8	USGS 12101500 [4]

[1] Area of watershed upstream of gaging station where samples were collected.

[2] Mean annual flow based on two USGS gaging stations (12150800 - Snohomish R.; 12155300 Pilchuck River) is 9,993 cfs.

[3] Mean annual flow based on USGS gaging station 12213100 at RM 5.8 is 3,825 cfs.

[4] USGS gaging station is located at RM 6.6, approximately 0.8 miles upstream.

The sampling bottle with nozzle was attached to a US DH-95 sampler (FISP, 2000) that was suspended by steel cable from each bridge deck (Figure 3a). Sampling followed USGS protocols (USGS, 2005) except that water was collected and composited from only three quarter points in the channel. Near-surface grab samples were collected for analysis of petroleum products (oil and grease, TPH-D, and TPH-G), as shown in Figure 3b.

Ecology conducted sample collection and processing activities according to EPA *clean hands / dirty hands* methods (EPA, 1996) to the extent possible to minimize the risk of contamination. However, a portable glove box was not used while compositing and filtering samples because it proved to be cumbersome.

Field QA samples collected during river water sampling are described in Appendix D, which also includes QC sample results and discussion of how these QC samples affected data quality.

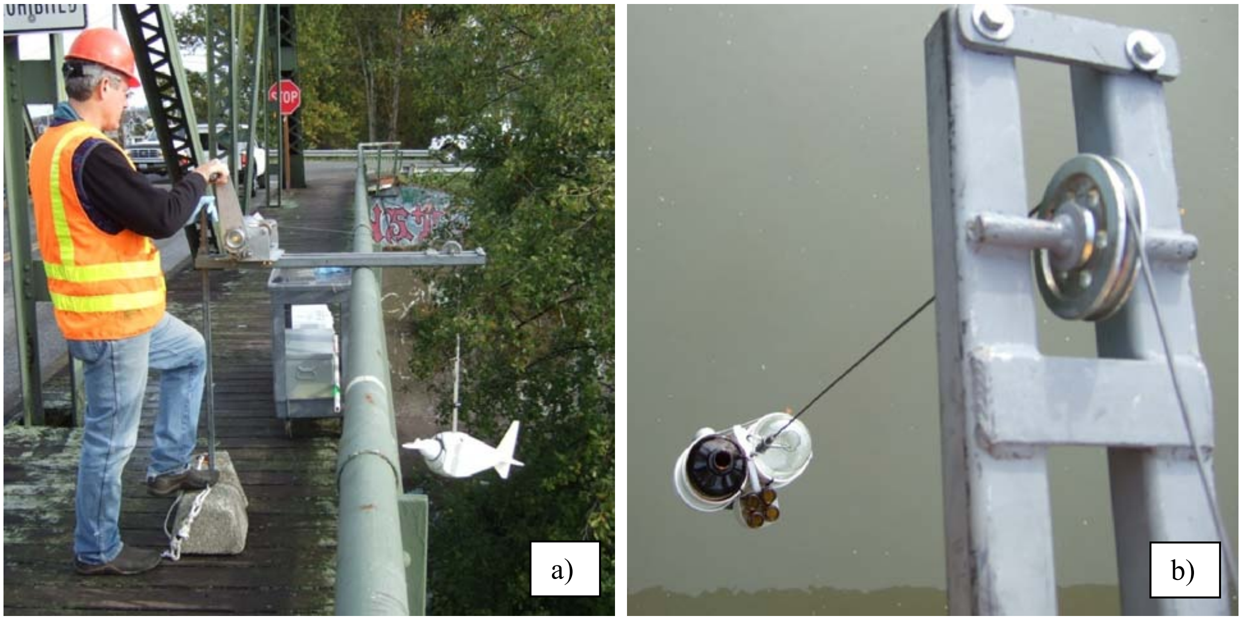

Figure 3. Collecting depth-integrated water samples and surface grabs.

River SPM

Ecology collected SPM from the five rivers only during the winter, as specified in the QA Project Plan. This was done by pumping mid-channel water through continuous-flow centrifuges in which solid material was retained. Sampling occurred within 24 hours of collecting discrete river water samples. A brief description of pump-and-centrifuge field methods follows (also see Coots and Osterberg, 2009; Gries and Sloan, 2009).

A Grundfos groundwater/well pump (Model SP4) was deployed and maintained at about 6/10 maximum mid-channel depth in each river. Water was pumped at about 2.8 gpm through Teflon-lined tubing to two Alpha Laval centrifuges (Sedisamp II, Model 101L). During this process, three discrete samples were collected from both inflow and outflow waters. The samples were composited and analyzed for TSS to assess the efficiency of centrifuges at retaining SPM [7].

After 16 - 22 hours, pumping ceased and centrifuges were shut off. The centrifuged SPM was collected while still at the sampling site. Residual water in the centrifuge bowls was removed using pre-cleaned glass syringes. Solids were collected using stainless steel spoons and Teflon-coated spatulas. Water and solids were placed in separate certified, pre-cleaned glass sample containers. Solids in the bowl water were later concentrated by laboratory centrifugation (approximately 2,000 rpm for at least 20 minutes) and added to the main mass of field-centrifuged solids. The total wet weight of solids collected was recorded. Subsamples were weighed and placed into separate jars for different analyses.

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[7] % Efficiency = $[(TSS_{inflow}-TSS_{outflow})/TSS_{inflow}]*100$

Prior to the first river sampling:

- The stainless steel pump was soaked for 48 hours in de-ionized water.
- All tubing and centrifuge parts were cleaned using a 10% solution of nitric acid, de-ionized water, acetone, and hexane.

Between river sampling events, centrifuge parts were cleaned similarly. However, tubing was cleaned using only laboratory detergent, 10% nitric acid, and copious de-ionized water. Water from each river was also pumped through the tubing for at least 15 minutes (>150 liters or >40 gallons) before collecting SPM.

Analytical Methods

This section provides a summary of the analytical methods used for the present study. Additional details can be found in Appendix C, the QA Project Plan (Coots and Osterberg, 2009), and Ecology's Manchester Environmental Laboratory (MEL) *Lab Users Manual* (MEL, 2008).

Marine and River Water

Standard preparation, cleanup, and analytical methods were used to measure the parameters listed in the *Goals and Objectives* section. Table 3 describes the methods used by laboratories to analyze the parameters in the different samples that were collected. The following should be noted:

- The fractions of organic carbon that the Horn Point Lab measured in marine water (DOC and POC) differed from those MEL measured in river water (DOC and TOC).
- MEL measured phosphorus in strong acid extracts of river water samples using a colorimetric method comparable to most nutrient monitoring studies.
- Frontier Geosciences measured concentrations of five metals in marine water samples using methods similar those MEL used to measure the same metals in river water samples.
- The detection limits and reporting limits for oil and grease in river water were based on a grab sample size of one liter.
- MEL's organic chemical analyses provided results for as many as 32 chlorinated pesticides, 55 semivolatile organic compounds (BNAs), and 22 individual PAHs.
- Analytical Perspectives reported concentrations for 209 PCB congeners, and Pacific Rim Labs reported concentrations for 36 PBDE congeners.

SPM from the Marine Water Column and Rivers

Material from the Hood Canal sediment traps was analyzed for percent solids, TOC, five metals, PCBs, and PBDEs. Sediment that was combined from traps previously recovered from Carr and Case Inlets was analyzed for the same metals, PCBs, and PBDEs. Samples of SPM collected from each of the rivers were analyzed for percent solids, TOC, the same five metals, PCBs, and PBDEs. Enough suspended sediment was centrifuged from four of the rivers to also be analyzed for TPH-D, BNAs, PAHs, and chlorinated pesticides. Laboratory methods used for the various analyses are included in Table 3.

Table 3. Analyses of marine water column, river water, and SPM samples.

Parameters	Samples	Method	Method Description	Laboratory
Conventional Parameters, Nutrients, and Hardness (mg/L)				
% Solids	SPM	EPA 160.3		
TSS	S, F	SM 2540 D	Gravimetric	MEL
DOC	S	SM 5310	Combustion; IR detection	Horn Pt
POC			Combustion/oxidation; Thermal conductivity detection	
DOC and TOC	F		Combustion; IR detection	MEL
TOC	SPM	PSEP EPA 415.1	Combustion; IR detection	MEL
Nutrients [1]	F	SM 4500	Colorimetry	MEL
Hardness	F	EPA 200.7	ICP; Calculation	MEL
Total metals [2] (µg/L)	S, F SPM	FGS 054 EPA 200.8	ICP-MS	FGS MEL
Dissolved metals [2] (µg/L)	S, F			
Petroleum-Related Products (mg/L)				
Oil and Grease (HEM)	F	EPA 1664A	Gravimetric	MEL
TPH-D	F, SPM	ECY 97-602	GC/FID	MEL
TPH-G	F		Purge and trap; GC/FID	MEL
Organic Compounds				
Chlorinated Pesticides (ng/L) [3]	S, F	EPA 8081	GC/ECD	MEL
PAHs (µg/L) [4]	S, F SPM	EPA 8270 SIM	GC/MS	MEL
Semivolatile Organic Compounds BNAs (µg/L) [5]	S, F	EPA 8270	Capillary GC/MS	MEL
209 PCB Congeners (pg/L)	S, F SPM	EPA 1668A	GC/HRMS	AP, PRL
36 PBDE Congeners (pg/L)	S, F SPM	EPA 1614		PRL

[1] Includes total nitrogen (TN), nitrate+nitrite-N, ammonia-N, total phosphorus (TP), and ortho-phosphate (ortho-P)

[2] Includes arsenic, cadmium, copper, lead, and zinc.

[3] See Appendix E, Table E-2, for list of 32 chlorinated pesticides measured.

[4] See Appendix E, Table E-8, for list of 22 PAH compounds measured.

[5] See Appendix E, Table E-14, for list of 55 semivolatile organic compounds measured.

See LEGEND on following page.

LEGEND:

Analytes or Parameters

BNAs = base/neutral/acid extractable, semivolatile organic compounds
DOC = dissolved organic carbon
PAHs = polycyclic aromatic hydrocarbon compounds
PCBs = polychlorinated biphenyls
PBDEs = polybrominated diphenyl ethers
TOC = total organic carbon
TPH-D = total petroleum hydrocarbons - diesel fraction
TPH-G = total petroleum hydrocarbons - gasoline fraction
TOC = total organic carbon
TSS = total suspended solids

Sample Type

F = freshwater (river samples)
S = seawater (ocean boundary and Puget Sound water samples)
SPM = suspended particulate matter (trap and centrifuge samples)

Method

ECD = electron capture detection
ECY = Washington State Department of Ecology (method number)
EPA = U.S. Environmental Protection Agency (method number)
FID = flame ionization detection
GC = gas chromatography
HR = high resolution
ICP = inductively-coupled plasma detection
MS = mass spectrometric confirmation
PSEP = Puget Sound Estuary Program Protocols and Guidelines (PSEP, 1986; PSEP, 1997)
SIM = selective ion monitoring
SM = Standard Methods (APHA, 2005)

Laboratories

AP = Analytical Perspectives, Inc.
FGS = Frontier GeoSciences, Inc.
Horn = University of Maryland Environmental Laboratory, Horn Point, Maryland
MEL = Manchester Environmental Laboratory
PRL = Pacific Rim Laboratories, Inc.

Data Quality

Data Verification

Laboratory chemists, MEL's QA Officer, and project staff conducted data quality reviews. The reviews evaluated the acceptability of sampling and analytical results based on the measurement quality objectives (MQOs) outlined in the QA Project Plan. This section describes the data quality review process and summarizes the findings. Additional details can be found in Appendix D.

Field Data Quality Review and Findings

Project staff reviewed field notes and found that measurements were made consistent with methods described in the QA Project Plan, except as noted in the *Sampling Methods* section. Three minor data quality concerns were identified:

- Some salinity results from marine water column CTD profiles were flagged as suspect.
- Water depths recorded for river samplings (quarter points and pump intake depths) were only accurate to ± 1 foot due to water levels that changed with tides or flows.
- Flow rates and the water volume pumped to collect SPM from the Puyallup River (December 2009) were uncertain because debris sometimes accumulated in the tubing and impeded flow.

Analytical Data Quality Review and Findings

MEL and contract laboratory chemists conducted initial QA reviews to verify that samples were handled and analyzed according to QA Project Plan requirements. The reviews focused on:

- Sample storage conditions and holding times.
- Sample preparation, extraction, and analytical methods.
- Instrument calibrations.
- Method detection limits (MDLs) and reporting limits (RLs).
- Lab QC sample results.

MEL staff found that the results, with few exceptions, reflected the storage conditions, holding times, and analytical methods listed in the QA Project Plan. Results that met all MQOs were accepted without qualification.

Results were assigned a "J" qualifier code (indicating an estimated value) if the detected concentrations were less than the RL, or if one or more lab QC samples failed to meet MQOs. For example, chemical concentrations were qualified with a "J" if spiked QC samples showed consistently low recovery. However, the number of "J" qualifier codes assigned for different reasons was not easily quantified. Ecology's QA Officer assigned an "N" qualifier code for PCB and PBDE congeners that could only be tentatively identified (or "NJ" if also below reporting limits). A "UJ" qualifier code was assigned to sample results for various reasons but usually because concentrations were less than ten times (<10 X) those measured in batch-specific method blanks. This indicated potential contamination from sample handling and analysis in the laboratory. Analytes for which this occurred were lead, zinc, Lindane, di-N-butyl phthalate, PCB-011, PBDE-047, PBDE-099, and PBDE-100. Consistent with laboratory best practices (EPA and MEL), results assigned "N", "NJ", "U" and "UJ" qualifiers were not used in analyses unless stated otherwise.

Analytical results were rarely rejected (0.5% of all individual chemical concentrations reported). The chemicals for which concentrations were sometimes assigned a "REJ" qualifier code were 2-chloronaphthalene, 3-nitroaniline, 4-chloroaniline, acenaphthylene, benzoic acid, n-nitroso-diphenylamine, PBDE-007, PBDE- 010, and PBDE-015.

In terms of traditional measures of data quality:

- *Accuracy* of results was ensured by verifying calculations of final concentrations. Only a few corrections were required. The accuracy of metals results for marine water samples was also assessed by analyzing certified reference materials (CRM) [8]. CRM results were generally within the range of acceptable values, with exceptions often close to the limits of the acceptable range. Sample results were not qualified based on CRM analyses.
- *Bias* was evaluated by examining the recoveries of parameters spiked into de-ionized water or samples. Concentrations in laboratory control samples, matrix spikes, surrogate spikes, and internal standards were generally recovered within MQOs for the different parameters. Sample results were assigned a "J" when results for more than one QC sample were outside the MQOs. The nature of any potential analytical bias (high or low) was not preserved in this report or in Ecology's EIM database.
- *Precision* was assessed by analyzing laboratory and matrix spike duplicates. A relative percent difference (RPD) between concentrations in duplicates and their associated field samples that did not meet the relevant MQO was cause to assign a "J" qualifier [9].

MEL summarized data quality review findings in laboratory narratives and compiled final analytical results in printed-copy format and electronic data deliverables (EDDs) [10]. Project staff used these to conduct a similar data quality review and to apply study-specific data quality rules, as documented in Appendix D. This review resulted in some changes to laboratory-assigned qualifier codes and to reported concentrations. Important modifications included:

- Results for TSS, organic carbon, nutrients (nitrogen and phosphorus compounds), hardness, metals, and oil and grease were reported down to the MDL.
- Sample results were assigned a "UJ" only if they were less than or equal to three times (≤ 3X) the batch-specific method blank concentration.
- Concentrations of DOC and POC in marine water samples were adjusted to account for concentrations detected in method and field blanks.

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[8] National Research Council Canada CASS-4 and NASS-5 CRMs were the only reference materials analyzed during this study.

[9] Relative standard deviation (RSD) control limits applied to results for more than two lab replicates.

[10] Copies of laboratory narratives may be requested from the authors.

- Concentrations of metals in marine water samples were recalculated (the contract laboratory had subtracted the mean method blank concentration).

Rules pertaining to each of the modifications listed above are described in Appendix D. The number of each type of revision made by project staff to laboratory qualifier codes is shown in Tables D-1 to D-4. Reporting down to the MDL (instead of the RL) did not affect any marine water column data, but 62 river water sample results (1.2% of freshwater samples) were changed from nondetects ("U") to "J"-qualified or unqualified results. Of more than 19,000 individual chemical analyses of marine and river water samples, project staff assigned "UJ" or "J" qualifiers codes to 432 results received from MEL (2.3%) due to parameter concentrations in the lab method blanks.

Field Quality Assurance Sample Review and Findings

The various field QA samples from marine and river water sampling are described and discussed in Appendix D. Field QA sample results are presented in Tables D-5 through D-14.

Results for the field replicates and duplicates usually indicated a homogeneous environment and repeatable analytical results (Tables D-5 to D-8, D-11, D-13, and D-14). No chemical qualifier code was assigned to field replicate results that were substantially different because there were no pre-defined MQOs for such samples and the results may reflect spatial or temporal variability.

Bottle, filter, transfer, and equipment blanks sometimes contained measurable concentrations of copper, dissolved lead, zinc, PCB congeners, and PBDE congeners (Tables D-9, D-10, D- 12, and D-14). This indicated potential for marine and river water samples to become contaminated with low concentrations of these parameters during routine sampling, handling, and analysis. Field blank concentrations exceeding those in method blanks appeared to implicate sampling equipment and the sampling process as sources of contamination. Similar concentrations in field and method blanks indicated contamination likely occurred in laboratory settings.

Chemical concentrations in field blanks were not subtracted from sample results. Despite attempts to mimic marine water column and river water sampling procedures described in *Sampling Methods*, field blanks could not be created in exactly the same manner. Field blanks were exposed to sources of contamination longer than were marine and river water samples. For example, marine water was only exposed to ambient air while clean sample containers were being filled, whereas the associated field blanks were also exposed to air while being created. There was also evidence that rinsing sampling devices with ambient marine or river water eliminated or at least reduced contamination from the cleaning, storage, and handling processes. Therefore, subtracting field blank concentrations would inappropriately underestimate sample concentrations. Further discussion can be found in Appendix D.

Data Usability

Field measurements were nearly all usable. CTD results flagged as "suspect" did not affect interpretation of water column profiles because the suspect results always represented a single depth or limited depth range. Uncertain pumping rates and volumes pumped did not prevent calculation of centrifuge efficiency or alter chemistry results for samples of SPM.

In terms of traditional descriptions of data usability:

- *Representativeness*. Marine water column samples were collected from locations representing ocean boundary and main basin waters and from depths representing layers defined by the Box Model. River water samples were depth-integrated and SPM samples were time-integrated. Whether the results for marine and river water samples collected during three seasons represented average seasonal or annual conditions could not be determined.
- *Completeness*. The total number of water samples collected, the number of SPM samples collected from rivers, and the total number of QC samples created were similar to what was planned. The total number of analyses conducted using these samples also reflected plans. Only the deepest sediment traps deployed in Hood Canal were recovered, so the number of marine SPM samples and analyses failed to meet targets.
- *Comparability*. Sampling and analytical methods were chosen based on their history of previous use within and outside of the region. With the exception of oil and grease, analytical detection and reporting limits were similar to ones achieved for other studies. Limits for oil and grease were elevated relative to a related study (Herrera, 2010b) because these limits were based on a one-liter sample size instead of four liters.

Based on all data quality reviews, this study collected samples that were reasonably representative of environmental conditions, stored and handled appropriately, and analyzed for parameters of interest using methods comparable to other regional studies. Most laboratory results met study MQOs. Those that did not were appropriately qualified. All analytical results were deemed usable for the purposes of the present study except for:

- A few results for individual BNA and PAH compounds that were rejected.
- Some results for several PCB and PBDE congeners qualified with "N" and "NJ".
- Results for dissolved lead and zinc concentrations in marine water column samples (discussed below).

Marine water column samples sometimes contained dissolved metal concentrations greater than the associated total metal results. In most cases, the dissolved form was within 100% - 120% of the total concentration. This indicated a high fraction of the total metal concentration was in dissolved form and that the analysis could not distinguish between two low concentrations. However, some dissolved metal results were as much as 250% of the total. These samples appeared to reflect contamination of the dissolved sample at some stage of collection and handling. The marine water column data for metals were handled as follows:

- Arsenic and cadmium concentrations in marine water column samples were low, and it was often difficult to distinguish between them [11]. There was no evidence of sample contamination from filter blank results (Table D-9, Appendix D). Dissolved concentrations were included in summary statistics and data analyses.
- The dissolved copper concentration exceeded the corresponding total concentration in only two marine water column samples. The ratios of dissolved to total copper were 109% and 123%. All dissolved copper data were considered usable.
- Dissolved lead and zinc concentrations were more variable than those of the other metals and sometimes were more than two times the corresponding total concentration. For these reasons it was difficult to determine which dissolved results were analytically indistinguishable from total results and which reflected field or lab contamination. Therefore, descriptive statistics for dissolved lead and dissolved zinc are not presented in this report, and dissolved concentrations of these chemicals were not used in analyses.

Overall, perhaps the three greatest limitations on data usability are:

- Concentrations of organic chemicals detected in less than 50% of all samples (e.g., oil and grease in river water) or that were highly variable when detected (e.g., PBDEs in marine water samples) may not represent the normal range and variability. Uncertainty associated with estimates of loading or ocean exchange for these chemicals is relatively high.
- Concentrations of some organic chemicals (TPH, BNAs, chlorinated pesticides) were seldom detected in marine water column or river water samples. Consequently, transport estimates for these chemicals based on one-half the RL or MDL are likely biased high and also uncertain.
- Data for toxic chemicals associated with marine SPM collected during this study were limited because of the failure to recover most sediment traps. Estimates of the downward flux of toxic chemicals due to sedimentation will be limited and difficult to apply to other areas of Puget Sound and the ocean boundary.

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[11] For 21 arsenic results where the dissolved concentration exceeded the total, the average ratio was 1.05 (max=1.13). For 16 cadmium results, the average exceedance ratio was 1.08 (max=1.25).

Results

Marine Water Column

Ecology collected marine water column samples at seven sites during three seasonal sampling events (July 2009, October 2009, and January 2010). Sampling depths targeted surface and bottom waters, the division between layers being determined by CTD profiles and Box Model-defined boundaries. Details of sampling activities and water column conditions are provided in Appendix B, Tables B-1 and B-2. Collection depths from each location and sampling event are shown with vertical water density profiles and Box Model layers in Figures B-1 through B-7 of Appendix B.

Density profiles revealed that water column stratification at the three ocean boundary water sites varied seasonally. Stratification at these sites was strongest during July, became slightly degraded in October, and was absent in January apart from a near-surface freshwater lens. The stratification depths observed at the four Puget Sound basin sites did not differ markedly between the sampling events and were consistent with divisions defined by the Box Model. Stratification in the South Sound basin was always weak-to-absent, except for a shallow lens of freshwater from recent heavy rains was present at the surface in January 2010.

For each sampling location, the total number of samples collected and analyzed is summarized in Table 4. Nearly 500 analyses were conducted by a total of five laboratories. This section summarizes the marine water column results, with complete results tabulated in Appendix E and available from Ecology's EIM database.

Conventional Parameters

The TSS results from marine water column sampling are summarized in Table 5. With the exception of several elevated TSS concentrations in the Whidbey basin and at the San Juan de Fuca (SJdF) North station, values at all sites were between 0.8 and 2.3 mg/L over the course of the three sampling events. The average concentration of TSS was significantly lower in samples collected during October than in samples collected at other times. Results of various statistical analyses are presented in the *Discussion* section.

Organic carbon concentration results for samples collected during October 2009 and January 2010 are also summarized in Table 5. Measured DOC and POC concentrations were summed to represent TOC concentrations.

The concentration of DOC averaged 0.76 mg/L (63.1 µM) across all samples and showed little variability (CV = 0.12). Concentrations differed little between the seven sampling sites and between the surface and deep water layers. The average DOC concentration was greater at Puget Sound basins sites than at ocean boundary water sites. Concentrations were also greater in October than in January, but the apparent temporal difference was small (< 0.20 mg/L).

Table 4. Inventory of marine water column samples collected and analyzed.

Parameter → Marine Site ↓	TSS	POC	DOC	Metals – Total [1]	Metals – Dissolved [1]	BNAs [2]	PAHs [3]	Chlor. Pesticides [4]	PCBs [5]	PBDEs [6]	Total
Hood Canal	6	4	4	6	6	6	6	6	6	6	56
South Sd Basin	6	4	4	6	6	6	6	6	6	6	56
Main Basin	6	4	4	6	6	6	6	6	6	6	56
Whidbey Basin	6	4	4	6	6	6	6	6	6	6	56
SJdF at Sill	6	4	4	6	6	6	6	6	6	6	56
SJdF North	6	4	4	6	6	6	6	6	6	6	56
Haro Str	6	4	4	6	6	6	6	6	6	6	56
Field QA samples	6	21	14	6	5	6	5	4	11	5	83
Total =	48	49	42	48	47	48	47	46	53	47	475

[1] Metals included arsenic, cadmium, copper, lead, zinc analyses.
[2] BNAs included 55 individual compounds.
[3] PAHs included 22 individual compounds.
[4] Chlorinated Pesticides included 33 individual compounds.
[5] PCBs included 209 individual congeners.
[6] PBDEs included 36 individual congeners.

Table 5. Summary statistics for TSS, DOC, POC, and TOC in the marine water column.

Parameter (mg/L)	Times Detected	Percent Detected	Min.	25th %ile	Median	Mean	CV	75th %ile	Max.
All 7 Stations									
TSS	42	100	0.80	1.2	1.6	1.8	0.60	1.9	6.0
DOC	28	100	0.61	0.70	0.75	0.76	0.12	0.81	0.97
POC	28	100	0.03	0.05	0.06	0.13	2.44	0.09	1.78
TOC *	28	100	0.66	0.75	0.81	0.89	0.43	0.87	2.75
Ocean Boundary Stations (3)									
TSS	18	100	1.0	1.2	1.6	1.9	0.59	2.2	6.0
DOC	12	100	0.61	0.66	0.70	0.70	0.09	0.71	0.81
POC	12	100	0.04	0.04	0.05	0.06	0.35	0.07	0.11
TOC *	12	100	0.66	0.73	0.75	0.76	0.08	0.77	0.89
Puget Sound Stations (4)									
TSS	24	100	0.8	1.2	1.4	1.7	0.61	1.7	5.5
DOC	16	100	0.71	0.75	0.78	0.80	0.10	0.84	0.97
POC	16	100	0.03	0.05	0.07	0.19	2.25	0.12	1.78
TOC *	16	100	0.74	0.81	0.85	0.99	0.48	0.99	2.75

CV = Coefficient of variation.
* Values for TOC are calculated as the sum of DOC and POC concentrations.

The average POC concentration was 0.13 mg/L (11 µM). Concentrations in surface waters of Puget Sound basin sites during October were the most variable (Figure 4) and exceeded concentrations measured in ocean boundary waters. The average POC concentration was greater in October samples than in January samples.

The pool of organic carbon was dominated by the dissolved fraction, with DOC averaging more than 90% of TOC. The October Whidbey Basin surface water sample was an exception. It contained an unusually high POC concentration (Figure 4) that was 65% of TOC.

As was true for DOC, average TOC concentrations were greater in Puget Sound basins than in boundary waters, and greater during the fall than in the winter. TOC concentrations in surface water samples collected in October exceeded those in the deep waters by an average of nearly 0.6 mg/L. However, by January, TOC concentrations at the two depths differed little.

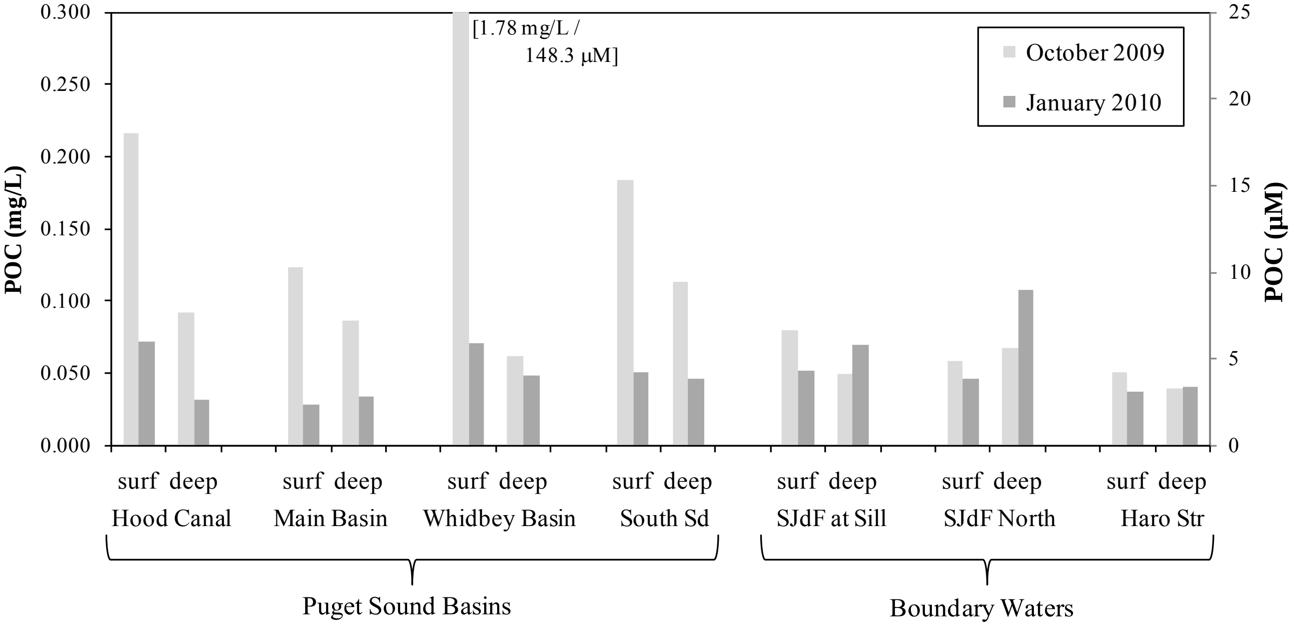


Figure 4. Summary of marine water column POC results.

Metals

Marine water column samples were analyzed for total and dissolved forms of arsenic, cadmium, copper, lead, and zinc. Summary statistics for marine metals are presented in Table 6, and complete results can be found in Table E-1 of Appendix E.

Dissolved metal results sometimes exceeded their corresponding total concentration. For the purposes of this project, all dissolved results for arsenic, cadmium, and copper were deemed usable. However, uncertainties associated with the results for dissolved lead and dissolved zinc caused these data to be excluded from analyses. See *Data Usability* section.

Table 6. Summary statistics for total and dissolved metals in the marine water column.

Parameter (µg/L)	Times Detected	Percent Detected	Min.	25th %ile	Median	Mean	CV	75th %ile	Max.
All 7 Stations									
Arsenic, Total	42	100	1.16	1.36	1.41	1.42	0.06	1.49	1.56
Arsenic, Dissolved	42	100	1.26	1.35	1.42	1.42	0.06	1.46	1.70
Cadmium, Total	42	100	0.059	0.079	0.084	0.085	0.12	0.091	0.112
Cadmium, Dissolved	42	100	0.067	0.074	0.081	0.083	0.13	0.089	0.111
Copper, Total	42	100	0.19	0.29	0.38	0.41	0.52	0.44	1.37
Copper, Dissolved	42	100	0.16	0.24	0.30	0.30	0.26	0.37	0.51
Lead, Total *	37	88	0.015	0.043	0.070	0.085	0.64	0.110	0.230
Zinc, Total *	42	100	0.41	0.55	0.69	0.86	1.23	0.84	7.44
Ocean Boundary Stations (3)									
Arsenic, Total	18	100	1.31	1.36	1.45	1.43	0.06	1.52	1.56
Cadmium, Total	18	100	0.080	0.087	0.089	0.090	0.07	0.092	0.105
Copper, Total	18	100	0.19	0.24	0.29	0.34	0.43	0.38	0.72
Lead, Total	15	83	0.025	0.050	0.070	0.086	0.62	0.109	0.230
Zinc, Total	18	100	0.41	0.52	0.58	0.69	0.39	0.79	1.44
Puget Sound Stations (4)									
Arsenic Total	24	100	1.16	1.35	1.41	1.40	0.07	1.47	1.54
Cadmium, Total	24	100	0.059	0.076	0.081	0.081	0.13	0.086	0.112
Copper, Total	24	100	0.26	0.36	0.40	0.47	0.51	0.46	1.37
Lead, Total	22	92	0.015	0.039	0.074	0.085	0.66	0.114	0.206
Zinc, Total	24	100	0.48	0.60	0.70	1.00	1.38	0.85	7.44

***** Summary statistics for concentrations of dissolved lead and zinc are not presented here. Dissolved concentrations often exceeded total concentrations to a degree that complicated distinguishing valid results from ones that reflected field or laboratory contamination.

Arsenic

The range of total arsenic concentrations measured in regional marine waters was 1.16 - 1.56 µg/L (Figure 5). The overall average concentration was 1.42 µg/L. Total arsenic concentrations were greater in January than in October and also greater in deep waters than in surface waters.

Results for dissolved arsenic are shown in Figure 6. Dissolved arsenic averaged 96% of the total concentration in one-half of all samples (21/42). However, the dissolved fraction marginally exceeded the total concentration in the remaining 21 samples. Filter blanks showed no evidence of contamination. Therefore, these apparently anomalous results were attributed to the analytical difficulty of differentiating between dissolved and total forms at such low concentrations.

Cadmium

Total cadmium concentrations, shown in Figure 7, ranged from 0.059 - 0.112 µg/L. The average concentration at all locations and depths was 0.085 µg/L. Ocean boundary water concentrations were greater than those in Puget Sound. In addition, the average deep water concentration exceeded that for surface waters.

Like arsenic, dissolved cadmium was the predominant form. In 23 samples, dissolved cadmium averaged 91% of the total concentration. The dissolved form exceeded the total concentration in the remaining 19 samples. Filter blanks again showed no evidence of contamination (similar to the arsenic results) so these exceedances were also attributed to difficulties distinguishing between the dissolved fraction and the total at low concentrations.

As with total concentrations, dissolved cadmium was greater in ocean boundary waters than in Puget Sound. Surface water dissolved concentrations at all sites except SJdF Sill increased from July to October and again from October to January (Figure 8). Dissolved cadmium was greater in deep waters than in surface waters during July and October. This was especially true for ocean boundary sites, where concentrations exceeded those in surface waters by as much as 0.028 µg/L. However, by January the ocean boundary sites had higher dissolved cadmium concentrations in the surface waters than in deep waters.

Copper

Total copper concentrations in the marine water column ranged from 0.19 - 1.37 µg/L (Figure 9) and were more variable than dissolved concentrations (Figure 10). Elevated total copper concentrations occurred on one occasion at the Hood Canal, Main Basin, SJdF North, and Haro Strait sites. The elevated results did not appear to be associated with any spatial or temporal pattern. Dissolved copper concentrations ranged from 0.16 - 0.51 µg/L, representing 30% to 100% of the total (average of 80%). Dissolved copper was greater than the total in only two samples.

The waters of Puget Sound contained greater concentrations of total and dissolved copper than did ocean boundary waters. For example, dissolved copper in Puget Sound ranged from 0.28 - 0.51 µg/L while boundary waters contained 0.16 - 0.28 µg/L. Total and dissolved copper concentrations were lowest in October in all but one location. The maximum observed total and dissolved copper concentrations were in the deep water sample collected from Hood Canal in July.

Lead

Total lead in the marine water column, shown in Figure 11, ranged from 0.015 - 0.230 µg/L. Total lead concentrations in the deep waters usually exceeded those in surface waters. October concentrations of total lead in five samples (SJdF North, surface; SJdF Sill, surface and deep; South Sound, surface and deep) were within three times the concentration in the associated laboratory method blank. These results were qualified as "UJ" (as described in Appendix D). Dissolved lead results were not usable for the purposes of this project (see *Data Usability*).

Zinc

The range of total zinc concentrations in the marine water column was 0.41 - 7.44 µg/L (Figure 12). The average for all locations, seasons, and depths was 0.86 µg/L. Total zinc concentrations in deep waters were often greater than in surface waters, especially during October and January. Dissolved zinc results were not usable for the purposes of this project (see *Data Usability*).

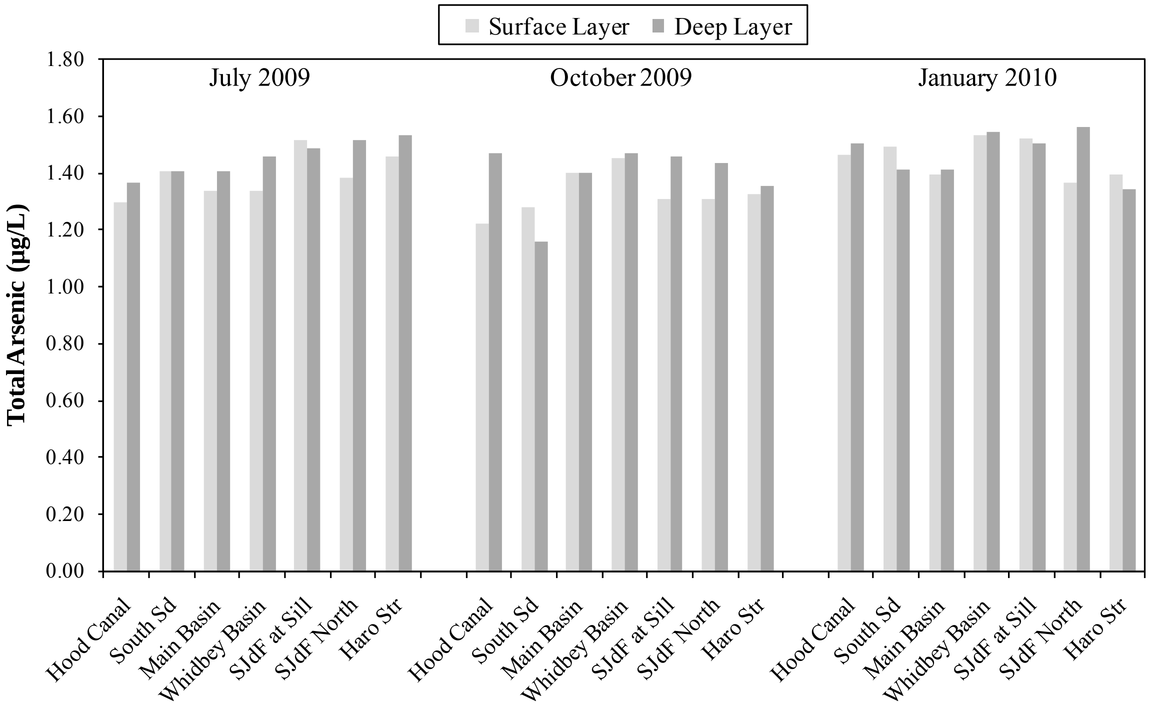


Figure 5. Concentrations of total arsenic in the marine water column.

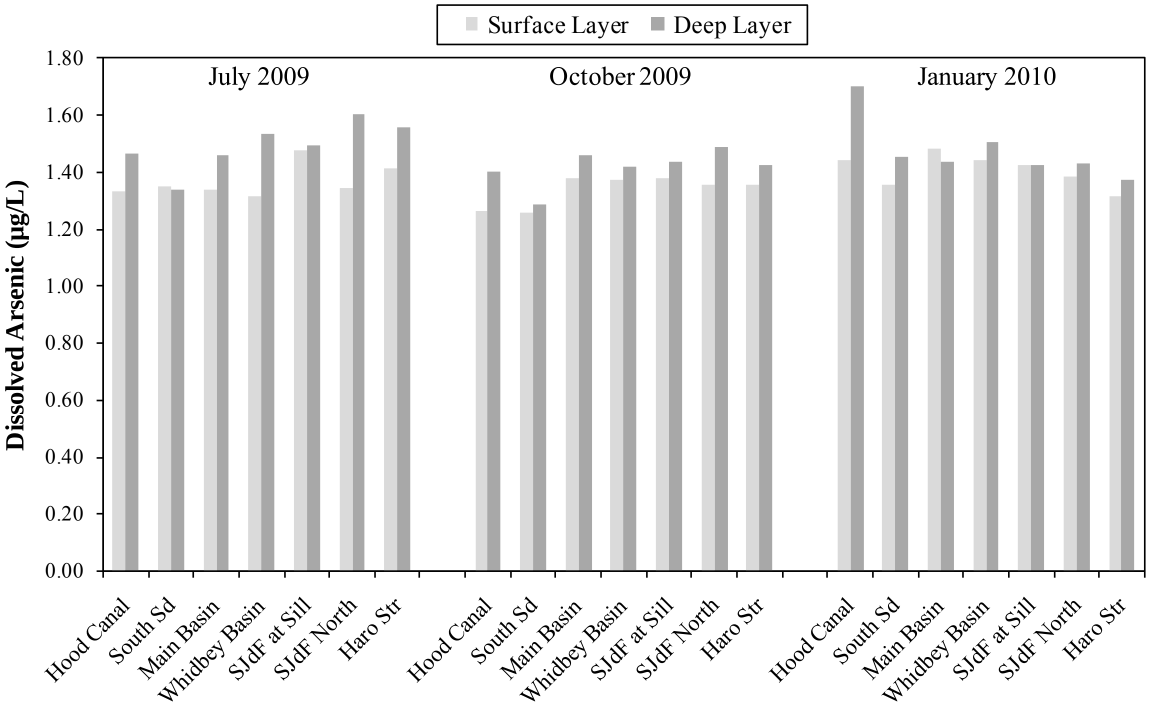


Figure 6. Concentrations of dissolved arsenic in the marine water column.

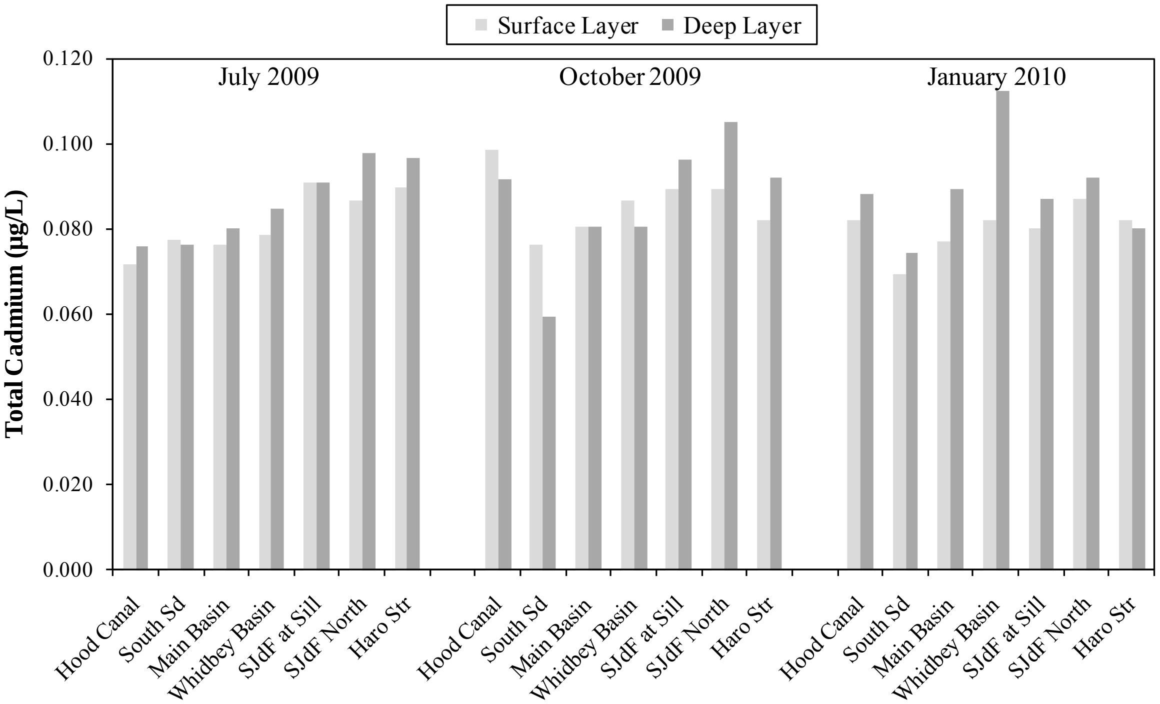


Figure 7. Concentrations of total cadmium in the marine water column.

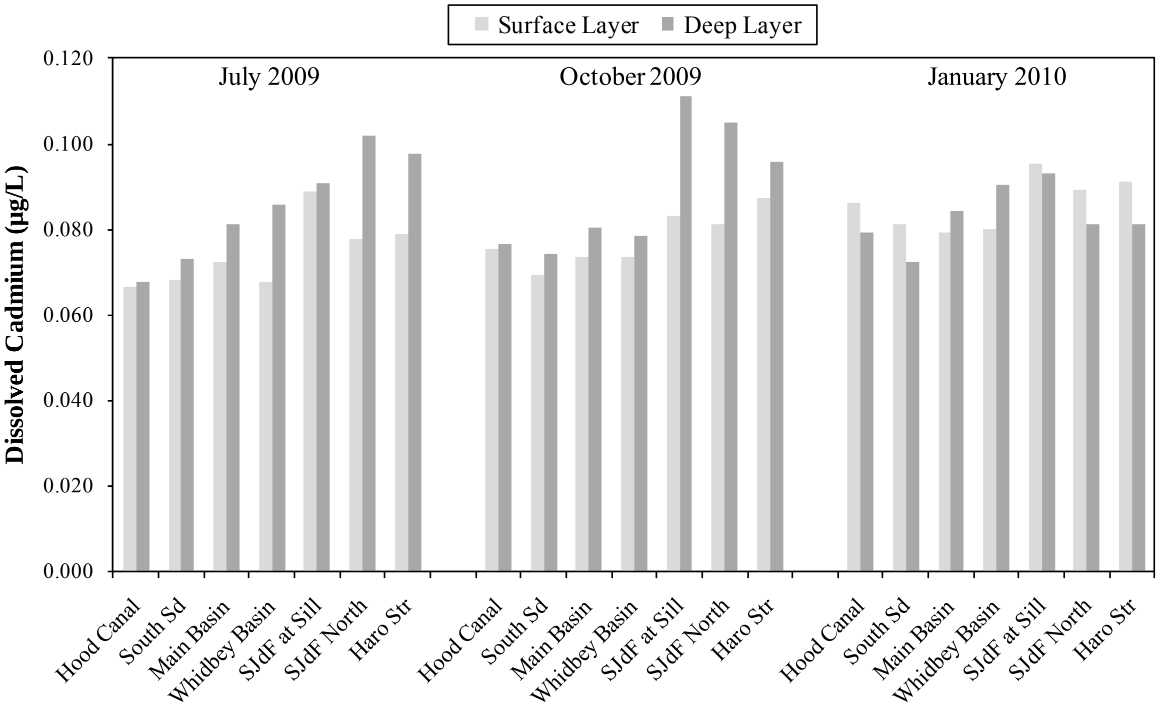


Figure 8. Concentrations of dissolved cadmium in the marine water column.

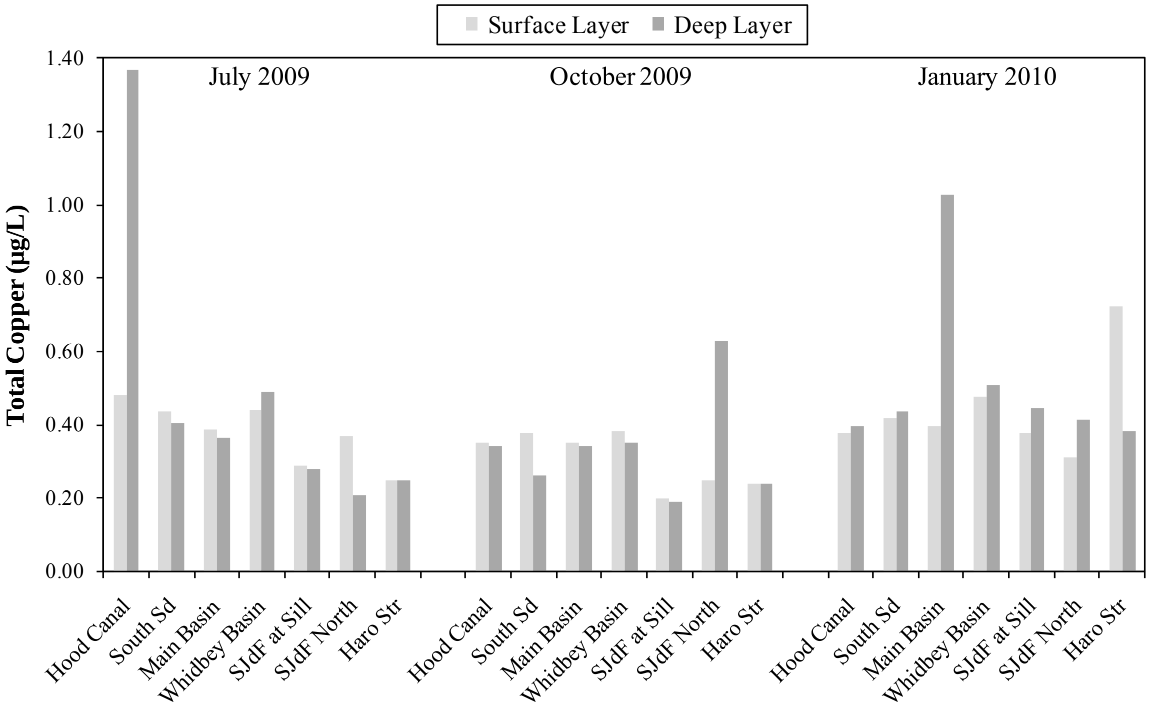


Figure 9. Concentrations of total copper in the marine water column.

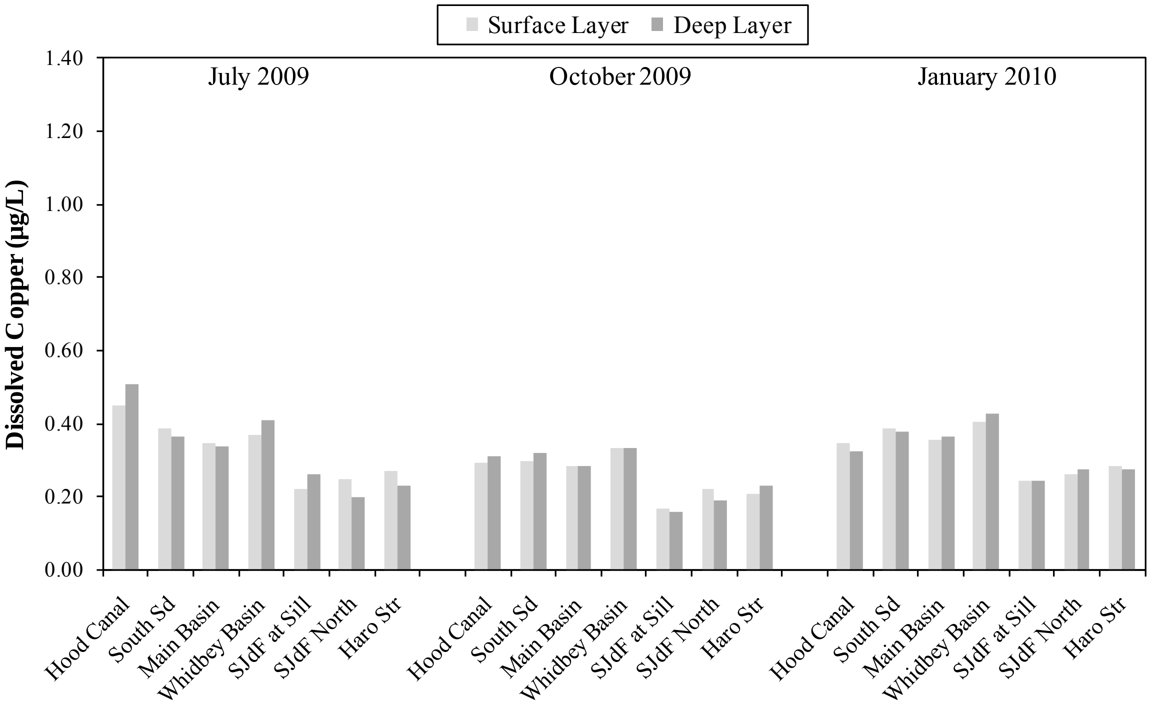


Figure 10. Concentrations of dissolved copper in the marine water column.

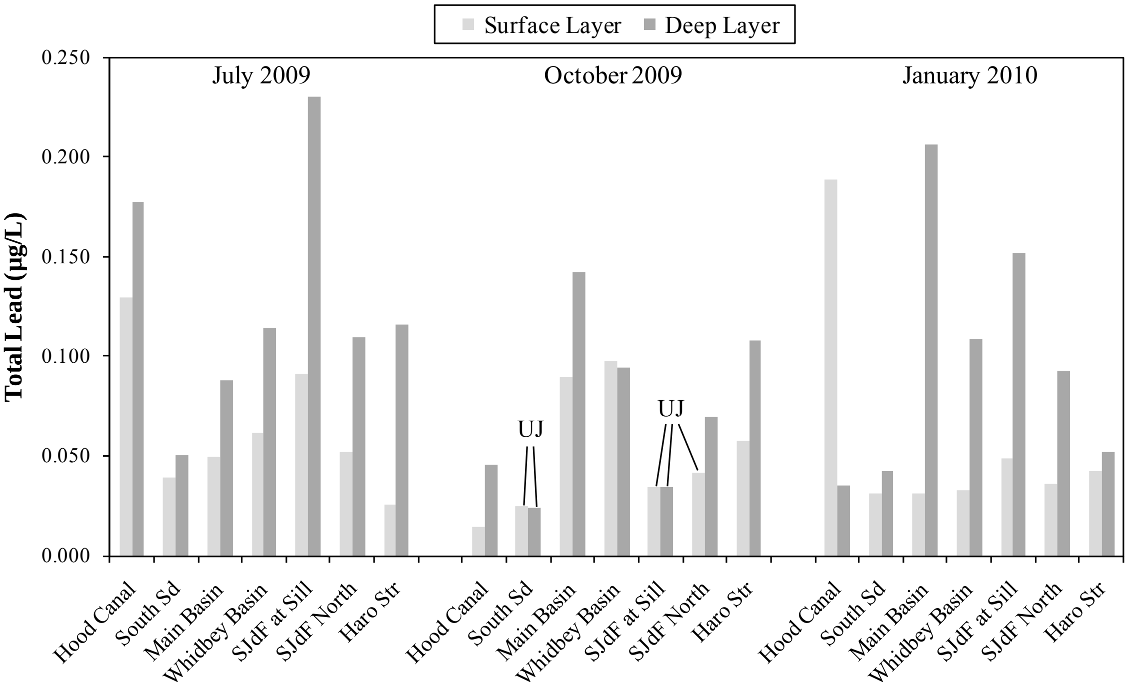


Figure 11. Concentrations of total lead in the marine water column.

Samples collected during October qualified as "UJ" were within three times the laboratory method blank concentration. Dissolved lead results not shown (see Data Usability).

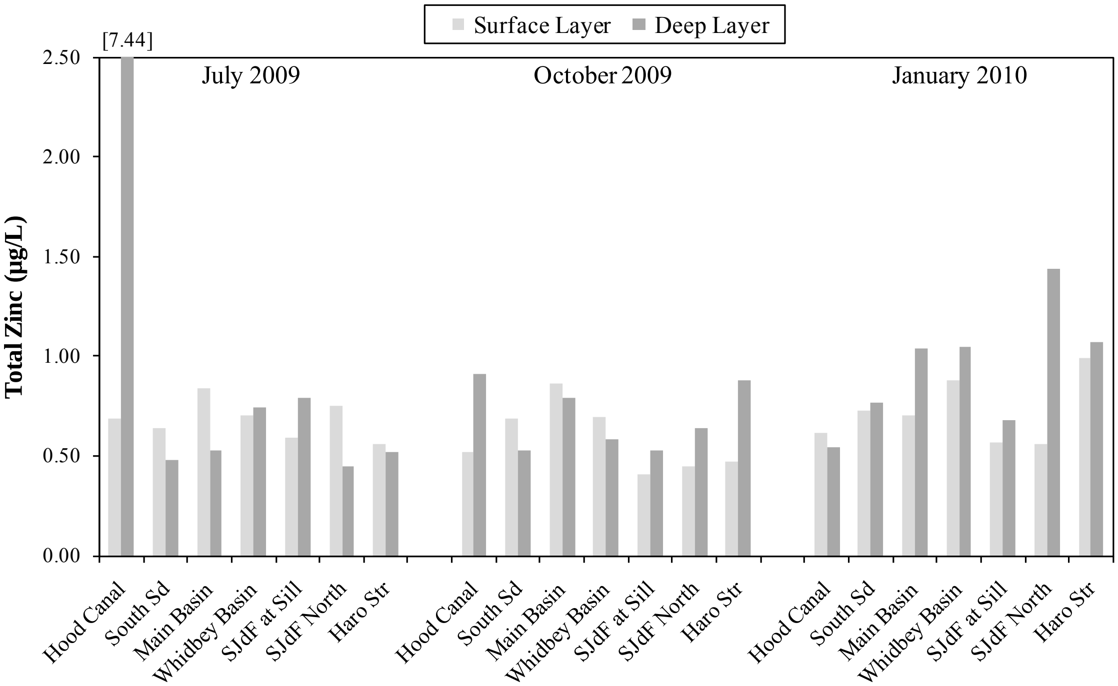


Figure 12. Concentrations of total zinc in the marine water column.

Dissolved zinc results not shown (see Data Usability).

Organics

Marine water column samples were analyzed for 33 chlorinated pesticide compounds, but only five were detected (Table 7). These compounds were found in samples collected during July and October, while no measurable concentrations were detected in January samples. Chlorinated pesticides were detected infrequently and only in the northern boundary waters.

Table 7. Summary of measurable chlorinated pesticides in the marine water column.

Date	Sampling Location	Water Column Layer	4,4'-DDE (ng/L)	Alpha-BHC (ng/L)	Beta-BHC	Delta-BHC (ng/L)	Hexachloro-benzene (ng/L)
7/8/09	SJdF North	surface	0.21 J				
		deep	0.39				
7/8/09	Haro Str	deep	0.21				
9/28/09	Whidbey	deep		0.21	0.32	0.25 J	
10/7/09	SJdF North	surface					0.21

Of the 55 BNA compounds targeted by the analyses, 11 were detected at least once (Table 8). All of these except Triclosan were detected in samples collected during July. A narrow range of cholesterol concentrations was detected in October and January samples. Triclosan was only detected in the samples collected during October. No measureable concentrations of any compounds were found in January.

PAH analyses targeted 22 compounds. PAHs were not detected in any marine water column sample at the detection limits (from 0.0005 to 0.033 µg/L).

PCBs and PBDEs

Results for marine water column PCBs and PBDEs are summarized in Table 9. All results were method blank-qualified at the congener level before calculating homolog totals.

PCBs were detected in all marine water column samples (Figure 13). Total PCBs ranged from 6.09 to 75.1 pg/L, averaging 26.3 pg/L. The sum of the congeners in the tetra- and penta-chlorinated homolog groups comprised an average of 80% of the total PCBs.

Table 8. Summary of measurable BNA compounds in the marine water column.

Date	Sampling Location	Water Column Layer	2,4-Dichlorophenol (µg/L)	2-Methylphenol (µg/L)	3B-Coprostanol (µg/L)	4-Chloro-3-Methylphenol (µg/L)	Bis(2-Ethylhexyl) Phthalate (µg/L)	Bisphenol A (µg/L)	Caffeine (µg/L)	Cholesterol (µg/L)	Ethanol, 2-Chloro-, Phosphate (3:1) (µg/L)	Phenol (µg/L)	Triclosan (µg/L)
7/7/09	Hood Canal	surface	0.06 J	0.01 J	1.2 J	0.06 J	0.05 J			0.62 J			
		deep	0.16 J	0.04 J		0.33 J	0.01 J	0.19 J				0.02 J	
7/7/09	SJdF at Sill	deep				0.03 J							
7/8/09	SJdF North	deep				0.02 J							
7/8/09	Haro Str	deep	0.06 J	0.01 J		0.09 J	0.06 J						
7/9/09	South Sd	surface							0.03 J	0.76 J	0.1		
		deep				0.03 J				0.64 J			
7/10/09	Whidbey	surface	0.04 J	0.01 J		0.02 J				0.75 J			
9/28/09	Whidbey	surface								1.1			
		deep								0.73 J			
9/29/09	Main Basin	surface								0.73 J			
		deep								0.71 J			
9/30/09	Hood Canal	surface								0.77 J			
		deep								0.7 J			
10/1/09	South Sd	surface								0.73 J			
		deep								0.73 J			
10/7/09	SJdF at Sill	surface								0.73 J			0.048 J
		deep								0.71 J			0.048 J
10/7/09	SJdF North	surface								0.73 J			0.051 J
		deep								0.72 J			0.05 J
10/7/09	Haro Str	surface											0.047 J
		deep								0.74 J			0.051 J

Table 9. Summary statistics for PCB and PBDE homologs in the marine water column.

Congener summation rules are described in Appendix D. Congeners in each homolog group are listed in Appendix E (Tables E-20 to E-22, and E-24). Concentrations of tentatively-identified congeners (results qualified as N or NJ) were not included in homolog or overall totals. Note: Homolog concentrations in a single sample can be summed to equal the total concentration in that sample, but summing the homolog statistics below will not result in the total concentration statistics.

Parameter (pg/L)	Times Detected	Percent Detected	Min.	25th %ile	Median	Mean	CV	75th %ile	Max.
PCB homologs and totals (pg/L)									
Mono-chlorinated	11	26	0.40	0.96	1.73	4.28	1.45	2.84	18.7
Di-chlorinated	22	52	1.03	2.58	3.58	3.65	0.47	4.09	7.31
Tri-chlorinated	27	64	0.67	1.61	2.41	3.21	0.63	4.74	8.79
Tetra-chlorinated	42	100	2.84	11.9	14.0	16.5	0.47	21.4	37.1
Penta-chlorinated	31	74	0.98	2.45	3.50	4.08	0.55	5.38	8.92
Hexa-chlorinated	22	52	0.87	1.26	2.25	2.85	0.70	3.38	7.39
Hepta-chlorinated	3	7	1.63	1.74	2.06	2.24	0.32	2.80	3.04
Octa-chlorinated	2	5	0.29	0.29	0.78	0.78	0.89	1.27	1.27
Nona-chlorinated	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
PCB-209	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total PCBs	42	100	6.09	14.6	24.0	26.3	0.57	36.8	75.1
PBDE homologs and totals (pg/L)									
Mono-brominated	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Di-brominated	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tri-brominated	1	2	10.7	n/a	10.7	10.7	1.00	n/a	10.7
Tetra-brominated	3	7	87.5	106	163	279	0.96	480	586
Penta-brominated	6	14	51.0	91.5	194	404	1.25	521	1,380
Hexa-brominated	3	7	61.1	69.4	94.2	126	0.68	192	224
Hepta-brominated	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Octa-brominated	2	5	43	43.0	121	121	0.91	199	199
Nona-brominated	2	5	399	399	1,870	1,870	1.11	3,330	3,330
PBDE-209	5	12	904	945	1,300	4,200	1.47	5,820	15,200
Total PBDEs	10	24	51.0	266	749	2,860	1.98	3,100	18,700

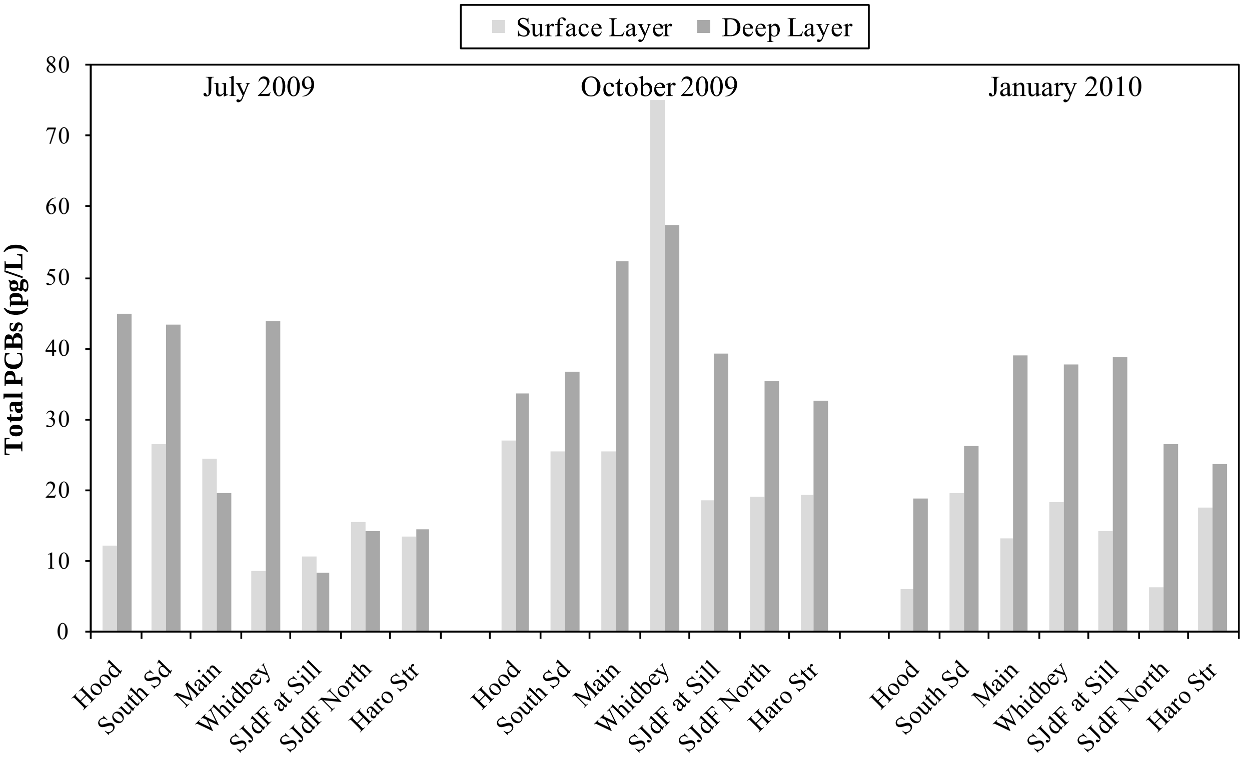


Figure 13. Summary of results for total PCBs in marine water column samples.

Tentatively-identified congeners (qualified as N or NJ) were not included in total PCB sums.

The average concentration of total PCBs in Puget Sound was greater than the average in ocean boundary water samples. October samples usually contained greater concentrations than those in samples collected at other times. Deep layer total PCB concentrations generally exceeded surface water concentrations (Figure 13). One notable exception was that July samples from all three boundary water sites had nearly identical surface and deep layer concentrations. Another exception was the October surface sample from Whidbey Basin, where the highest total PCB concentration of the study was observed (75.1 pg/L). This latter sample also had extremely elevated results for TSS, POC, dissolved lead, and dissolved zinc.

Measureable concentrations of PBDEs were detected in 10 of the 42 samples. Detected total PBDEs ranged from 51 to 18,700 pg/L and were highly variable (CV=1.98). The average total PBDE concentration was 2,860 pg/L, while the median value was much lower at 749 pg/L. Penta-brominated congeners and PBDE-209 were detected most frequently.

The maximum detected total PBDE concentration of 18,700 pg/L was measured in the January sample from the deep water layer at the Haro Strait site. The only other chemical concentration elevated in this sample was total zinc. The next highest concentration of total PBDEs was 3,190 pg/L, also from the Haro Strait site but in the October surface water sample. These and other PBDE concentrations were identified as statistical outliers (Appendix J, Table J-1), but were included in analyses because there was no evidence that the samples had been contaminated.

Marine SPM

As previously mentioned, after a deployment period of three months only one of the five sediment trap moorings was successfully recovered. The particulate sample collected from this mooring represented the deep layer of Hood Canal. Analyses included % solids, TOC, five metals, PCB congeners, and PBDE congeners. To partially compensate for the paucity of marine SPM samples, archived particulates collected from traps deployed in Case and Carr Inlets during the spring of 2008 were submitted for the same analyses of metals, PCBs, and PBDEs. Marine SPM results are presented in Table 10. The Case+Carr results were qualified as estimated values ("J") because the samples were analyzed beyond recommended holding times.

Table 10. Results for sediment trap collections of marine suspended particulates.

Parameter	Hood Canal	Case+Carr Inlets
Conventionals (%)		
TOC	2.75	n/a
Total Recoverable Metals (mg/Kg dry)		
Arsenic	7.53	5.72 J
Cadmium	0.87	1.04 J
Copper	82.0	18.5 J
Lead	9.13	8.78 J
Zinc	90.0	72.0 J
PCB Homologs (ng/Kg dry) *		
Mono-chlorinated	ND	35.3 J
Di-chlorinated	429	840 J
Tri-chlorinated	280	1,290 J
Tetra-chlorinated	343 J	1,230 J
Penta-chlorinated	948	2,290 J
Hexa-chlorinated	642	2,920 J
Hepta-chlorinated	284	909 J
Octa-chlorinated	11.6 J	249 J
Nona-chlorinated	ND	53.4 J
PCB-209	27.8	32.3 J
Total PCBs	2,970	9,850 J
PBDE Homologs (ng/Kg dry) *		
Mono-brominated	n/a	n/a
Di-brominated	14 UJ	17.4 UJ
Tri-brominated	10.2 J	68.7 J
Tetra-brominated	138 J	498 J
Penta-brominated	131 J	269 J
Hexa-brominated	43.6 J	58.4 J
Hepta-brominated	54.1 J	41.2 J
Octa-brominated	57.3 J	28.4 J
Nona-brominated	270 J	92.1 J
PBDE-209	879	174 UJ
Total PBDEs	1,580 J	1,060 J

* Homolog and total concentrations do not include tentatively-identified results (those qualified with "N" or "NJ").

Of the five metals analyzed, Hood Canal particulate concentrations exceeded those found in Case+Carr particulates for four of these metals. Differences in particulate copper concentrations between the two sites were especially large, with Hood Canal concentrations more than four times higher than those measured in Case+Carr solids. Cadmium was the only metal for which Case+Carr particulate concentrations were greater than Hood Canal values, although the difference was small (0.17 mg/Kg dry).

Sediment trap collections revealed marked differences in particulate PCB concentrations between the two sites. Solids from the Case+Carr sample had a total PCB concentration over three times that found in the Hood Canal particulates, and all 10 PCB homolog concentrations were higher in the Case+Carr sample.

In contrast, PBDE homolog concentrations varied between the two locations. Congeners with lower levels of bromination (tri-, tetra-, and penta-BDEs) were found in higher concentrations in Case+Carr SPM. Hexa- and hepta-brominated congeners had similar concentrations at the two sites. Octa-, nona-, and deca-BDEs had higher concentrations in Hood Canal SPM. Overall, the concentration of total PBDEs in Hood Canal particulates was 50% higher than that measured in Case+Carr SPM.

River Water

Ecology sampled the five largest rivers flowing into Puget Sound three times between late July 2009 and early January 2010. Sampling conditions in each river spanned a range of discharges and conditions. The upper panels of Figures 14-18 highlight the mean daily flow in each river on each sampling date atop hydrographs of mean daily flow for the calendar year. For context, hydrographs of long-term median daily flow are also shown for each river. Periods of relatively high flow appear as the darkest areas, while periods of relatively low flow appear under the white areas. In general, the rivers had lower-than-normal flows in 2009, but periods of higher flows did occur in late spring and late fall.

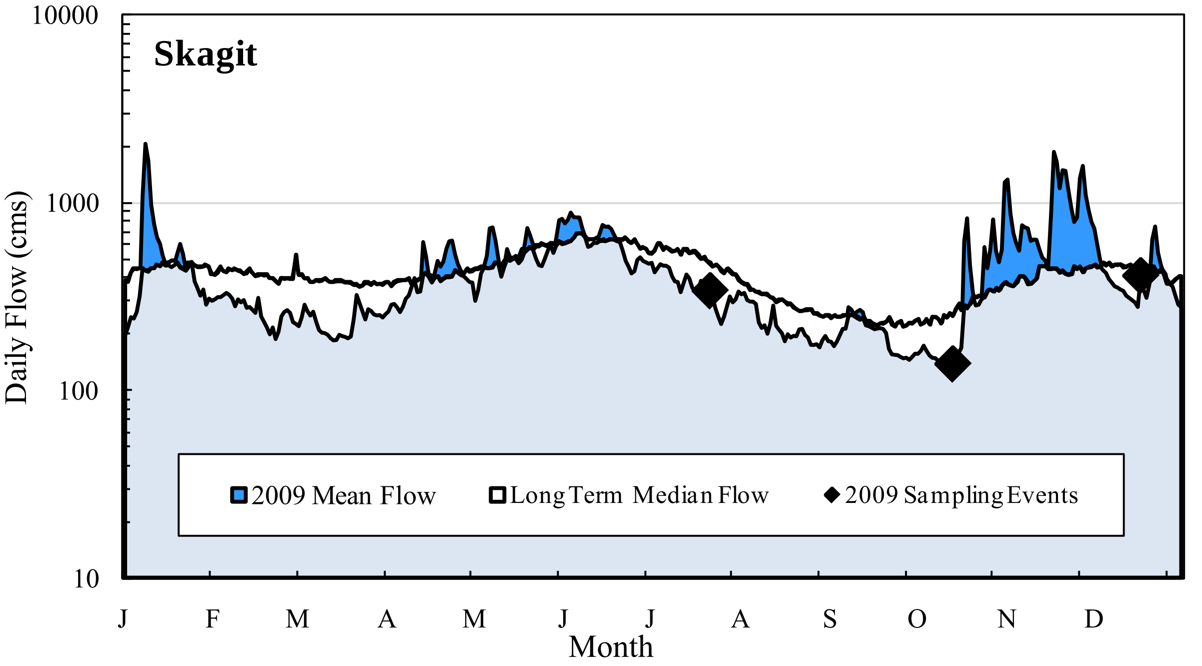
Daily flows encountered while sampling were usually below the long-term median flow for the same dates. Exceptions (higher-than-normal flows) were encountered in the Stillaguamish (October 2009), the Snohomish (December 2009), and the Nooksack (January 2010). Overall, mean daily flows ranged from 13.3 cms (470 cfs) in the Stillaguamish in July to 521 cms (18,500 cfs) in the Skagit in December (Table 11). These flows represented baseflows and runoff-related flows, with the flow regime determined after examining:

- Seasonal hydrographs.
- Mean daily flows preceding and following each sampling (lower panels of Figures 14-18).
- Recent climate records (especially for precipitation).
- Other evidence (long-term flow records, turbidity).

In July, dry-season baseflows were evident in all rivers except the Puyallup (Figure 18). The Puyallup was highly turbid, carrying a high concentration of suspended solids (233 mg/L). However, the relatively high TSS was consistent with long-term ambient monitoring data for late-summer and was probably due to silts in glacier meltwaters enhanced by recent high air temperatures.

In October, baseflows were encountered while sampling the Skagit and Nooksack (Figures 14 and 16). The Snohomish and Stillaguamish were sampled during late stages of obvious runoff events (Figures 15 and 17). It was less obvious in Figure 18 that Puyallup River flow was related to runoff. However, elevated flow and concentrations of suspended solids reflected an early stage of runoff from 1.33 inches of rain that fell upstream the day before.

Sampling during December 2009 and January 2010 found wet-season baseflows in the Stillaguamish and Puyallup. The other three rivers had flows in the rising or falling stage of runoff-related events. River water in the Skagit was running clear when sampling began but became visibly turbid soon afterward.



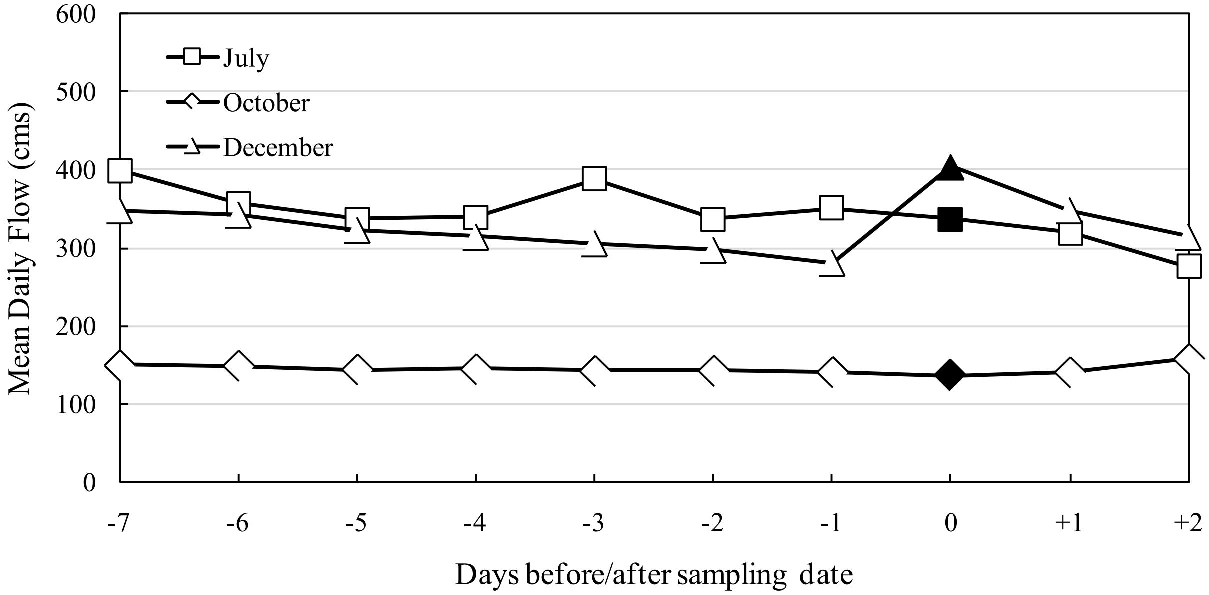
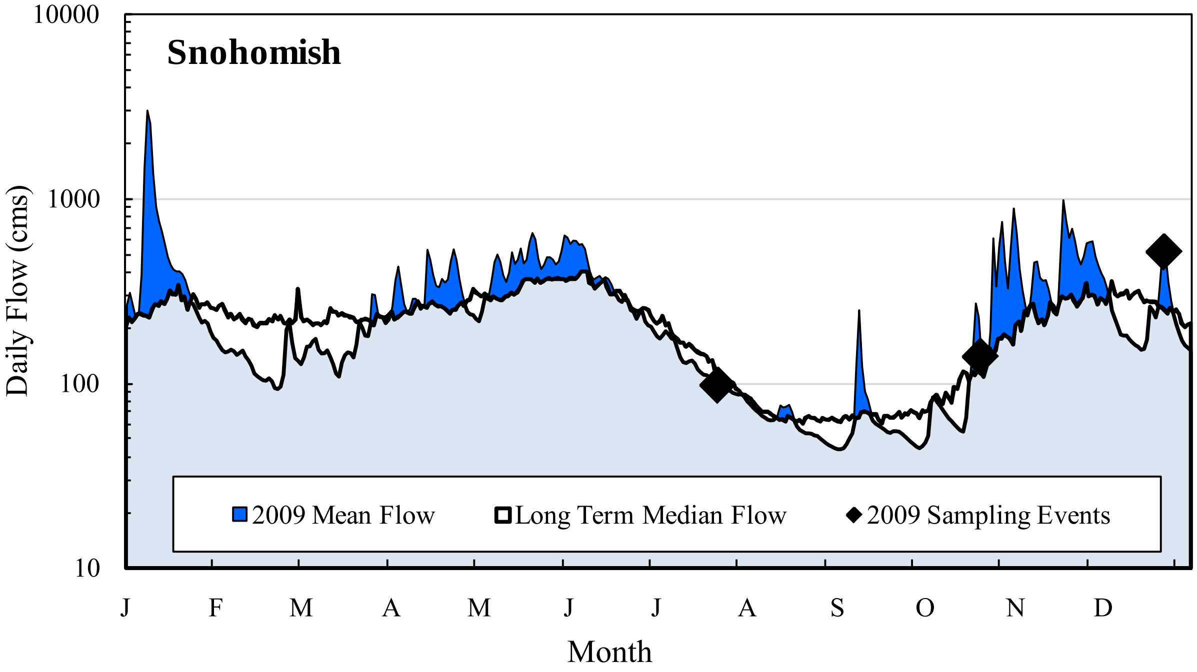


Figure 14. Skagit River daily flows.

- Upper: Sampling events are shown as black diamonds on the hydrograph for mean daily flows during 2009 (shaded beneath). Relative to long-term median flows, periods of high flow appear as the darkest areas and periods of low flow appear under the white areas.
- Lower: Mean daily flows prior to, during, and immediately after each sampling event (solid black symbols).

July and October sampling occurred during baseflows, while sampling in December was during the late stages of a runoff event.



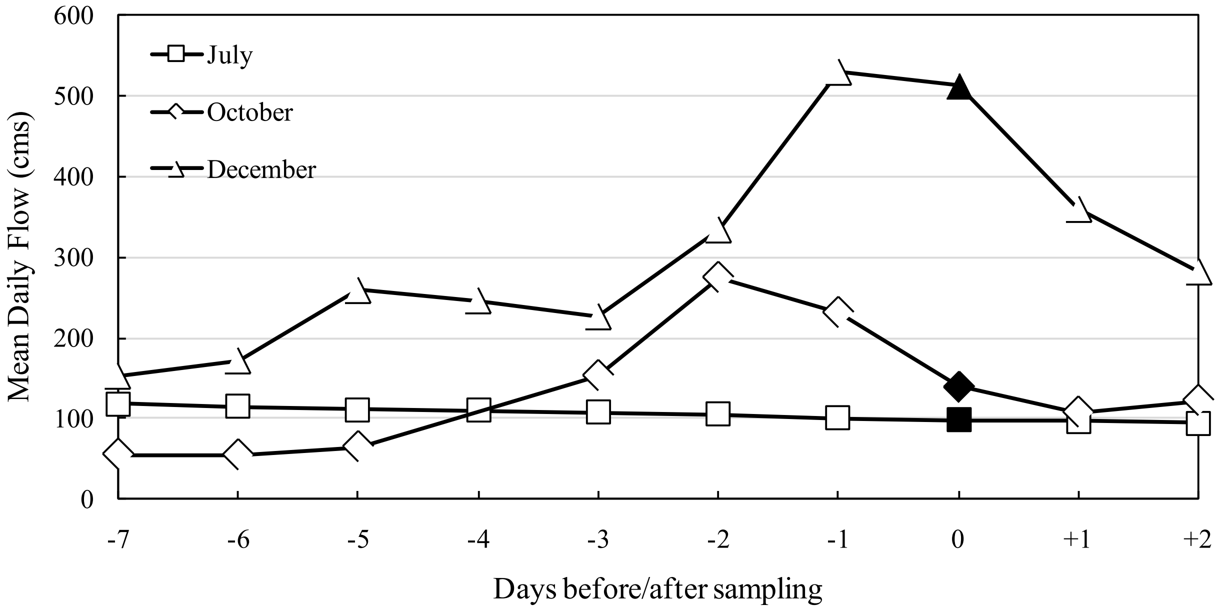


Figure 15. Snohomish River daily flows.

- Upper: Sampling events are shown as black diamonds on the hydrograph for mean daily flows during 2009 (shaded beneath). Relative to long-term median flows, periods of high flow appear as the darkest areas and periods of low flow appear under the white areas.
- Lower: Mean daily flows prior to, during, and immediately after each sampling event (shown as solid black symbols).

Sampling in July was during baseflows. October and December sampling events occurred near the end and peak of runoff events, respectively.

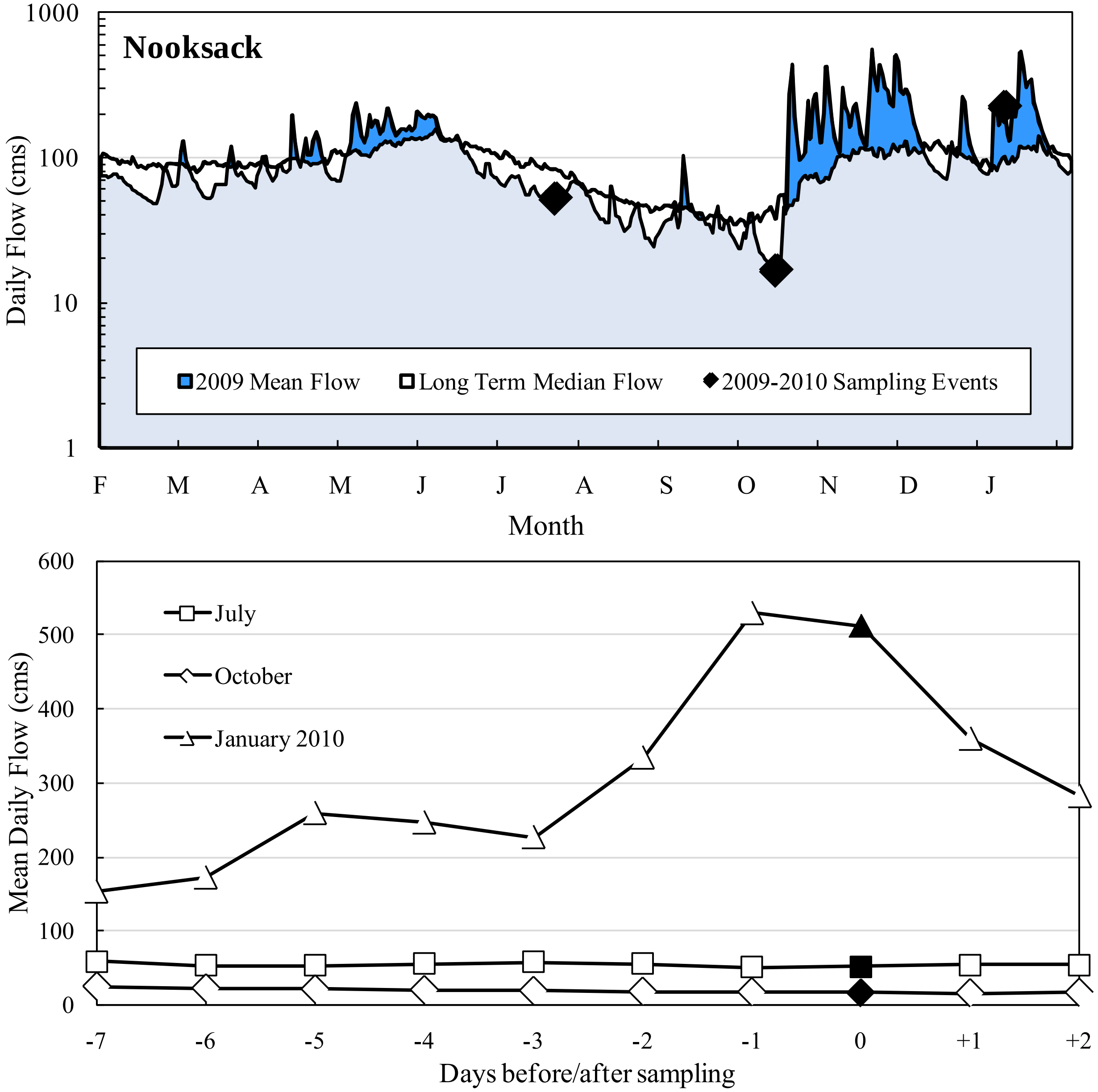


Figure 16. Nooksack River daily flows.

- Upper: Sampling events are shown as black diamonds on the hydrograph for mean daily flows during 2009 (shaded beneath). Relative to long-term median flows, periods of high flow appear as the darkest areas and periods of low flow appear under the white areas.
- Lower: Mean daily flows prior to, during, and immediately after each sampling event (solid black symbols).

  July and October sampling occurred during baseflows, while sampling in January 2010 was near the peak of a runoff event.

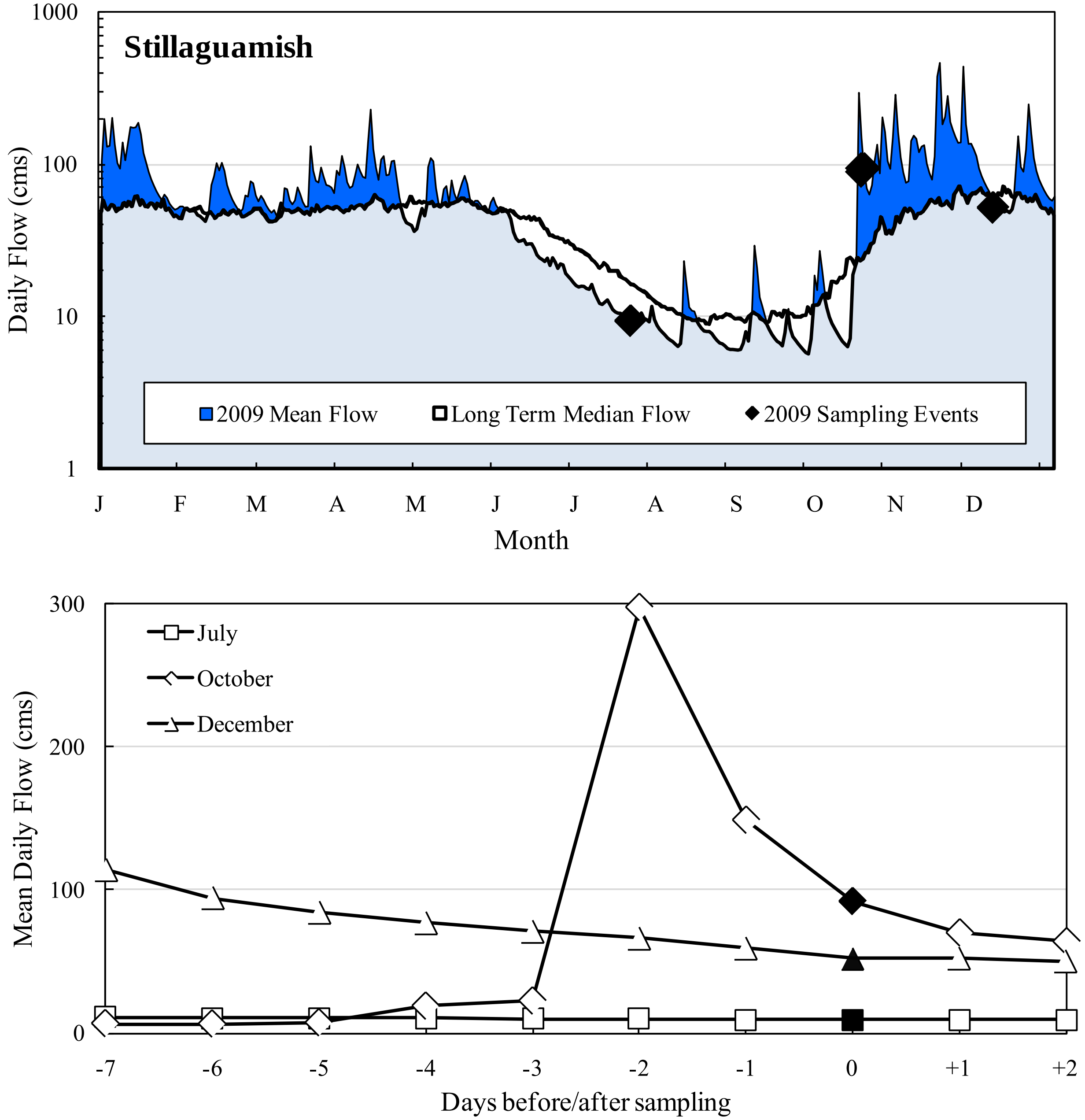


Figure 17. Stillaguamish River daily flows.

- Upper: Sampling events are shown as black diamonds on the hydrograph for mean daily flows during 2009 (shaded beneath). Relative to long-term median flows, periods of high flow appear as the darkest areas and periods of low flow appear under the white areas.
- Lower: Mean daily flows prior to, during, and immediately after each sampling event (solid black symbols).

July and December sampling occurred during baseflows, while sampling in October was during the falling stage of a runoff event.

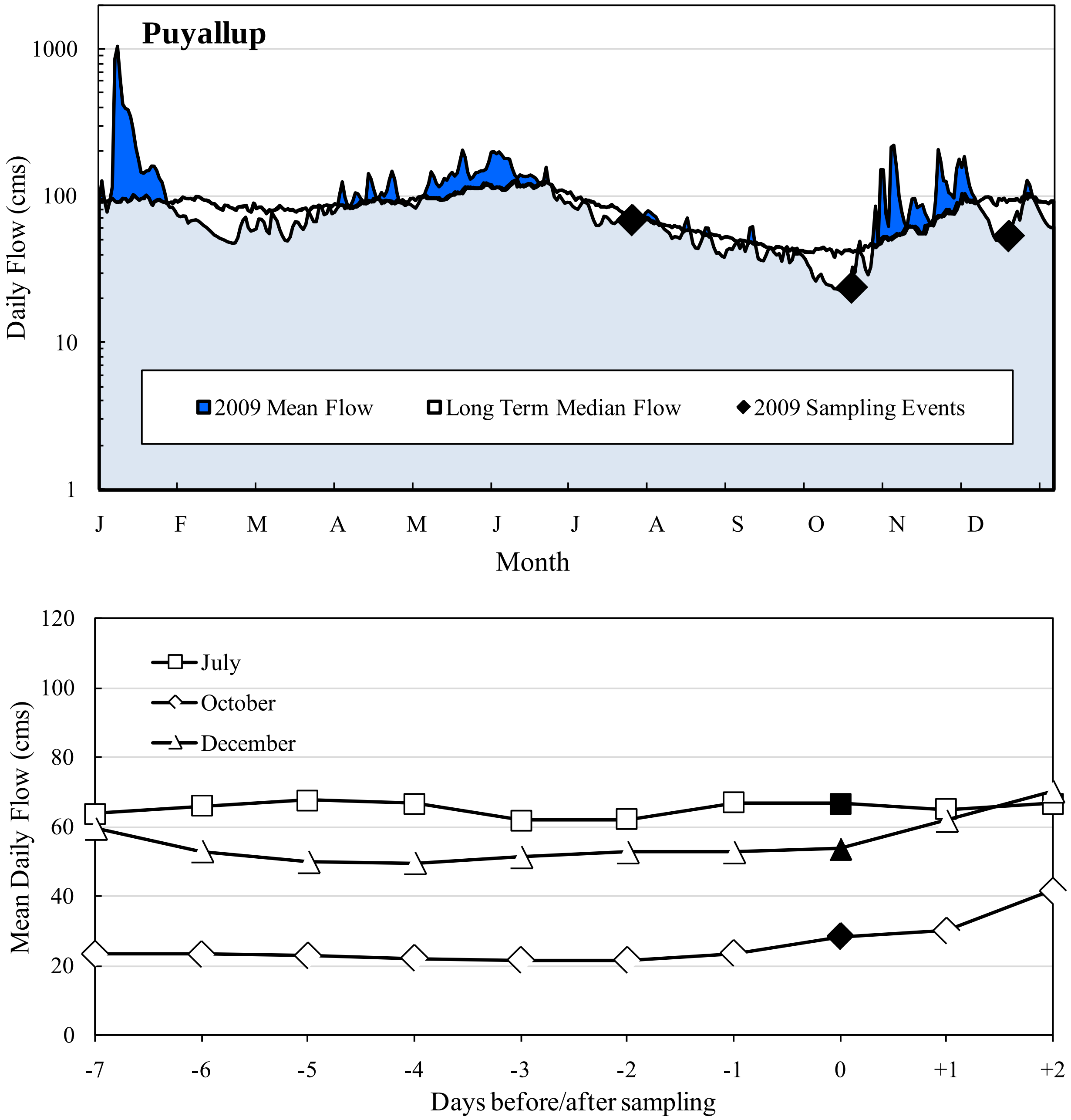


Figure 18. Puyallup River daily flows.

- Upper: Sampling events are shown as black diamonds on the hydrograph for mean daily flows during 2009 (shaded beneath). Relative to long-term median flows, periods of high flow appear as the darkest areas and periods of low flow appear under the white areas.
- Lower: Mean daily flows prior to, during, and after each sampling event (solid black symbols).

Sampling in July was during late seasonal runoff from melting Mt. Rainier glaciers. October sampling was during runoff from 1.33" of rainfall that fell upstream the previous day. The December sampling occurred under winter baseflow conditions, just prior to a runoff event.

Table 11 summarizes the mean daily flows for each river and sampling date, either measured or predicted from gaging station records. Base or runoff-related flow designations are also shown.

Flow conditions did not hinder sampling efforts except as follows. Swift currents made collecting water samples and pumping SPM from the desired depth (0.6 times the maximum mid-channel depth) more difficult. Sampling the Stillaguamish River in December was also complicated by the constant presence of disintegrating ice floes.

Table 11. Summary of field sampling activities for five major rivers discharging to Puget Sound.

River	Date	Mean Daily Flow [1]		Flow Type
		cfs	cms	
Summer – Sampling Event 1				
Skagit	7/21/09	10,500	297	Base
Snohomish	7/22/09	3,470	98.3	Base
Nooksack	7/21/09	1,840 [2]	52.1	Base
Stillaguamish	7/22/09	470 [2]	13.3	Base
Puyallup	7/23/09	2,380	67.4	-- [3]
QA replicate				
Fall – Sampling Event 2				
Skagit	10/13/09	5,400	153	Base
Snohomish	10/20/09	4,940	140	Runoff
Nooksack	10/12/09	590	16.7	Base
Stillaguamish	10/19/09	3,240	91.8	Runoff
Puyallup	10/15/09	1,000	28.3	Runoff
QA replicate				
Winter – Sampling Event 3				
Skagit	12/17/09	13,850	392	Runoff
Snohomish	12/22/09	18,400	521	Runoff
Nooksack	01/06/10	7,880	223	Runoff
Stillaguamish	12/08/09	~1,900	53.8	Base
Puyallup	12/14/09	1,860	52.7	Base
QA replicate				

[1] Flow predicted from stage height recorded at nearby USGS gaging station.
[2] Flow measured by Ecology stream monitoring staff on day of sampling.
[3] Neither baseflow nor related to recent precipitation. Suspended solids were related to seasonal runoff from glaciers, not from recent precipitation events.

The final number of samples collected (328) and analyses conducted (534) was similar to what was planned (Coots and Osterberg, 2009). Table 12 summarizes the analyses conducted on whole or filtered water samples.

Table 12. Inventory of analyses conducted on river water samples.

Parameter → River ↓	TSS	TOC	DOC	Nutrients *	Hardness	Total Metals **	Dissolved Metals **	Oil & Grease	TPH-D	TPH-G	BNAs	PAHs	Chlorinated Pesticides	PCBs	PBDEs	Total
Skagit	3	3	3	15	3	15	15	3	3	5	3	3	3	3	3	83
Snohomish	3	3	3	15	3	15	15	3	3	5	3	3	3	3	3	83
Nooksack	3	3	3	15	3	15	15	3	3	5	3	3	3	3	3	83
Stillaguamish	3	3	3	15	3	15	15	3	3	5	3	3	3	3	3	83
Puyallup	3	3	3	15	3	15	15	3	3	5	3	3	3	3	3	83
QC samples	3	3	3	10	3	30	30	3	3	5	5	5	5	6	5	119
Total	18	18	18	85	18	105	105	18	18	30	20	20	20	21	20	534

* *Nutrients* include total nitrogen (TN), nitrate+nitrite, ammonia, total phosphorus, and ortho-phosphate (5 analyses per sample).

** 5 analyses (arsenic, cadmium, copper, lead, and zinc) per sample.

Conventional Parameters and Nutrients

Table 13 summarizes results for conventional parameters and nutrients. TSS ranged from a minimum 2.6 mg/L to a maximum 233 mg/L, and averaged 38 mg/L. The greatest concentrations of TSS in four rivers were associated with fall or winter runoff events (Figure 19). The maximum TSS in the Puyallup River (233 mg/L), measured in July, was from seasonal melting of glaciers. The overall mean TSS decreased to 24 mg/L when this value was excluded.

TOC and DOC averaged 1.3 mg/L and 1.5 mg/L, respectively. DOC exceeded TOC in 10 of 15 samples, averaging 115% of TOC. Organic carbon was consistently lowest in the summer. Concentrations were greatest in fall or winter and were usually associated with runoff events or increased TSS (Figure 20).

The mean concentration of total nitrogen (TN), 0.285 mg/L, was 85% dissolved inorganic forms. Concentrations of nitrate+nitrite nitrogen averaged about five times those of ammonia nitrogen. TN in all of the rivers was lower in the summer than in fall and winter (Figure 21), with the Skagit River containing the lowest concentrations. Concentrations of total phosphorus (TP) were associated with TSS, indicating that elevated TP concentrations would be expected in rivers carrying a high load of solids. Ortho-phosphate averaged 41% of TP. Ortho-P concentrations were greatest in the Puyallup River and least in the Skagit River (Figure 22).

Table 13. Summary statistics for conventional parameters and nutrients in river water.

Parameter	Times Detected	Percent Detected	Min.	25th %ile	Median	Mean	CV	75th %ile	Max.
Conventional Parameters (mg/L)									
TSS	15	100	2.6	5.1	11.9	38.0*	1.56	51.2	233
TOC	15	100	0.5	0.6	1.1	1.33	0.66	2.0	3.3
DOC	15	100	0.6	0.8	1.0	1.47	0.65	2.0	4.0
Nutrients (mg/L)									
Total Nitrogen (TN)	15	100	0.057	0.140	0.321	0.285	0.62	0.386	0.656
Nitrite (NO_2^-) + Nitrate (NO_3^-) Nitrogen	15	100	0.045	0.087	0.276	0.221	0.65	0.307	0.544
Ammonia Nitrogen	10	67	0.007	0.010	0.025	0.041	1.17	0.046	0.162
Total Phosphorus	15	100	0.006	0.016	0.032	0.054	1.15	0.078	0.250
Ortho-phosphate	15	100	0.003	0.005	0.010	0.014	0.89	0.019	0.048

* The mean concentration of TSS was 24 mg/L when the maximum (Puyallup River) value was excluded.

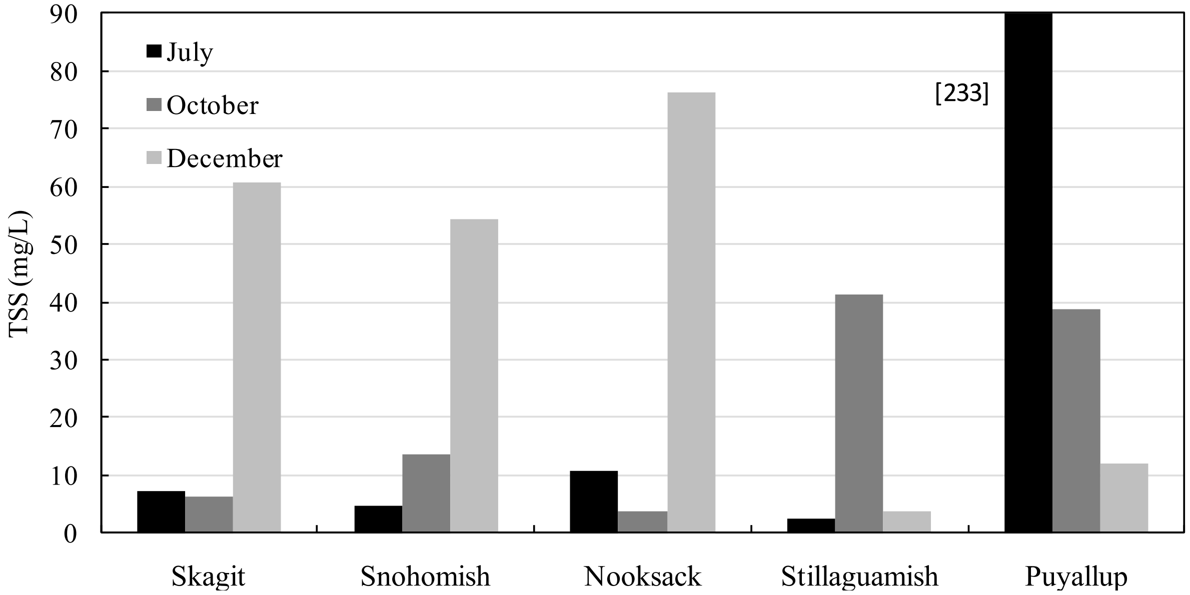


Figure 19. TSS near the mouths of major rivers discharging to Puget Sound in 2009.

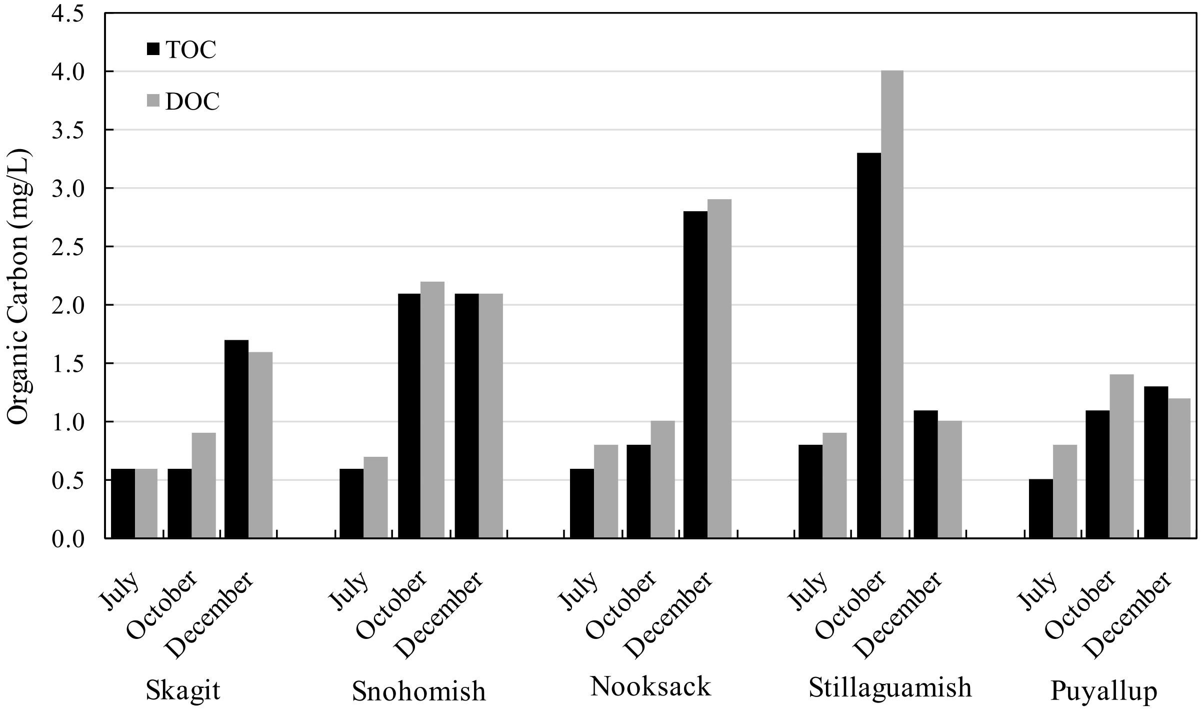


Figure 20. Organic carbon near the mouths of major rivers discharging to Puget Sound in 2009.

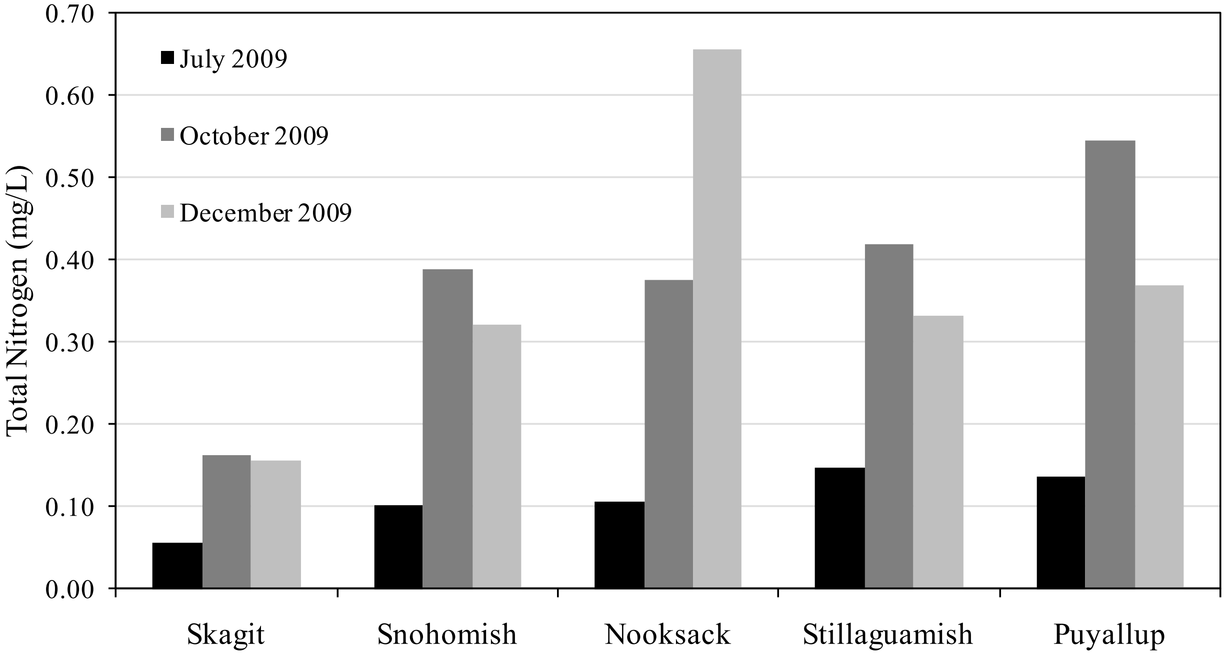


Figure 21. Total nitrogen near the mouths of major rivers discharging to Puget Sound in 2009.

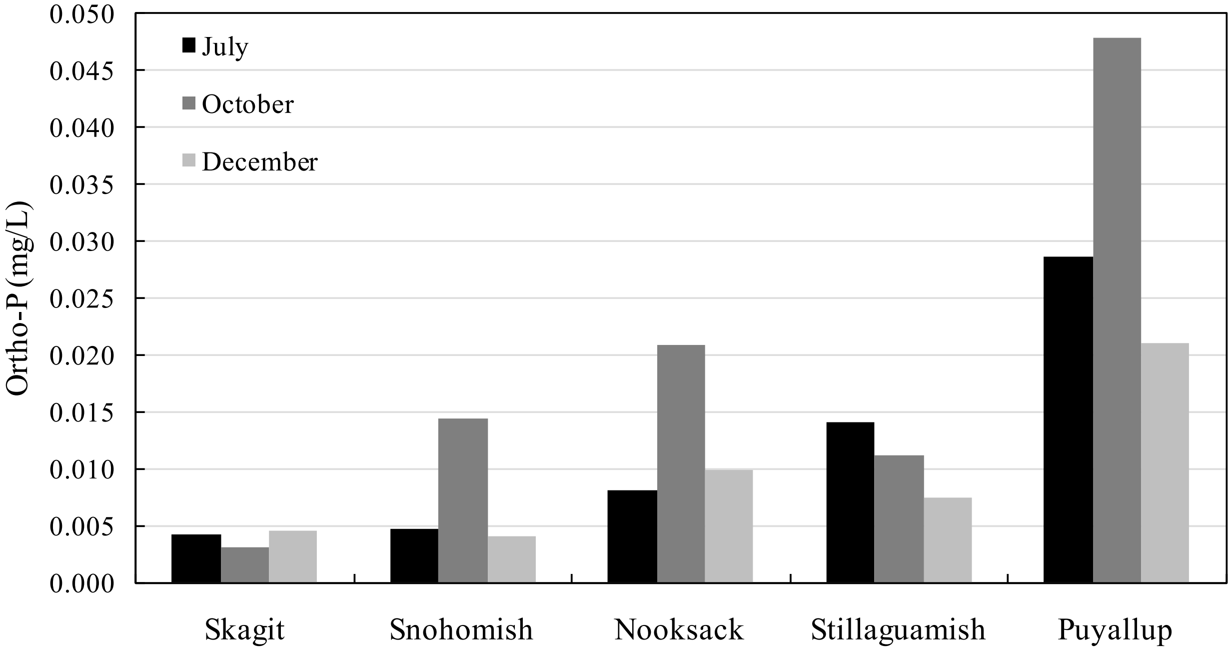


Figure 22. Ortho-phosphate near the mouths of major rivers discharging to Puget Sound in 2009.

Metals

Table 14 summarizes results for hardness, as well as for total recoverable and dissolved fractions of the five metals. The mean hardness for all water samples was 27.3 mg/L (as $CaCO_3$), and the low coefficient of variation (0.41) indicated relatively little variability between rivers. Mean values for total metal concentrations, ranked from high to low, were 6.41 µg/L zinc, 2.99 µg/L copper, 0.75 µg/L arsenic, 0.44 µg/L lead, and 0.012 µg/L cadmium. High total metal concentrations were associated with high TSS that usually accompanied runoff-related flows. This is shown for total copper and total zinc in Figures 23-24. Seasonal variability in concentrations of total arsenic, cadmium, and lead was similar.

The dissolved fraction generally made up the majority of total arsenic and cadmium concentrations. But the majority of copper, lead, and zinc was in particulate form. The relative contribution of particulate metals (total concentration minus dissolved concentration) tended to increase with TSS.

Table 14. Summary statistics for hardness and five metals measured in river water samples.

Parameter	Times Detected	Percent Detected	Min.	25th %ile	Median	Mean	CV	75th %ile	Max.
Hardness (mg/L)	15	100	13.2	20.5	29.9	29.8	0.41	35.6	62
Metals (µg/L)									
Arsenic, Total	15	100	0.26	0.52	0.73	0.75	0.41	0.99	1.24
Arsenic, Dissolved	15	100	0.300	0.463	0.500	0.524	0.30	0.595	0.860
Cadmium, Total	15	100	0.005	0.005	0.007	0.012	0.88	0.018	0.040
Cadmium, Dissolved	9	60	0.003	0.003	0.005	0.008	1.23	0.008	0.035
Copper, Total	15	100	0.75	1.13	1.81	2.99	0.99	4.33	11.6
Copper, Dissolved	15	100	0.35	0.547	1.00	1.20	0.82	1.57	4.19
Lead, Total	13	87	0.05	0.10	0.30	0.44	0.96	0.78	1.42
Lead, Dissolved	11	73	0.014	0.027	0.040	0.059	1.27	0.051	0.28
Zinc, Total	14	93	2.4	3.2	4.55	6.41	0.71	9.7	17.7
Zinc, Dissolved	15	100	0.70	0.92	1.40	1.88	0.65	2.95	4.40

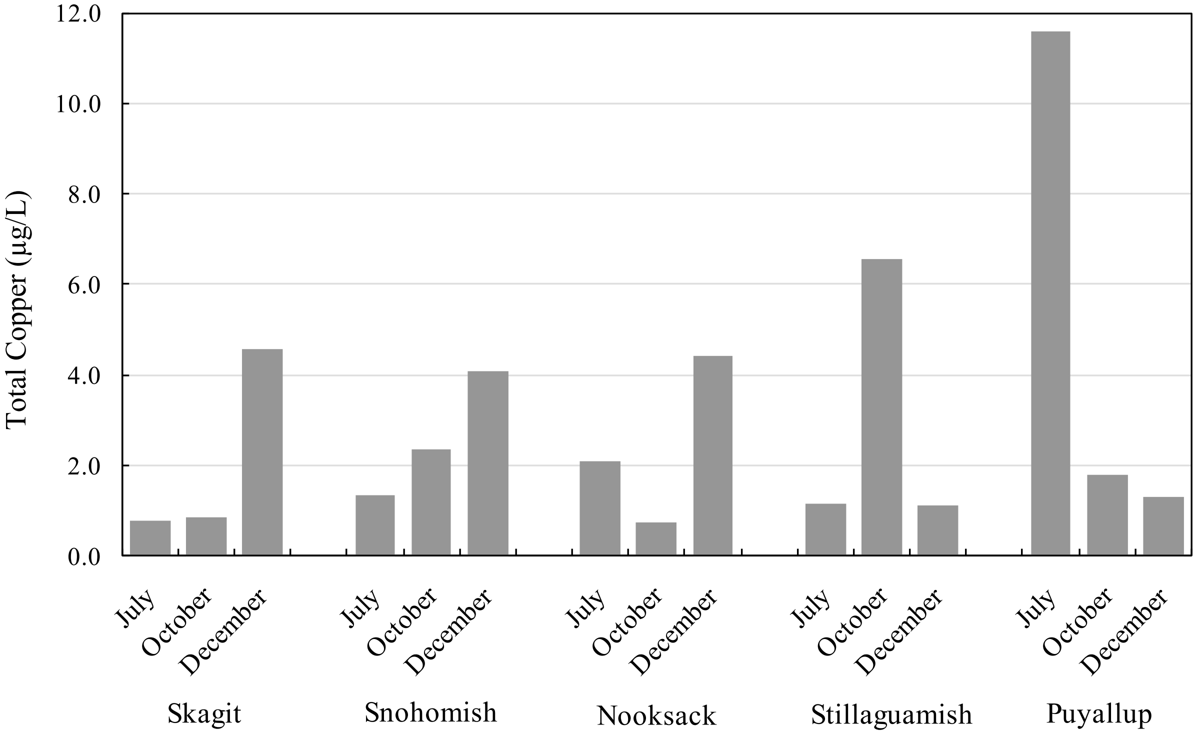


Figure 23. Total copper near the mouths of major rivers discharging to Puget Sound in 2009.

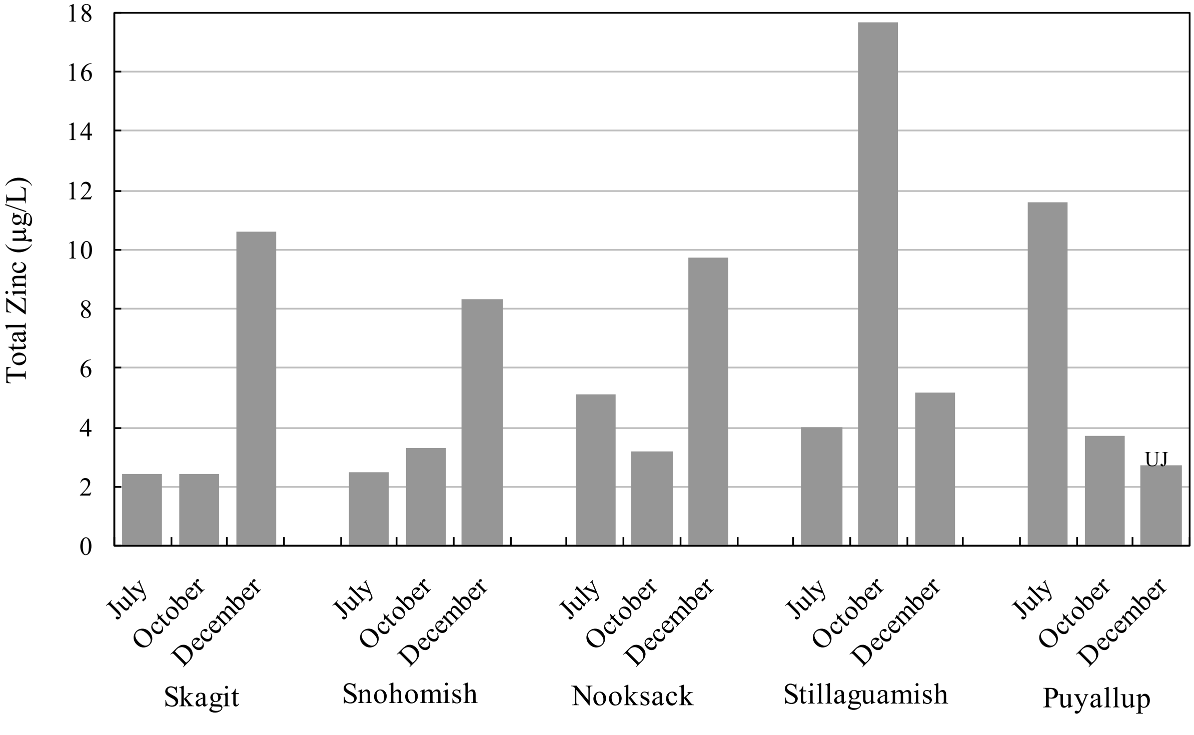


Figure 24. Total zinc near the mouths of major rivers discharging to Puget Sound in 2009.

Organics

Concentrations of 55 BNA, 22 PAH, and 32 chlorinated pesticide compounds were seldom detected. When detected, the compounds were often present in the corresponding method blank at a similar concentration. Table 15 summarizes results for these groups of organics. It shows that only five of the more than 100 compounds in these classes were detected in two or more samples:

- 4-methylphenol (various origins).
- Cholesterol (a biogenic steroid sometimes used as a marker for fecal material).
- Triethyl citrate (food additive, ingredient in cosmetics and pharmaceuticals, plasticizer).
- 1-methyl naphthalene (an occasional pesticide).
- Retene (a biomarker for higher order plants).

Measured concentrations were in the 0.0009 - 0.110 µg/L range. If one-half the RL was used to represent concentrations in nondetect samples, total PAH concentrations were in the range of 0.076 - 0.106 µg/L, and averaged 0.084 µg/L. The subset of seven carcinogenic PAH (cPAH) compounds [12] had toxic equivalent (TEQ) concentrations in the range of 0.009 - 0.014 µg/L, and a mean TEQ of 0.011 µg/L.

Table 16 summarizes results for petroleum-related compounds, total PCBs, and total PBDEs. Petroleum-related compounds were seldom detected. Oil and grease was detected in 40% of the samples (6 of 15), with MDLs ranging from 0.5 to 1.5 mg/L. Measured concentrations ranged from 0.9 - 2.8 mg/L, and averaged 1.6 mg/L. TPH-D or TPH-G were never detected despite MDLs of approximately 0.006 mg/L and 0.014 mg/L, respectively.

PCBs were present in all five rivers and 15 river water samples, with maximum concentrations recorded in three rivers during the fall (Figure 25). Total concentrations were always low: 2.6 - 59 pg/L. After assigning a "UJ" to congener concentrations less than three times (< 3X) those in corresponding method blanks, the average concentration of total PCBs was 16.3 pg/L [13]. The congeners detected most frequently were in the tri-chlorinated, tetra-chlorinated, and penta-chlorinated homolog groups. Congeners in the tri-chlorinated through hexa-chlorinated homolog groups made up an average 84% of total PCBs.

In contrast, PBDEs were detected in less than half of the river water samples. Total concentrations averaged 55.6 pg/L, but results were highly variable (CV = 1.67) within a range of 10.9 - 265 pg/L. PBDEs were detected in all five rivers during the summer, only in the Nooksack and Puyallup Rivers during the fall, and in no river during the winter. Congeners belonging to the tri-brominated and penta-brominated homolog groups were detected most frequently.

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[12] Carcinogenic PAH compounds (cPAH) include benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene

[13] If tentatively identified congeners were included, the mean concentration increased 55% to 25.3 pg/L.

Table 15. Summary of measurable BNAs, chlorinated pesticides, and PAHs in river waters.

		BNAs (µg/L)									PAHs (µg/L)					Chlorinated Pesticides (ng/L)	
Tributary	Date (2009)	2-methyl phenol	4-methyl phenol	4-nonyl phenol	BEHP	Bisphenol-A	Cholesterol	DINOP	Triclosan	Triethyl citrate	1-methyl naphthalene	2-methyl naphthalene	Benzo(a) anthracene	Naphthalene	Retene	Endosulfan sulfate	Hexachloro benzene
Skagit	10/13	--	--	--	--	--	0.63 J	--	--	0.058 J	0.0049 J	0.0089 J	--	--	--	--	--
	12/17	--	--	0.052 J	--	--	0.56 J	--	--	--	--	--	--	--	0.11	--	--
Snohomish	07/21	--	--	--	--	--	--	--	--	--	--	--	--	0.01	--	--	--
	10/20	--	0.093 J	--	--	--	0.73 J	--	--	--	--	--	--	--	--	--	--
	12/22	--	--	--	--	--	--	--	--	--	--	--	0.0009 J	--	0.003 J	--	--
Nooksack	10/12	--	--	--	--	--	--	--	--	0.06 J	0.0039 J	--	--	--	--	--	--
	01/06/10	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0097 J	0.42	
Stillaguamish	10/19	--	0.05 J	--	--	0.072 J	0.49 J	--	--	--	--	--	--	--	--	--	1.6
	12/08	--	0.13 J	--	--	--	0.51 J	--	--	--	--	--	--	--	--	--	--
Puyallup	07/23	0.0058 J	--	--	--	--		--	--	--	--	--	--	--	--	--	--
	10/15	--	--	--	--	--	1.4	--	--	--	--	--	--	--	--	--	--
	12/14	--	--	--	0.074 J	--	0.57 J	--	--	--	--	--	--	0.024	0.0015 J	--	--
QA REP [1] (Puyallup)	10/15	--	--	--	--	--	1.4	0.16 J	0.081	0.31 J	0.0034 J	--	--	--	--	--	--

BEHP = Bis(2-Ethylhexyl) Phthalate; DINOP = Di-N-Octyl Phthalate

[1] QA replicate included only because some analytes were uniquely detected in this field replicate.

Table 16. Summary statistics for petroleum-related compounds, PCBs, and PBDEs in river waters.

Congener summation rules are described in Appendix D. Congeners in each homolog group are listed in Appendix E (Tables E-20 to E-22, and E-24). Concentrations of tentatively-identified congeners (results qualified as N or NJ) were not included in homolog or overall totals. Note: Homolog concentrations in a single sample can be summed to equal the total concentration in that sample, but summing the homolog statistics will not result in the total concentration statistics.

Parameter	Times Detected	Percent Detected	Min.	25th %ile	Median	Mean	CV	75th %ile	Max.
Petroleum-related compounds (mg/L)									
TPH-D and TPH-G	0	0	-	-	-	-	-	-	-
Oil and Grease	6	40	0.9	1.4	1.4	1.6	0.40	1.6	2.8
PCB homologs and totals (pg/L)									
Mono-chlorinated	5	33	1.71	1.75	1.80	2.03	0.21	2.14	2.73
Di-chlorinated	9	60	0.71	1.78	2.04	2.52	0.62	2.98	6.14
Tri-chlorinated	13	87	0.80	2.11	3.37	3.73	0.68	3.91	9.68
Tetra-chlorinated	12	80	0.54	1.40	2.10	3.85	1.16	4.51	16.5
Penta-chlorinated	13	87	0.81	1.16	2.74	5.76	1.38	6.49	28.7
Hexa-chlorinated	12	80	0.60	1.12	2.66	3.00	0.77	3.86	8.63
Hepta-chlorinated	2	13	0.72	--	1.11	1.11	--	--	1.51
Octa-chlorinated	2	13	1.14	--	1.21	1.21	--	--	1.28
Nona-chlorinated	0	0	--	--	--	--	--	--	--
PCB-209	1	7	1.09	--	1.09	1.09	--	--	1.09
Total PCBs	15	100	2.61	5.95	9.96	16.27 *****	0.95	19.2	59.0
PBDE homologs and totals (pg/L)									
Mono-brominated	0	0	--	--	--	--	--	--	--
Di-brominated	0	0	--	--	--	--	--	--	--
Tri-brominated	4	27	5.18	7.94	11.6	10.4	0.35	12.9	13.3
Tetra-brominated	1	7	17.0	--	17.0	17.0	--	--	17.0
Penta-brominated	4	27	10.8	11.2	12.6	17.6	0.64	24.0	34.2
Hexa-brominated	0	0	--	--	--	--	--	--	--
Hepta-brominated	0	0	--	--	--	--	--	--	--
Octa-brominated	0	0	--	--	--	--	--	--	--
Nona-brominated	0	0	--	--	--	--	--	--	--
PBDE-209	1	7	260	--	260	260	--	--	260
Total PBDEs	7	47	10.9	13.4	22.3	55.6	1.67	33.0	265

***** The mean concentration of total PCBs in river water would be approximately 60% higher if concentrations of tentatively-identified congeners (“N” and “NJ”) were also included.

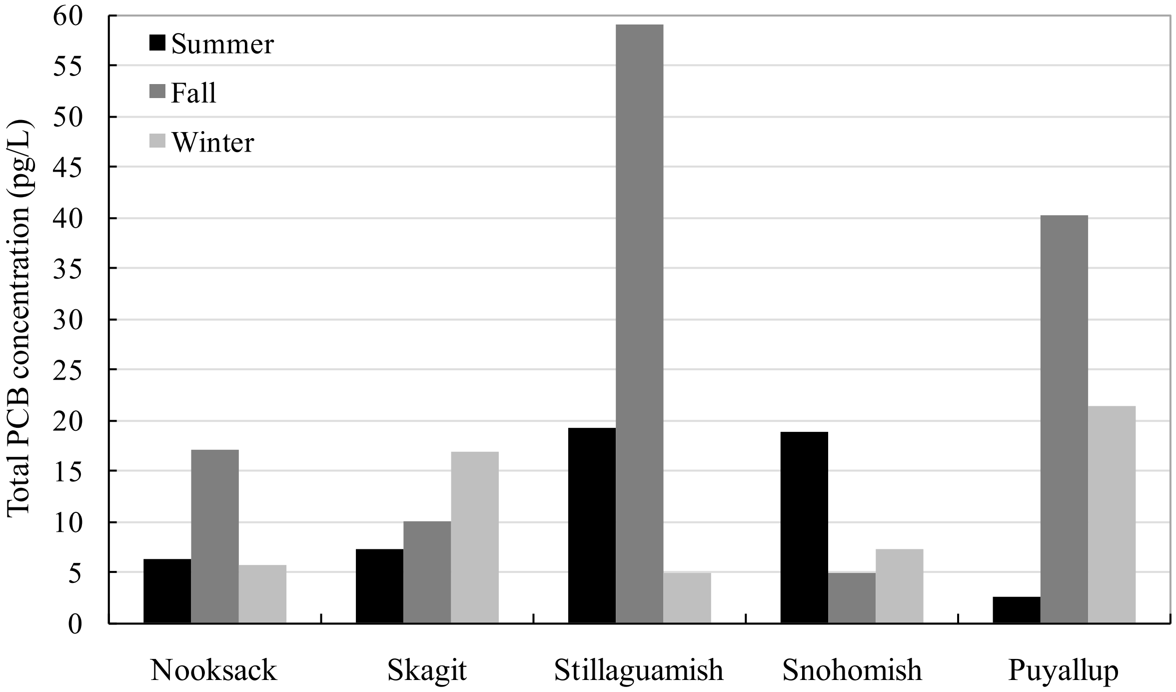

Figure 25. Total PCBs near the mouths of major rivers discharging to Puget Sound in 2009.

River SPM

Collecting suspended solids from river water using pump-and-centrifuge methods required an average of 18 hours per site (Table 17), not including setup and demobilization time. River water was usually pumped at rates of 10 - 13 liters (2.6 - 3.4 gallons) per minute. At these pump rates, SPM retention efficiencies were highly correlated with inflowing TSS concentrations ($r^2 = 0.95$), and the mean efficiency was 72%. Five samples of suspended solids were collected by the centrifuges, one from each river. Sample mass ranged from 153 to 960 wet grams, which was equivalent to approximately 67 to 660 dry grams.

Table 17. Collection of suspended solids from five rivers by continuous-flow centrifuges.

River	Start Date	End Date	Average Pump Rate		Pump Time (hrs)	Volume Pumped (liters)	Inflow TSS (mg/L)	Outflow TSS (mg/L)	Estimated Efficiency (%)
			gpm	L/hr					
Skagit	12/16/09	12/17/09	2.31	524	17.13	8,970	65.8	22.1	66
Snohomish	12/22/09	12/23/09	2.37	539	16.00	8,620	42.6	8.8	79
Nooksack	01/05/10	01/06/10	2.34	531	14.67	7,790	168	97.8	42
Stillaguamish	12/08/09	12/09/09	2.64	599	22.00	13,180	6.4	0.3	95
Puyallup	12/13/09	12/14/09	2.59	588	20.08	11,800	72.2	17.7	75

Conventional Parameters

Table 18 summarizes results for the five samples of suspended river solids. Suspended particulate matter contained 0.36 - 1.88% TOC (mean = 1.2 %).

Metals

Mean concentrations of total metals were rank ordered as were whole water samples: 68.7 mg/kg zinc, 36.5 mg/Kg copper, 7.79 mg/Kg arsenic, 5.86 mg/Kg lead, and 0.16 mg/Kg cadmium.

Organics

BNAs were rarely detected. Only cholesterol, its degradate (3-beta coprostanol), and BEHP were found in all samples. TPH-D, analyzed in BNA extracts, was not detected. Unlike whole water, 16 of 22 PAH compounds were detected in more than one-half the SPM samples. Individual PAHs averaged less than 20 µg/Kg, except for retene (mean = 230 µg/Kg). Mean concentrations of high and low molecular weight PAHs were similar. Total PAHs, excluding retene, ranged from 32 - 210 µg/Kg and averaged 119 µg/Kg. Pesticides were virtually absent from particulates collected this time of year (winter). PCBs were measured in all samples, as were PBDEs. The average concentrations of total PCBs and total PBDEs were 408 ng/Kg and 1680 ng/Kg, respectively.

Table 18. Summary statistics for parameters measured in SPM collected from five rivers.

Parameter (dry weight basis units)	Times Detected	Percent Detected	Min.	25th Percentile	Median	Arithmetic Mean	CV	75th Percentile	Max.
Conventional Parameters (%)									
TOC	5	100	0.36	0.81	1.46	1.23	0.48	1.59	1.88
Metals (mg/Kg)									
Arsenic	5	100	1.45	5.21	6.62	7.79	0.59	11.65	13.3
Cadmium	5	100	0.04	0.11	0.17	0.16	0.49	0.21	0.24
Copper	5	100	17.2	24.6	33.0	36.5	0.43	52.1	53.5
Lead	5	100	1.57	3.74	5.35	5.86	0.54	8.66	9.55
Zinc	5	100	20.3	45.4	77.4	68.7	0.48	91	106
BNAs (µg/Kg)									
3-Beta Coprostanol	5	100	220	235	260	340	0.55	400	670
4-Methylphenol	3	60	43	45	52	58	0.32	72	78
4-Nonylphenol	1	20	15	-	15	15	1.0	-	15
Benzoic acid	1	20	310	-	310	310	1.0	-	310
BEHP	5	100	170	215	510	490	0.67	655	1,000
Bisphenol A	1	20	20	-	20	20	1.0	-	20
Cholesterol	5	100	410	928	1,300	2,560	1.33	3,200	8,600
Phenol	1	20	26	-	26	26	1.0	-	26
TPH-D	0	0	-	-	-	-	-	-	-
PAHs (µg/Kg)									
1-Methylnaphthalene	5	100	3.6	4.9	6.4	9.3	0.65	14.3	18
2-Chloronaphthalene	0	0	-	-	-	-	-	-	-
2-Methylnaphthalene	5	100	6.1	7.4	11	15.2	0.67	23.3	30
Acenaphthene	0	0	-	-	-	-	-	-	-
Acenaphthylene	0	0	-	-	-	-	-	-	-
Anthracene	4	80	1.5	1.5	2.1	3.1	0.79	4.6	6.6
Benzo(a)anthracene	4	80	1.6	2.6	4.1	4.2	0.53	5.8	6.9
Benzo(a)pyrene	3	60	2.8	3.0	3.7	4.5	0.48	6.1	6.9
Benzo(b)fluoranthene	4	80	2.0	5.0	9.5	8.8	0.59	12.5	14

Table 18 (continued). Summary statistics for parameters measured in SPM collected from five rivers.

Parameter (dry weight basis units)	Times Detected	Percent Detected	Min.	25th Percentile	Median	Arithmetic Mean	CV	75th Percentile	Max.
PAHs (µg/Kg)									
Benzo(g,h,i)perylene	5	100	1.8	2.0	5.2	5.7	0.74	8.8	12
Benzo(k)fluoranthene	2	40	1.7	1.7	1.9	1.9	0.15	2.1	2.1
Total Benzofluoranthenes	4	80	2.0	6.1	11.4	9.7	0.56	13.4	14
Carbazole	0	0	--	--	--	--	--	--	--
Chrysene	5	100	2.3	2.7	9.6	8.3	0.67	13	15
Dibenzo(a,h)anthracene	2	40	0.9	0.9	1.0	1.0	0.14	1.1	1.1
Dibenzofuran	5	100	1.4	1.6	3.2	3.9	0.78	5.4	8.8
Fluoranthene	5	100	2.1	2.9	8.9	9.0	0.74	14	18
Fluorene	4	80	1.1	2.5	4.1	4.2	0.63	6.0	7.6
Indeno(1,2,3-c,d)pyrene	5	100	0.9	1.2	3.1	3.6	0.77	5.6	7.5
Naphthalene	5	100	2.7	3.2	8.8	9.0	0.74	13	19
Phenanthrene	5	100	6.7	6.7	22	20	0.66	30	36
Pyrene	5	100	3.5	4.2	11	11	0.64	18	18
Retene	5	100	60	90	280	230	0.63	333	400
Individual PAHs *	82	71	--	--	--	--	--	--	--
Low molecular weight PAHs	5	100	20.9	23.2	55.1	59.1	0.68	88.1	117
High molecular weight	5	100	10.6	15.6	64.3	51.8	0.70	78.6	93.3
Total PAHs	5	100	31.5	38.9	119	111	0.68	167	211
Chlorinated Pesticides (µg/Kg)									
DDE, DDT, hexachlorobenzene, pentachloroanisole	1 each	<1	--	--	--	--	--	--	--
Other pesticides	0	0	--	--	--	--	--	--	--
PCBs and PBDEs (ng/Kg)									
Total PCBs	5	100	150	202	366	408	0.67	557	845
Total PBDEs	5	100	522	671	1,033	1,676	1.03	2,230	4,696

* 82 detected concentrations out of 105 possible results (23 individual PAH compounds measured per sample x 5 samples).

Discussion

Marine Water Column

Comparison with Historical Data

Serdar (2008) conducted a review of readily available data collected since 1995 on selected toxic chemicals in Puget Sound and the boundary waters of the Straits of Juan de Fuca and Georgia. Little existing data were found, especially for organic compounds. Despite the paucity of existing data for the region, the information compiled provides an indication of the range of concentrations that might be expected for each target chemical. Table 19 presents a comparison of results from the present 2009-10 study to existing data.

While data collected for the present study were in good agreement with concentration ranges from historical data (with few exceptions), the 2009-10 results yielded new insights into the variability and range of ambient concentrations:

- Total and dissolved measurements of arsenic, cadmium, and copper agreed well with previously reported values, but also revealed slightly broader ranges of ambient concentrations. Arsenic and cadmium results tended to be somewhat higher than comparable data, while copper concentrations were generally lower than historical values.
- Previously reported total lead concentrations for the region were at the low end of the range of 2009-10 project results, which tended to be markedly higher and more variable. Nearly half of the project measurements were above the highest historical concentration.
- Total zinc concentrations were in good agreement with previous measurements. The exception was the maximum concentration of 7.44 mg/L measured in the deep water sample collected from Hood Canal in July 2009. This was five times greater than the concentration measured in any other sample and may represent the high end of the concentration range for total zinc in marine ambient waters [14].
- The mean concentration of total PCBs in regional marine waters (26.3 pg/L) and for boundary waters (20.4 pg/L) were lower than the mean concentrations reported by Dangerfield et al. (2007) for surface and deep Canadian waters. The diversity of sites and multiple depths sampled for the present study may provide a better indication of the variability in total PCBs concentrations that can be expected in regional waters.
- Total PBDE concentrations spanned a wide range throughout the region. Previously available data were limited and provided a low estimate of typical ambient concentrations. Current project data, however, exposed marked variability in total PBDEs. Concentrations were below detection limits in more than 75% of project samples, but detected total PBDE concentrations were often at least 10 times greater than those reported by Dangerfield et al. (2007). There was no evidence from QC data that the samples had been contaminated. One explanation for the dissimilar results may be that the discrete samples from the present study

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[14] It was noted that concentrations of most metals in Hood Canal SPM were also greater than those measured in SPM collected from traps deployed in the more developed South Sound region.

captured heterogeneous concentrations of PBDEs that could be diluted when collecting time-integrated pump samples as was done by Dangerfield et al.

- Organic carbon concentrations throughout Puget Sound and the oceanic boundary waters were very similar to those reported by Johannessen et al. (2008).
    - Results of the present study indicate that the organic carbon concentration records taken from Ecology's EIM database and used by Pelletier and Mohamedali (2009) were above typical ambient concentrations. Past methods used to collect and handle seawater samples for analysis of organic carbon were likely susceptible to contamination. The rigorous sampling procedures used throughout the present study (see Appendix C) appeared to be more successful at preventing contamination.
    - A single high POC result (1.78 mg/L) fell outside the range of concentrations observed by Johannessen et al. (2008; maximum observed POC of 0.36 mg/L). However this result is not unrealistic and may be representative of POC concentrations associated with elevated productivity, as there was high TSS and a strong phytoplankton bloom (revealed by CTD fluorescence profile) at the time of sample collection.
    - The median concentration of TOC in deep waters entering Puget Sound (0.73 mg//L) was greater than the mean of 0.53 mg/L TOC reported for deep waters further west in the Strait of Juan de Fuca (Johannessen et al., 2008) and for typical mid-ocean concentrations (0.5 mg/L; J. Sharp, pers. comm.).

Table 19. Marine water column results compared to previously reported concentration ranges.

Parameter	Present Study Results					Historical Data		
	N	Median	Mean	Low	High	Reported Values Low	Reported Values High	Data Sources*
Conventional Parameters (mg/L)								
TSS	42	1.6	1.75	0.8	6.0	0.0	64.1	4, 7
DOC	28	0.754	0.757	0.611	0.969	< 0.44	2.16	3, 7
POC	28	0.059	0.133	0.028	1.780	< 0.01	> 5.0	3, 7
TOC	28	0.807	0.891	0.660	2.749	< 0.48	79	3, 7
Metals (µg/L)								
Arsenic, Total	42	1.41	1.42	1.16	1.56	0.41	2.0	1, 8, 9
Arsenic, Dissolved	42	1.42	1.42	1.26	1.70	0.42	2.0	1, 8, 9
Cadmium, Total	42	0.084	0.085	0.059	0.112	0.040	0.075	1, 8, 9
Cadmium, Dissolved	42	0.081	0.083	0.067	0.111	0.031	0.076	1, 8, 9
Copper, Total	42	0.38	0.41	0.19	1.37	0.19	1.3	1, 4, 5, 8, 9
Copper, Dissolved	42	0.30	0.31	0.16	0.51	0.31	1.0	1, 4, 5, 6, 8
Pb Total	37	0.070	0.085	0.015	0.230	< 0.006	0.069	1, 4, 5, 8, 9
Zn Total	42	0.69	0.87	0.41	7.44	0.20	1.3	1, 4, 5, 8
Organics (pg/L)								
Total PCBs	42	24.0	26.3	6.09	75.1	40.3	43.5	2
Total PBDEs	10	749	2,860	51	18,700	14.8	23.4	2

* Data sources:

1. Crecelius (1998) data from the Straits of Georgia and Juan de Fuca, 1997.
2. Dangerfield et al. (2007) data from Boundary Pass and Rosario Strait, Strait of Georgia.
3. Johannessen et al. (2008) data from the Straits of Juan de Fuca and Georgia, 2003.
4. Johnson (2009) data from the Strait of Juan de Fuca, Guemes Channel, and Commencement Bay, 2008-2009.
5. Johnson (2009) summary of King County Department of Natural Resources and Parks data from the Strait of Juan de Fuca for the period 1997-2000.
6. Johnson (2009) summary of Johnson and Summers (1999) data from Commencement Bay, 1997-1998.
7. Pelletier and Mohamedali (2009) summary of EIM data for various Box Model regions; POC calculated as the difference of TOC and DOC.
8. Serdar (2008) summary of KCDNR data for Puget Sound, 1996-2002.
9. Serdar (2008) summary of EIM data for Puget Sound, 1995-2007.

Patterns and Relationships

The nonparametric Kruskal Wallis Test and Test of Medians were used to determine the significance of differences in parameter concentrations. These tests were used because chemical concentrations seldom reflected a normal distribution and only some log-normal distributions became normal when transformed (Appendix J, Table J-1). Test results provided in Table J-2 showed that concentrations of some chemicals were statistically different between regions, seasons, and depth layers.

- **Regional differences**. Comparing all sample results from the three ocean boundary sites (from both depths and all seasons) to those from the four Puget Sound basin sites revealed:
    - Mean concentrations of DOC, TOC, total and dissolved copper, and total PCBs were significantly greater in Puget Sound samples than in ocean boundary waters.
    - Mean concentrations of total and dissolved cadmium in ocean boundary waters were significantly greater than in the basins of Puget Sound.

- **Seasonal differences**. Comparisons of the seasonal mean chemical concentrations (measured at all stations and depths) yielded the following:
    - TSS, total arsenic, and total and dissolved copper concentrations were significantly lower in October than in July or January.
    - Concentrations of all forms of organic carbon were significantly higher in October 2009 than in January 2010.
    - Total PCB concentrations were greatest in the fall.

- **Water column depth layer differences.** Results from all stations and seasons were pooled by collection depth for comparison of surface and deep layer concentrations. Samples were additionally separated by region to test for layer differences within the boundary waters or the Puget Sound basin waters.
    - For the entire sampling area, mean concentrations of total and dissolved arsenic and total lead were significantly lower in the surface layer than in the deep layer.
    - In the Puget Sound basins, dissolved arsenic had significantly greater mean concentrations in the deep layer compared to the surface layer.
    - In ocean boundary waters, mean concentrations of dissolved arsenic, total and dissolved cadmium, and total lead in the deep layer were significantly greater than those in the surface layer.
    - For ocean boundary waters, the mean DOC concentration in the surface layer was significantly greater than the mean DOC in the deep layer.
    - Mean concentrations of total PCBs were significantly lower in the surface layer of ocean boundary waters, Puget Sound basins, and all locations combined than in the deep layer (Figure 26).

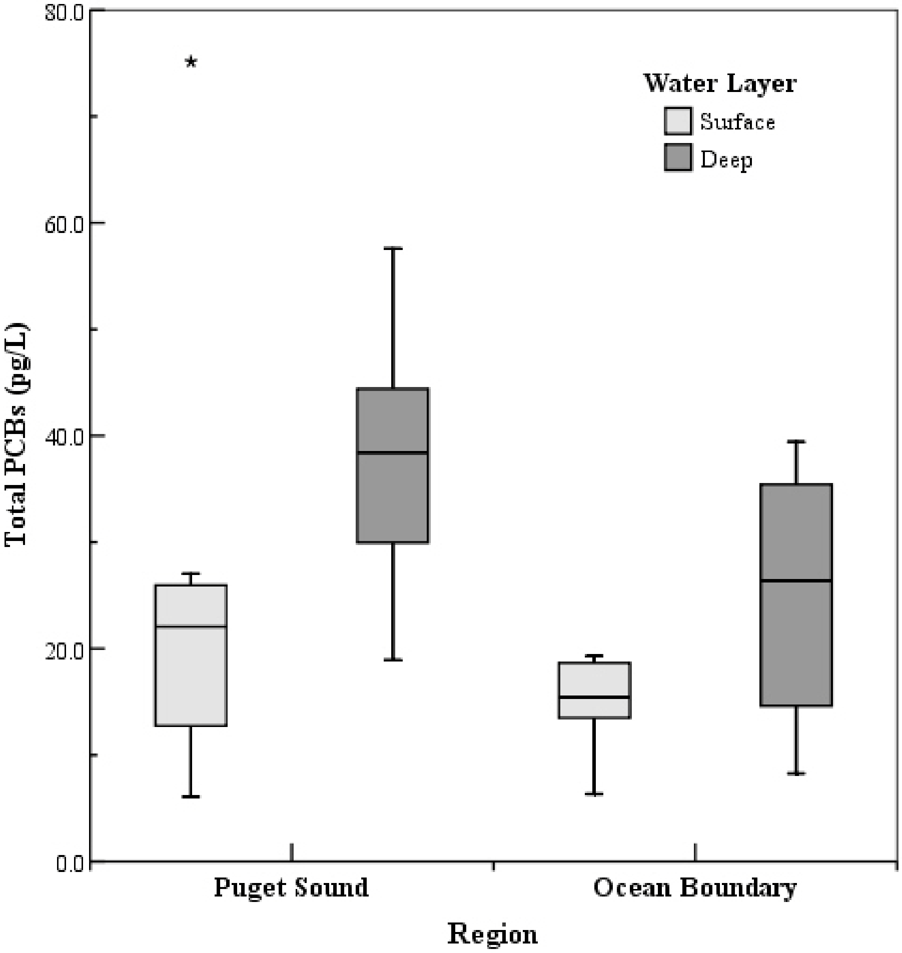

Figure 26. Total PCB concentrations in surface and deep marine water column samples.

Spearman rank correlation analysis was conducted to identify relationships between different chemicals. Results are presented in Appendix J, Table J-3. Significant relationships included:

- Suspended solids were negatively correlated with organic carbon. Both dissolved and particulate forms of organic carbon tended to decrease with increasing TSS.
- Organic carbon was negatively correlated with total and dissolved forms of arsenic and cadmium. When DOC (the main fraction of TOC) was relatively high, concentrations of these metals were low.
- Concentrations of most metals species were positively correlated.
- Total PCBs appeared linked to the presence of particles, as indicated by positive correlations with TSS.
- Total PCB concentrations were negatively correlated with TOC, and its main constituent DOC, in water column samples. (There was no correlation between PCBs and POC.)
- There was no apparent relationship between concentrations of PBDEs and other parameters.

Of the spatial patterns, temporal trends, and parameter relationships identified through statistical analyses, an interesting discovery was that total PCB concentrations in the deep waters were significantly higher than in the surface waters. This was true for all samples but also for the four Puget Sound basin sites and the three ocean boundary water sites separately (Figure 26). This finding was somewhat counterintuitive, as major sources of PCBs were expected to be surface inputs from urban-industrial centers (e.g., stormwater, surface runoff, atmospheric deposition). PCBs from land-based sources may have diminished by the time they reached the mid-basin and ocean boundary sampling sites because:

- Total PCB concentrations derived from land-based sources are diluted by Puget Sound surface waters containing lower PCB concentrations.
- Suspended, particle-bound PCBs settle through the water column into deeper waters.
- Total PCBs are transported downslope from the nearshore environment because of bathymetry- or density-driven focusing processes.

The significant positive correlation between total PCBs and TSS (Table J-3) suggests that sedimentation and sediment focusing contribute to total PCB concentrations in deep waters greater than those in surface waters.

Ocean Exchange

One objective of the present 2009-10 study was to measure concentrations of toxic chemicals in ocean boundary waters. These are generally considered to be near the west entrance to the Strait of Juan de Fuca. However, models of Puget Sound circulation and transport consider the north end of Admiralty Inlet to be the main seaward boundary (Pelletier and Mohamedali, 2009; Babson et al., 2006). This is where higher salinity and density deep waters flow *into* Puget Sound, and lower salinity and density surface waters flow *out of* the Sound. Accordingly, water column samples were collected from sites in the Strait of Juan de Fuca and Haro Strait (Figure 1) where deep water chemistry better represents that of water entering Puget Sound.

Samples were collected from central locations in four Puget Sound basins (Figure 1), but only results from the Main, Whidbey, and Hood Canal basin sites were used to represent water flowing out of Puget Sound for ocean exchange calculations [15]**.** Chemical concentrations measured in these samples were weighted in proportion to predicted flows from each basin into Admiralty Inlet and used to represent concentrations that exit Puget Sound [16]. To represent chemical concentrations in water leaving Puget Sound through Deception Pass (near Anacortes, Washington), Whidbey Basin surface water sample results were used.

The direction of net exchange with the ocean (ocean exchange) for different chemicals was evaluated using estimates of annual mass transport into and out of Puget Sound. A range of annual mass transport was calculated using 25th and 75th percentile chemical concentrations.

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[15] Results for Strait of Juan de Fuca and Haro Strait surface samples were not used to represent water flowing out of Puget Sound because they may have been influenced by sources outside of Puget Sound (Fraser River water).

[16] The Box Model predicted that Main, Whidbey, and Hood Canal basins contribute 56.4%, 27.4%, and 16.2% of the flow into Admiralty Inlet, respectively.

These were multiplied by Box Model-predicted flows into and out of Puget Sound across the two seaward boundaries:

- The long-term median flow of deep water *into* Puget Sound through Admiralty Inlet was -18,555 cms (-5.85 x 10^{11} m^3/year).
- The long-term median flow of surface water *out of* Puget Sound was 20,300 cms (6.40 x 10^{11} m^3/year), with 18,771 cms flowing out through Admiralty Inlet and 1,529 cms flowing out through Deception Pass.

Results of ocean exchange calculations are presented in Tables 20-22. Concentration ranges for TSS, TOC, metals, and organic compounds measured in deep ocean boundary waters are shown in Table 20. The table also presents probable ranges for annual chemical mass transport into Puget Sound. Table 21 shows concentrations of the same chemicals in Puget Sound surface waters, along with ranges for chemical mass transport out of Puget Sound. Table 22 combines results from the previous tables to yield estimates of net chemical exchange between Puget Sound and the ocean boundary waters. Example calculations follow.

The procedure for calculating net exchange of total arsenic, based on median concentrations, is described here. First, the mass of arsenic imported into Puget Sound was calculated by multiplying the median deep boundary water concentration (1.49 µg/L = 1.49 mg/m^3) by the annual incoming volume of water (-5.85 x 10^{11} m^3/year). This resulted in an estimate of -8.72 x 10^{11} mg/year, equivalent to -872 mT/year (see Table 20). Second, the mass of total arsenic exported from Puget Sound through Admiralty Inlet was calculated as the flow-weighted median surface water concentration of the three most northern Puget Sound stations times the outflow volume. The mass exported through Deception Pass was calculated as the median surface water concentration measured at the Whidbey Basin site times the Deception Pass outflow volume. The total exported mass was estimated to be 895 mT/year (Table 21). Finally, the net exchange based on median concentrations, 23 mT/year, was the sum of the exported and imported masses (see Table 22).

The net ocean exchange is positive - out of Puget Sound - for most chemicals. This assumes that the chemical concentrations measured in marine water column samples for the present study adequately represent those transported into and out of the Sound.

Estimates of net exchange predicted that copper and organic carbon were exported from Puget Sound. The export resulted from concentration differentials combined with the net flow of water out of the Sound. For copper, mean and median concentrations in deep boundary waters were not significantly different from those in surface waters leaving the Sound [17]. Nevertheless, the flow-weighted median total copper concentration exiting Puget Sound (0.40 µg/L) was 43% greater than the median value for incoming boundary deep waters (0.28 µg/L). Factors contributing to the concentration differential included:

- Relatively high copper concentrations in surface runoff (the median concentration of total copper in 15 river water samples was 1.81 µg/L).
- Formation of copper complexes that remain dissolved in surface waters.

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[17] Kruskal Wallis (means), p = 0.18; Test of Medians, p = 0.64.

TOC concentrations in surface waters of Puget Sound were significantly greater than concentrations in deep waters near the ocean boundary [18]. The flow-weighted median TOC concentration in surface waters leaving Puget Sound (1.17 mg/L) was 60% greater than the median deep water concentration near the ocean boundary (0.73 mg/L). The difference was likely due to:

- Organic carbon loading from surface runoff (rivers).
- Primary productivity in the euphotic zone (especially when the water column was stratified).
- Decomposition of organic carbon in deep waters.

Table 22 shows that TSS, arsenic, zinc, and PAHs were probably exported from Puget Sound. For these parameters, there was no more than a 13% difference between concentrations in surface waters leaving and concentrations in deep boundary waters entering Puget Sound [19]. Therefore, the net flow of water out of Puget Sound played more of a role in the export of these chemicals than did concentration differences. These chemicals could have been imported into Puget Sound if 75th percentile concentrations were used to represent inflows and 25th percentile concentrations represented outflows.

The negative net exchange values in Table 22 indicated that cadmium and lead were imported into Puget Sound. For cadmium, the median concentration in deep boundary waters (0.92 µg/L) was significantly greater than the median for surface waters leaving Puget Sound (0.80 µg/L) [20]. As in the case of copper, concentrations of lead were not significantly different for inflow and outflow waters. However, the median concentration in deep boundary waters (0.109 µg/L total lead) was sufficiently higher than and the flow-weighted median concentration in surface waters leaving Puget Sound (0.065 µg/L) to cause a net import. Only if the 75th percentile concentration of total lead was used to represent outflows and the 25th percentile concentration represented inflows was export indicated.

The direction of net exchange for total PCBs and total PBDEs between ocean boundary waters and Puget Sound was unclear based on results of the present study. Combinations of annual mass transport into or out of Puget Sound indicated these chemicals could be imported or exported (Table 22). Net ocean exchange for total PCBs could range from an export of approximately 2-12 kg/yr to an import of approximately 1-11 kg/yr. Total PBDE concentrations were detected in four deep boundary water samples and two surface water samples. Variable concentrations (CV = 2) led to a large interquartile range for PBDE concentrations and net annual ocean exchange estimates that indicated total PBDEs might be exported or imported. Total PCBs and total PBDEs were likely exported because concentrations in deep boundary waters entering and surface waters leaving Puget Sound were not significantly different [21] and net flow of water is out of Puget Sound. Any net import of total PCBs or total PBDEs into Puget Sound would need to be confirmed by means of future sampling and analysis. If

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[18] Kruskal Wallis and Test of Medians, $p<0.01$.

[19] Test of Medians showed no significant difference between inflow and outflow concentrations for these chemicals.

[20] Test of Medians, $p<0.02$. The mean concentration of total cadmium in deep boundary waters was also significantly greater than the mean concentration in Puget Sound surface layer waters (Kruskal Wallis, $p<0.02$).

[21] Kruskal Wallis test results for chemistry of deep boundary water vs. surface Puget Sound waters: $p<0.27$ for total PCBs and $p<0.64$ for total PBDEs.

confirmed, and caused by a substantial concentration differential, then the explanation might involve:

- Adsorption of total PCBs and PBDEs to suspended particles in surface runoff (rivers) entering the Sound.
- Dilution and settling of such suspended particles into the deep waters of major basins before being transported beyond ocean boundaries.
- Ongoing sources of PCBs and PBDEs contributing to the deep boundary waters entering Admiralty Inlet.

To summarize, ranges of values for net ocean exchange of various chemicals were presented in this section (Table 22). The ranges were derived from different estimates of annual chemical mass transport into and out of Puget Sound. Each mass transport estimate was based on two variables – annual flow and chemical concentration. Annual flows across the two boundaries between the Sound and the ocean (Admiralty Inlet and Deception Pass) were long-term median values predicted by the Puget Sound Toxics Box Model [22]. Concentration ranges were calculated from the limited chemical results of the present study.

As such, this evaluation of net ocean exchange was exploratory in nature. Furthermore, this evaluation did not attempt to address transport and fate processes within Puget Sound (e.g., chemical partitioning, horizontal transport, sedimentation and resuspension, burial, volatilization, and biological degradation) that are better examined by modeling.

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[22] Calculations did not incorporate interannual variability in flows.

Table 20. Chemical concentrations in deep ocean boundary waters and estimates of annual mass transport *into* Puget Sound.

Percentile concentrations were derived from results for Haro Strait, SJdF North, and SJdF Sill stations.
Annual mass transport estimates were based on the concentrations shown and the predicted median annual flow of deep water into Admiralty Inlet for 2000-2050 (see text). Flows and transports into the Sound are shown as negative values.

			Percentile Concentrations			Range of Mass Transport *into* Puget Sound (mT/year)		
Parameter	UOM	N	25%	Median	75%	25%	Median	75%
Conventional Parameters and Metals								
TSS	mg/L	9	1.2	1.6	2.0	-700,000	-940,000	-1,200,000
DOC	mg/L	6	0.63	0.66	0.69	-370,000	-380,000	-410,000
POC	mg/L	6	0.04	0.06	0.07	-25,000	-34,000	-41,000
TOC	mg/L	6	0.70	0.73	0.75	-410,000	-430,000	-440,000
Arsenic, Total	µg/L	9	1.44	1.49	1.52	-842	-872	-889
Arsenic, Dissolved	µg/L	9	1.43	1.44	1.50	-835	-841	-875
Cadmium, Total	µg/L	9	0.091	0.092	0.097	-53	-54	-57
Cadmium, Dissolved	µg/L	9	0.091	0.096	0.102	-53	-56	-60
Copper, Total	µg/L	9	0.24	0.28	0.41	-140	-160	-240
Copper, Dissolved	µg/L	9	0.20	0.23	0.26	-120	-140	-150
Lead, Total [1]	µg/L	8	0.087	0.11	0.12	-51	-63	-73
Zinc, Total [1]	µg/L	9	0.53	0.68	0.88	-310	-400	-520
Total PAHs								
Σ Nondetects (ND = ½ RL)	µg/L	0	0.080	0.080	0.084	-47	-47	-49
Σ Nondetects (ND = MDL)	µg/L	0	0.024	0.050	0.081	-14	-29	-48
Total PCBs								
Σ Congeners or Homologs	pg/L	9	14.6	26.4	35.4	-0.0086	-0.0155	-0.0207
Total PBDEs								
Σ Detected values only	pg/L	4	290	1,740	7,000	-0.17	-1.0	-4.1
Σ All values (ND = ½ EQL)	pg/L	9	760	830	1,600	-0.44	-0.49	-0.94
Σ All values (ND = EQL_{max})	pg/L	9	130	135	370	-0.076	-0.079	-0.22
Σ All values (ND = 0)	pg/L	9	0.0	0.0	370	0.000	0.000	-0.22

[1] Summary statistics for concentrations of dissolved lead and zinc are not presented because dissolved concentrations sometimes exceeded total concentrations such that distinguishing valid results from ones that reflected field or laboratory contamination was difficult.

UOM = units of measure
N = number of detected values upon which estimates were based
ND = nondetect
½ RL = one-half reporting limit; MDL = method detection limit; EQL_{max} = maximum estimated quantitation limit (similar to RL) for individual PBDE congeners

Table 21. Concentrations of chemicals in surface Puget Sound waters and estimates of annual mass transport *out of* Puget Sound.

Percentile concentrations were derived from results for Main, Whidbey, and Hood Canal stations. Annual mass transport estimates were based on concentrations shown and the predicted median annual flows of surface water out through Admiralty Inlet and Deception Pass for 2000-2050.

			Flow-weighted (see text) Percentile Concentrations			Range of Annual Mass Transport *out of* Puget Sound through Admiralty Inlet (mT/yr)				Percentile Concentrations			Range of Mass Transport *out of* Puget Sound through Deception Pass (mT/yr)		
Parameter	UOM	N	25%	Median	75%	25%	Median	75%	N	25%	Median	75%	25%	Median	75%
Conventional Parameters and Metals															
TSS	mg/L	9	1.3	1.7	2.2	780,000	1,000,000	1,300,000	3	1.7	2.6	4.05	82,000	125,000	195,000
DOC	mg/L	6	0.77	0.80	0.82	460,000	470,000	490,000	2	0.87	0.87	0.87	42,000	42,000	42,000
POC	mg/L	6	0.18	0.32	0.46	110,000	190,000	270,000	2	0.93	0.93	0.93	45,000	45,000	45,000
TOC	mg/L	6	0.96	1.12	1.28	570,000	661,000	755,000	2	1.80	1.80	1.80	87,000	87,000	87,000
As Total	µg/L	9	1.36	1.39	1.42	803	825	841	3	1.39	1.45	1.49	67.2	70.0	72.0
As Dissolved	µg/L	9	1.35	1.37	1.42	797	812	840	3	1.34	1.37	1.41	64.8	66.2	67.9
Cd Total	µg/L	9	0.078	0.079	0.082	46	47	49	3	0.081	0.082	0.084	3.9	4.0	4.1
Cd Dissolved	µg/L	9	0.072	0.074	0.077	43	44	46	3	0.071	0.074	0.077	3.4	3.5	3.7
Cu Total	µg/L	9	0.38	0.40	0.42	230	240	250	3	0.41	0.44	0.46	20	21	22
Cu Dissolved	µg/L	9	0.33	0.35	0.37	190	210	220	3	0.35	0.37	0.39	17	18	19
Pb Total [1]	µg/L	9	0.047	0.066	0.087	28	39	51	3	0.047	0.061	0.080	2.3	3.0	3.8
Zn Total [1]	µg/L	9	0.72	0.77	0.80	430	450	480	3	0.70	0.70	0.79	34	34	38
Total PAHs															
Σ Nondetects (ND = ½ RL)	µg/L	0	0.079	0.080	0.081	47	47	48	0	0.078	0.078	0.080	3.8	3.8	3.9
Σ Nondetects (ND = MDL)	µg/L	0	0.036	0.049	0.065	21	29	39	0	0.036	0.049	0.064	1.7	2.4	3.1
Total PCBs															
Σ Congeners or Homologs	pg/L	9	15.8	20.8	30.1	0.0094	0.0138	0.0178	3	13.6	18.4	46.8	6.5E-4	8.9E-4	2.2E-3
Total PBDEs															
Σ Detects only	pg/L	2	460	460	460	0.27	0.27	0.27	1	1,300	1,300	1,300	0.063	0.063	0.063
Σ All values (ND = ½ EQL)	pg/L	9	600	770	1,100	0.36	0.46	0.65	3	800	840	1,100	0.039	0.041	0.053
Σ All values (ND = EQL_{max})	pg/L	9	140	160	350	0.083	0.095	0.21	3	130	140	720	6.3E-3	6.8E-3	0.035
Σ All values (ND = 0)	pg/L	9	0.0	0.0	230	0.000	0.000	0.14	3	0.0	0.0	650	0.000	0.000	0.031

[1] Summary statistics for concentrations of dissolved lead and zinc are not presented here. Dissolved concentrations sometimes exceeded total concentrations such that distinguishing valid results from ones that reflected field or laboratory contamination was difficult.

Abbreviations as in Table 20.

Table 22. Range of net ocean exchange of various chemicals based on estimated annual mass transport *into* and *out of* Puget Sound. *Positive net exchange transport values indicate export from Puget Sound.*

		Range of Annual Mass Transport *into* Puget Sound (Table 20)			Range of Annual Mass Transport *out of* Puget Sound (Table 21)			Range of Estimated Net Annual Ocean Exchange (*Sum of values in appropriate columns to the left*)				
Parameter	UOM	25%	Median	75%	25%	Median	75%	25% *in*/ 25% *out*	Median *in*/ Median *out*	75% *in*/ 75% *out*	Low 75% *in*/25% *out*	High 25% *in*/75% *out*
Conventional Parameters and Metals												
TSS	mT/yr	-700,000	-940,000	-1,200,000	860,000	1,100,000	1,500,000	160,000	160,000	300,000	-340,000	800,000
DOC	mT/yr	-370,000	-380,000	-410,000	500,000	510,000	530,000	130,000	130,000	120,000	90,000	160,000
POC	mT/yr	-25,000	-34,000	-41,000	150,000	230,000	320,000	125,000	200,000	280,000	110,000	300,000
TOC	mT/yr	-410,000	-430,000	-440,000	650,000	750,000	840,000	240,000	320,000	400,000	210,000	430,000
As Total	mT/yr	-842	-872	-889	870	895	913	28	23	24	-19	71
As Dissolved	mT/yr	-835	-841	-875	861	878	908	26	37	33	-14	73
Cd Total	mT/yr	-53	-54	-57	50	51	53	-3.2	-2.9	-3.9	-7	-0.4
Cd Dissolved	mT/yr	-53	-56	-60	46	47	50	-7.1	-8.8	-10	-14	-3.7
Cu Total	mT/yr	-140	-160	-240	250	260	270	110	100	30	10	130
Cu Dissolved	mT/yr	-120	-140	-150	210	230	240	90	90	90	60	120
Pb Total [1]	mT/yr	-51	-63	-73	30	42	55	-21	-21	-18	-43	4.3
Zn Total [1]	mT/yr	-310	-400	-520	460	480	510	150	80	-10	-60	200
Total PAHs												
∑ Nondetects (ND = ½ RL)	mT/yr	-47	-47	-49	51	51	52	3.9	4.1	3.0	1.9	5.1
∑ Nondetects (ND = MDL)	mT/yr	-14	-29	-48	23	32	42	8.8	2.6	-5.8	-25	28
Total PCBs												
∑ Congeners or Homologs	mT/yr	-0.0086	-0.0155	-0.0207	0.0100	0.0147	0.0201	0.0014	-0.0008	-0.0006	-0.0107	0.0115
Total PBDEs												
∑ Detected values only	mT/yr	-0.17	-1.0	-4.1	0.33	0.33	0.33	0.16	-0.67	-3.77	-3.8	0.16
∑ All values with ND = ½ EQL	mT/yr	-0.44	-0.49	-0.94	0.40	0.50	0.70	-0.041	0.011	-0.24	-0.54	0.26
∑ All values with ND = EQL_{max}	mT/yr	-0.076	-0.079	-0.22	0.089	0.10	0.24	0.013	0.021	0.025	-0.13	0.16
∑ All values with ND = 0	mT/yr	-0.00	-0.00	-0.22	0.000	0.000	0.17	0.000	0.000	-0.049	-0.22	0.17

[1] Summary statistics for concentrations of dissolved lead and zinc are not presented here. Dissolved concentrations often exceeded total concentrations such that distinguishing valid results from ones that reflected field or laboratory contamination was difficult.

Abbreviations as in Table 20.

Sedimentation Rates for Toxics

Sediment traps deployed in Hood Canal from October 2009 through January 2010 collected marine particulates from that basin's deep layer. Archived mid-water solids from the Case and Carr Inlets, composited from material collected from March to June 2008 (Norton, 2009), were resurrected for comparison.

Sedimentation rates (g/cm^2/yr) were calculated for both locations by dividing the total dry mass of solids collected by the surface area of the traps, and by the duration of deployment. Since resuspended particulates could potentially be included in the trap material, these values should be considered estimates of *gross* sedimentation. Mass accumulation rates (mass/cm^2/yr; also called "downward flux") for each parameter were determined by multiplying the measured concentration by the sedimentation rate.

Sedimentation rates from the present study are summarized in relation to historical rates for other areas of Puget Sound in Table 23. The sedimentation rate in the deep waters of Hood Canal was comparable to rates measured by Norton (2009) in the Case+Carr Inlets. Both rates were markedly lower than rates typical of more urban embayments.

Table 23. Gross sedimentation rates for various areas of Puget Sound.

Source	Location	Mean Sedimentation Rate (dry g/cm^2/yr)
Present Study (2009-10)	Hood Canal	0.2
Present Study; Norton, 2009	Carr+Case Inlets	0.3
Norton, 2009	Eld Inlet	1.6
Norton, 2009	Budd Inlet	1.0
Norton and Boatman, 1998	Inner Budd Inlet	1.4
Norton, 1996	Inner Commencement Bay	1.5
Norton and Michelson, 1995	Elliott Bay Waterfront	0.7

Analyses conducted on the Hood Canal solids and on the archived Case+Carr Inlet material from Norton (2009) allowed estimation of the downward flux for various parameters. The measured concentrations and calculated mass accumulation rates are presented in Table 24.

Downward flux of organic carbon was low at both sites relative to rates found in more urban embayments. Norton (2009) measured average TOC accumulation rates of 0.048 and 0.033 g/cm^2/yr in the Eld and Budd Inlets, while the Case+Carr Inlet solids averaged 0.011 g/cm^2/yr. The Hood Canal TOC accumulation rate from the present study was even lower at 0.007 g/cm^2/yr. Likely contributing factors included distance from anthropogenic inputs, lower biological productivity during the late fall and early winter period of deployment, and depth of collection (below the surface mixed layer).

Table 24. Summary of mass accumulation rates for solids, TOC, metals, PCBs, and PBDEs.

All concentrations reported on a dry weight basis.

Parameter	Hood Canal		Case+Carr Inlets	
	Concentration	Mass Accumulation Rate ($g/m^2/yr$)	Concentration	Mass Accumulation Rate ($g/m^2/yr$)
Solids (g)	7.9	2,400	20.7*	3,440
TOC (%)	2.75	66	4.47*	154
As (mg/Kg)	7.53	0.018	5.72	0.020
Cd (mg/Kg)	0.87	0.002	1.04	0.004
Cu (mg/Kg)	82.0	0.197	18.5	0.064
Pb (mg/Kg)	9.13	0.022	8.78	0.030
Zn (mg/Kg)	90.0	0.217	72.0	0.248
PCBs (ng/Kg)	2,970	7.1E-6	9,850	33.9E-6
PBDEs (ng/Kg)	1,580	3.8E-6	1,060	3.6E-6

* Values from Norton (2009)

Metals concentrations in Hood Canal particulates were slightly higher than those from the Case+Carr Inlets for four of the five metals analyzed. With the exception of copper, however, mass accumulation rates of all metals were similar at these sites. Hood Canal copper concentrations were more than four times higher than those measured in Case+Carr Inlet SPM, and the resulting mass accumulation rate in Hood Canal was estimated to be three times greater than that of the Case+Carr Inlets.

Total PCB concentrations were markedly higher in SPM from the Case+Carr Inlets than in SPM collected from Hood Canal. This was consistent with expectations, as South Puget Sound is more highly developed and has more potential sources of PCBs than Hood Canal. Mass accumulation rates in the Case+Carr Inlets and Hood Canal were estimated to be 0.0339 and 0.0071 $mg/m^2/yr$, respectively.

Differences in total PBDE concentrations and mass accumulation rates between the two sites were minor. Rates of total PBDE accumulation were estimated to be 0.0038 and 0.0036 $Kg/m^2/yr$ in Hood Canal and Case+Carr Inlets, respectively.

Rivers

Comparison with Historical Data

Average concentrations of TSS, TOC, and nutrients in the five rivers, based on three seasonal samples, were within ranges obtained from EIM data and other studies (Table 25). The mean values were also remarkably similar to historical median or mean values (Appendix I, Table I-4). In general, the same was true for river water hardness and total metal concentrations (Table 26; Appendix I, Table I-5).

Table 27 compares the concentrations of organic compounds that were measured or estimated for the present 2009-10 study with concentrations reported by other studies. TPH concentrations were never detected. The detection frequency for oil and grease was 40% (6/15), and the measured concentrations ranged from 0.9 - 2.8 mg/L in the five rivers. The mean concentration of 1.6 mg/L changed little when nondetect values were included (1.7 mg/L when ND = ½ RL; 1.2 mg/L when ND = MDL). According to Herrera (2010a), this mean concentration would be observed with reasonable frequency in all land use categories except commercial/industrial.

Possible reasons for the low detection frequency and low mean concentrations included:

- The compounds were not present at the time of sampling (e.g., lost due to volatilization).
- Standard sampling methods failed to collect the surface-most layers most likely to contain compounds less dense than water.
- Current analytical methods could not detect the compounds after the dilution that occurred between points of discharge and sampling locations.

MEL seldom detected PAHs in whole river water samples even with low detection limits. Six of the 15 samples contained concentrations of individual PAHs in the 0.0009 - 0.11 µg/L range. Assuming nondetect concentrations are one-half the RL, total PAH concentrations ranged from 0.076 - 0.11 µg/L. Assuming nondetect concentrations are one-half the MDL, the range was 0.012 - 0.055 µg/L. Using the latter assumption, the range of cPAH concentrations was 0.009 - 0.014 µg/L. This was within the range of cPAH concentrations measured in Lower Green River near Tukwila (<0.001 - 0.040 µg/L; Willston, 2008).

The range of total PCB concentrations measured in the five rivers (2.6 - 59 pg/L) was lower than the range reported for the Green/Duwamish River system (83 - 814 pg/L). It was also lower than most probability-of-exceedance concentrations listed for different land uses in Herrera (2010a). Lower concentrations of toxic organic compounds would generally be expected in the five rivers sampled for the present study than in the Green/Duwamish River system, other areas of commercial/industrial land use, or highway runoff.

Table 25. Concentrations of conventional parameters and nutrients (mg/L) measured in major rivers discharging to Puget Sound.

River	Study/ Data Source	TSS	TOC	DOC	Total Nitrogen	Nitrite/Nitrate Nitrogen	Ammonia - Nitrogen	Total Phosphorous	Ortho-Phosphorous
Skagit	Present Study Mean (n=3 or as noted) Range	24.8 6.4-60.8	1.0 0.6-1.7	1.0 0.6-1.6	0.13 0.057-0.163	0.08 0.045-0.126	0.046 (1) --	0.033 0.006-0.086	0.004 0.003-0.005
	EIM Range [1]	1.0-1,230	0.5-7.0	--	0.033-0.48	0.020-0.200	0.010-2.65	0.003-0.737	0.001-0.030
	Wise et al., 2007 Range [2]	13.6-78.5	--	--	0.13-0.17	--	--	0.02-0.05	--
Snohomish	Present Study Mean and Range	24.3 4.7-54.5	1.6 0.6-2.1	1.7 0.7-2.2	0.271 0.102-0.389	0.211 0.077-0.281	0.044 0.008-0.079	0.032 0.009-0.053	0.008 0.004-0.014
	EIM Range	1.0-260	0.8-6.1	--	0.030-0.840	0.073-0.368	0.010-0.780	0.005-0.160	0.002-0.100
	Wise et al., 2007 Range	9.7-42.4	--	--	0.32-0.34	--	--	0.02-0.03	--
Nooksack	Present Study Mean and Range	30.3 3.7-76.3	1.4 0.6-2.8	1.6 0.8-2.9	0.379 0.106-0.656	0.325 0.087-0.544	0.022 (1) --	0.046 0.021-0.090	0.013 0.009-0.021
	EIM Range	1.0-2,600	--	--	0.097-1.22	0.076-0.684	0.010-0.510	0.009-0.132	0.004-0.121
	Embrey & Frans, 2003 [3] Range	8-2,890	0.7-6.8	--	--	0.13-0.94	<0.015-0.08	<0.01-.30	<0.01-0.02
	Wise et al., 2007 Range	48-301	--	--	0.49-0.55	--	--	0.05-0.20	--
Stillaguamish	Present Study Mean and Range	15.9 2.6-41.3	1.7 0.8-3.3	2.0 0.9-4.0	0.299 0.147-0.418	0.243 0.088-0.341	0.019 0.007-0.039	0.035 0.016-0.072	0.011 0.008-0.014
	EIM Range	0.1-2,700	1.4-2.0	--	0.054-0.767	0.010-0.728	0.010-0.760	0.008-0.698	0.002-0.110
Puyallup	Present Study Mean and Range	94.5 11.9-233	1.0 0.5-1.3	1.1 0.8-1.4	0.351 0.137-0.545	0.240 0.110-0.309	0.066 0.010-0.162	0.124 0.044-0.250	0.033 0.021-0.048
	EIM Range	1.0-2,890	0.9-9.1	1.1-3.2	0.074-0.826	0.056-0.399	0.004-0.580	0.010-1.66	0.007-0.120
	Wise et al., 2007 Range	77.1-407	--	--	0.27-0.41	--	--	0.09-0.15	--

[1] Derived from EIM data representing similar locations in each river and equivalent analytical methods.

[2] Flow-weighted annual mean concentrations for 1997, 2000, and 2001 based on LOADEST model annual loads and annual flows.

[3] Based on approximately 40 samples collected near Brennan, Washington, in 1996-1998.

Table 26. Hardness and concentrations of metals in major rivers discharging to Puget Sound.

River	Study/ Data Source	Hardness	Total Arsenic	Total Cadmium	Total Copper	Total Lead	Total Zinc
		mg/L	µg/L				
Skagit	Present Study Mean (n=3 or as noted) and Range	26.4 21.8-29.9	0.75 0.43 - 1.24	0.012 0.006-0.020	2.06 0.77-4.56	0.31 0.05-0.78	5.1 2.4-10.6
	EIM Range [1]	13-48	0.45-1.09	--	0.280-12.0	0.023-0.47	0.55-9.34
Snohomish	Present Study Mean and Range	15.4 13.2-17.4	1.00 0.92-1.14	0.015 0.005-0.030	2.60 1.35-4.08	0.34 0.09-0.63	4.7 2.5-8.3
	EIM Range	3.0-52.0	0.48-1.9	--	0.39-5.9	0.020-1.50	0.61-33.9
Nooksack	Present Study Mean and Range	46.2 38.1-62.0	0.55 0.26-1.01	0.017 0.005-0.040	2.41 0.75-4.41	0.32 0.05-0.82	6.0 3.2-9.7
	EIM Range	10.0-71.0	0.23-5.22	--	0.27-21	0.020-3.86	0.34-35.3
Stillaguamish	Present Study Mean and Range	27.0 19.2-31.9	0.79 0.52-1.12	0.011 0.005-0.020	2.95 1.16-6.58	0.58 (2) 0.37-0.79	9.0 4.0-17.7
	EIM Range	11.0-43.0	0.37-2.65	--	0.50-18.0	0.020-0.450	0.45-20
Puyallup	Present Study Mean and Range	33.9 27.7-40.8	0.68 0.52-0.92	0.007 0.005-0.010	4.91 1.32-11.6	0.81 (2) 0.20-1.42	7.7 (2) 3.7-11.6
	EIM Range	14.0-60.4	0.33-1.16	0.003-0.200	0.45-41.4	0.022-6.30	0.21-43.5
Green/Duwamish	Williston (2009) King County (2007) [1,2]	--	0.34-2.4	--	13.1	--	21.3
Surface Runoff	PSTLA (Herrera, 2010a) [3] Concentration Range	--	0.2 -14.9	0.0002 - 9.2	0.1 - 110	0.02 - 309	0.28 - 527

[1] Range of total arsenic concentrations measured during 2006-2008.

[2] Mean copper and zinc concentrations derived from 2003-2005 total annual loads and discharges listed in Table 5-9.

[3] Range of values from Herrera (2010a), Table 2: Probability of exceedance concentrations used to represent major land use types and highways.

Table 27. Concentration of organic compounds in river discharges and surface runoff to Puget Sound.

River	Study/ Data Source	Oil and Grease		Total PAH	cPAH *	Total PCBs	Total PBDEs
		Including ND=MDL/2	Detects only	Including ND=MDL/2			
		µg/L				pg/L	
Skagit, Snohomish, Nooksack, Stillaguamish, and Puyallup	Present Study Mean (n) Range	920 (15) 250 – 2,800	1,600 (6) 900 – 2,800	0.032 (15) 0.012 - 0.055	0.011 (15) 0.009 - 0.014	16.1 (15) 2.6 - 59.0	55.6 (7) 10.9 - 265
Green/Duwamish	Williston (2009) [1] Range	--		0.015 - 0.05	<0.001 - 0.040	38 - 2,360	--
	Gries and Sloan (2009) [2]	--		--	1.2 - 14.3	140 - 1,600	--
Total Surface Runoff	Phase II probability of exceedance concentrations (Herrera, 2010a) [3]	3.7 - 26,400		0.001 - 56.6	0.0002 - 11.8	16 - 810,000	0.30 - 810

* Carcinogenic PAH compounds (cPAH) include benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene.

[1] Based on PAH data collected in 2008.

[2] Estimated range for annual flow-weighted mean concentrations.

[3] Range of values from Herrera et al. (2010a), Table 2: Probability of exceedance concentrations used to represent major land use types and highways.

Patterns and Relationships

The same graphic and statistical methods used to explore marine water column results were used to examine the river water data obtained from this study. Few differences in mean or median concentrations of the various chemicals could be attributed to different seasons, rivers, or flow regimes. This was expected from such a limited data set. However, some statistically significant relationships were identified. As with the marine water column results, most chemicals measured in river waters were not normally distributed (Appendix J, Table J-4) and the nonparametric Kruskal Wallis Test and Test of Medians were conducted. Results are shown in Appendix J, Tables J-5 and J-6. They show the following significant differences between seasons:

- TSS was lowest during the summer (excluding Puyallup River result).
- TOC and DOC were lowest in the summer (Figure 27a).
- Total nitrogen (TN) and nitrate+nitrite N were lowest during the summer (Figure 27b).
- Ammonia nitrogen concentrations were highest during the fall (not shown).
- Concentrations of total lead and zinc were highest in winter (not shown).

The only chemicals for which the mean concentrations (across all seasons) differed between the five rivers were:

- Ortho-phosphate concentrations were highest in the Puyallup River (Figure 28a).
- Hardness was lowest in the Snohomish River and highest in the Nooksack and Puyallup Rivers (not shown).
- Dissolved arsenic concentrations were lowest in the Nooksack River (Figure 28b).

The flow regimes assigned to each seasonal sampling in each river (base or runoff-related in Table 11) were not significant determinants of mean chemical concentrations. This was no doubt due to the limited number of samplings conducted in different systems with high natural variability. Total PCB concentrations were greater during runoff-related events, but the significance level was only $p<0.16$.

Spearman rank-correlations showed significant relationships between many chemical pairings. These are summarized in Appendix J, Table J-6. Total phosphorus (TP) and total metal concentrations were correlated with TSS. The total fractions of the five metals covaried. PCB homologs that were more polar (fewer chlorine atoms) correlated with chemicals such as ortho-phosphate and dissolved metals, while non-polar homologs (more chlorines) sometimes correlated with parameters common in particulate form (TSS, TOC, TN, TP, and total metals).

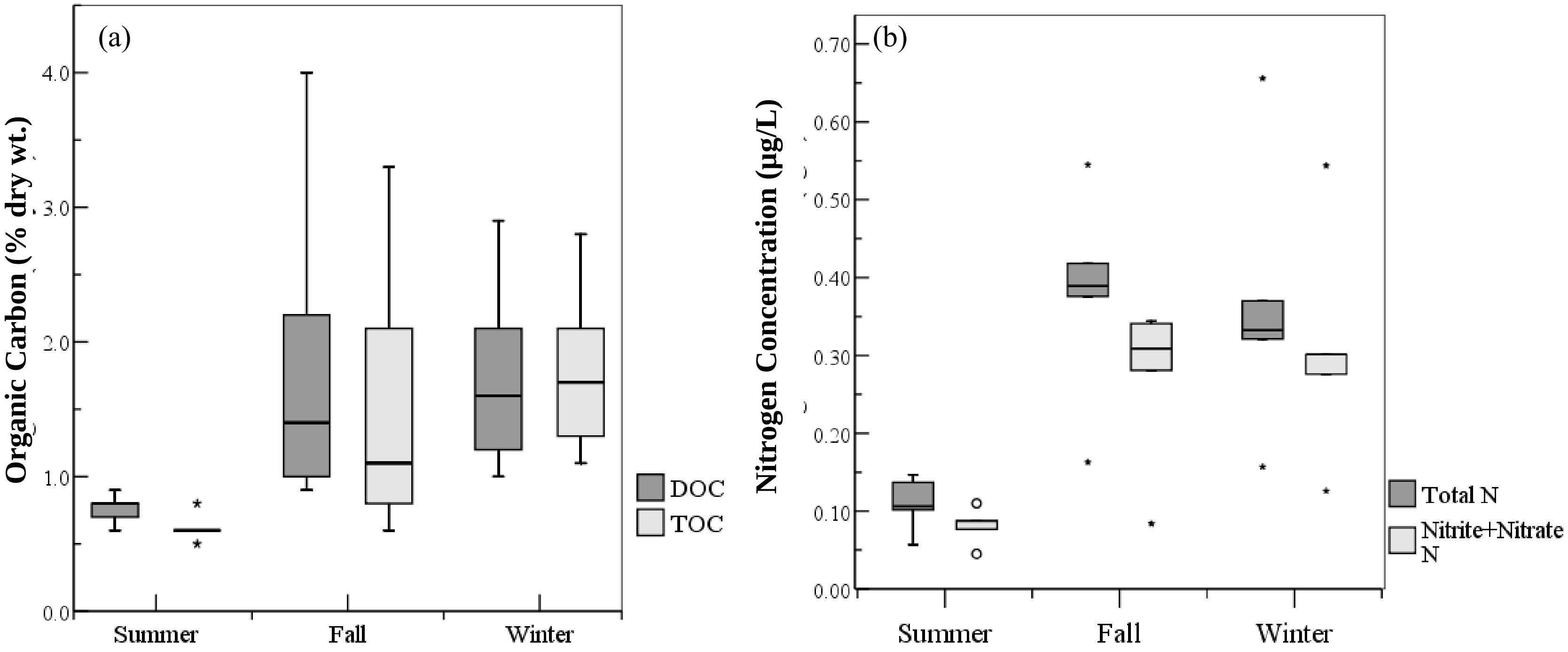

Figure 27. Box plots showing seasonal concentrations of organic carbon and nitrogen species.

*The heavy bars are median concentrations, with the boxes representing the interquartile range. Possible outliers appear as *.*

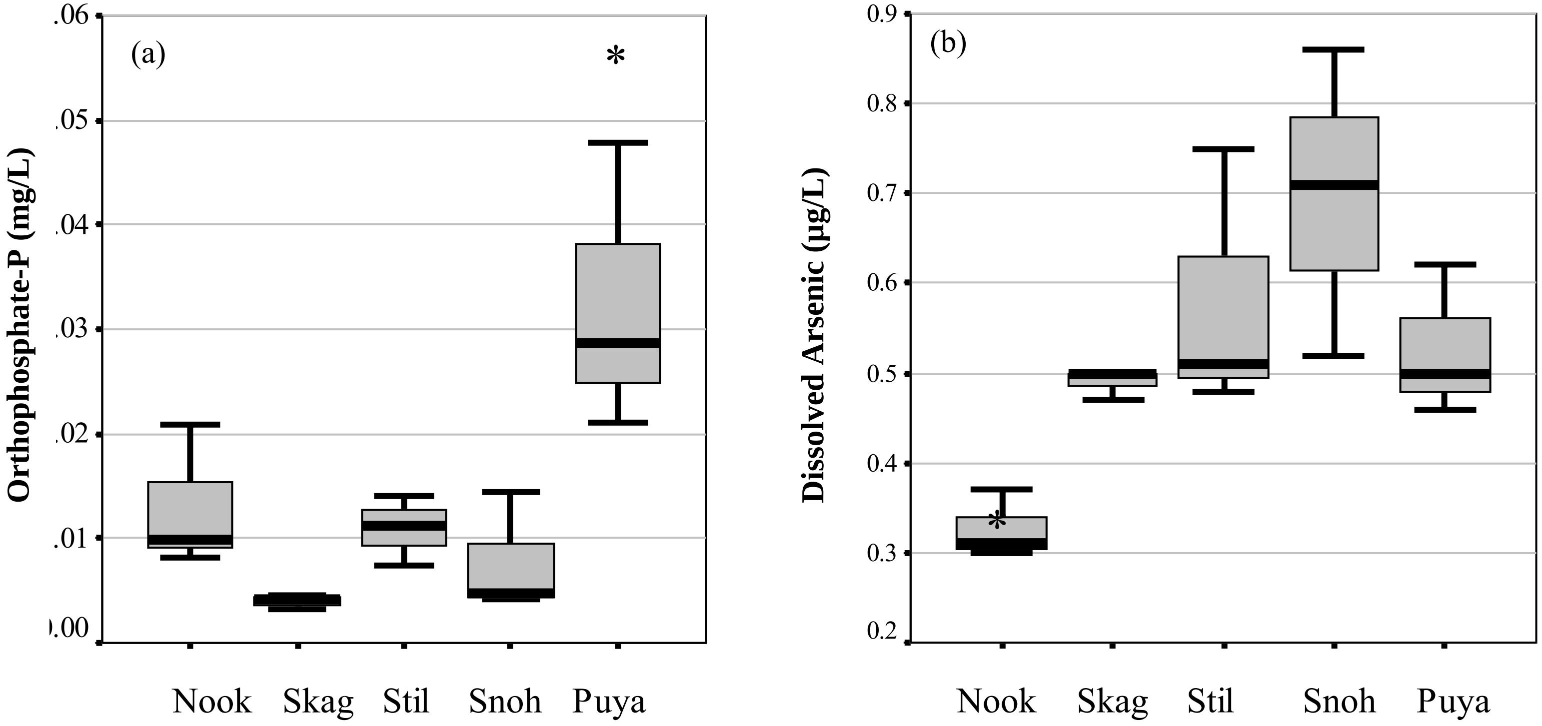

Figure 28. Box plots showing river water concentrations of ortho-phosphate and dissolved arsenic.

The heavy bars show median concentrations, with the boxes representing the interquartile range.

***** *Concentration significantly different from the mean concentration.*

Abbreviations: Nook = Nooksack, Skag = Skagit, Stil = Stillaguamish, Snoh = Snohomish, Puya = Puyallup.

Loading

Instantaneous mass loading rates for TSS, TOC, total nitrogen, total phosphorus, and total metals for the five rivers were calculated by multiplying the mean daily flows (Table 11) by the chemical concentrations measured on the same date (Appendix G, Table G-1). The results are shown as daily loads in Table 28. Total arsenic daily loads for the three smaller rivers studied here ranged from 0.96 - 19 kg/day. This was similar to the 0.13 - 7.28 kg/day arsenic load associated with SPM from the Green/Duwamish River system (Gries and Sloan, 2009) despite different mean annual flows.

Daily loading rates for petroleum-related compounds, total PCBs, and total PBDEs are presented in Table 29. Rates for oil and grease, TPH-D, and TPH-G were based on nondetect concentrations set at one-half the RL and at the MDL. The range of estimated daily loads for the sum of all petroleum-related compounds was 445 - 94,500 kg. The daily loading of total PCBs from the five rivers ranged from 0.015 - 0.57 g. This was lower than but comparable to the 0.06 - 1.2 g PCBs/ day load associated with SPM measured in the Green/Duwamish River system (Gries and Sloan, 2009). Daily loading of total PBDEs was between 0.11 - 5.6 g (using one-half the single highest RL when no PBDEs were detected). Daily loading was not calculated for BNAs, PAHs, or chlorinated pesticides because of their low frequency of detection.

Much of the variability in the daily loads was due to the wide range in mean daily flows. To reduce the influence of flows, instantaneous loads were also normalized to the area of each watershed above the gaging station where sampling occurred (see Table 2). Summary statistics for daily loading across all rivers and sampling events are presented in Table 30 (not normalized) and Table 31 (area-normalized). These rates of daily loading can be compared to results from ongoing and future studies.

Table 28. Instantaneous loads of conventional parameters, nutrients, and total metals from major rivers discharging to Puget Sound.

Instantaneous loads (kg/day) were calculated using measured concentrations and mean daily flow.

		Skagit			Snohomish			Nooksack			Stillaguamish			Puyallup		
		Jan 2010	Jul 2009	Oct 2009	Jul 2009	Oct 2009	Dec 2009	Jul 2009	Oct 2009	Dec 2009	Jul 2009	Oct 2009	Dec 2009	Jul 2009	Oct 2009	Dec 2009
Daily Flow	cfs	7,880	10,500	5,400	3,470	4,940	18,400	1,760	587	13,800	320	350	1,900	2,380	1,000	1,860
	cms	223	297	153	98.3	140	521	49.8	16.6	391	9.1	9.9	53.8	67.4	28.3	52.7
Parameter - Loading (kg/day)																
TSS		1.85E5	8.46E4	2.05E6	3.99E4	1.64E5	2.45E6	4.694	5.3E3	1.47E6	3.0E3	3.54E4	1.72E4	1.36E6	9.47E4	5.42E4
TOC		15,400	7,930	57,400	5,090	25,400	94,500	2,580	1,150	54,000	924	2,830	5,110	2,910	2,690	5,920
Total Nitrogen		1,460	2,150	5,300	866	4,700	14,500	456	540	12,600	170	358	1,540	798	1,330	1,680
Total Phosphorus		188	77.9	2,890	78.1	392	2,400	91.3	36.9	1,740	19.9	61.5	72.1	1,460	195	199
Arsenic, Total		14.6	56.8	41.9	7.81	11.4	51.3	1.59	3.73	19.5	0.84	0.96	2.42	5.36	1.47	2.37
Cadmium, Total		0.23	0.79	0.68	0.042	0.12	1.4	0.022	0.072	0.77	5.8E-3	0.017	0.033	0.058	0.015	0.023
Copper, Total		20	110	150	11	29	180	9.0	11	85	1.30	5.6	5.2	68	4.4	6.0
Lead, Total		2.8	6.6	26	0.76	3.6	28	0.43	0.72	16	0.017	0.68	1.7	8.3	0.49	0.27
Zinc, Total		62	320	360	21	40	370	22	46	190	4.6	15	39	68	9.1	6.4

E = exponent.

Table 29. Instantaneous daily loads for petroleum-related compounds, total PCBs, and total PBDEs from major rivers discharging to Puget Sound.

Instantaneous loads (kg/day) were calculated using measured concentrations and mean daily flow.

		Skagit			Snohomish			Nooksack			Stillaguamish			Puyallup		
		Jul 2009	Oct 2009	Dec 2009	Jul 2009	Oct 2009	Dec 2009	Jul 2009	Oct 2009	Jan 2010	Jul 2009	Oct 2009	Dec 2009	Jul 2009	Oct 2009	Dec 2009
Daily Flow	cfs	10500	5400	13800	3470	4940	18400	1760	587	7880	320	350	1900	2380	1000	1860
	cms	297	153	391	98.3	140	521	49.8	16.6	223	9.1	9.9	53.8	67.4	28.3	52.7
Parameter - Loading (kg/day)																
Oil and Grease (ND=½RL)		36,000	*13,000*	*91,000*	24,000	*11,000*	72,000	6,000	*1,300*	*53,000*	1,600	*770*	*13,000*	5,200	*2,200*	*12,500*
Oil and Grease (ND=MDL)		36,000	*6,600*	*51,000*	24,000	*6,000*	72,000	6,000	*720*	*29,000*	1,600	*430*	*7,000*	5,200	*1,200*	*6,800*
TPH-D (ND=½RL)		*2,300*	*1,100*	*1,000*	*760*	*1,030*	*1,350*	*370*	*120*	*580*	*100*	*77*	*400*	*520*	*210*	*140*
TPH-D (ND=MDL)		*150*	*79*	*54*	*51*	*73*	*72*	*26*	*8.6*	*29*	*6.9*	*5.1*	*28*	*35*	*15*	*7.3*
TPH-G (ND=½RL)		*1,800*	*920*	*2,400*	*590*	*850*	*3,150*	*300*	*100*	*1,400*	*81*	*60*	*320*	*410*	*170*	*320*
TPH-G (ND=MDL)		*360*	*180*	*470*	*120*	*170*	*630*	*60*	*20*	*270*	*16*	*12*	*65*	*82*	*34*	*64*
PCBs (g)		1.9E-4	1.3E-4	5.7E-4	1.6E-4	6.0E-5	3.3E-4	2.8E-5	7.4E-5	2.5E-5	2.2E-5	5.1E-5	2.3E-5	1.5E-5	9.8E-5	1.1E-4
PBDEs (g)		3.4E-4	*1.6E-3*	*4.2E-3*	1.2E-4	1.5E-3	5.6E-3	1.5E-4	1.3E-4	*5.4E-4*	2.6E-5	*1.1E-4*	*5.8E-4*	6.3E-5	6.5E-4	5.7E-4

Daily load in *italics* if >10% was based on nondetect values.

E = exponent.

Table 30. Summary statistics for instantaneous daily loads from five major rivers discharging to Puget Sound.

Instantaneous Loading (kg/day)								
Parameter	Detection Frequency	Calculation Basis (N)	Minimum	25%	Median	Mean	75%	Maximum
TSS	15/15	15	3.0	38	85	540	770	2,450
TOC	15/15	15	920	2,800	5,100	19,000	20,000	94,000
Total Nitrogen	15/15	15	170	670	1,500	3,200	3,400	14,000
Total Phosphorus	15/15	15	20	75	190	660	920	2,900
Arsenic, Total	15/15	15	0.843	1.98	5.36	14.8	17.1	56.8
Cadmium, Total	15/15	15	0.0058	0.022	0.058	0.28	0.45	1.4
Copper, Total	15/15	15	1.3	5.8	11	47	76	180
Lead, Total (Detects only)	13/15	13	0.017	0.58	1.7	6.5	7.4	28
Zinc, Total (Detects only)	14/15	14	4.6	18	40	100	130	370
Oil and Grease (Detects only)	6/15	6	1,600	5,400	15,000	24,000	33,000	72,000
Oil and Grease (ND=½RL)	6/15	15	*770*	*3,700*	*12,500*	*23,000*	*30,000*	*91,000*
Oil and Grease (ND=MDL)	6/15	15	*430*	*3,400*	*6,600*	*17,000*	*26,000*	*72,000*
TPH-D (ND=½RL)	0/15	15	*77*	*170*	*520*	*670*	*1,000*	*2,300*
TPH-D (ND=MDL)	0/15	15	*5*	*12*	*29*	*43*	*63*	*150*
TPH-G (ND=½ RL)	0/15	15	*60*	*240*	*410*	*850*	*1,100*	*3,200*
TPH-G (ND=MDL)	0/15	15	*12*	*47*	*82*	*170*	*230*	*630*
Total PCBs (Detects only)	15/15	15	0.015	0.026	0.074	0.126	0.146	0.573
Total PBDEs ((Detects only)	7/15	7	0.026	0.090	0.13	0.21	0.24	0.65
Total PBDEs (ND=max RL)	7/15	15	*0.026*	*0.12*	*0.54*	*1.1*	*1.1*	*5.6*

Daily load in *italics* if >10% was based on nondetect values.

Table 31. Summary statistics for area-normalized instantaneous daily loads from five major rivers discharging to Puget Sound.

Watershed areas (km^2) above gaging stations: Skagit = 8,010, Snohomish = 4,440, Nooksack = 2,045, Stillaguamish = 1,445, Puyallup = 2,455.

Area-normalized loading (kg/km^2-day)								
Parameter	Detection Frequency	Calculation Basis (N)	Minimum	25%	Median	Mean	75%	Maximum
TSS	15/15	15	2.1	11	23	150	150	720
TOC	15/15	15	0.56	1.1	1.9	5.2	4.6	26
Total Nitrogen	15/15	15	0.12	0.24	0.32	1.0	0.90	6.2
Total Phosphorus	15/15	15	0.010	0.021	0.050	0.19	0.22	0.85
Arsenic, Total	15/15	15	5.84E-04	8.71E-04	1.82E-03	3.25E-03	3.89E-03	1.16E-02
Cadmium, Total	15/15	15	4.0E-06	1.0E-05	2.4E-05	7.0E-05	6.0E-05	3.8E-04
Copper, Total	15/15	15	9.3E-04	2.5E-03	4.4E-03	1.2E-02	1.7E-02	4.2E-02
Lead, Total (Detects only)	13/15	13	1.2E-05	2.0E-04	4.7E-04	1.7E-03	2.2E-03	7.7E-03
Zinc, Total (Detects only)	14/15	14	2.6E-03	6.2E-03	1.1E-02	2.6E-02	3.4E-02	9.1E-02
Oil and Grease (Detects only)	6/15	6	1.1	2.3	3.7	5.4	5.1	16.2
Oil and Grease (ND=½RL)	6/15	15	*0.53*	*1.3*	*3.0*	*6.0*	*7.0*	*26*
Oil and Grease (ND=MDL)	6/15	15	*0.30*	*0.97*	*2.8*	*4.2*	*5.19*	*16*
TPH-D (ND=½RL)	0/15	15	*0.053*	*0.078*	*0.17*	*0.17*	*0.25*	*0.30*
TPH-D (ND=MDL)	0/15	15	*0.003*	*0.005*	*0.011*	*0.011*	*0.015*	*0.019*
TPH-G (ND=½ RL)	0/15	15	*0.04*	*0.09*	*0.15*	*0.21*	*0.23*	*0.71*
TPH-G (ND=MDL)	0/15	15	*0.01*	*0.02*	*0.03*	*0.04*	*0.05*	*0.14*
Total PCBs (Detects only)	15/15	15	6.19E-09	1.45E-08	2.35E-08	3.02E-08	3.81E-08	7.39E-08
Total PBDEs ((Detects only)	7/15	7	1.8E-08	2.6E-08	4.3E-08	7.3E-08	6.7E-08	2.6E-07
Total PBDEs (ND=max RL)	7/15	15	*1.8E-08*	*5.2E-08*	*2.1E-07*	*2.5E-07*	*3.0E-07*	*1.3E-06*

Daily load in *italics* if >10% was based on nondetect values.

Conclusions

The primary purpose of the present 2009-10 study was to measure toxic chemical concentrations in Puget Sound marine waters, ocean boundary waters (Strait of Juan de Fuca and Haro Strait), and freshwater near the mouths of the five largest rivers discharging to Puget Sound. The concentration data obtained will help identify the largest remaining sources of uncertainty in the Puget Sound Toxics Box Model and the data gaps that still require field studies or analysis.

Marine Water and SPM

Major findings from the marine water column sampling portion of this study include:

- Low concentrations of suspended solids, organic carbon, metals, PCBs, and PBDEs were routinely detected in marine water samples. Chlorinated pesticides, BNAs, and PAHs were rarely or never detected in the same samples. Analytical detection limits were not adequate to detect these organic compounds at sampling sites far removed from sources.
- The range of total PCB concentrations measured for ambient marine waters was 6.1 - 75 pg/L. Average concentrations in the ocean boundary waters (20.4 pg/L) and Puget Sound (30.7 pg/L) were significantly different and both were lower than those previously reported for the Strait of Georgia (42 pg/l) by Canadian researchers (Dangerfield et al., 2007).
- Total PCB concentrations in the deep waters were significantly greater than those in the surface waters. This was true for the ocean boundary waters and Puget Sound. A significant positive relationship between total PCBs and TSS suggested that sedimentation may play a key role in the fate of PCBs in Puget Sound.
- The range of detected total PBDE concentrations in marine waters (51 - 18,700 pg/L) was much wider than the range of total PCB concentrations. Total PBDEs concentrations were often 10 times higher in the present study than concentrations reported by Canadian researchers (Dangerfield et al., 2007) and apparently not related to TSS. No evidence suggested the higher concentrations were due to sample contamination. Potential sources of high PBDE concentrations were not identified.
- Organic carbon concentrations in marine water samples resembled concentrations previously reported for the Strait of Georgia (Johannessen et al., 2008) but were substantially lower than marine water concentration records in Ecology's EIM database.
- Estimates of two-directional transport across Box Model boundaries (Admiralty Inlet and Deception Pass) were calculated from concentrations of toxic chemicals in Puget Sound surface waters and deep ocean boundary waters. Estimates showed that most chemicals were probably exported from Puget Sound. Notable exceptions were cadmium and possibly lead, which appeared to be imported into Puget Sound. This was due to significantly higher concentrations in incoming ocean boundary waters than in the surface waters flowing out of the Sound. The direction of net exchange for total PCBs and total PBDEs at the ocean boundaries could not be determined from data collected.

- Samples of SPM collected by sediment traps moored in Hood Canal and the Case+Carr Inlets contained similar concentrations of organic carbon, metals, and PBDEs. PCB concentrations in Case+Carr SPM were more than three times greater than those in Hood Canal SPM.

River Water and SPM

Major findings from the river water sampling portion of this study include:

- Concentrations of TSS, organic carbon, nutrients, hardness, and metals were within the concentration ranges reported from previous studies by Ecology and other monitoring programs (Inkpen and Embry, 1998; Wise et al., 2007).
- River water samples seldom contained detectable concentrations of petroleum-related compounds, BNAs, PAHs, or chlorinated pesticides. SPM centrifuged from December 2009 and January 2010 contained detectable concentrations of a number of PAHs.
- The mean concentration of total PCBs measured in surface water from the five rivers was 16.3 pg/L. The range of concentrations measured was 2.6 - 59 pg/L. This range is somewhat lower than that measured by King County in the Green/Duwamish Rivers (83 - 814 pg/L). This is likely because land use in the lower watershed of the Green/Duwamish Rivers is more urban and industrial in character than the rivers sampled for this 2009-10 study.
- PBDEs were detected in 7 of the 15 river water samples. Total PBDE concentrations were highly variable ranging from 10.9 - 265 pg/L, with an average of 55.6 pg/L.
- Total PAH concentrations in SPM (excluding retene) ranged from 32 - 210 μg/Kg, with an average of 120 μg/Kg. Concentrations of individual PAHs were <20 μg/Kg, except for retene which averaged 230 μg/Kg.
- Few other organic compounds (BNAs, TPH-D, chlorinated pesticides) were detected in SPM.
- Estimated daily loading of total PCBs for the five rivers ranged from 0.015 - 0.57 g/day.
- Estimated daily loading of total PBDEs for the five rivers ranged from 0.017 - 5.63 g/day.

Notable relationships between parameters include:

- TSS concentrations were significantly correlated with, and explained between 63% and 86% of the variability in, concentrations of total phosphorus and total metals.
- TOC, DOC, total nitrogen, and nitrate+nitrite concentrations were significantly lower during July than during the other two sampling periods.
- Congeners belonging to the more polar PCB homolog groups (those with fewer chlorine atoms) were significantly correlated with many parameters in the dissolved phase (ortho-phosphate and dissolved metals). Congeners in the more highly-chlorinated PCB homologs were significantly correlated with TSS, TOC, and parameters often found in particulate form (total nitrogen and total phosphorus).

Recommendations

The following recommendations pertain to the use of present 2009-10 study results for modeling purposes and for future monitoring programs. In particular, more monitoring is needed to better define the normal range of concentrations for various toxic chemicals in marine and river waters.

- Selected study results should be used to revise input values to the Box Model and to calibrate the model.
- Future sampling should place more emphasis on collection and analysis of suspended particulate matter (SPM) in order to improve frequency of detection for hydrophobic compounds such as PAHs.
- More intensive water column sampling should be conducted near the ocean boundaries (Admiralty Inlet sill and Deception Pass). Samples should be analyzed for a reduced suite of chemicals, with priority given to chemicals exhibiting high variability (PBDEs) in the present study. This would improve the assessment of chemical exchange between ocean boundary waters and Puget Sound.
- Depth-integrated water sampling of large rivers should be conducted with focus on increased sampling frequency, a reduced suite of chemicals, and improved detection limits for organic contaminants. More frequent sampling during all phases of runoff-related events is needed to understand seasonal and other temporal patterns. This would facilitate a better characterization of loading during baseflow conditions and runoff-related events.
- Estimates of petroleum-related compound loadings to Puget Sound should be improved by:
  - Refining sampling methods or developing new methods better suited to capturing such compounds.
  - Refining analytical methods for measuring different petroleum fractions in whole water or other collection media (adsorbent material).
- Standard operating procedures (SOPs) for the collection and analysis of seawater samples for DOC and POC should be revised. For example, all equipment used for sample collection and processing should be made exclusively of glass or lined with Teflon.

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Appendix A. Glossary, Acronyms, Abbreviations, and Units of Measurement

Glossary

Ambient: Something commonly found in one's immediate surroundings. In this case, ambient concentrations of toxic chemicals are those within the normal range found in a box within the Puget Sound Toxics Box Model and not influenced by point sources of pollution.

Analyte: Water quality constituent being measured (parameter).

Baseflow: Groundwater discharge. The component of total streamflow that originates from direct groundwater discharges to a stream.

Basin: A drainage area or watershed in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Biota: Flora (plants) and fauna (animals).

Box Model: The simplest type of model. A box model assumes the object being modeled has the shape of a box and substances inside the box are distributed uniformly. In this case, the Puget Sound Toxics Box Model assumes different basins and water layers have the shape of a box and that chemical concentrations in each box are all the same.

Congener: In chemistry, congeners are related chemicals. For example, polychlorinated biphenyls (PCBs) are a group of 209 related chemicals that are called congeners.

Conventional pollutants: Non-toxic pollutants.

Euphotic zone: The uppermost part of a waterbody that receives enough light to allow photosynthesis to occur.

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values. The calculation is performed by: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the values.

Harmonic Mean: A second expression of central tendency (average) among multiple values. The calculation takes the reciprocal of the arithmetic mean of the reciprocals. The harmonic mean is commonly used when average rates are calculated. It tends to mitigate the impact of large outlier values but aggravate the impact of small ones.

Homolog: One of several groups of similar organic chemical compounds whose successive members have a regular difference in composition. For example, mono-chlorinated biphenyls compounds contain one chlorine atom and belong to the homolog group, and bi-phenyl compounds containing 2-9 chlorine atoms belong to the other nine homolog groups.

Load(ing): The mass substance (suspended sediment or contaminant) passing by a horizontal or vertical plane per unit time. For example, the metric tons of sediment calculated to be transported downstream of a particular location.

Marine: Of or having to do with an ocean or sea (salt water).

Marine water column: The vertical column of water representing the entire depth of a marine waterbody. For the present 2009-2010 study, water samples were collected from various subsurface depths in the marine water column, not just dipped from the surface.

Nonpoint source: Pollution entering waters of the state from dispersed land-based or water-based activities, including atmospheric deposition, surface water runoff, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Ocean boundary waters: Strait of Juan de Fuca and Haro Strait

Ortho-phosphate: The soluble inorganic phosphate ion (PO_4^{3-}) reported as the mass of phosphorus per unit volume (µg P/liter).

Outlier: A number (or observation) that deviates markedly from other numbers in a sample population (group of observations).

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Particulate: Solid matter, such as a grain of fine sand, small enough to be suspended in a gas or liquid.

Pesticide: Any substance or mixture of substance intended for preventing, destroying, repelling or mitigating any pest. Pests include nuisance microbes, plants, fungus, and animals.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Contamination, or alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Pycnocline: Depth at which water density increases most rapidly with depth.

Runoff: The variety of ways by which water moves across the land, including surface (diffuse) runoff and channelized runoff.

Seawater: Water from a sea or ocean, averaging 35 grams of dissolved salts per liter (parts per thousand).

Sediment: Solid fragmented material (soil and organic matter) that is transported and deposited by water and covered with water (example, river or lake bottom).

Spatial: How concentrations differ among various parts of the river.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

Suspended sediment: Solid fragmented material (soil and organic matter) in the water column.

Temporal trends: Characterize trends over time.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation

X th percentile: A statistical number obtained from a distribution of a data set, above which 100-X % of the data exists and below which X % of the data exists.

Acronyms and Abbreviations

AP	Analytical Perspectives
BEHP	Bis 2-ethylhexyl phthalate
BMP	Best management practices
BNA	(Base/neutral/acid extractable) semivolatile organic compound
cPAH	Carcinogenic PAH compounds [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene)]
CRM	Certified reference material
CTD	Conductivity, temperature, depth measurement devices
CV	Coefficient of variation (standard deviation divided by the mean)
Ecology	Washington State Department of Ecology
DDD	Dichloro-diphenyl-dichloroethane
DDE	Dichloro-diphenyl-trichloroethylene
DDT	Dichloro-diphenyl-trichloroethane
DOC	Dissolved organic carbon
DUP	Duplicate

EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
EDL	Estimated detection limit
EQL	Estimated quantitation limit
Frontier	Frontier Global (formerly Frontier Geosciences)
GFF	Glass fiber filter
GIS	Geographic Information System software
GPS	Global Positioning System
HDPE	High-density polyethylene
HEM	Hexane-extractable material (synonymous with oil and grease)
HPAH	High molecular weight PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, and pyrene]
KCDNR	King County Department of Natural Resources
LPAH	High molecular weight PAHs [acenaphthylene, acenaphthene, anthracene, fluorene, naphthalene, and phenanthrene]
MDL	Method detection limit
MEL	Manchester Environmental Laboratory
MQO	Method quality objective
MS/MSD	Matrix spike/matrix spike duplicate
N	Number
n/a	Not applicable
NAD	North American Datum
ND	Not detected, nondetect
NPDES	National Pollutant Discharge Elimination System
NTR	National Toxics Rule
Ortho-P	Ortho-phosphate
P	Phosphorus
p	Probability of a result as extreme as the one observed assuming the null hypothesis is true
PAH	Polycyclic aromatic hydrocarbon compounds
PBDE	Polybrominated diphenyl ethers
PBT	Persistent, bioaccumulative, and toxic substance
PCB	Polychlorinated biphenyls
POC	Particulate organic carbon
POTW	Publically-owned treatment works
PRL	Pacific Rim Laboratories
PSTLA	Puget Sound Toxics Loading Analysis
QA	Quality assurance
QC	Quality control
REP	Replicate
RL	Reporting Limit
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
Sd	Sound
SJdF	Strait of Juan de Fuca

SOP	Standard operating procedure
SPM	Suspended particulate matter
SRM	Standard reference materials
Stdev	Standard deviation
Str	Strait
TEQ	Toxic Equivalents (for carcinogenic PAHs, relative to toxicity of benzo(a)pyrene)
TOC	Total organic carbon
TPAH	Total PAHs (sum of HPAH and LPAH concentrations)
TPH	Total petroleum hydrocarbons
TPH-D	Total petroleum hydrocarbons - diesel fraction
TPH-G	Total petroleum hydrocarbons - gasoline fraction
TSS	(See Glossary above)
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Metals

As	Arsenic
Cd	Cadmium
Cu	Copper
Pb	Lead
Zn	Zinc

Units of Measurement

cfs	cubic feet per second
cm	centimeters
cms	cubic meters per second, a unit of flow.
dw	dry weight
ft	feet
g	gram, a unit of mass
gpm	gallons per minute
kg	kilograms, a unit of mass equal to 1,000 grams.
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters.
L	liters
m	meter
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
ng/Kg	nanograms per kilogram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units
rpm	revolutions per second
µg/Kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
µM	micromolar (a chemistry unit)

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Appendix B. Sampling Sites and Field Records

Puget Sound Toxics Box Model

Marine Water Column Sampling

Marine SPM Sampling

River Water Sampling

Puget Sound Toxics Box Model

The Puget Sound Toxics Box Model depicted below, taken from Pelletier and Mohamedali (2009), provides context for the sampling conducted for the present 2009-2010 study. It shows the relative volume of surface and deep water layers in Puget Sound basins, the relative volume of surface runoff to each surface layer, and the relative volume exchanged between each basin and layer. To address data gaps identified by the Box Model, the present study analyzed toxic chemicals in samples collected from surface and deep layers of the four main basins and from the five rivers representing the largest sources of surface runoff. Samples were also collected from surface and deep layers in ocean boundary waters outside Admiralty Inlet.

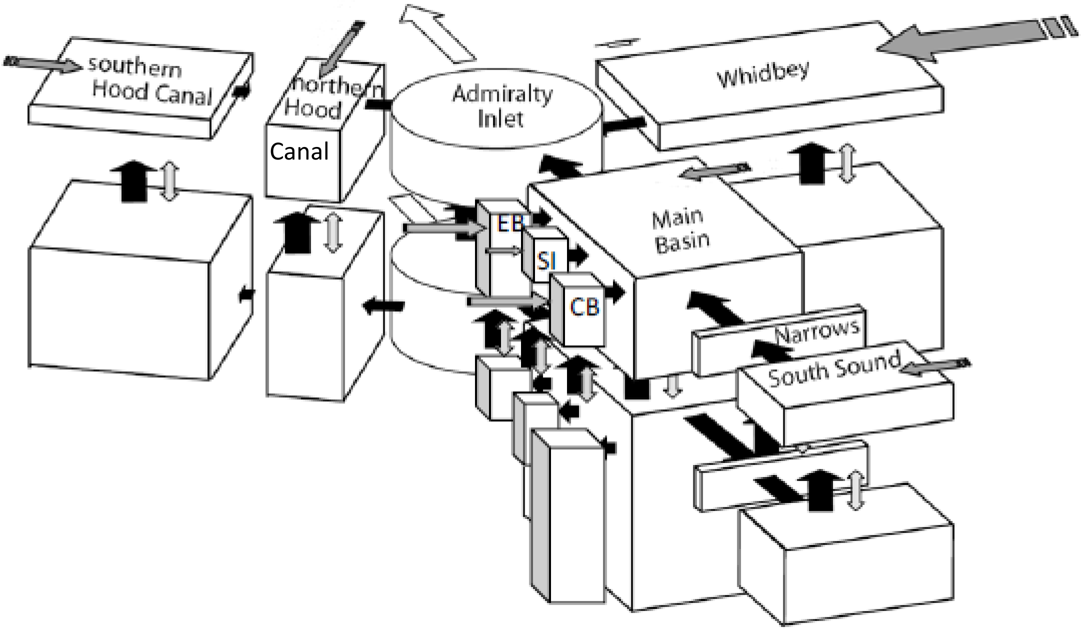

Figure B-1. Diagram of the Box Model of water circulation and transport in Puget Sound.

Grey arrows with dashed ends represent river inputs.
White arrows show exchange with the Strait of Juan de Fuca (ocean boundary waters).
Black arrows show advective transport.
Two-way grey arrows represent mixing between compartments.

Boxes are scaled to show relative volumes of water.
Arrows for rivers are log-scaled.

EB = Elliott Bay; SI = Sinclair Inlet; CB = Commencement Bay.

Marine Water Column Sampling

Table B-1. Sampling depths at Puget Sound basin sites relative to Box Model features and stratification. Two GO-FLO samplers were deployed simultaneously, collecting water at depths A and B.

Station	Seasonal Sampling Event	Date	Station Depth (m)	Box Model Surface/Deep Division (m)	Approx. Pycnocline Depth (m)	Sample Depth A (m)	Sample Depth B (m)	Water Column Layer
Hood Canal	1	7/7/09	152	13	10-15	5	7	surface
						40	35	deep
	2	9/30/09	150		5	2	5	surface
						80	85	deep
	3	1/13/10	n/a		10	25	30	surface
						100	105	deep
South Sound	1	7/9/09	165	30	<10	10	15	surface
						85	90	deep
	2	10/1/09	180		none	10	15	surface
						80	85	deep
	3	1/11/10	170		5	10	10	surface
						90	90	deep
Main	1	7/9/09	160	50	62	15	20	surface
						95	100	deep
	2	9/29/09	230		57	20	25	surface
						80	85	deep
	3	1/12/10	n/a		<5	20	20	surface
						80	80	deep
Whidbey	1	7/10/09	149	9	10	5	10	surface
						75	80	deep
	2	9/28/09	148		8	5	10	surface
						45	40	deep
	3	1/26/10	152		17	15	20	surface
						95	100	deep

Table B-2. Sampling depths at ocean boundary water sites relative to Box Model features and stratification. Two GO-FLO samplers were deployed simultaneously, collecting water at depths A and B.

Station	Seasonal Sampling Event	Date	Station Depth (m)	Box Model Surface/Deep Layer Division (m)	Approx. Pycnocline Depth (m)	Sample Depth A (m)	Sample Depth B (m)	Water Column Layer
SJdF at Sill	1	7/7/09	156	50	30	10	15	surface
						45	50	deep
	2	10/7/09	154		none	15	20	surface
						95	100	deep
	3	2/2/10	156		none	15	20	surface
						120	125	deep
SJdF North	1	7/8/09	136	50	85	15	20	surface
						110	115	deep
	2	10/7/09	134		55	15	20	surface
						95	100	deep
	3	2/2/10	140		<5	15	20	surface
						120	125	deep
Haro Strait	1	7/8/09	183	50	<90	15	20	surface
						115	120	deep
	2	10/7/09	185		50, 115	15	20	surface
						95	100	deep
	3	2/1/10	184		<5	15	20	surface
						95	100	deep

SJdF = Strait of Juan de Fuca.

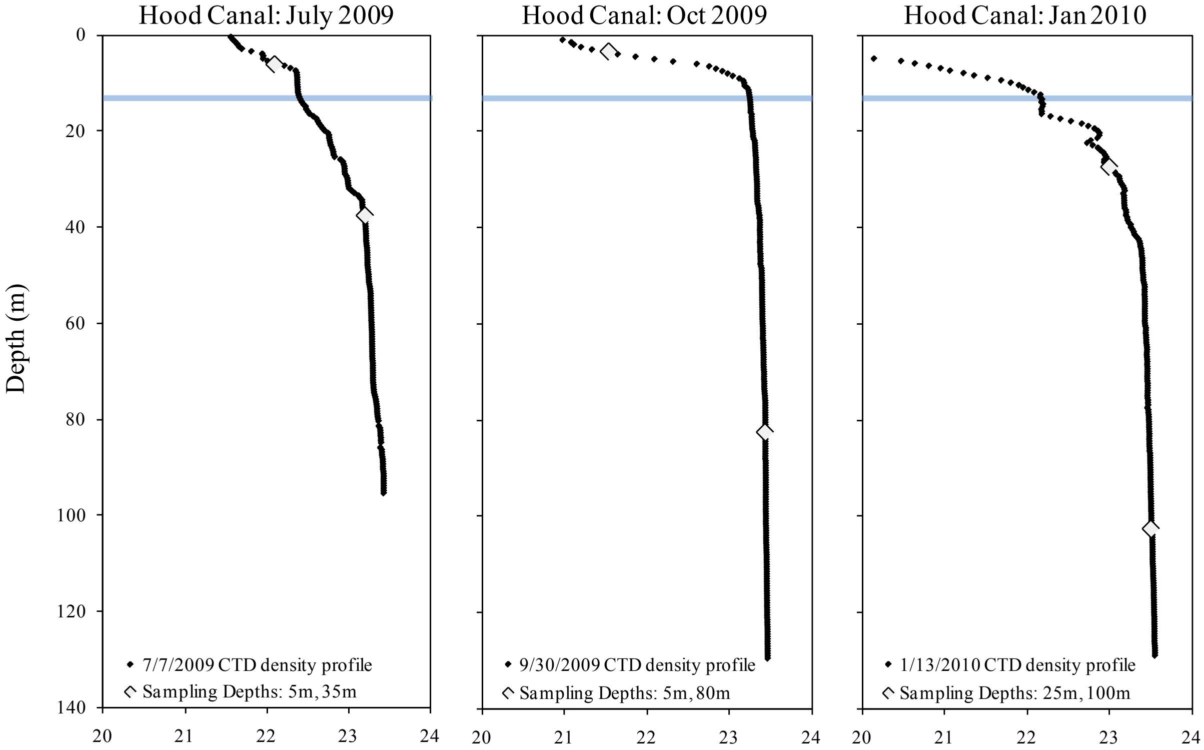

Figure B-2. Hood Canal water column sampling depths in relation to density profiles.
Density (x-axis) given in kg/m^3. Depth of the division between Box Model layers is shown at 13m.

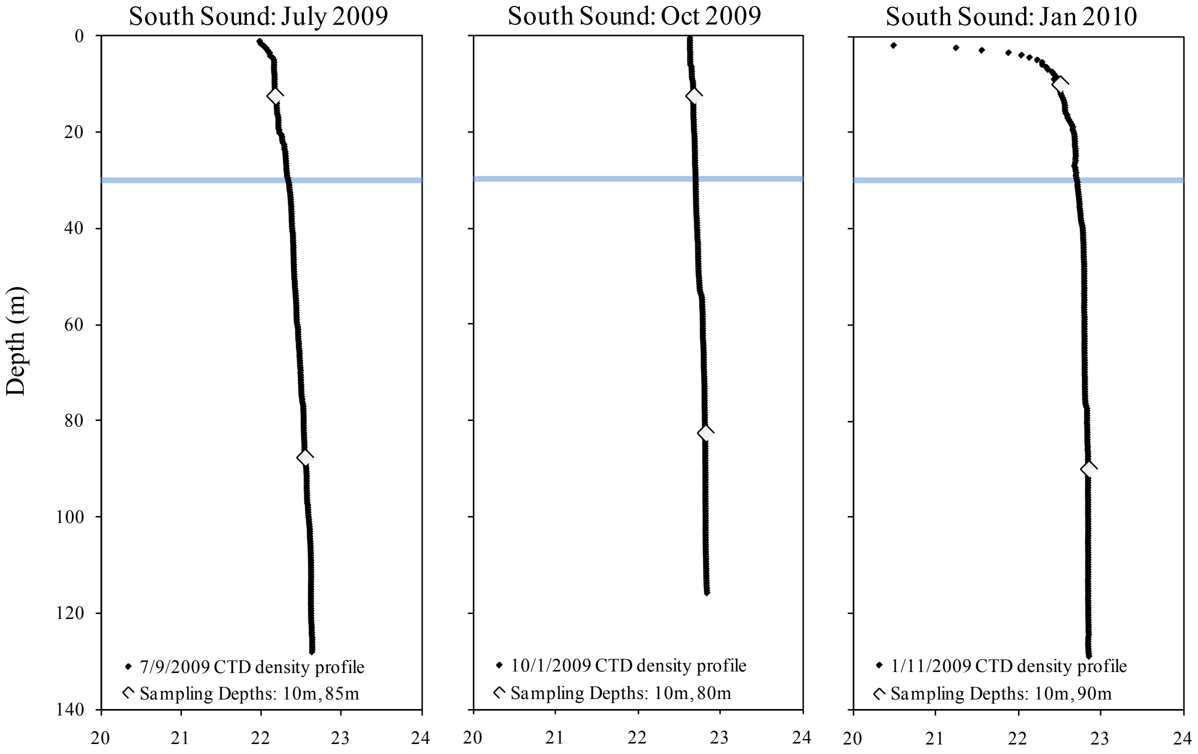

Figure B-3. South Sound water column sampling depths in relation to density profiles.
Density (x-axis) given in kg/m^3. Depth of the division between Box Model layers is shown at 30m.

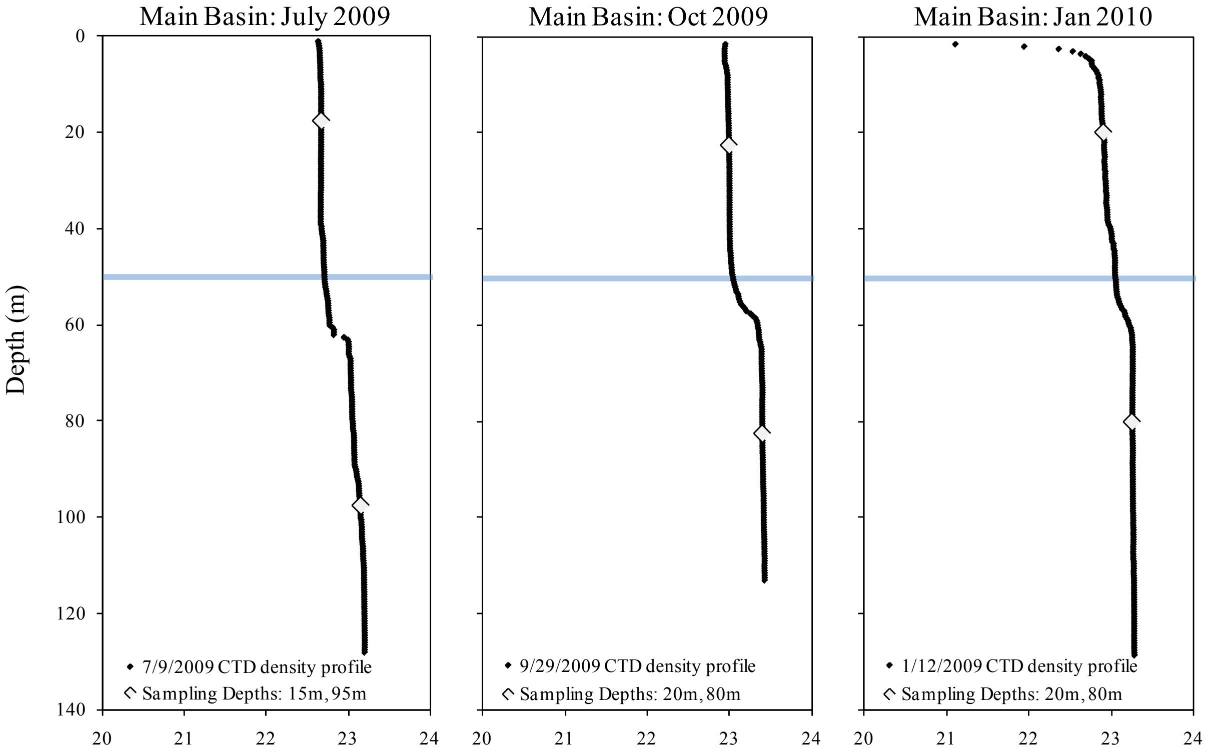

Figure B-4. Main Basin water column sampling depths in relation to density profiles. *Density (x-axis) given in kg/m*^{3}*. Depth of the division between Box Model layers is shown at 50m.*

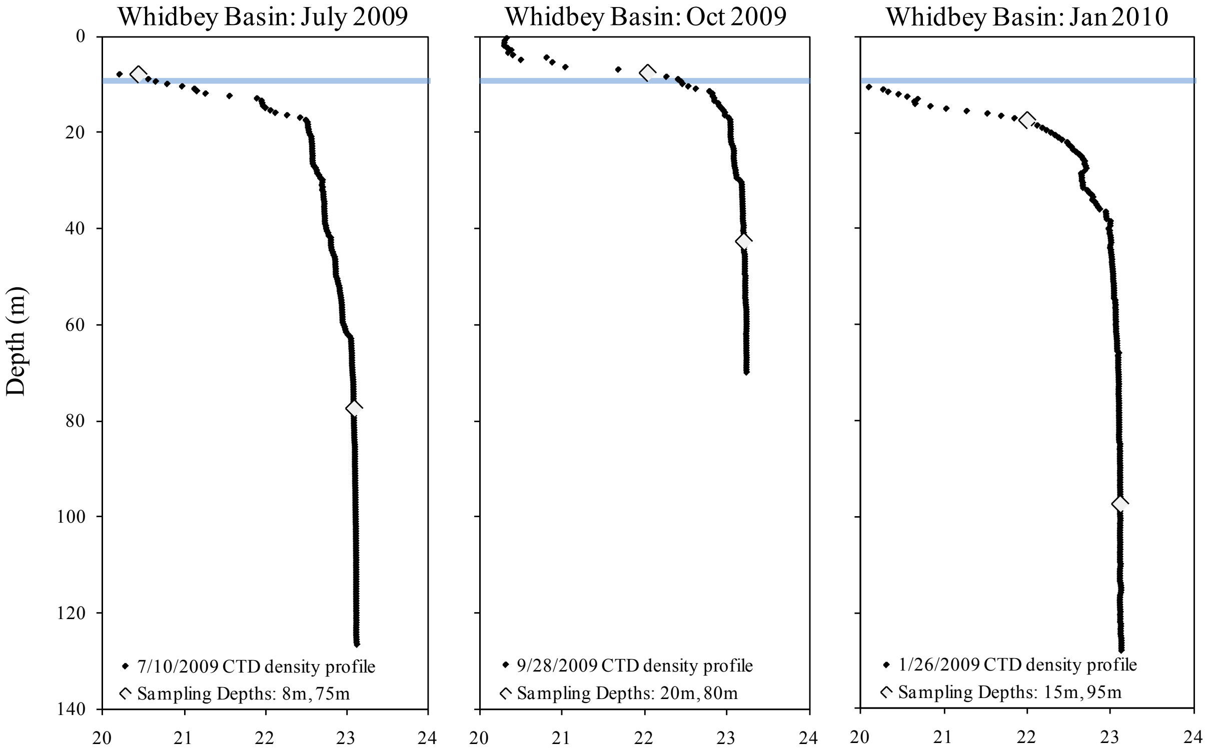

Figure B-5. Whidbey Basin water column sampling depths in relation to density profiles. *Density (x-axis) given in kg/m*^{3}*. Depth of the division between Box Model layers is shown at 9m.*

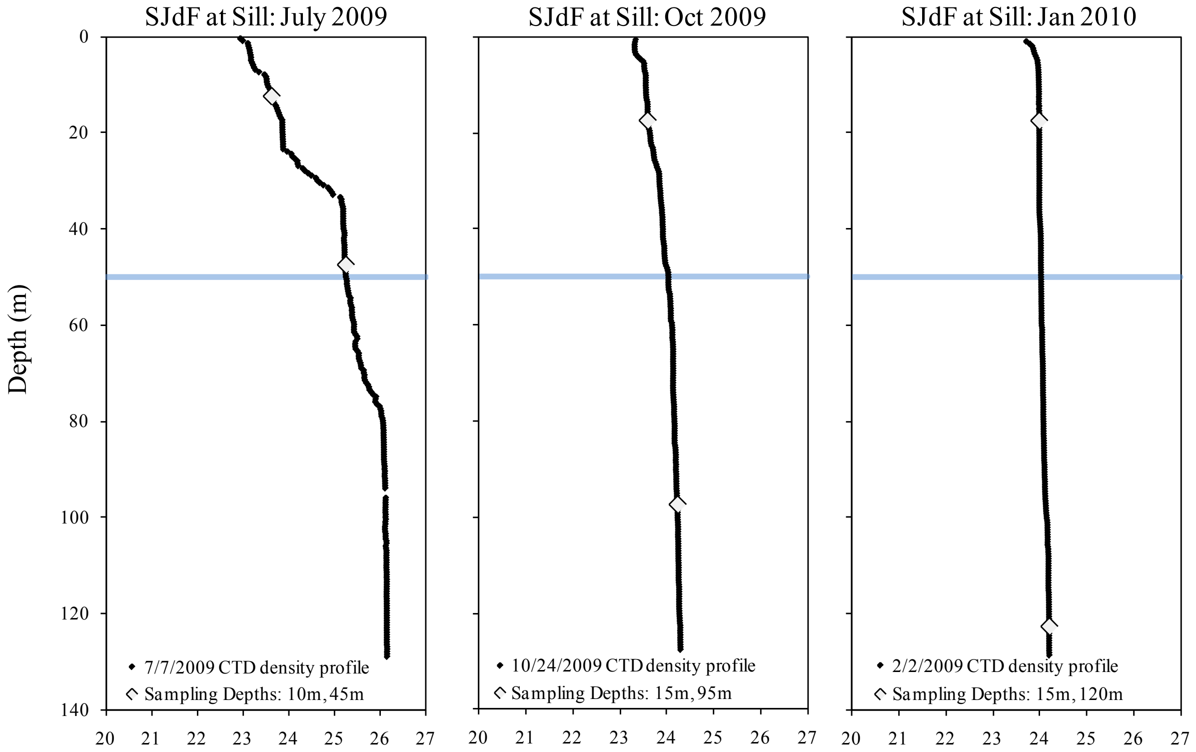

Figure B-6. SJdF at Sill water column sampling depths in relation to density profiles. *Density (x-axis) given in kg/m^3. Depth of the division between Box Model layers is shown at 50m.*

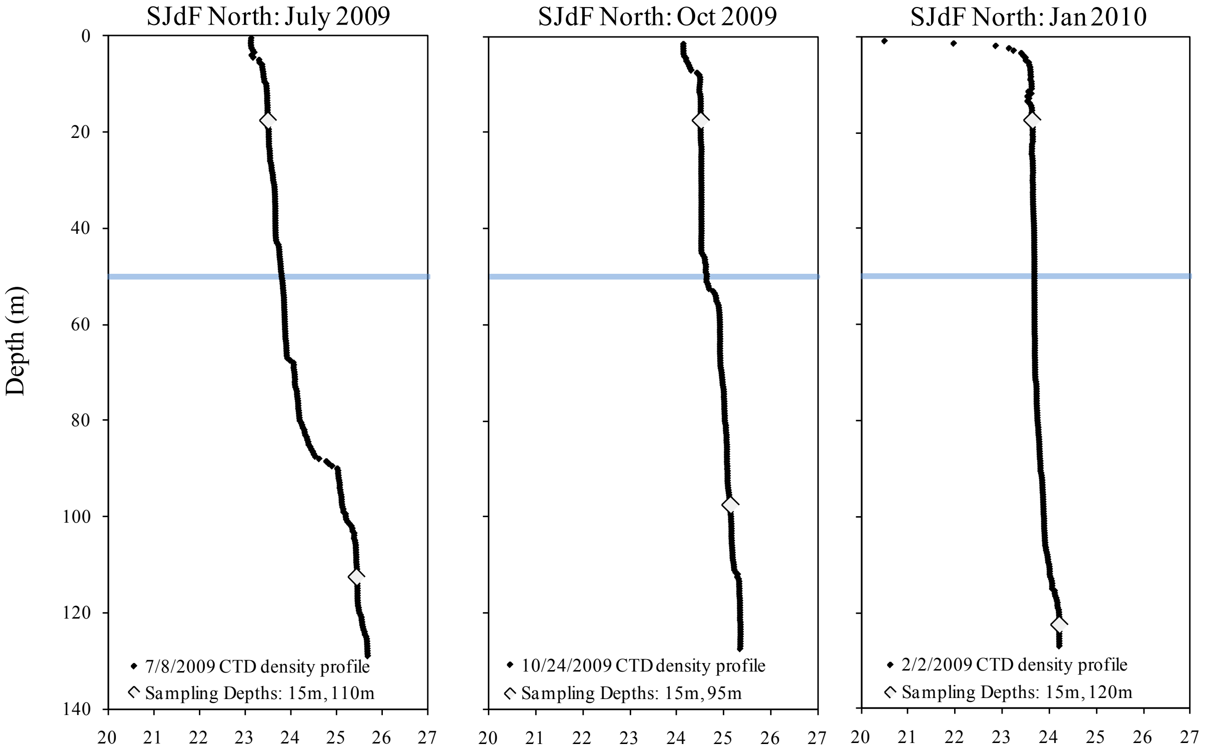

Figure B-7. SJdF North water column sampling depths in relation to density profiles. *Density (x-axis) given in kg/m^3. Depth of the division between Box Model layers is shown at 50m.*

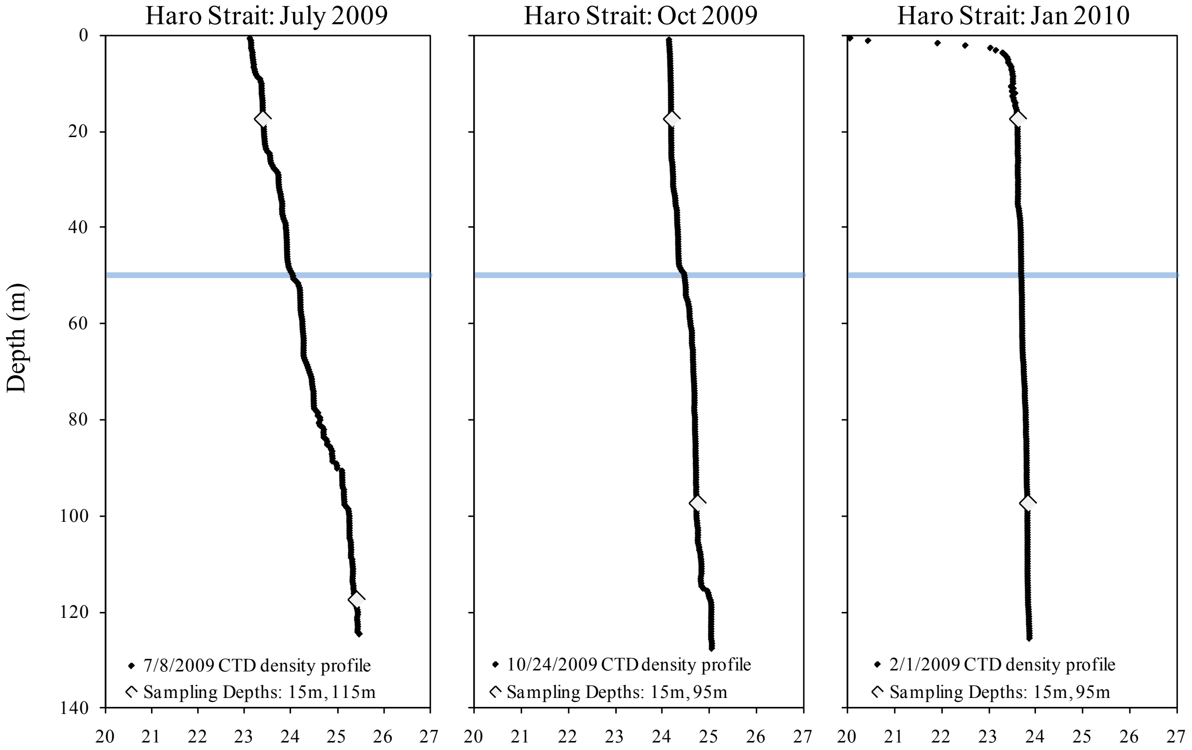

Figure B-8. Haro Strait water column sampling depths in relation to density profiles.
Density (x-axis) given in kg/m^3*. Depth of the division between Box Model layers is shown at 50m.*

Marine SPM Sampling

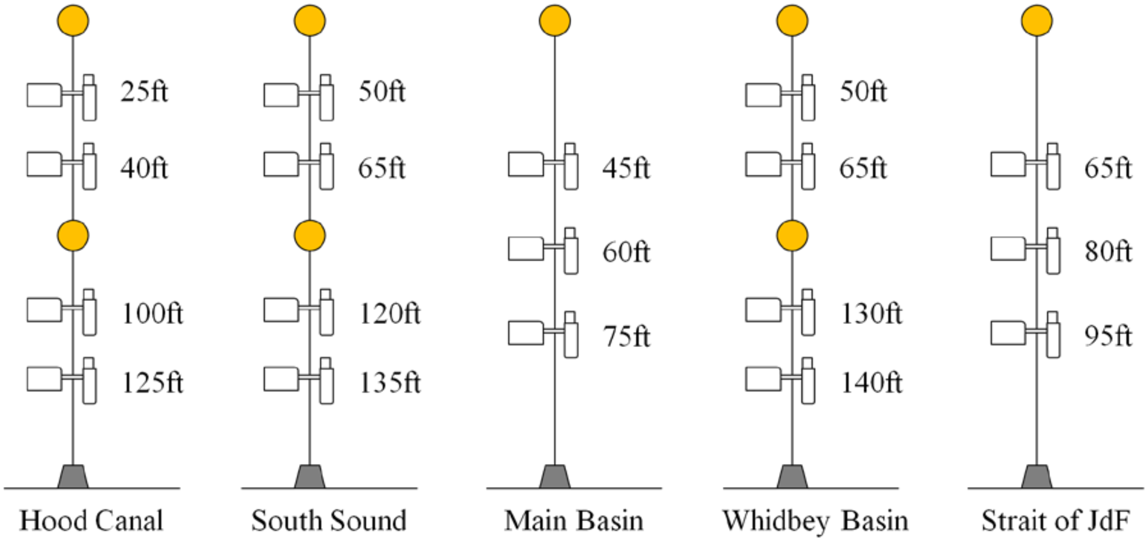

Figure B-9. Configuration of sediment trap deployments at each mooring location.

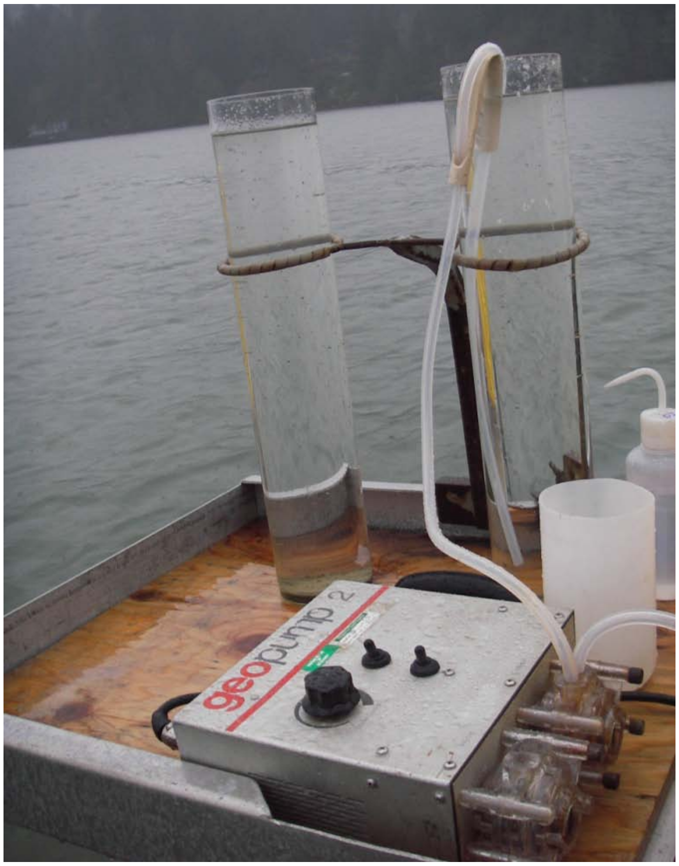

Figure B-10. Drawing overlying water from glass sediment trap cylinders.

River Water Sampling

Table B-3. Summary of water sampling activities at the five major rivers discharging to Puget Sound.

River	Date	Start Time	End Time	Channel Depths Sampled (ft)				Mean Daily Flow [1]		Flow Type	Conditions/Notes
				Left	Center	Pump/ (Channel)	Right	ft^3/s (cfs)	m^3/s (cms)		
Nooksack	7/21/09	0928	1200	5.5	5.7	-	6.6	1,840 [2]	52.1	Base	USGS predicted flow of 1,760 cfs.
Skagit	7/21/09	1603	1932	5.2	4.1	-	8.4	10,500	297	Base	Approx. 50% of long-term mean flow for July [4].
Stillaguamish	7/22/09	0900	1125	11.7	8.7	-	6.4	470 [2]	13.3	Base	USGS predicted flow of 333 cfs.
Snohomish	7/22/09	1417	1711	15	13.2	-	17.6	3,470	98.3	Base	Current slowing with flood tide near end of sampling.
Puyallup	7/23/09	0907	1225	2.6	4.2	-	7.5	2,380	67.4	-- [3]	Water chalky brown except near small tributary. Glacial silts from late seasonal snow melt?
QA REP											
Nooksack	10/12/09	1353	1625	4.3	4.8	-	5.4	590	16.7	Base	Flow 38% of long-term mean October baseflow
Skagit	10/13/09	0823	1153	2.8	3.3	-	6.3	5,400	153	Runoff	Low flow, quite shallow. 44% of long-term mean flow for October [4].
Stillaguamish	10/19/09	1129	1300	14.8	11.5	-	8.6	3,240	91.8	Base	Falling stage. Still five times monthly mean baseflow [4].
Snohomish	10/20/09	1030	1211	20.5	23.6	-	26	4,940	140	Runoff	Falling stage of runoff event.
Puyallup	10/15/09	0847	1043	2.9	5.5	-	7	1,000	28.3	Runoff	Early phase runoff.
QA REP		1304	1522								
Nooksack	01/06/10	1039	1222	8.7	11.1	6 (10-10.5)	11.2	7,880	223	Runoff	Strong current, high turbidity. Flow based on USGS 15-minute records. Discharge 300% mean baseflow [4].
Skagit	12/17/09	0921	1110	9.0	7.5	~**4.5** (7.5)	7.5	13,850	392	Runoff	Water clear initially, turning visibly turbid later.
Stillaguamish	12/08/09	1326	1534	13.2	11.3	7.8 (13.2)	8.7	~1,900	53.8	Runoff	Clear and cold, with ice on banks and in river. USGS 15-minute flow records, stage variable.
Snohomish	12/22/09	1525	1733	≤18.0	≤25.1	9-11 (32)	≤30.5	18,400	521	Base	Swift current, changing water levels.
Puyallup	12/14/09	0949	1147	3.5	4.8	4.2 (7)	6.7	1,860	52.7	Base	Light rain throughout evening. Becoming colder – morning frost.
QA REP		1355	1510	3.4	5.3		6.5				

[1] Flow predicted from stage height recorded at nearby USGS gaging station.

[2] Flow measured by Ecology stream monitoring staff on day of sampling.

[3] Sampling conditions reflected neither baseflow nor runoff related to recent precipitation. Suspended solids were related to seasonal runoff from glaciers, not from recent precipitation events.

[4] From Sinclair and Pitz (1999).

QA REP = Quality assurance replicate.

Figure B-11. Skagit River sampling site.

Top: Aerial view of Riverside Drive (Old Highway 99) bridge over the Skagit River.
Bottom: Photograph taken from the northwest, just downstream (shown as star at top).

Figure B-12. Snohomish River sampling site.

Top: Aerial view of Airport Way / Avenue D bridge over the Snohomish River in the City of Snohomish.

Bottom: Photograph taken from the north side of the river just downstream of the bridge (shown as star at top).

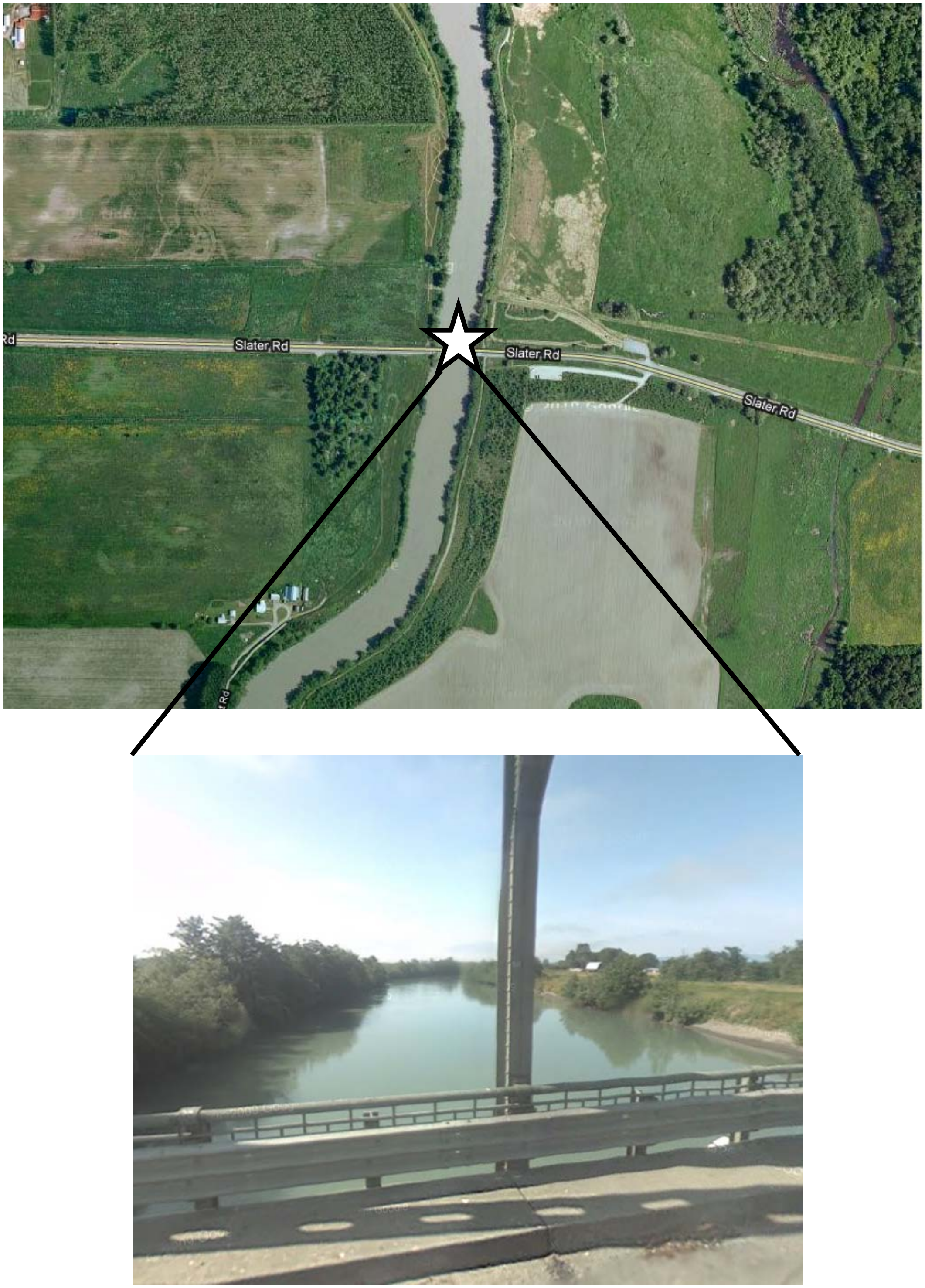

Figure B-13. Nooksack River sampling site.

Top: Aerial view of the Slater Road bridge over the Nooksack River (south of Ferndale, Washington).

Bottom: Photograph taken from the bridge deck looking approximately south (downstream).

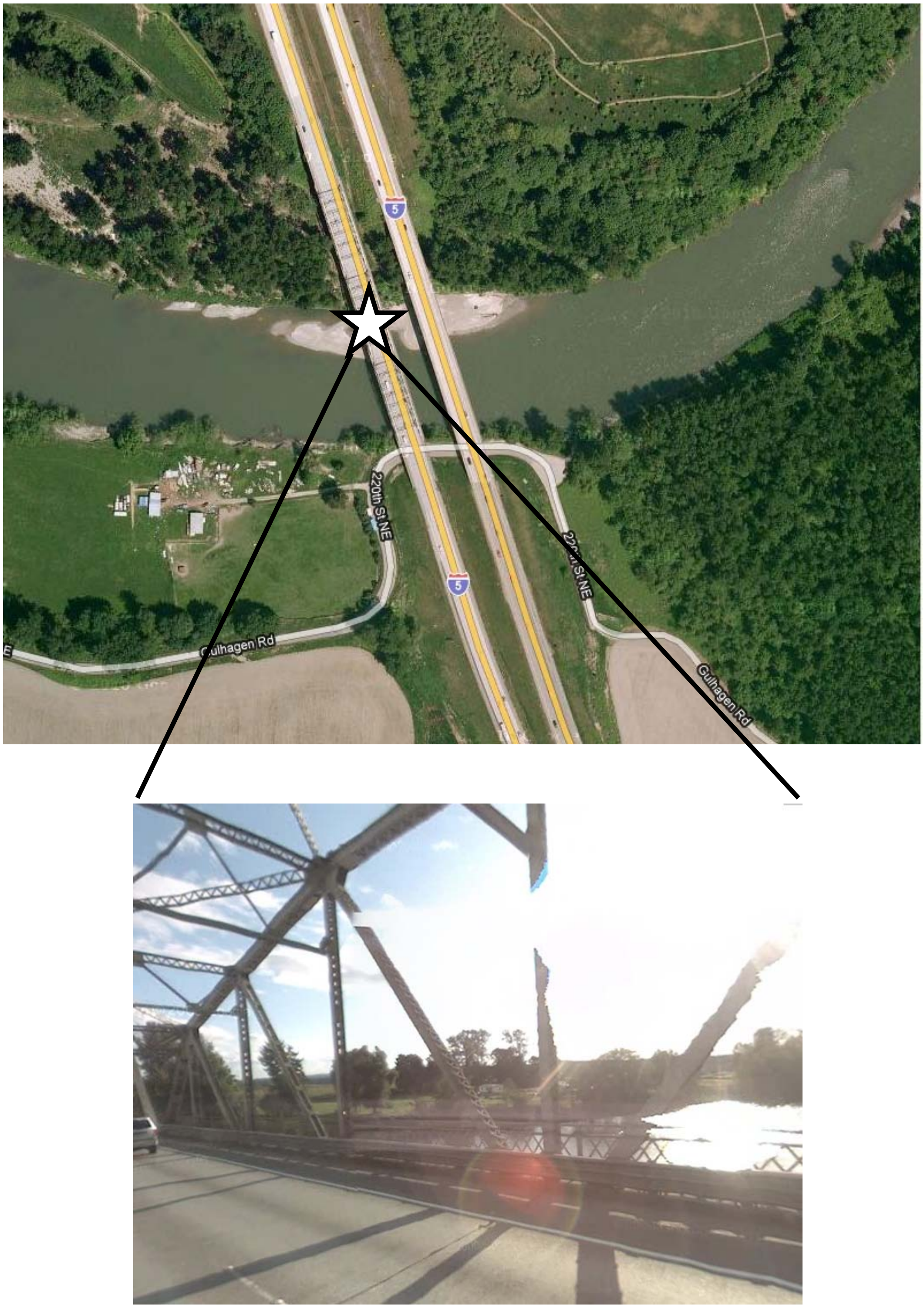

Figure B-14. Stillaguamish River sampling site.

Top: Aerial view of the Interstate-5 bridges over the Stillaguamish River near Silvana (west of Arlington, Washington).

Bottom: Photograph taken from the western (southbound) span of the bridge looking southwest.

Figure B-15. Puyallup River sampling site.

Top: Aerial view of the 66th Avenue bridge over the Puyallup River west of the City of Puyallup.

Bottom: Photograph taken from the north bank of the river, just upstream of the bridge (location shown as star at the top).

Appendix C. Sampling and Analysis Methods

Sampling for Trace Levels of Analytes in Marine Waters using GO-FLO Samplers

Sampling Marine Waters for Organic Carbon

Sample Containers, Preservation, and Holding Times

Analytical Methods

Sampling for Trace Levels of Analytes in Marine Waters using GO-FLO Samplers

Effective control of contamination during the collection and handling of marine water column samples is of paramount importance. Many of the target analytes are ubiquitous on the sampling platform and equipment, often at several orders of magnitude higher than concentrations expected in ambient waters. Introduction of contamination at this stage will negate all care taken in subsequent analytical steps.

These field protocols are intended to provide a step-by-step procedure for the collection of contamination-free water samples from depth in marine waters. Guidance was taken from the sampling literature, and to the extent possible EPA *clean hands / dirty hands* techniques are employed (EPA, 1996). Performance of these protocols should be routinely measured through the collection and analysis of field blanks and replicates.

Overview

While there is no “standard” method for obtaining at-depth samples of marine waters for trace analyses, a proven and widespread technique involves the deployment of one or more Teflon-coated GO-FLO samplers (General Oceanics, Inc.) on a non-metallic hydrowire (typically Kevlar). The sampling procedures employed in the present study are based on this “standard” foundation as follows:

> Two Teflon-coated GO-FLO samplers are mounted back-to-back (or several meters apart) on a non-metallic Vectran rope and are lowered by hand into the water with their end caps *closed* to avoid potential contamination from the microlayer at the water surface. The samplers open automatically by hydrostatic pressure release at a depth of approximately 10 meters. Site water flushes through the open samplers as they are lowered to the predetermined sampling depth. The samplers are remotely triggered by Teflon-coated messengers. A non-metallic windlass drum and Acetal sheave facilitate recovery of the GO-FLO samplers and ensure that the rope does not contact potentially contaminating materials. Once on-board, the sampler end caps are kept covered by polyethylene bags to minimize atmospheric exposure, and the samplers are secured in a purpose-built storage cabinet.
>
> Subsampling activities are conducted within a simple portable glove box. Water samples are decanted from each GO-FLO sampler via clean Teflon tubing that connects to the sampler drain valve inside the storage cabinet and to a Teflon petcock inside the glove box. In this way, sample bottles for the various analytes are filled in an environment isolated from major air- and ship-borne contamination sources. If the project lead judges the protection of a glove box to be unnecessary, the GO-FLO samplers may simply be drained through Teflon tubing and into the various analyte sample bottles (with minimal exposure to potential atmospheric contaminants).
>
> At the completion of a sampling cruise, the GO-FLO samplers undergo cleaning and storage procedures.

Principal equipment

- 10-liter GO-FLO samplers (2) – Teflon-coated with Teflon drain valves and air vent screws; spare parts kit.
- Vectran 12-strand rope (600 ft) – marked at 1- and 5-meter increments.
- Teflon-coated messengers.
- Snatch block and non-metal sheave – Ronstan single snatch block with Trunnion head and Acetal sheave.
- Non-metallic line weight – 20-lb. lead weight encased in epoxy resin.
- Cabinet for clean storage and transportation of GO-FLO samplers – constructed of UHMW polyethylene and Teflon materials.
- Large polyethylene bags capable of completely enclosing a single 10-liter GO-FLO sampler.
- Elasticized polyethylene "shower caps" (Saranwrap Quick Covers) or 2-gallon Ziplock bags.
- Talc-free Nitrile gloves.
- Clinometer or like instrument.
- Metals tubing train – 2-in. segment of MasterFlex 73 (3/8" O.D.) connects to GO-FLO drain valve, 6-ft segment of Teflon tubing (3/16" I.D.), and 2-ft segment of MasterFlex 73 tubing (3/8" O.D.) at peristaltic pump.
- Metals filter – in-line Gelman capsule filter, 0.45 µm.
- Peristaltic pump.

General rules

- Personnel must wear clean Nitrile gloves during all sampling and subsampling operations. If glove contamination is detected or suspected, work must be halted, the contaminated gloves removed, and a new pair of clean gloves put on. Wearing multiple layers of clean gloves allows the old pair to be quickly stripped with minimal disruption to the work activity.
- The upper ball valve of each GO-FLO sampler must be covered with an elasticized polyethylene "shower cap" at all times except during active deployment. The drain valve of each GO-FLO sampler must be covered with a Nitrile glove at all times except during active deployment and sample decanting.
- Samplers are transported around the vessel within polyethylene bags when possible, and are handled only by gloved personnel. The samplers should never be placed directly on deck or any hard surface where foreign particles might be lodged in the ball valves and cause contamination of subsequent samples. Improper use and handling of GO-FLO samplers can result in permanent contamination.
- Ensure at all times that the Vectran 12-strand rope does not make contact with any part of the vessel (other than the Acetal sheave and windlass drum). When not in use, remove the rope from the snatch block and coil it inside a clean polyethylene bag. Place the bagged rope within a sealed plastic container to minimize exposure to air- and ship-borne contaminants.
- Store the snatch block, line weights, and messengers in clean polyethylene bags when not in use.

- All polyethylene storage bags are considered "one-time use." That is, once a piece of equipment is removed from its storage bag, a separate clean bag must be used for subsequent storage.

Preparation

- Upon arrival at the sampling location, turn the engine off and wait 10 minutes before placing any sampling equipment in the water. Allow the vessel to drift during all sampling operations and conduct all sampling on the windward side of the vessel to minimize contamination from shipboard sources.
- Remove the snatch block from its polyethylene storage bag and secure it to the A-frame.
- Tie off the bitter end of the Vectran rope to a plastic cleat to secure it in case of mishap. Feed the working end of the rope over the sheave, being careful not to touch any metal objects that could embed foreign particles in the braid. Keep as much standing rope inside the covered plastic container as possible.
- Remove the line weights from storage bags and attach the weights to the loop eye at the working end of the Vectran rope. Lift the weights overboard and lower them into the water so that at least 10 meters of rope extend above the weights. Secure the rope to a plastic cleat to maintain this configuration, and replace any extra rope into the rope storage box.
- Arm the GO-FLO samplers and secure each to the Vectran rope – *This is a 2-person activity and personnel must wear clean gloves*. Layering of gloves is recommended to facilitate rapid discarding of dirty/contaminated gloves. Technicians should work carefully but quickly, striving to minimize the duration of atmospheric exposure for GO-FLO samplers secured to the Vectran rope. Follow the procedures listed below for the first GO-FLO sampler, and then repeat the procedure to arm and secure the second GO-FLO sampler.
  - Technician #1 (T1) removes the sampler from the storage cabinet (keeping it inside the polyethylene bag in which it was stored).
  - Technician #2 (T2) places a clean polyethylene bag flat on a stable surface away from contamination sources. T1 places the GO-FLO sampler (still inside its polyethylene storage bag) on the bag.
  - T2 puts on clean gloves and reaches inside the storage bag to arm the GO-FLO sampler; contact with the GO-FLO sampler is only made by T2. T1 assists by stabilizing the sampler and manipulating the storage bag for T2.
    - Reverse the spring over the pulley to release tension.
    - Pull the pressure release valve all the way out and position the lanyard poly-balls on either side between the valve and the stainless steel frame.
    - Attach the lanyard to the plunger mechanism by inserting the slack loop into the trip release.
    - Re-span the spring by rotating it over the pulley so that the spring and the lanyards are under tension.
    - *Optional:* Test the closing mechanism to verify that it functions properly.
      - Push the pressure release valve to cause the ball valves to move to the open position.
      - Press the plunger to release the lanyard, which results in bottle closure.
      - Re-arm the GO-FLO sampler after this check.

  - T1 carries the armed sampler (still inside the storage bag) to the Vectran rope. T2 reaches inside the storage bag and checks that the protective "shower cap" and Nitrile glove are securely covering the upper ball valve and drain valve, respectively. T2 then removes the GO-FLO sampler from the storage bag. T1 discards the storage bag and secures the GO-FLO sampler to the Vectran rope at the 10-meter marking above the line weights.
  - T1 puts on clean gloves, and the above procedure is repeated for the remaining GO-FLO sampler. Mount the second sampler above the first and note the distance between the vertical centers of the samplers. Samplers are typically spaced two to five meters apart to ensure triggering of the lower sampler by a serial messenger.
- To prepare the samplers for serial firing, attach a Teflon-coated messenger by its lanyard to the plunger mechanisms of the upper GO-FLO sampler, and then snap the messenger onto the Vectran rope between the two samplers.

Deployment

- GO-FLO samplers armed using the above procedures are set to be deployed in a *closed* position to avoid potential contamination from the surface microlayer. If the number of line weights needed to overcome the buoyancy of the air trapped in the GO-FLO samplers becomes prohibitive, consider deploying the samplers in the *open* position. The ball valves can be easily released to the *open* position by depressing the pressure release piston. Note that the poly-balls on the lanyards are under tension and will snap quite suddenly when the pressure release piston is pressed in. Keep hands well clear of the poly-balls, and use a pen wrapped in either a polyethylene bag or a clean glove to depress the pressure valve.
- By convention, at the water surface the GO-FLO samplers are at 0 meters depth. Record the depth marking at which the GO-FLO samplers are mounted on the Vectran rope. This length of rope between each sampler and the line weights is called the "Weight Segment". In calm conditions when the rope angle (deviation from vertical) is negligible, the length of rope from the depth of the GO-FLO samplers in the water column to the surface (called the Sampler Segment) is equal to the total length of rope payed out (Total Length) minus the Weight Segment.

  Sampler Segment = (Total Length) – (Weight Segment)

- Immediately before deployment, remove the protective "shower cap" from the upper ball valve and the Nitrile glove from the drain valve of each GO-FLO sampler. Wearing clean gloves, check that all drain valves and air vent screws are tightly closed.
- Lower the samplers quickly and completely through the water surface to minimize contact with the surface microlayer. Once submerged, slowly lower the GO-FLO samplers by hand to ~15-20 meters depth. The hydrostatic pressure release valve should cause the ball valves to open at approximately 10 meters.
- Verify that the ball valves have opened properly: the parcel of air trapped in each sampler will be visible as it bubbles to the surface. If bubbles are not seen and there is concern that a sampler did not open, raise the rope slowly until the status of the ball valves can be assessed visually. However, note that contamination risks increase as the samplers approach the surface and the vessel. If water conditions are turbid or rough, assume that the bottle is open

and accept that redeployment may be necessary. The weight of a retrieved sampler will be indicative of it being empty or filled with water.

- Lower the GO-FLO samplers to the desired sampling depth.
- Pay out additional rope as needed to adjust for significant rope angles (e.g., caused by strong currents or wind).
    - Read the Total Length and subtract the Weight Segment to determine the Sampler Segment.
    - Measure the angle of the rope from vertical (called Rope Angle) using a clinometer.
    - Calculate the actual depth of the GO-FLO samplers, the "Sampler Depth":

      (Sampler Depth) = (Sampler Segment) x cosine (Rope Angle)

    - Use the vessel's depth sounder for general verification (GO-FLO samplers should be detected by the sounder).
- Remove a Teflon-coated messenger from its storage bag, attach it to the Vectran rope, and release. This messenger will trigger closure of the upper GO-FLO sampler, followed by release of the serial messenger and subsequent triggering of the lower GO-FLO sampler.
- Allow adequate time for the messenger to reach the GO-FLO samplers before retrieval.

Recovery

- Use the windlass to recover the GO-FLO samplers, and feed the rope into the storage container as it is collected to minimize the potential for contact with contamination sources. It may be necessary to have the vessel's engine running to avoid complete draw-down of the battery by the windlass. In that case, engine assistance may only be used to raise the samplers to a depth of 10 meters. Above (i.e., shallower than) 10 meters depth, the engine must be off to avoid introducing excess contamination to the water column through which the GO-FLO samplers will travel. After the engine is off, allow at least one minute for ship-influenced water to dissipate before resuming sampler recovery.
- Once the GO-FLO samplers are retrieved to deck level, quickly inspect for leakage. If leakage is detected or suspected, prepare all samplers for re-deployment as follows:
    - Empty each GO-FLO sampler.
    - Rinse the sample chamber, the drain valve, and the air vent screw with de-ionized water.
    - Wearing clean gloves, and with the GO-FLO samplers still mounted on the Vectran rope, re-arm the samplers.
    - Re-deploy the GO-FLO samplers.
- If no leakage is apparent, immediately place clean polyethylene "shower caps" on the GO-FLO samplers' top ball valves. Rinse the samplers' drain valves with de-ionized water and cover each with a Nitrile glove.
- Remove the messengers and place them in a polyethylene bag for storage.
- Disengage the GO-FLO samplers individually and transport each to the storage cabinet. *This is a 2-person activity and all personnel must wear clean gloves*. Follow the steps below for the first GO-FLO sampler, and then repeat for the second sampler.

  - T1 supports the GO-FLO sampler to be removed, and T2 releases the screws that secure the sampler to the line.
  - While T1 holds the GO-FLO sampler, T2 places a clean polyethylene bag over the unit. T1 adjusts so that the sampler is completely contained in the bag.
  - T1 carries the GO-FLO sampler to the storage cabinet; T2 acts as a spotter. The sampler should not make contact with any part of the vessel.
  - T1 places the GO-FLO sampler inside the storage cabinet in an upright position (it should remain in the polyethylene bag). T1 secures the GO-FLO sampler inside the cabinet using bungee cords.
  - T2 puts on clean gloves, opens the GO-FLO sampler's air vent screw, and removes the glove from the drain valve.
  - Inside the glove box (situated under the cabinet), T1 removes a clean Teflon tubing/ petcock assembly from its storage bag. The open end of the tubing remains covered with foil, and the petcock remains protected by a Nitrile glove until subsampling activities commence. T1 feeds the tubing from inside the glove box to the GO-FLO sampler cabinet, and checks that the petcock inside the glove box is closed.
  - T2 receives the Teflon tubing at the storage cabinet, removes the foil from the end, and connects the tubing to the drain valve's compression fitting. T2 opens the drain valve, and T1 makes sure that the petcock isn't leaking in the glove box.
- Wearing clean gloves, remove the line weights and place them in polyethylene bags for storage. Release the Vectran rope from the snatch block. Coil the rope, place it in a polyethylene bag, and store it within the sealed container to protect against air- and ship-borne contaminants. Place the snatch block in a polyethylene bag for storage.

Subsampling

- Begin decanting from the GO-FLO samplers as soon as possible to prevent settling, biological activity, or adsorptive losses.
- Prior to the cruise, pre-labeled bottles for a specific sampling location and depth (henceforth called a "set") will have been assembled in two large, layered polyethylene bags. Wearing clean gloves, remove the outer polyethylene bag and transfer the set (still contained in the inner polyethylene bag) to the inside of the glove box.
- Place a wide-mouthed waste container inside the glove box.
- The flow of water from a GO-FLO sampler is controlled from inside the glove box using the Teflon petcock. Remove the protective Nitrile glove to access a petcock. Be extremely careful, and ensure that nothing in the glove box makes contact with the exposed petcock at any time.
- Drain the first 0.5 liters of water from each GO-FLO sampler into the waste container before decanting sample water for chemical analyses.
- Decant whole-water subsamples.
  - Remove the analyte bottle(s) from the set bag as they are needed, and follow analyte-specific handling procedures (e.g. bottle rinses).
  - The recommended sequence for decanting analyte samples is as follows:

        - GO-FLO sampler #1:
            1. Total Suspended Solids – 2 L
            2. DOC and POC – 1 L
            3. PCB Congeners – 2.5 L
            4. PBDE Congeners – 1 L
            5. Chlorinated Pesticides – 1 L
            6. Backup volume in case of mishap – 1 L
        - GO-FLO sampler #2:
            7. PAHs – 1 L
            8. BNAs – 3.5 L
    - Filtration for DOC and POC is carried out immediately after their 1-liter subsample is decanted from the GO-FLO sampler (i.e., while other analyte subsamples are still being drained from the samplers). Filtration protocols are detailed elsewhere in this Appendix.
    - After each analyte bottle is filled, attach a sample tag with the required identification information (e.g., sample I.D., date/time, location, analyte, etc.). Seal the individual bottle inside a polyethylene bag and then inside another polyethylene bag.
    - *Do not* allow the mouth of an analyte bottle to contact the petcock at any time.
    - *Do not* swirl or shake the GO-FLO samplers to re-suspend settled material, as this can alter partitioning between dissolved and particulate size fractions.
- Observing *clean hands / dirty hands* guidelines, set up a clean tubing train for collecting metals samples from GO-FLO #2.
    - Use the peristaltic pump to flush 250 mL of sample water through the tubing train before rinsing and filling the total metals bottle. Label and double-bag the bottle.
    - Attach the in-line metals filter to the tubing train. Remove the end of the tubing train from the drain valve of GO-FLO #2 and place it in a bottle of laboratory-provided reagent water. Use the peristaltic pump to flush the filter with 750 mL of reagent water. Re-connect the end of the tubing train to the drain valve of sampler #2, and flush the filter with 250 mL of sample water before rinsing and filling the dissolved metals bottle with filtrate. Label and double-bag the bottle.
- Remove the set of subsample bottles from the glove box and place them in a cooler on ice.

Between stations or sampling events

- To minimize the risk of contamination to the GO-FLO samplers during short-term storage, adhere to the following precautions:
    - Store the samplers in polyethylene bag(s) inside the storage cabinet, and only remove a sampler just prior to deployment.
    - All valves (i.e., ball valves, air vent screws, drain valves) should be stored in their final closed position.
    - Cover the upper ball valve with an elasticized "shower cap," even when the sampler is inside a polyethylene storage bag.
    - Protect the drain valve by storing it covered by a Nitrile glove.
- If contamination of any GO-FLO sampler is suspected, stop using the sampler and return it to the lab for a thorough cleaning.

Extended storage

- Prior to long-term storage, rinse the GO-FLO samplers with de-ionized water.
- Ensure that all valves are in their final closed position.
- Cover the upper ball valve with a clean elasticized "shower cap," and place a clean Nitrile glove over the drain valve.
- Store the GO-FLO samplers in one or more clean polyethylene bag(s) and secure them in the storage cabinet.
- If GO-FLO samplers are not to be used within 30-60 days, return the samplers to the lab and schedule a thorough cleaning and maintenance. Procedures will be guided by existing standard techniques for the cleaning of Teflon-coated sampling equipment for priority pollutant sampling.

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Sampling Marine Waters for Organic Carbon

The following standard operating procedures (SOPs) represent a modified version of those used by Horn Point Marine Laboratory, University of Maryland (Lane, 2000).

Procedure for collecting particulate organic carbon (POC) samples

Equipment

- All-glass filter apparatus, pre-washed with 10% HCl (400 mL capacity filter column, scintered filter support with silicone stopper for 1000 ml side arm flask).
- Stainless steel forceps, similarly pre-cleaned.
- Certified pre-cleaned 30-50 ml amber glass DOC storage vials.
- GFF filters (25 mm diameter, 0.7 µm pore size), pre-combusted at 450°C for 90 min, handled with clean forceps only, and stored in aluminum foil packets on which the filter number is pre-recorded.

Filtration Procedure

- Assemble filtration apparatus with pre-combusted filter in place (unpatterned side up) between scintered support and funnel.
- Connect side arm flask to hand pump using pharmaceutical grade tubing.
- Apply gentle vacuum with hand pump (<10 inches Hg or <5 psi) and, ideally, filter water sample for no more than 5 minutes.
    - Volumes requiring 5 minutes filtration may be estimated by filtering incremental volumes of sample water through a discardable filter.
    - Multiple filtrations/filters may be needed to collect sufficient filtrate for DOC analysis.
- Record *total volume filtered* to 3 significant places (e.g., 1020 ml, 102 ml, 10.2 ml).
- Use clean forceps to fold used filter, still on scintered column, in half (top side of filter with POC is folded in on itself).
- Enclose individual used filters in aluminum foil packets.
- Record date/time, sample identification number, and filtrate volume legibly on exterior of aluminum foil packet with a permanent marker (CAUTION: do not puncture foil packet).
- Store aluminum foil packet in a plastic bag and refrigerate in the dark.

Drying Filters

- Within 48 hours, transfer POC filter in aluminum foil packets to laboratory environment.
- Partially open packets using cleaned forceps, place in convection oven, and dry overnight at 60°C.
- Close aluminum foil packet and place in dry plastic bag for shipment.
- Re-label aluminum foil packet if any information on label is no longer visible.

Procedure for collecting dissolved organic carbon (DOC) samples
(DOC is also referred to as NPOC or non-purgeable organic carbon)

- Collect one duplicate sample for every 10 samples to increase precision.
- Rinse side arm flask with approximately ½ sample volume expected to be filtered for POC.
- Remove filter column from flask (leaving filter in place between support and funnel), swirl filtrate thoroughly in flask and discard.
- Reassemble apparatus.
- Filter remaining volume for POC.
- Record station, date, and total volume filtered through filter for POC procedure (see above).
- Remove filter (described above).
- Rinse sample vial(s):
  - Transfer a few milliliters filtrate vial and cap.
  - Shake filtrate and discard.
- Fill vial with at least 20 mLs filtrate.
- Store vial in refrigerator in the dark (4°C).
- DO NOT FREEZE OR ADD ACID!
- Ship overnight within 2 weeks, using ice packs to keep samples cold but not frozen.

Sample Containers, Preservation, and Holding Times

Table C-1. Sample containers, requested volumes, preservation, and holding times for marine water column samples.

Parameter	Bottle Type and Volume	Sample Volume Requested	Preservation	Holding Time
TSS	1 L Poly	2 L	Cool to $\leq 6^{\circ}$ C	7 days
DOC	40 mL Amber Glass	40 mL	Filter in field w/ 0.7 µm GFF filter; Cool to $\leq 6^{\circ}$ C	28 days
POC	1 L Amber Glass	variable	Dry filter w/in 2 days; Cool to $\leq 6^{\circ}$ C	28 days
Total Metals	1000 mL HDPE	1 L	HNO_3 to pH < 2; Cool to $\leq 6^{\circ}$ C *	6 months
Dissolved Metals	1000 mL HDPE	1 L	Filter in field w/ 0.45 µm filter; HNO_3 to pH < 2; Cool to $\leq 6^{\circ}$ C *	6 months
Semivolatiles (BNA)	1 Gallon Glass	3 L	Cool to $\leq 6^{\circ}$ C	7 days
PAHs	1 L Amber Glass	1 L	Cool to $\leq 6^{\circ}$ C	7 days
Chlorinated Pesticides	1 L Amber Glass	1 L	Cool to $\leq 6^{\circ}$ C	7 days
PCB Congeners	2.5 L Amber Glass	2.5 L	Cool to $\leq 6^{\circ}$ C	1 year
PBDE Congeners	1 L Amber Glass	1 L	Cool to $\leq 6^{\circ}$ C	1 year
Total 13.54 L				

* Metals samples were acidified at the analyzing laboratory to avoid introducing contamination in the field and for safety of staff.

Table C-2. Sample containers, requested mass, preservation, and holding times for marine particulate samples.

Parameter	Bottle Type and Volume	Sample Mass Requested * (wet weight)	Preservation	Holding Time
Percent Solids	2 oz Glass	50 Grams	Cool to ≤ 6° C	7 days
TOC			Cool to ≤ 6° C; may freeze at -18°C	14 days; 6 months frozen
Total Recoverable Metals			Cool to ≤ 6° C; may freeze at -18°C	6 months
Semivolatiles (BNA)	8 oz Glass	250 Grams	Cool to ≤ 6° C	14 days; 1 year frozen
PAHs				
Chlorinated Pesticides		250 Grams	Cool to ≤ 6° C	14 days; 1 year frozen
PCB Congeners		50 Grams	Cool to ≤ 6° C; may freeze at -18°C	1 year
PBDE Congeners		50 Grams	Cool to ≤ 6° C; may freeze at -18°C	1 year
Total 650 Grams				

* The minimum mass required to obtain specified detection limits for each analysis is less than the mass requested by analytical laboratories listed here and in the QA Project Plan.

Table C-3. Sample containers, requested volumes, preservation, and holding times for river water samples.

Parameter	Bottle Type and Volume	Sample Volume Requested	Preservation	Holding Time
TSS	1 L Poly	2 L	Cool to $\leq 6^o$ C	7 days
TOC	60 mL Poly	50 mL	1:1 HCl to pH < 2; Cool to $\leq 6^o$ C	28 days
DOC	60 mL Poly	50 mL	Field filter w/ 0.45 µm; 1:1 HCl to pH < 2; Cool to $\leq 6^o$ C	28 days
Hardness	125 mL Poly	100 mL	H_2SO_4 to pH <2; Cool to $\leq 6^o$ C	6 months
Nutrients: Ortho-phosphate	125 mL Amber Poly	125 mL	Field filter w/ 0.45 µm; Cool to $\leq 6^o$ C	48 hours
Nutrients: Total phosphorus	60 mL Poly	50 mL	1:1 HCl to pH < 2; Cool to $\leq 6^o$ C	28 days
Nutrients: Ammonia, Nitrate+Nitrite, and Total Nitrogen	125 mL Clear Poly	125 mL	Pre-acidify w/ H_2SO_4; Cool to $\leq 6^o$ C	28 days
Total Metals	500 mL HDPE	350 mL	HNO_3 to pH < 2; Cool to $\leq 6^o$ C	6 months
Dissolved Metals	500 mL HDPE	350 mL	Field filter w/ 0.45 µm; HNO_3 to pH < 2; Cool to $\leq 6^o$ C	6 months
TPH-D	1 L Amber Glass	3 L	Cool to $\leq 6^o$ C	14 days
TPH-G	40 mL VOAs	360 mL	1:1 HCl to pH < 2; Cool to $\leq 6^o$ C	14 days
Oil and grease	1 L Glass	3 L	1:1 HCl, pH < 2; Cool to $\leq 6^o$ C	28 days
BNAs	1 Gallon Glass	3 L	Cool to $\leq 6^o$ C	7 days
PAHs	1 L Amber Glass	1 L	Cool to $\leq 6^o$ C	7 days
Chlorinated Pesticides	1 L Amber Glass	1 L	Cool to $\leq 6^o$ C	7 days
PCB Congeners	2.5 L Amber Glass	2.5 L	Cool to $\leq 6^o$ C	1 year
PBDE Congeners	1 L Amber Glass	1 L	Cool to $\leq 6^o$ C	1 year
Total 18.06 L				

Table C-4. Sample containers, requested mass, preservation, and holding times for river particulate samples.

Parameter	Bottle Type and Volume	Sample Mass Requested * (wet weight)	Preservation	Holding Time
Percent Solids	2 oz Glass	50 Grams	Cool to ≤ 6° C	7 days
TOC			Cool to ≤ 6° C; may freeze at -18°C	14 days; 6 months frozen
Metals Total Recoverable			Cool to ≤ 6° C; may freeze at -18°C	6 months; 2 years frozen
BNAs **	8 oz Glass	250 Grams	Cool to ≤ 6° C; may freeze at -18°C	14 days; 1 year frozen
PAHs **				
TPH-D **			Cool to ≤ 6° C	14 days
PCB Congeners		50 Grams	Cool to ≤ 6° C; may freeze at -18°C	1 year
PBDE Congeners		50 Grams	Cool to ≤ 6° C; may freeze at -18°C	1 year
Total 450 Grams				

* The minimum mass required to obtain specified detection limits for each analysis is less than the mass requested by analytical laboratories listed here and in the QA Project Plan.

** Insufficient particle mass was collected at the Stillaguamish River to conduct these analyses.

Analytical Methods

Table C-5. Summary of marine water column sample analyses.

Number of samples analyzed includes field QA samples.

Parameter	Samples Analyzed	Final Reporting Limits	Preparation/ Extraction	Cleanup	Analytical Method	Method Description
Conventionals (mg/L)						
TSS	48	0.5 - 2.0	-	-	SM 2540 D	Gravimetric
POC	48	0.015 *	Acidification of dried samples	-	SM 5310	Combustion/oxidation Thermal conductivity
DOC	42	0.018 *	Filter 0.7 µm GFF	-		Combustion, Infrared detection
Total Recoverable and Dissolved Metals (µg/L)						
Arsenic	48 (total) and 47 (diss.)	0.05	• Reductive co-precipitation • Acid Digest • For dissolved metals, prefilter through 1.2 µm glass microfiber filters	-	FGS 054	ICP-MS
Cadmium		0.01				
Copper		0.05				
Lead		0.05				
Zinc		0.25				
Organic Compounds (µg/L unless noted otherwise)						
BNAs	48	0.08 - 3.6	Extraction	-	EPA 8270	Capillary GC/MS
PAHs	47	0.01- 0.02	Solid Phase	-	EPA 8270 SIM	GC/MS
Chlor. Pesticides (ng/L)	46	0.2 - 1.0	EPA 3510	-	EPA 8081	GC/ECD
PCB Congeners (pg/L)	53	3.9 - 0.6	Dichloromethane	Acid/base wash	EPA 1668A	GC/HRMS
PBDE Congeners (pg/L)	47	24 - 255			EPA 1614	

* These values are detection limits. The detection limit for POC is based on filtering 0.75 liters of seawater.

EPA = U.S. Environmental Protection Agency
FGS = Frontier GeoSciences
GC/HRMS = Gas Chromatography / High Resolution Mass Spectrometry
GC/MS = Gas Chromatography / Mass Spectrometry
ICP-MS = Inductively-coupled plasma detector, mass spectrometer confirmation
SIM = Selective Ion Monitoring
SM = Standard Methods (APHA, 2005)

Table C-6. Summary of river water sample analyses.

Number of samples analyzed includes field QA samples.

Parameter	Samples Analyzed	Final Reporting Limits	Preparation Method	Cleanup Method	Analytical Method	Method Description
Conventionals, Nutrients, and Hardness (mg/L)						
TSS	18	0.6 - 4.3	-	-	SM 2540 D	Gravimetric
TOC		1.0	Acidification	-	SM 5310 C	Combustion to CO_2 Infrared detection
DOC			Filtration (0.45 *µ*m), Acidification			
Nutrients *	17	0.003 - 0.025	Reaction, Reduction or Digestion	-	SM 4500	Colorimetric
Hardness	18	0.3	Acidification	-	EPA 200.7	ICP, Calculation
Petroleum Products (mg/L)						
Oil and Grease	18	1.6 - 5.6	Hexane extraction	-	EPA 1664A	Gravimetric
TPH-D		0.02 - 0.13	Extraction	Acid/ silica	ECY 97-602	GC/FID
TPH-G	30	0.14	Acidification and Extraction			Purge and Trap GC/FID
Total Recoverable and Dissolved Metals (µg/L)						
Arsenic, Copper	21 (total) and 21 (diss.)	0.10	Acidification and Filtration (0.45*u*m) + Acidification	-	EPA 200.8	ICP - MS
Cadmium, Lead		0.02 - 0.10				
Zinc		1.0 - 5.0				
Organic Compounds (µg/L unless noted otherwise)						
BNAs	19	0.08 - 3.4	Extraction	-	EPA 8270	Capillary GC/MS
PAHs	19	0.01 - 0.02	Solid Phase Extraction	-	EPA 8270 SIM	GC/MS
Chlorinated Pesticides (ng/L)	19	0.2 - 11	Extraction, EPA 3510	-	EPA 8081	GC/ECD
PCBs (pg/L)	21	3.8 - 11.4	Dichloromethane Extraction	Acid/ base wash	EPA 1668A	High Resolution GC/MS
PBDEs (pg/L)	20	12 - 280			EPA 1614	

* Total persulfate, nitrite plus nitrate, and ammonia nitrogen; total available and ortho-phosphate.
GC/FID = Gas chromatography/flame ionization detection
GC/ECD = Gas chromatography/electron capture detection

Table C-7. Summary of analyses for SPM collected from marine sediment traps and rivers.

Parameter	Sediment Trap Samples	Suspended River Solids	Final Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method	Method Description
Conventional parameters (%)							
Percent Solids	1	5	1	-	-	EPA 160.3	
TOC			0.1	-	-	PSEP, 1986/1997 EPA 415.1	
Metals - Total Recoverable (mg/Kg)							
Arsenic, Cadmium, Copper, Lead	2	5	0.05 - 0.1	SW-846 3050B	-	EPA 200.8	ICP - MS
Zinc			2.5 - 5.0				
Organic compounds (µg/Kg unless noted otherwise)							
TPH-D (mg/Kg)	-	4	10 - 44	SW-846 Extraction	-	EPA 8270	GC/FID
BNAs			21 - 740				Capillary GC/MS
PAHs			1.4 - 14	Soxhtherm Extraction	Silica Gel	EPA 8270 SIM	GC/MS
Chlorinated Pesticides			0.12 – 3.2	Extraction EPA 3541	-	EPA 8081	GC/ECD
PCB Congeners (ng/Kg)	2	5	4 - 22	Soxhlet Extraction	Acid/base wash	EPA 1668A	High Resolution GC/MS
PBDE Congeners (ng/Kg)			14 - 174			EPA 1614	

Appendix D. Data Quality

Study-Specific Data Quality Rules

Chemical Qualifier Code Revisions

Field QA Sample Descriptions and Results

Study-Specific Data Quality Rules

Assigning chemical qualifiers

- No chemical qualifier code was assigned when:
    - a concentration was greater or equal to the estimated quantitation limit (EQL), practical quantitation limit (PQL), or reporting limit (RL) listed by the laboratory, *and*
    - all or nearly all lab QC sample results were within specified control limits, *and*
    - the analyte of interest was positively identified.
- An “N” qualifier code was assigned to an otherwise unqualified result when the analyte could not be positively identified but there was evidence it was present [third condition above not met].
- A “J” qualifier code, indicating an estimated concentration, was assigned when:
    - a result was greater than or equal to the EQL, PQL, or RL, *and*
    - some lab QC sample results were outside specified control limit, *and*
    - the analyte of interest was positively identified.
- An “NJ” was assigned to an estimated concentration of a tentatively identified analyte.
- A “J” qualifier code, indicating an estimated concentration, was assigned when a detected concentration was less than the EQL, PQL or RL, but greater than or equal to the estimated detection limit (EDL) or method detection limit (MDL) listed by the laboratory. Concentrations were reported down to the listed EDL or MDL whenever possible.
- Valid EIM result data qualifiers (e.g., “G” or “L”) that preserve evidence of low or high analytical bias were not assigned.
- An “REJ” qualifier code was assigned when the presence or absence of an analyte was not verified because of serious problems associated with the sample analysis or lab QC sample performance (results consistently or well outside of control limits). The result was unusable.
- A “U” was assigned when the analyte was not detected at or above a defined numeric value. Depending on the parameter and analytical purpose, nondetect values were set at the quantitation limit (EQL, PQL, or RL) or the detection limit (EDL or MDL). Sometimes results were presented using both methods of assigning concentrations to nondetect results.
- A “UJ” qualifier code was assigned to an individual analytical result for a variety of reasons:
    - The analyte was not detected at or above a quantification limit that is uncertain.
    - Initial or ongoing instrument calibrations were unacceptable.
    - Results for one or more lab QC samples were outside control limits.
    - The analyte was also detected in the lab method blank (see below).

Assigning chemical qualifiers and data flags due to elevated method blank concentrations

- No chemical qualifier code was assigned to a sample concentration that was ≥ a quantitation limit (EQL, PQL, or RL) and ≥ 10 times the concentration in the associated method blank.
- A "J" qualifier code was assigned to a sample concentration greater than or equal to three times (≥3 X) and less than or equal to ten times (≤ 10X) the concentration detected in the associated method blank. A "B" flag was entered into the associated EIM comment field to indicate that "J" was assigned because of the elevated blank concentration.
- A "UJ" qualifier code was assigned to a sample concentration ≥ EDL or MDL and less than three times (< 3X) the concentration detected in the associated method blank. A "B" flag was entered into the associated EIM comment field to indicate that "UJ" was assigned because of the elevated blank concentration and that the result may be used for some purposes.

Correcting for analytes detected in method blanks

Sample concentration results were not corrected for the presence of the same analyte in the batch-specific method blank. Exceptions included the following marine water column sample results:

- DOC. The mass of carbon (µg C) measured on batch-specific filter adsorption blanks was added to the µg C measured in filtered marine water column samples.
- POC. The µg C measured on batch-specific filter trip blanks was subtracted from the µg C measured on marine water column sample filters. The resulting sample concentration was then adjusted for the µg C (DOC) measured on batch-specific filter adsorption blanks.
- Metals. The contract laboratory adjusted the measured concentrations of metals in marine water column samples by subtracting the mean concentration measured in 3 batch-specific "preparation" (method) blanks. Ecology staff derived the original (uncorrected) lab result by adding the mean preparation blank concentration to the reported results. A different chemical qualifier code was then assigned if appropriate.

Correcting for analytes detected in field blanks

Sample results were not modified when field blanks (bottle, filter, transfer, and sampler blanks) showed presence of the same analyte. This decision was based on the following lines of evidence:

- Field blanks, although attempting to mimic sampling processes, were exposed to sources of contamination that the marine and river water samples were not.
  - Marine water column samples were thoroughly pre-rinsed with seawater.
  - Marine water column and river water samples were not exposed to ambient air to the same extent as were field blanks.
- The "fingerprint" of organic compounds (PCB and PBDE congeners) in field blanks was different from that found in field samples.

Summing analytes to estimate total concentrations

Summing rules were developed from Ecology internal *Guidance for Calculating Total Values of Selected Analytes for the EAP Toxics Studies Unit and EIM Parameter Names to Use (2008):*

- If some of the individual analytes were detected (greater than or equal to EDL or MDL), then only detected concentrations were summed to represent the total concentration.
- If none of the individual analytes was detected (greater than or equal to EDL or MDL), then various alternatives were taken:
    - For summed PAH values, ½ the RL was assigned to each PAH compound.
    - For summed PAH values, the MDL was assigned to each PAH compound.
    - For total PCBs and total PBDEs, the largest nondetect concentration (RL) for an individual congener was used.

Using nondetect values

Descriptive statistics and other statistical analyses, as well as estimates of annual mass exchange and loading of toxic chemicals, sometimes involved chemicals or chemical classes that were never or seldom detected in the water samples collected. Therefore, it was important to determine how to use nondetect ("U") values in statistics and calculations.

Several options were considered for using nondetect values for toxic chemicals such as petroleum-related compounds, BNAs, PAHs, chlorinated pesticides, and PBDEs. For statistical summaries and analyses, nondetect values were not used unless stated otherwise in the report. For calculations of annual mass fluxes and loadings, based on multiplying mean water concentrations by predicted water flux or river flow, nondetect values were used as follows:

- When all or most samples had detected concentrations, nondetect values were not used to calculate mean water concentrations.
- When a parameter was never or seldom detected, flux and loading calculations were based on:
    - Nondetects = 1/2 the RL.
    - Nondetects = the detection limit (EDL or MDL), if available.

Chemical Qualifier Code Revisions

Table D-1. Summary of data qualifier changes made to marine water column results (not including field QA samples) during project staff review.

QC Code Change	TSS	POC	DOC	As	As dissolved	Cd total	Cd dissolved	Cu total	Cu dissolved	Pb total	Pb dissolved	Zn total	Zn dissolved	Chlor Pest	BNAs	PAHs	PCBs	PBDEs	Total Changes
"_" → J	-	-	-	-	-	-	-	1	3	2	1	35	31	-	-	-	-	-	73
"_" → UJ	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
J → "_"	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	3
J → UJ	-	-	-	-	-	-	-	-	-	5	3	-	2	-	1	-	-	-	11
U → J	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3
U → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
U1 → U2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
B → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	10
UJ → "_"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
UJ → J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	7
B Flag *	-	-	-	-	-	-	-	1	3	8	8	38	37	51	37	2	38	110	333
Total Changes	0	0	0	0	0	0	0	2	6	17	16	73	71	51	38	2	48	119	443

* Entered into EIM, separate from chemical qualifier codes, to clearly denote presence of analyte in method blank(s).

Table D-2. Summary of data qualifier changes made to marine water field QA sample results during project staff review.

QC Code Change	TSS	POC	DOC	As	As dissolved	Cd total	Cd dissolved	Cu total	Cu dissolved	Pb total	Pb dissolved	Zn total	Zn dissolved	Chlor Pest	BNAs	PAHs	PCBs	PBDEs	Total Changes
"_" → J	-	-	-	-	-	-	-	-	1	-	-	5	4	-	-	-	-	-	10
"_" → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
J → "_"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
J → UJ	-	-	-	-	-	-	-	2	1	1	1	1	-	-	-	-	-	-	6
U → J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
U → UJ	-	-	-	-	-	-	-	1	1	1	1	-	1	-	-	-	-	-	5
U1 → U2	-	2	3	3	3	3	3	-	-	-	1	-	-	-	-	-	-	-	18
B → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6
UJ → "_"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
UJ → J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
B Flag *	-	-	-	-	-	-	-	3	3	2	2	6	5	4	6	-	10	14	55
Total Changes	0	2	3	3	3	3	3	6	6	4	5	12	10	4	6	0	16	15	101

* Entered into EIM, separate from chemical qualifier codes, to clearly denote presence of analyte in method blank(s).

Table D-3. Summary of data qualifier changes made to river water results (not including field QA samples) during project staff review.

QC Code Change	TSS	TOC	DOC	Ammonia	Nitrate+Nitrite	Total N (TN)	Total P (TP8)	Ortho-P	Hardness	As total	As dissolved	Cd total	Cd dissolved	Cu total	Cu dissolved	Pb total	Pb dissolved	Zn total	Zn dissolved	HEM	TPH-D	TPH-G	Chlor Pest	BNAs	PAHs	PCBs	PBDEs	Total Changes
"_" → J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2	-	-	-	-	-	-	-	-	-	5
"_" → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
J → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
U → "_"	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3
U → J	-	7	6	2	-	-	-	-	-	-	-	15	8	-	-	3	2	7	4	5	-	-	-	-	-	-	-	59
U → UJ	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	3
U1 → U2	-	-	-	5	-	-	-	-	-	-	-	-	5	-	-	-	4	-	-	-	-	-	-	-	-	-	-	14
B Flag *	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	8	-	7	-	-	-	-	16	12	10	15	27	96
Total Changes	0	7	7	8	0	0	0	0	0	0	0	15	15	0	0	16	6	17	5	5	0	0	16	12	11	15	27	182

* Entered into EIM, separate from chemical qualifier codes, to clearly denote presence of analyte in method blank(s).

Table D-4. Summary of data qualifier changes made to river water QC sample results during project staff review.

QC Code Change	TSS	TOC	DOC	Ammonia	Nitrate+Nitrite	Total N (TN)	Total P (TP8)	Ortho-P	Hardness	As total	As dissolved	Cd total	Cd dissolved	Cu total	Cu dissolved	Pb total	Pb dissolved	Zn total	Zn dissolved	HEM	TPH-D	TPH-G	Chlor Pest	BNAs	PAHs	PCBs	PBDEs	Total Changes
"_" → J	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
"_" → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
J → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
U → "_"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
U → J	-	1	1	1	-	-	-	-	-	-	-	3	2	-	1	1	1	3	1	1	-	-	-	-	-	-	-	16
U → UJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2	-	-	-	-	-	-	-	-	-	5
U1 → U2	-	-	-	-	-	-	-	-	-	3	3	3	4	1	-	-	2	-	-	-	-	-	-	-	-	-	-	16
B Flag *	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	4	-	4	-	-	-	-	5	3	4	8	7	36
Total Changes	0	1	1	1	0	0	0	0	0	3	3	6	6	3	1	8	3	9	1	1	0	0	5	3	4	8	7	74

* Entered into EIM, separate from chemical qualifier codes, to clearly denote presence of analyte in method blank(s).

Field Quality Control Sample Descriptions and Results

Field replicates

Replicate sampling involved the analysis of two samples collected in an identical manner and in close spatial and temporal proximity. Field replicates provide a measure of field precision and allow for the assessment of the environmental variability of concentrations of target parameters.

Marine water column field replicates
- Parameters analyzed: All.
- Procedure: Following water collection from a regular sampling site, the GO-FLO samplers were immediately redeployed and collection was repeated at the same location and depth.

River water field replicates
- Parameters analyzed: All.
- Procedure: First, the complete set of depth-integrated river water samples was collected (compositing from three quarter points). After these samples were processed and stored, the river was sampled a second time using a new, acid-cleaned sampler.

Results for each replicate sample are presented beside the regular station sample results in Tables D-5, D-7, and D-8 for marine water, and in Tables D-11, D-13, and D-14 for river water. Replicate results were in good agreement with their corresponding station sample results for most parameters, as indicated by low relative percent difference (RPD) values. Marine water POC, marine water dissolved lead, and river water total cadmium occasionally had elevated RPDs that were attributable to low measured concentrations (i.e., near the analytical method detection limit) that exaggerated differences.

Elevated RPDs for other parameters suggested environmental variability. Slightly elevated RPDs for total PCB replicate sample pairs in both marine and river waters showed that samples collected in close spatial and temporal proximity may yield slightly variable concentration measurements, likely as a consequence of the affinity of these chemicals for particulates. Marine total lead and freshwater dissolved copper replicate pairs also had instances of anomalously high RPDs, but the observed variability was nowhere above what might be expected for samples collected up to three hours apart in dynamic bodies of water. As such, replicate results did not warrant the re-qualification of any project data.

For the purposes of this report, field replicates were used for QA assessment only; field replicate results were not averaged with their corresponding station sample results for data analyses presented in this document.

Field Duplicates

Duplicate sampling involved the analysis of two samples obtained from a single water collection. Field duplicates allow for the evaluation of analytical variability, or lab precision.

Marine water column field duplicates

- Parameters analyzed: TSS, DOC, POC, and PCB congeners.
- Procedure: Two samples for a given parameter were decanted from a single GO-FLO water collection. Organic carbon samples were processed simultaneously on separate clean filtration apparatuses.

Results for each duplicate sample are presented beside their corresponding station samples in Tables D-6 and D-7. These pairs of results generally agreed very well, as indicated by their low RPDs. Thus, duplicates were not used to re-qualify any project data.

For the purposes of this report, the results of the field duplicate analyses were not averaged with their corresponding station sample results.

Bottle and transfer blanks

Bottle blanks involved the analysis of analyte-specific blank water that was carried unopened into the field and treated as a sample. Transfer blanks involved pouring the same lab-provided blank water into a sample bottle in the field. These types of blanks allow for the evaluation of contamination arising from the sample bottles themselves, from general bottle handling, and from the atmosphere during sample transfers. Results also allow evaluation of the cleanliness of the blank water that was used for other field QA samples, such as equipment blanks.

Marine water column bottle blanks

- Parameters analyzed: PCB congeners.
- Procedure: Lab blank water obtained from Analytical Perspectives was brought unopened into the field and treated as a sample.

River water transfer blanks

- Parameters analyzed: Total metals, chlorinated pesticides, BNAs, PAHs, PCB congeners, and PBDE congeners.
- Procedure: For total metals, blank water from MEL's metals lab was transferred (by pouring) to an acidified sample bottle. For organics, blank water from MEL's organics lab was carried in 1-gallon glass containers and transferred into individual sample bottles.

Results for the two marine PCB bottle blanks are presented in Table D-10. Both bottle blanks showed low concentrations of four PCB congeners in Analytical Perspectives reagent water. These congeners were not detected in the corresponding method blanks, suggesting that the detected contamination was associated with bottle transport and handling. From only two blanks it was unclear whether this congener-specific contamination might be pervasive throughout the marine water column samples. For the purposes of this project, results were not re-qualified at the congener level based on this potential contamination.

Results for the freshwater transfer blanks are given in Tables D-12 and D-14. A low concentration of zinc was detected in the total metals transfer blank, likely attributable to atmospheric exposure during the unprotected transfer process. No contamination was detected in the transfer blanks for chlorinated pesticides and BNAs, and only a low concentration of naphthalene was detected in the PAH transfer blank. The results for both PCB and PBDE transfer blanks were deemed unusable due to the improper creation of these samples (blank water should have come from Analytical Perspectives and Pacific Rim laboratories, not MEL). Overall, transfer blanks for river water sampling did not warrant re-qualification of project results.

Tubing and filter blanks

Tubing and filter blanks were created by mimicking transfers through tubing and contact with filtration apparatuses that occur during regular sampling. These blanks help assess metals contamination arising from the pumping and filtration systems.

Marine water column tubing and filter blanks

- Parameters analyzed: Total and dissolved metals.
- Procedure: Metals reagent water (supplied by Frontier Geosciences) was drawn directly from its bottle using a peristaltic pump and a clean tubing train. The tubing train was flushed with 250-500 mL of reagent water before rinsing and filling the tubing blank bottle. A new, clean filter was connected in-line and the filter was flushed with at least 500 mL of blank water before filling the filter blank bottle.

River water filter blanks

- Parameters analyzed: Dissolved metals.
- Procedure: Reagent water from MEL's metals lab was filtered through a clean filtration apparatus, and the filtrate was poured into a pre-acidified sample bottle.

Results for tubing and filter blanks from marine sampling are presented in Table D-9. Lead and zinc were detected in the tubing blank. It had been necessary to modify the tubing train in the field prior to conducting this tubing blank (using a Teflon-coated tubing cutter of uncertain cleanliness), and the detected lead and zinc were likely attributable to that adjustment. Project results for marine metals were not re-qualified based on tubing and filter blanks.

Results for the freshwater filter blank are shown in Table D-12. Very low concentrations of dissolved copper and zinc were detected in the blank, but these were deemed insufficient to warrant the re-qualification of project results for river water metals.

Sampler blanks

Sampler blanks involved the placement of analyte-specific laboratory reagent water into the sampling gear (GO-FLO samplers for marine water, DH-95 bottle/cap/nozzle set-up for river water) to mimic sample water contact with the collection equipment. These blanks allow assessment of contamination arising from pre-cleaning methods, the sampling equipment itself, and sample decanting procedures.

Marine water column sampler blanks

- Parameters analyzed: All.
- Procedure: GO-FLO samplers were rinsed thoroughly with analyte-specific blank water and emptied, re-filled with blank water, and then a subsample was decanted through clean Teflon tubing following standard procedures. Sampler blanks were conducted using GO-FLO

samplers immediately after acid-cleaning, as well as samplers that had been used (or "conditioned") by previous deployments to collect site water.

River water sampler blanks

- Parameters analyzed: Total and dissolved metals, chlorinated pesticides, BNAs, PAHs, PCB congeners, and PBDE congeners.
- Procedure: The DH-95 bottle/cap/nozzle was rinsed with analyte-specific blank water and emptied, re-filled, assembled, and left for two minutes to approximate the duration that a typical water collection would be in contact with the sampling gear. In September 2009 the sampler was left exposed to the bridge atmosphere for the two minutes, while in December 2009 the opening of the bottle/cap/nozzle was covered with a nitrile glove to minimize exposure to airborne contaminants.

Results for marine sampler blanks are presented in Tables D-9 and D-10. All parameter results for the July 2009 "used" sampler blank were discarded, for these blanks were improperly created using blank water that was not obtained from the appropriate analytical laboratories. Blanks created immediately after acid-cleaning the sampling equipment detected low concentrations of total and dissolved lead and zinc, as well as several BNA and PAH compounds and a number of PCB congeners. However, "used" sampler blanks revealed that nearly all of these contaminants were absent after normal use of the equipment during sampling. During deployment the GO-FLO samplers were flushed with site water as they were lowered to the collection depth, and this appeared to be sufficient to remove residual contamination from pre-cleaning procedures.

Potential PCB contamination from marine sampling gear was investigated in January 2010. A blank was first created using an acid-cleaned sampler. Next the sampler was deployed to a depth of 60 meters (flushing to depth) where site water was collected. Finally a "used" (or "conditioned") sampler blank was created. A bottle blank was also conducted to determine the presence of congener-specific contamination from the laboratory reagent water used in the creation of the sampler blanks. After accounting for congener-specific, low-level contamination from the lab water and from cleaning procedures (i.e., contamination that was noted to "wash away" during deployment), only three to six PCB congeners appeared to persist in the "conditioned" sampler blank. These lines of evidence suggested that much of the residual contamination from pre-cleaning procedures was removed by the thorough flushing of the sampler during deployment.

Results for river sampler blanks are shown in Tables D-12 and D-14. September 2009 sampler blanks appeared to have been influenced by exposure to the bridge atmosphere during creation. This exposure was well in excess of that experienced by regular samples during standard collection procedures, and so the results of these sampler blanks were deemed unrepresentative. Despite precautions in December 2009, those sampler blanks also appear to have been exposed to contamination sources not experienced during normal sampling activities.

This contention is supported by PCB congener *fingerprints*, which showed that field blanks tended to contain greater abundance of mono- to tri-chlorinated congeners and relatively lower concentrations of tetra- to hepta-chlorinated congeners. This was not the pattern for river water or marine water column samples. If PCBs in water samples were derived from the same sources as field blanks, then similar total concentrations and similar congener compositions would be expected. Therefore, the sources of elevated PCB congener concentrations in field blanks were different from the sources of PCBs in marine water column or river water samples.

One explanation is that the high-quality de-ionized water used to create most field blanks (<15 pg/L) effectively scavenged PCBs from the ambient air (to which field blanks were exposed longer than actual water samples).

Overall, it was concluded that sampler blanks did not exactly reproduce conditions encountered during normal sampling procedures. Sampler blanks reflected opportunities for contamination not shared with actual marine and river water samples, and so sampler blank results were not used to further interpret or qualify sample results.

Organic Carbon Blanks

A variety of field blanks were created to evaluate the newly developed protocols for marine organic carbon sampling. These included the following:

Laboratory filter blanks

- Purpose: Quantification of the mass of "background" carbon inherent in a typical filter.
- Procedure: The analytical lab (Horn Point) retained and analyzed several clean, unused filters from the batch that was sent for field sampling.

Filter trip blanks

- Purpose: Quantification of the mass of carbon that accumulated on a filter during typical transport and handling activities.
- Procedure: A filter from the batch provided by the analytical lab was carried unopened into the field and treated as a POC sample. During October 2009 and January 2010 sampling, a total of eight filter trip blanks were conducted.

Adsorption blanks

- Purpose: Determination of the concentration of carbon that was adsorbed to a typical filter during filtration.
- Procedure: Standard marine carbon filtration procedures were followed, but using two "stacked" filters. After subtracting the background carbon mass inherent in a typical filter, the mass of carbon measured on the lower filter and the volume of sample water filtered were used to calculate the concentration of adsorbed carbon. The mass of carbon adsorbed was assumed to increase linearly with the volume of sample filtered.

Results for the various organic carbon blanks were used to blank-correct marine sample results. The average mass of background carbon inherent in a filter was 8.40 µg C, and the average mass accumulated during transport and handling was 4.84 µg C. That combined mass of carbon (13.24 µg C) accounted for an average of 25% of each regular project sample's total measured (i.e., uncorrected) POC. After these "filter effects" were subtracted from POC measurements, the average carbon concentration contributed by adsorption of DOC to the filter (mg C per liter filtered) was 0.0045 mg/L C, accounting for approximately 7% of the remaining total measured POC. This adsorbed carbon was also subtracted from the total measured POC to arrive at a final result. For DOC, the only blank correction needed was to add the carbon that was lost due to adsorption during filtration (proportional to the volume filtered).

Example series of measurements and calculations for blank-correction of POC results

a) The POC sample was obtained by filtering 600 mL of sample water.
b) The instrument-measured carbon signal of the sample filter = 1445 µVolts.
c) The average carbon signal measured in three lab filter blanks = 168 µVolts.
d) Sample filter carbon signal, corrected for average lab filter blank carbon signal, equals:
    1445 – 168 = 1277 µVolts.
e) Average carbon signal measured in three filter trip blanks = 74.7 µVolts.
f) Sample filter carbon signal, corrected for average filter trip blank carbon signal, equals:
    1277 – 74.7 = 1202.3 µVolts.
g) "K-factor" (provided by the lab) allows conversion of a carbon signal to mass:
    "K-factor" = 23.0 µVolts / µg carbon.
h) Mass of carbon on filter, corrected for lab and field filter blanks, equals:
    1202.3 / 23.0 = 53.6 µg carbon.
i) Calculate the carbon concentration of the three individual adsorption blanks. For example, the creation of one adsorption blank had involved "stacked" filtration of 435 mL of sample water. After correcting the measured carbon signal for lab and field filter blanks and then applying the K-factor, the mass of adsorbed carbon was 2.51 µg carbon. Thus, the carbon adsorbed to the filter was:
    2.51 / 435 = 0.006 mg/L carbon.
    That is, 0.006 mg carbon was adsorbed to the filter for every liter filtered.
j) The average carbon concentration of the three adsorption blanks = 0.0045 mg/L carbon.
k) The mass of carbon adsorbed for the sample of interest equals:
    600 mL filtered X 0.0045 mg/L carbon = 2.70 µg carbon.
l) The mass of carbon on the filter, corrected for the adsorbed mass, equals:
    53.6 – 2.7 = 50.9 µg carbon.
m) Finally, the concentration of POC in the sample water equals:
    50.9 µg carbon / 600 mL filtered = 0.085 mg/L POC.

Table D-5. Summary of field replicate results for marine water samplings.

Non-detect values for the listed BNA compounds are given at the reporting limit (RL). Total PCB values are sums of detected congeners (unqualified and J-qualified results). PCB homolog and congener results for field replicates are detailed in Tables D-7 and D-8, respectively.

Parameter	Field Replicates									
	July 2009			Sept 2009			Jan 2010			Mean RPD
	Sample	QA Rep	RPD	Sample	QA Rep	RPD	Sample	QA Rep	RPD	
Conventional Parameters (mg/L)										
TSS	3.5	2.1	50	1.1	1.1	0.0	0.8	1.0	22	24
POC	-	-	-	0.093	0.063	38	0.071	0.028	86	62
DOC	-	-	-	0.756	0.747	1.1	0.771	0.799	3.6	2.4
Metals (µg/L)										
Arsenic, total	1.46	1.44	1.4	1.47	1.36	7.8	1.53	1.56	1.9	3.7
Arsenic, dissolved	1.54	1.46	5.3	1.40	1.35	3.6	-	-	-	4.5
Cadmium, total	0.085	0.085	0.0	0.092	0.080	14	0.082	0.080	2.5	5.5
Cadmium, dissolved	0.086	0.086	0.0	0.077	0.093	19	-	-	-	9.0
Copper, total	0.49	0.45	8.5	0.34	0.31	9.2	0.48	0.47	2.1	7.1
Copper, dissolved	0.41	0.39	5.8	0.31	0.30	4.2	-	-	-	5.0
Lead, total	0.114	0.056	68	0.046 J	0.025 UJ	-	0.033 J	0.048 J	37	53
Lead, dissolved	0.033 J	0.021 J	44	0.018 J	0.021 UJ	-	-	-	-	44
Zinc, total	0.74 J	0.99 J	29	0.91 J	0.48 J	62	0.88 J	0.76 J	15	35
Zinc, dissolved	0.69 J	0.72 J	4.3	0.70 J	0.46 J	42	-	-	-	23
Chlorinated Pesticides (ng/L)										
All 33 chlorinated pesticide compounds	ND	ND	-	ND	ND	-	ND	ND	-	-
BNAs (µg/L)										
4-Chloro-3-Methylphenol	0.91 UJ	0.006 J	-	0.8 UJ	0.85 UJ	-	-	-	-	-
Cholesterol	0.91 UJ	0.84 U	-	0.7 J	0.74 J	5.6	-	-	-	5.6
54 other BNA compounds	ND	ND	-	ND	ND	-	-	-	-	-
PAHs (µg/L)										
All 22 PAH compounds	ND	ND	-	ND	ND	-	ND	ND	-	-
PCB Congeners (pg/L)										
Total PCBs	43.92 J	31.12 J	34	33.583 J	19.058 J	55	18.39 J	22.59 J	20	36
PBDE Congeners (pg/L)										
BDE-099	10.9 UJ	53.9 J	-	17.9 UJ	14.1 UJ	-	-	-	-	-
BDE-100	10 UJ	19.4 J	-	10 UJ	10 UJ	-	-	-	-	-
34 other PBDE congeners	ND	ND	-	ND	ND	-	-	-	-	-
Total PBDEs	127.6 U	73.3 J	-	122.5 U	130.2 U	-	-	-	-	-

Table D-6. Summary of field duplicate results for marine water samplings.

Non-detect values for POC are given at the method detection limit (MDL). Total PCB values are sums of detected congeners (unqualified and J-qualified results). PCB homolog and congener results for field duplicates are detailed in Tables D-7 and D-8, respectively.

Parameter	Field Duplicates									
	July 2009			Sept 2009			Jan 2010			Mean RPD
	Sample	QA Dup	RPD	Sample	QA Dup	RPD	Sample	QA Dup	RPD	
TSS (mg/L)	2.6	2.4	8.0	1.1	0.9	20	-	-	-	14
	3.5	2.5	33	-	-	-	-	-	-	33
POC (mg/L)	-	-	-	0.063	0.068	7.6	0.028	0.049	55	31
	-	-	-	0.058	0.051	13	0.011 U	0.011 U	-	13
DOC (mg/L)	-	-	-	0.035	0.045	25	0.799	0.757	5.4	15
	-	-	-	0.802	0.722	11	0.084	0.162	63	37
Total PCBs (pg/L)	31.12 J	30.31 J	2.6	-	-	-	-	-	-	2.6

Table D-7. Summary of PCB homolog totals in field replicates and field duplicates for marine water samplings.

Homolog totals and Total PCB values are sums of detected congeners (unqualified and J-qualified results). PCB congener results for field replicates and field duplicates are detailed in Table D-8.

PCB Homolog (pg/L)	Field Replicates										Field Duplicates		
	July 2009			Sept 2009			Jan 2010			Mean RPD	July 2009		
	Sample	QA Rep	RPD	Sample	QA Rep	RPD	Sample	QA Rep	RPD		Sample	QA Dup	RPD
Mono-CBs	5.21 U	10.2 U	-	2.793 J	5 U	-	3.91 U	4.15 U	-	-	10.2 U	10.3 U	-
Di-CBs	4.09 J	3.15 J	26	3.783 J	2.14 J	55	3.91 U	1.7 J	-	41	3.15 J	2.6 J	19
Tri-CBs	4.87 J	10.2 U	-	4.814 J	0.798 J	143	3.91 U	1.28 J	-	143	10.2 U	1.84 J	-
Tetra-CBs	18.748 J	11.34 J	49	14.27 J	11.58 J	21	15.96	11.99 J	28	33	11.34 J	14.58 J	25
Penta-CBs	8.822 J	9.73 J	9.8	6.623 J	3.45 J	63	2.43 J	2.55 J	4.8	26	9.73 J	8.72 J	11
Hexa-CBs	7.39 J	6.9 J	6.9	1.3 J	1.09 J	18	3.91 U	5.07 J	-	12	6.9 J	2.57 J	91
Hepta-CBs	5.21 U	10.2 U	-	4.13 U	5 U	-	3.91 U	4.15 U	-	-	10.2 U	10.3 U	-
Octa-CBs	5.21 U	10.2 U	-	4.13 U	5 U	-	3.91 U	4.15 U	-	-	10.2 U	10.3 U	-
Nona-CBs	5.21 U	10.2 U	-	4.13 U	5 U	-	3.91 U	4.15 U	-	-	10.2 U	10.3 U	-
PCB-209	5.21 U	10.2 U	-	4.13 U	5 U	-	3.91 U	4.15 U	-	-	10.2 U	10.3 U	-
Total PCBs	43.92 J	31.12 J	34	33.583 J	19.058 J	55	18.39 J	22.59 J	20	36	31.12 J	30.31 J	3

Table D-8. Summary of PCB congener detects in field replicates and duplicates for marine water samplings.

Congener concentrations are listed only if detected in at least one of these blanks. U- and UJ-qualified results are not shown.

PCB Congener (pg/L)	Field Replicates						Field Duplicates	
	July 2009		Sept 2009		Jan 2010		July 2009	
	Sample	QA Rep	Sample	QA Rep	Sample	QA Rep	Sample	QA Dup
PCB-001	1.3 NJ		2.46 NJ					
PCB-002	1.4 NJ		0.336 NJ					
PCB-003	1.82 NJ		0.399 J					
PCB-004	2.27 J		1.62 J	1.35 J		1.7 J		
PCB-006			0.397 J					
PCB-008	1.82 J	3.15 J	1.41 J	0.79 J			3.15 J	2.6 J
PCB-016			0.503 J					
PCB-017	2.43 J		0.687 NJ			0.935 NJ		
PCB-018/030	2.44 J		1.12 J	0.877 NJ	1.22 NJ	1.28 J		1.8 NJ
PCB-019			0.348 J					
PCB-020/028			1.06 J	0.798 J		0.949 NJ		1.84 J
PCB-021/033			0.595 J					
PCB-022			0.35 J					
PCB-031			0.822 J			0.854 NJ		
PCB-032			0.34 NJ					
PCB-040/071	0.731 J							0.775 NJ
PCB-044/047/065	6.5	5.42 J	5.48 J	5.39 J	14.6	6.57 J	5.42 J	5.67 J
PCB-049/069	1.26 J	1.36 NJ	0.482 NJ	0.654 NJ	1.36 J	1.22 J	1.36 NJ	1.32 J
PCB-051	3.74 J	3.16 J	4.01 J	3.6 J	8.69 NJ	3.78 NJ	3.16 J	3.77 J
PCB-052	2.51 J	2.76 J	1.24 J	1.54 J	2.28 NJ	2.67 J	2.76 J	2.59 J
PCB-061/070/074/076	1.54 J		1.05 J					
PCB-064								0.594 NJ
PCB-066	0.867 J							
PCB-068	1.6 J		0.96 J	1.05 J	2.71 NJ	1.53 J		1.23 J
PCB-086/087/097/108/119/125	1.29 NJ		0.903 J					
PCB-090/101/113	3.01 J	2.75 J	1.09 J	1.87 J	2.43 J		2.75 J	3.47 J
PCB-095	2.35 J	2.34 J	0.933 J	1.58 J		2.55 J	2.34 J	3.01 J
PCB-099	0.974 NJ							
PCB-105	0.932 J		0.371 NJ					
PCB-110	2.53 J	2.63 J	0.841 J	0.867 NJ	1.52 NJ	1.12 NJ	2.63 J	1.85 NJ
PCB-118	1.42 NJ	2.01 J	0.573 J	0.852 NJ			2.01 J	2.24 J
PCB-129/138/163	2.98 J	2.49 J	0.609 J	1.09 J		2.15 J	2.49 J	2.25 NJ
PCB-147/149	1.94 J	2.19 J	0.366 NJ			1.41 J	2.19 J	1.64 NJ
PCB-153/168	2.47 J	2.22 J	0.383 J	0.642 NJ	1.11 NJ	1.51 J	2.22 J	2.57 J
PCB-169			0.337 J					
PCB-194				0.806 NJ				1.41 NJ
Total PCBs								
…including N,NJ	52.124 J	32.48 J	34.756 J	23.756 J	35.92 J	30.228 J	32.48 J	40.629 J
…excluding N,NJ	43.92 J	31.12 J	33.583 J	19.058 J	18.39 J	22.59 J	31.12 J	30.31 J

Table D-9. Summary of equipment blank results for marine water samplings.

Non-detect values for POC and metals are given at the method detection limit (MDL). Non-detect values for organic compounds are given at the reporting limit (RL).

Parameter	Tubing	Filter	Used Sampler		Acid-Cleaned Sampler	
	July 2009	July 2009	July 2009	Sept 2009	Sept 2009	Jan 2010
Conventional Parameters (mg/L)						
POC	-	-	-	-	0.063	0.011 U
	-	-	-	-	0.068 (Dup)	0.011 U (Dup)
DOC	-	-	-	-	0.035	0.084
Metals (µg/L)						
Arsenic, total	0.006 U	-	-	0.006 U	-	0.006 U
Arsenic, dissolved	-	0.006 U	-	0.006 U	-	0.006 U
Cadmium, total	0.003 U	-	-	0.003 U	-	0.003 U
Cadmium, dissolved	-	0.003 U	-	0.003 U	-	0.003 U
Copper, total	0.023 UJ	-	-	0.027 UJ	-	0.029 UJ
Copper, dissolved	-	0.033 UJ	-	0.08 J	-	0.05 UJ
Lead, total	0.015 J	-	-	0.012 UJ	-	1.85
Lead, dissolved	-	0.005 U	-	0.010 UJ	-	1.81
Zinc, total	0.440 J	-	-	0.250 UJ	-	0.350 J
Zinc, dissolved	-	0.130 UJ	-	0.510 J	-	0.390 J
Chlorinated Pesticides (ng/L)						
All 33 chlor pest compounds	-	-	ND	-	ND	-
BNAs (µg/L)						
2-Methylphenol	-	-	0.02 J	0.81 U	0.013 J	0.82 U
4-Chloro-3-Methylphenol	-	-	0.04 J	0.81 UJ	0.82 UJ	0.82 U
4-Methylphenol	-	-	0.03 J	0.81 U	0.82 U	0.82 U
Bis(2-Ethylhexyl) Phthalate	-	-	5.8	0.16 U	0.083 J	0.16 U
Bisphenol A	-	-	0.24 J	0.33 U	0.08 J	0.33 U
Butyl benzyl phthalate	-	-	2	0.33 U	0.33 U	0.33 U
Diethyl phthalate	-	-	1.1	0.16 U	0.16 U	0.16 U
Dimethyl phthalate	-	-	0.04 J	0.16 U	0.16 U	0.16 U
Ethanol, 2-Chloro-, Phosphate (3:1)	-	-	0.11 NJ	0.081 UJ	0.082 UJ	0.082 U
Phenol	-	-	0.06 J	0.33 U	0.33 U	0.33 U
Triclosan	-	-	0.17 NJ	0.057 J	0.082 U	0.082 U
45 other BNA compounds	-	-	ND	ND	ND	ND
PAHs (µg/L)						
1-Methylnaphthalene	-	-	0.037	-	0.01 U	0.01 U
2-Methylnaphthalene	-	-	0.061	-	0.01 U	0.01 U
Fluorene	-	-	0.016	-	0.01 U	0.01 UJ
Naphthalene	-	-	0.096	-	0.049	0.01 U
Phenanthrene	-	-	0.021	-	0.01 U	0.01 U
17 other PAH compounds	-	-	ND	-	ND	ND
PBDE congeners (pg/L)						
All 36 PBDE congeners	-	-	ND	-	ND	ND

Table D-10. Summary of PCB congener detects in equipment blanks for marine water samplings.

Congener concentrations are listed only if detected in at least one of these blanks. Table continues on the following page.

PCB Congener (pg/L)	July 2009	September 2009		January 2010			
	Used Sampler	Bottle Blank	Acid-Cleaned Sampler	Bottle Blank	Acid-Cleaned Sampler	Site Reference	Used Sampler
PCB-001	15.4	2.5 J	2.35 NJ	2.01 J	3.06 J		2.57 J
PCB-002	3.65 NJ	3.21 NJ	1.17 NJ	2.41 J	2.1 NJ	1.22 NJ	2.45 J
PCB-003	10.4 N	4.36 NJ	2.37 NJ	2.84 J	4.71 J	0.885 NJ	4.34 NJ
PCB-004	33.6		6.83		4.03 J		2.69 J
PCB-006	9.09		1.15 J				
PCB-007	3.37 J						
PCB-008	38.5		5.66		4.01 J	1.45 J	2.75 J
PCB-009	2.88 J						
PCB-011	46						
PCB-012/013	6.36						
PCB-015	24.6		1.55 J				
PCB-016	25.6		1.84 J		0.849 NJ		
PCB-017	26.9		3.79 J		2.19 J		2.06 NJ
PCB-018/030	48.6	0.968 J	3.58 NJ	1.3 J	2.66 J	1.45 NJ	2 J
PCB-019	8.42		1.09 NJ				
PCB-020/028	29.4		2.48 J		1.27 J	1.3 NJ	
PCB-021/033	25		3.2 J				
PCB-022	13.6						
PCB-025	4.99 J						
PCB-026/029	6.97						
PCB-027	4.58 J						
PCB-031	34		2.51 J		1.76 J	0.82 NJ	
PCB-032	13.9		1.22 NJ		0.719 NJ		
PCB-035	3.2 NJ						
PCB-037	27.4						
PCB-040/071	13.8						
PCB-041	3.37 J						
PCB-042	8.32						
PCB-044/047/065	212		101		35.7	6.76 J	19.7
PCB-046	3.04 J						
PCB-048	5.93						
PCB-049/069	34		2.99 J		1.12 NJ	1.23 J	
PCB-050/053	11.9						
PCB-051	124		75.1		24.8	3.33 J	15.9
PCB-052	157		6.94	1.11 NJ	2.88 J	2.68 J	1.61 NJ
PCB-056	8.47						
PCB-059/062/075	1.66 NJ						
PCB-060	3.27 J						
PCB-061/070/074/076	78		5.83 J				
PCB-064	18.5						
PCB-066	11.6 N		1.67 J				
PCB-068	28.5		18.2		4.22 NJ		3.57 NJ
PCB-077	16.3						
PCB-082	8.93						
PCB-083	4.99 NJ						
PCB-084	44.4		2.63 J				
PCB-085/116	12.4						
PCB-086/087/097/108/119/125	63.6		8.5 J				

PCB Congener (pg/L)	July 2009	September 2009		January 2010			
	Used Sampler	Bottle Blank	Acid-Cleaned Sampler	Bottle Blank	Acid-Cleaned Sampler	Site Reference	Used Sampler
PCB-090/101/113	105		10.8 J		2.24 NJ	2.65 NJ	
PCB-091	11.2 N						
PCB-092	18.7						
PCB-095	134		7.24 NJ		1.55 J	2.05 NJ	
PCB-096	1.89 NJ						
PCB-099	27		2.81 NJ				
PCB-105	13.9		3.1 NJ				
PCB-107/124	2.06 NJ						
PCB-109	3.11 J						
PCB-110	84.1		9.37		1.51 NJ		
PCB-118	32.5		6.33		0.946 NJ	1.63 J	
PCB-128/166	4.16 NJ						
PCB-129/138/163	26.7		5.95 J			1.49 NJ	
PCB-130	2.52 NJ						
PCB-132	14.4 N		2.93 NJ				
PCB-134	3.01 J						
PCB-135/151	14.8						
PCB-136	11.3						
PCB-137	1.67 J						
PCB-139/140	0.966 NJ						
PCB-141	5.4						
PCB-144	2.03 NJ						
PCB-146	3.22 J						
PCB-147/149	31.9		3.98 NJ			1.44 NJ	
PCB-153/168	16.1		2.28 NJ			2.31 J	
PCB-156/157	2 J						
PCB-158	2.4 NJ						
PCB-164	1.62 NJ						
PCB-170	1.39 NJ						
PCB-174	1.9 NJ						
PCB-179	1.62 NJ						
PCB-180/193	2.72 NJ						
PCB-183	1.19 NJ						
PCB-187	1.62 NJ						
Total PCBs							
…including N,NJ	1928.486	11.038 J	318.44 J	9.67 J	102.324 J	32.695 J	59.64 J
…excluding N,NJ	1839.3	3.468 J	284.32 J	8.56 J	88.62 J	19.39 J	48.06 J

Table D-11. Summary of field replicate results for river water samplings.

Total PCB and PBDE values are sums of detected congeners (unqualified and J-qualified results). PCB homolog and congener results for field replicates are detailed in Tables D-13 and D-14, respectively.

Parameter	Field Replicates									
	July 2009			Sept 2009			Dec 2009			Mean RPD
	Sample	QA Rep	RPD	Sample	QA Rep	RPD	Sample	QA Rep	RPD	
Conventional Parameters (mg/L)										
TSS	233	235	0.85	38.7	40.5	4.6	11.9	13.2	10	5.2
TOC	0.5 J	0.4 J	22	1.1	1.3	17	1.3	1.2	8.0	16
DOC	0.8 J	0.9 J	12	1.4	1.3	7.4	1.2	1.2	0.0	6.5
Ammonia	0.01	0.009 J	11	0.162	0.179	10	-	-	-	11
Nitrate+Nitrite	0.11	0.105	4.7	0.309	0.320	3.5	-	-	-	4.1
Total Nitrogen	0.137	0.132	3.7	0.545	0.580	6.2	-	-	-	5.0
Total Phosphorus	0.250	0.197	24	0.0795	0.110	32	-	-	-	28
Ortho-phosphate	0.0287	0.0319	11	0.0478	0.0527	9.8	-	-	-	10
Hardness	27.7	28.1	1.4	40.8	39.5	3.2	33.2	33.5	0.90	1.8
Metals (µg/L) [1]										
Arsenic, total	0.92	0.98	6.3	0.6	0.68	13	0.52	0.53	1.9	7.1
Arsenic, dissolved	0.46	0.47	2.2	0.62	0.64	3.2	0.5	0.49	2.0	2.5
Cadmium, total	0.01 J	0.02 J	67	0.006 J	0.006 J	0.0	0.005 J	0.006 J	18	28
Cadmium, dissolved	0.003 J	0.002 U	-	0.003 J	0.003 J	0.0	0.002 U	0.002 J	-	0.0
Copper , total	11.6	11.6	0.0	1.81	2.16	18	1.32	1.22	7.9	8.6
Copper, dissolved	4.19	0.78	137	0.91	0.73	22	0.63	1.64	89	83
Lead, total	1.42	1.49	4.8	0.2	0.28	33	0.11 UJ	0.08 UJ	-	19
Lead, dissolved	0.006 U	0.006 U	-	0.035	0.034	2.9	0.024	0.022	8.7	5.8
Zinc, total	11.6	22.2	63	3.7 J	3.4 J	8.5	2.7 UJ	2.8 UJ	-	36
Zinc, dissolved	2	4.2	71	1.2	1.5	22	1	2	67	53
Petroleum-related Products (mg/L) [2]										
Oil and grease	0.9 J	1 J	11	1.8 U	1.8 U	-	5.5 U	5.5 U	-	11
TPH-D #2 Diesel	0.05 U	0.05 U	-	0.05 U	0.05 U	-	0.02 U	0.02 U	-	-
TPH-D Lube Oil	0.13 U	0.13 U	-	0.12 U	0.12 U	-	0.04 U	0.04 U	-	-
TPH-G	0.14 U	0.14 U	-	0.14 U	0.14 U	-	0.14 U	0.14 U	-	-
Chlorinated Pesticides (ng/L) [2]										
All 33 chlorinated pesticide compounds	ND	ND	-	ND	ND	-	-	-	-	-
BNAs (µg/L) [2]										
2-Methylphenol	0.0058 J	0.81 U	-	0.8 U	0.78 U	-	-	-	-	-
Cholesterol	0.79 U	0.81 U	-	1.4	1.4	0.0	-	-	-	0.0
Di-N-Octyl Phthalate	0.16 U	0.16 U	-	0.16 U	0.16 J	-	-	-	-	-
Pentachlorophenol	0.079 UJ	0.081 UJ	-	0.083 NJ	0.081 NJ	2.4	-	-	-	2.4
Triclosan	0.079 U	0.081 U	-	0.08 U	0.081	-	-	-	-	-
Triethyl citrate	0.31 U	0.33 U	-	0.32 U	0.31 J	-	-	-	-	-
49 other BNA compounds	ND	ND	-	ND	ND	-	-	-	-	-
PAHs (µg/L) [2]										
1-Methylnaphthalene	0.01 UJ	0.01 U	-	0.01 U	0.0034 J	-	-	-	-	-
21 other PAH compounds	ND	ND	-	ND	ND	-	-	-	-	-
PCB Congeners (pg/L) [2]										
Total PCBs	2.61 J	6.701 J	88	40.18 J	33.35 J	19	21.497 J	23.509 J	8.9	39
PBDE Congeners (pg/L) [2]										
BDE-100	10.9 J	10.8 J	0.92	11.1 UJ	10 UJ	-	10 UJ	10.7 UJ	-	0.92
BDE-209	250 U	250 UJ	-	260	260		250 U	250 U	-	-
34 other PBDE congeners	ND	ND	-	ND	ND	-	ND	ND	-	-
Total PBDEs	10.9 J	10.8 J	0.92	265.18	260	2.0	250 U	250 U	-	1.5

[1] Non-detect results for metals are given at the method detection limit (MDL).

[2] Non-detect results for petroleum-related products, chlorinated pesticides, BNAs, PAHs, PCB congeners, and PBDE congeners are given at the reporting limit (RL).

Table D-12. Summary of field QA sample results for river water samplings.

Total PCB and PBDE values are sums of detected congeners (unqualified and J-qualified results).

Parameter	Bottle / Filter Blanks	Acid-Cleaned Sampler Blanks	
	July 2009	Sept 2009	Dec 2009
Metals (µg/L) [1]			
Arsenic, total	0.05 U	0.05 U	0.05 U
Arsenic, dissolved	0.03 U	0.03 U	0.03 U
Cadmium, total	0.003 U	0.003 U	0.003 U
Cadmium, dissolved	0.002 U	0.002 U	0.002 U
Copper, total	0.02 U	0.12 J	0.33
Copper, dissolved	0.04 J	0.26	0.31
Lead, total	0.02 UJ	0.01 UJ	0.02 J
Lead, dissolved	0.006 U	0.007 J	0.037
Zinc, total	2.8 J	2.3 UJ	2.3 J
Zinc, dissolved	0.3 J	1.4	2.8
Chlorinated Pesticides (ng/L) [2]			
All 33 chlorinated pesticide compounds	ND	ND	-
BNAs (µg/L) [2]			
2-Methylphenol	0.82 U	0.82 U	-
Cholesterol	0.82 U	0.82 UJ	-
Di-N-Octyl Phthalate	0.16 U	0.16 U	-
Pentachlorophenol	0.082 UJ	0.082 U	-
Triclosan	0.082 U	0.082 U	-
Triethyl citrate	0.33 U	0.33 U	-
49 other BNA compounds	ND	ND	-
PAHs (µg/L) [2]			
1-Methylnaphthalene	0.01 U	0.01 U	-
Naphthalene	0.01	0.01 U	-
20 other PAH compounds	ND	ND	-
PCB Congeners (pg/L) [2]			
Total PCBs	11.2 U	47.066 J	13.959 J
PBDE Congeners (pg/L) [2]			
BDE-099	382	22.8 UJ	-
BDE-100	81.9	10 UJ	-
BDE-154	18.3 NJ	10 UJ	-
33 other PBDE congeners	ND	ND	-
Total PBDEs	807.9	124 U	-

[1] Non-detect results for metals are given at the method detection limit (MDL).

[2] Non-detect results for petroleum-related products, chlorinated pesticides, BNAs, PAHs, PCB congeners, and PBDE congeners are given at the reporting limit (RL).

Table D-13. Summary of PCB homolog totals in field replicates for river water samplings.

Homolog totals and Total PCB values are sums of detected congeners (unqualified and J-qualified results). PCB congener results for field replicates are detailed in Table D-14.

PCB Homolog (pg/L)	Field Replicates									
	July 2009			Sept 2009			Dec 2009			Mean RPD
	Sample	QA Rep	RPD	Sample	QA Rep	RPD	Sample	QA Rep	RPD	
Mono-CBs	10.3 U	10.2 U	-	1.8 J	0.779 J	79	2.726 J	0.688 J	119	99
Di-CBs	10.3 U	10.2 U	-	2.04 J	4.8 J	81	3.91 U	1.39 J	-	81
Tri-CBs	10.3 U	10.2 U	-	5.2 J	5.696 J	9.1	3.557 J	5.232 J	38	24
Tetra-CBs	1.45 J	10.2 U	-	5.89 J	3.22 J	59	5.467 J	6.641 J	19	39
Penta-CBs	1.16 J	4.52 J	118	15.11 J	9.76 J	43	6.487 J	4.245 J	42	68
Hexa-CBs	10.3 U	0.761 J	-	8.63 J	7.59 J	13	3.26 J	4.7 J	36	25
Hepta-CBs	10.3 U	10.2 U	-	1.51 J	0.756 J	67	3.91 U	0.613 J	-	67
Octa-CBs	10.3 U	1.42 J	-	5 U	0.749 J	-	3.91 U	4.17 U	-	-
Nona-CBs	10.3 U	10.2 U	-	5 U	5 U	-	3.91 U	4.17 U	-	-
PCB-209	10.3 U	10.2 U	-	5 U	5 U	-	3.91 U	4.17 U	-	-
Total PCBs	2.61 J	6.701 J	88	40.18 J	33.35 J	19	21.497 J	23.509 J	8.9	39

Table D-14. Summary of PCB congener detects in field QA results for river water sampling.

Congener concentrations are listed only if detected in at least one of these blanks.

PCB Congener (pg/L)	Field Replicates						Bottle Blank	Acid-Cleaned Sampler Blanks	
	July 2009		September 2009		December 2009		July '09	Sept '09	Dec '09
	Sample	QA Rep	Sample	QA Rep	Sample	QA Rep	Result	Result	Result
PCB-001				0.779 J	0.976 J			2.99 J	0.752 NJ
PCB-002					1.73 NJ	0.832 NJ		0.956 J	
PCB-003			1.8 J		1.75 J	0.688 J		3.64 J	1.76 J
PCB-004				1.85 J				3 J	
PCB-005								0.469 J	
PCB-006				0.489 J				1.53 J	0.971 J
PCB-007								0.65 J	
PCB-008			2.04 J	1.72 J				5.37	2.4 J
PCB-009								0.734 J	
PCB-012/013								0.781 J	
PCB-015				0.741 J		1.39 J		2.19 J	1.2 J
PCB-016								2.98 J	0.66 J
PCB-017				0.826 J		0.885 NJ		2.39 J	0.943 J
PCB-018/030		10.2 NJ	1.69 J	1.86 J	1.49 J	1.98 J		4.43 J	1.55 J
PCB-019								0.744 J	
PCB-020/028	10.3 NJ	10.2 NJ	1.77 J	1.57 J	1.04 NJ	1.32 NJ		1.98 J	1.31 J
PCB-021/033				0.442 NJ	0.897 J	0.851 J		1.95 J	0.936 J
PCB-022				0.45 NJ		0.661 J		1.09 J	0.424 NJ
PCB-026/029								0.453 NJ	
PCB-027								0.406 NJ	
PCB-031	10.3 NJ		1.74 J	1.44 J	1.17 J	1.74 J		2.03 J	1.18 J
PCB-032				0.471 NJ		4.17 NJ		1.5 J	0.516 J
PCB-039				0.314 NJ					
PCB-040/071								0.568 NJ	3.75 NJ
PCB-044/047/065				1.75 NJ	1.57 J	1.95 J		1.74 J	0.726 NJ
PCB-049/069			1.27 NJ	1.06 J	0.751 J	0.988 J		0.891 NJ	0.533 J
PCB-052	1.45 J	10.2 NJ	2.76 J	2.16 J				1.65 J	0.974 UJ
PCB-061/070/074/076			3.13 J	1.72 NJ	1.72 J	2.31 J			
PCB-064					0.585 J	0.551 J		0.391 NJ	
PCB-066				0.641 NJ	0.841 J	0.842 J			
PCB-086/087/097/108/119/125				2.02 J		0.794 NJ			
PCB-090/101/113	10.3 NJ	1.69 J	3.04 J	2.65 J	1.76 J	2.11 J		0.601 NJ	
PCB-095			3.37 J	1.9 NJ	1.4 J	1.35 NJ		1.1 J	
PCB-099			1.63 J	1.08 J	0.497 J	0.48 NJ			
PCB-105			1.86 J	1.05 NJ		0.585 J			
PCB-110	1.16 J	1.44 J	2.66 J	2.28 J	1.58 J	1.55 J		0.519 J	0.434 NJ
PCB-118		1.39 J	2.55 J	1.73 J	1.25 J	1.11 NJ			
PCB-128/166						4.17 NJ			
PCB-129/138/163		10.2 NJ	3.19 J	2.67 J	1.85 J	1.92 J		0.653 J	
PCB-132				1.05 J					
PCB-135/151				1.04 NJ					
PCB-147/149			2.43 J	1.97 J	1.41 J	1.42 J			
PCB-153/168			3.01 J	1.9 J	1.17 NJ	1.36 J			
PCB-169		0.761 J							
PCB-177				0.765 NJ				0.686 NJ	
PCB-180/193				0.757 NJ		0.923 NJ			
PCB-187			1.51 J	0.756 J		0.613 J		0.707 NJ	0.616 NJ
PCB-194		1.42 J		0.749 J				0.442 NJ	
Total PCBs									
…including N,NJ	33.51 J	47.501 J	41.45 J	49.65 J	25.437 J	39.543 J	11.2 U	57.211 J	20.661 J
…excluding N,NJ	2.61 J	6.701 J	40.18 J	33.35 J	21.497 J	23.509 J	11.2 U	47.066 J	13.959 J

Appendix E. Analytical Results - Marine Water Column

Table E-1. Summary of Marine Water Results for Conventionals and Metals.

Non-detect results were assigned the method detection limit (MDL) value. POC and DOC samples were not collected in July 2009.

July 2009:

Parameter	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
Conventional Parameters (mg/L)														
TSS	1.9	1.5	2.2	1.7	1.6	1.6	1.6	2.0	2.6	3.5	1.4	1.4	1.6	1.4
POC	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
DOC	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Metals (µg/L)														
Arsenic, total	1.30	1.37	1.52	1.49	1.39	1.52	1.46	1.54	1.34	1.46	1.34	1.41	1.41	1.41
Arsenic, dissolved	1.34	1.47	1.48	1.50	1.35	1.61	1.42	1.56	1.32	1.54	1.34	1.46	1.35	1.34
Cadmium, total	0.072	0.076	0.091	0.091	0.087	0.098	0.090	0.097	0.079	0.085	0.076	0.080	0.077	0.076
Cadmium, dissolved	0.067	0.068	0.089	0.091	0.078	0.102	0.079	0.098	0.068	0.086	0.072	0.081	0.068	0.073
Copper, total	0.48	1.37	0.29	0.28	0.37	0.21	0.25	0.25	0.44	0.49	0.39	0.37	0.44	0.41
Copper, dissolved	0.45	0.51	0.22	0.26	0.25	0.20	0.27	0.23	0.37	0.41	0.35	0.34	0.39	0.37
Lead, total	0.129	0.177	0.091	0.230	0.052	0.109	0.025 J	0.116	0.061	0.114	0.049 J	0.088	0.039 J	0.050
Lead, dissolved	0.119	0.064	0.056	0.153	0.060	0.056	0.050	0.131	0.043 J	0.033 J	0.028 J	0.035 J	0.084	0.090
Zinc, total	0.69 J	7.44	0.59 J	0.79 J	0.75 J	0.45 J	0.56 J	0.52 J	0.70 J	0.74 J	0.84 J	0.53 J	0.64 J	0.48 J
Zinc, dissolved	1.25	2.30	0.70 J	0.72 J	0.36 J	0.51 J	0.36 J	0.63 J	1.78	0.69 J	0.62 J	0.50 J	0.41 J	0.68 J

October 2009:

Parameter	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
Conventional Parameters (mg/L)														
TSS	1.2	1.1	1.3	1.2	1.1	1.2	1.1	1.0	5.5	1.2	0.9	1.7	0.9	0.8
POC	0.216	0.093	0.08	0.049	0.058	0.068	0.051	0.039	1.78	0.061	0.123	0.086	0.184	0.114
DOC	0.874	0.756	0.805	0.611	0.802	0.625	0.697	0.716	0.969	0.968	0.773	0.755	0.844	0.831
Metals (µg/L)														
Arsenic, total	1.22	1.47	1.31	1.46	1.31	1.44	1.33	1.36	1.45	1.47	1.40	1.40	1.28	1.16
Arsenic, dissolved	1.26	1.40	1.38	1.44	1.36	1.49	1.36	1.43	1.37	1.42	1.38	1.46	1.26	1.29
Cadmium, total	0.099	0.092	0.089	0.096	0.089	0.105	0.082	0.092	0.087	0.081	0.081	0.081	0.076	0.059
Cadmium, dissolved	0.076	0.077	0.083	0.111	0.081	0.105	0.087	0.096	0.074	0.079	0.074	0.081	0.069	0.074
Copper, total	0.35	0.34	0.20	0.19 J	0.25	0.63	0.24	0.24	0.38	0.35	0.35	0.34	0.38	0.26
Copper, dissolved	0.29	0.31	0.17 J	0.16 J	0.22	0.19 J	0.21	0.23	0.33	0.33	0.28	0.28	0.30	0.32
Lead, total	0.015 J	0.046 J	0.035 UJ	0.035 UJ	0.042 UJ	0.070 J	0.058 J	0.108 J	0.098	0.095	0.090	0.143	0.025 UJ	0.024 UJ
Lead, dissolved	0.013 J	0.018 J	0.030 UJ	0.042 UJ	0.045 J	0.057 J	0.058 J	0.068 J	0.235	0.133	0.078	0.048 J	0.039 UJ	0.045 J
Zinc, total	0.52 J	0.91 J	0.41 J	0.53 J	0.45 J	0.64 J	0.47 J	0.88 J	0.69 J	0.58 J	0.86 J	0.79 J	0.69 J	0.53 J
Zinc, dissolved	0.38 UJ	0.70 J	0.45 J	0.43 J	0.58 J	0.47 J	0.71 J	0.66 J	1.42 J	1.06 J	0.46 UJ	0.69 J	0.73 J	0.36 J

Table E-1, continued. Summary of Marine Water Results for Conventionals and Metals.

Non-detect results were assigned the method detection limit (MDL) value.

January 2010:

Parameter	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
Conventional Parameters (mg/L)														
TSS	1.3	1.1	2.2	2.3	2.3	6.0	1.9	1.6	0.8	2.0	1.6	1.4	1.3	1.6
POC	0.072	0.031	0.051	0.07	0.046	0.108	0.037	0.041	0.071	0.048	0.028	0.034	0.05	0.047
DOC	0.705	0.712	0.691	0.646	0.705	0.667	0.697	0.702	0.771	0.808	0.754	0.724	0.811	0.786
Metals (µg/L)														
Arsenic, total	1.46	1.50	1.52	1.50	1.36	1.56	1.39	1.34	1.53	1.54	1.39	1.41	1.49	1.41
Arsenic, dissolved	1.44	1.70	1.42	1.42	1.38	1.43	1.31	1.37	1.44	1.50	1.48	1.43	1.35	1.45
Cadmium, total	0.082	0.088	0.080	0.087	0.087	0.092	0.082	0.080	0.082	0.112	0.077	0.089	0.069	0.074
Cadmium, dissolved	0.086	0.079	0.095	0.093	0.089	0.081	0.091	0.081	0.080	0.090	0.079	0.084	0.081	0.072
Copper, total	0.38	0.40	0.38	0.45	0.31	0.41	0.72	0.38	0.48	0.51	0.40	1.03	0.42	0.44
Copper, dissolved	0.35	0.33	0.24	0.24	0.26	0.27	0.28	0.27	0.41	0.43	0.36	0.37	0.39	0.38
Lead, total	0.189	0.035 J	0.049 J	0.152	0.036 J	0.093	0.043 J	0.052	0.033 J	0.109	0.031 J	0.206	0.031 J	0.042 J
Lead, dissolved	0.010 J	0.019 J	0.016 J	0.056	0.025 J	0.033 J	0.030 J	0.050 J	0.045 J	0.063	0.007 J	0.012 J	0.006 J	0.007 J
Zinc, total	0.62 J	0.55 J	0.57 J	0.68 J	0.56 J	1.44	0.99	1.07	0.88 J	1.05 J	0.71 J	1.04 J	0.73 J	0.77 J
Zinc, dissolved	0.54 J	0.54 J	0.40 UJ	0.41 J	0.46 J	0.73	0.65	0.43 J	0.81 J	0.76 J	0.75 J	0.59 J	0.59 J	0.69 J

Table E-2. July 2009 Chlorinated Pesticides Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4'-DDE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4'-DDT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	0.20 U	0.18	0.20 U	0.17	0.20 U	0.17	0.20 U	0.18	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18	0.20 U	0.17
4,4'-DDE	0.20 U	0.17	0.20 U	0.17	0.20 U	0.17	0.20 U	0.17	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18	0.20 U	0.17
4,4'-DDT	0.20 U	-	0.20 U	-	0.20 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-
Aldrin	0.20 U	0.062	0.20 U	0.06	0.20 U	0.06	0.20 U	0.062	0.20 U	0.06	0.21 U	0.065	0.21 U	0.064	0.20 U	0.061
Alpha-BHC	0.20 U	0.041	0.20 U	0.04	0.20 U	0.04	0.20 U	0.041	0.20 U	0.04	0.21 U	0.043	0.21 U	0.043	0.20 U	0.041
Beta-BHC	0.20 U	0.15	0.20 U	0.14	0.20 U	0.14	0.20 U	0.15	0.20 U	0.14	0.21 U	0.15	0.21 U	0.15	0.20 U	0.14
Chlorpyriphos	0.20 U	-	0.21 UJ	-	0.56 UJ	-	0.25 UJ	-	0.24 UJ	-	0.32 UJ	-	0.21 U	-	0.20 U	-
cis-Chlordane	0.20 U	0.092	0.20 U	0.089	0.20 U	0.089	0.20 U	0.092	0.20 U	0.089	0.21 U	0.096	0.21 U	0.095	0.20 U	0.09
Cis-Nonachlor	0.20 U	0.13	0.20 U	0.13	0.20 U	0.12	0.20 U	0.13	0.20 U	0.13	0.21 U	0.14	0.21 U	0.13	0.20 U	0.13
Dacthal (DCPA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDMU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delta-BHC	0.20 U	0.041	0.20 U	0.04	0.20 U	0.039	0.20 U	0.041	0.20 U	0.04	0.21 U	0.043	0.21 U	0.042	0.20 U	0.04
Dieldrin	0.51 U	0.21	0.50 U	0.2	0.49 U	0.2	0.51 U	0.21	0.50 U	0.2	0.53 U	0.21	0.53 U	0.21	0.50 U	0.2
Endosulfan I	0.20 U	0.092	0.20 U	0.09	0.20 U	0.089	0.20 U	0.092	0.20 U	0.09	0.21 U	0.096	0.21 U	0.095	0.20 U	0.091
Endosulfan II	0.20 U	0.075	0.20 U	0.074	0.20 U	0.073	0.20 U	0.075	0.31 UJ	0.074	0.21 U	0.079	0.25 UJ	0.078	0.20 U	0.074
Endosulfan Sulfate	0.20 U	0.16	0.20 U	0.16	0.20 U	0.16	0.20 U	0.16	0.20 U	0.16	0.21 U	0.17	0.21 U	0.17	0.20 U	0.16
Endrin	0.51 U	0.22	0.50 U	0.21	0.49 U	0.21	0.51 U	0.22	0.50 U	0.21	0.53 U	0.23	0.53 U	0.23	0.50 U	0.22
Endrin Aldehyde	0.20 U	0.15	0.20 U	0.15	0.20 U	0.15	0.20 U	0.15	0.20 U	0.15	0.21 U	0.16	0.21 U	0.16	0.20 U	0.15
Endrin Ketone	0.76 U	0.61	0.74 U	0.6	0.74 U	0.59	0.76 U	0.61	0.74 U	0.6	0.80 U	0.64	0.79 U	0.64	0.75 U	0.61
Gamma-BHC (Lindane)	13 UJ	0.26	2.6 UJ	0.05	2.9 UJ	0.049	3.7 UJ	0.051	2.8 UJ	0.05	3.0 UJ	0.054	3.3 UJ	0.053	2.8 UJ	0.05
Heptachlor	0.20 U	0.089	0.20 U	0.087	0.20 U	0.086	0.20 U	0.089	0.20 U	0.087	0.21 U	0.093	0.21 U	0.092	0.20 U	0.088
Heptachlor Epoxide	0.20 U	0.12	0.20 U	0.12	0.20 U	0.12	0.20 U	0.12	0.20 U	0.12	0.21 U	0.13	0.21 U	0.13	0.20 U	0.12
Hexachlorobenzene	0.20 U	-	0.20 U	-	0.20 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-
Methoxychlor	0.51 U	0.26	0.50 U	0.25	0.49 U	0.25	0.51 U	0.26	0.50 U	0.25	0.53 U	0.27	0.53 U	0.27	0.50 U	0.25
Mirex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxychlordane	0.20 U	0.074	0.20 U	0.072	0.20 U	0.072	0.20 U	0.074	0.20 U	0.072	0.21 U	0.078	0.21 U	0.077	0.20 U	0.073
Pentachloroanisole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxaphene	1.0 U	-	0.98 U	-	0.97 U	-	1.0 U	-	0.98 U	-	1.1 U	-	1.0 U	-	0.99 U	-
trans-Chlordane	0.20 U	0.15	0.20 U	0.15	0.20 U	0.14	0.20 U	0.15	0.20 U	0.15	0.21 U	0.16	0.21 U	0.16	0.20 U	0.15
Trans-Nonachlor	0.20 U	-	0.20 U	-	0.20 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-

Table E-3. July 2009 Chlorinated Pesticides Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	-	-	-	-	-	-	-	-	-	-	-	-
2,4'-DDE	-	-	-	-	-	-	-	-	-	-	-	-
2,4'-DDT	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	0.20 U	0.17	0.20 U	0.17	0.21 U	0.18	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18
4,4'-DDE	0.20 U	0.17	0.20 U	0.17	0.21 J	0.17	0.39	0.17	0.21 U	0.18	0.21	0.18
4,4'-DDT	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-
Aldrin	0.20 U	0.062	0.20 U	0.061	0.21 U	0.062	0.20 U	0.062	0.21 U	0.063	0.21 U	0.064
Alpha-BHC	0.20 U	0.041	0.20 U	0.041	0.21 U	0.041	0.20 U	0.041	0.21 U	0.042	0.21 U	0.042
Beta-BHC	0.20 U	0.15	0.20 U	0.14	0.21 U	0.15	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15
Chlorpyriphos	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-
cis-Chlordane	0.20 U	0.091	0.20 U	0.09	0.21 U	0.092	0.20 U	0.091	0.21 U	0.094	0.21 U	0.094
Cis-Nonachlor	0.20 U	0.13	0.20 U	0.13	0.21 U	0.13	0.20 U	0.13	0.21 U	0.13	0.21 U	0.13
Dacthal (DCPA)	-	-	-	-	-	-	-	-	-	-	-	-
DDMU	-	-	-	-	-	-	-	-	-	-	-	-
Delta-BHC	0.20 U	0.04	0.20 U	0.04	0.21 UJ	0.041	0.20 U	0.04	0.21 U	0.041	0.21 U	0.042
Dieldrin	0.51 U	0.2	0.50 U	0.2	0.51 U	0.21	0.51 U	0.2	0.52 U	0.21	0.52 U	0.21
Endosulfan I	0.20 U	0.092	0.20 U	0.091	0.21 U	0.093	0.20 U	0.092	0.21 U	0.094	0.21 U	0.094
Endosulfan II	0.20 U	0.075	0.20 U	0.074	0.21 U	0.076	0.20 U	0.075	0.21 U	0.077	0.21 U	0.077
Endosulfan Sulfate	0.20 U	0.16	0.20 U	0.16	0.21 U	0.16	0.20 U	0.16	0.21 U	0.17	0.21 U	0.17
Endrin	0.51 U	0.22	0.50 U	0.22	0.51 U	0.22	0.51 U	0.22	0.52 U	0.22	0.52 U	0.22
Endrin Aldehyde	0.20 U	0.15	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15	0.21 U	0.16	0.21 U	0.16
Endrin Ketone	0.76 U	0.61	0.75 U	0.61	0.77 U	0.62	0.76 U	0.61	0.78 U	0.63	0.78 U	0.63
Gamma-BHC (Lindane)	9.4 UJ	0.051	3.0 UJ	0.05	2.8 UJ	0.051	1.8 UJ	0.051	4.2 UJ	0.052	6.4 UJ	0.052
Heptachlor	0.20 U	0.089	0.20 U	0.088	0.21 U	0.09	0.20 U	0.089	0.21 U	0.091	0.21 U	0.091
Heptachlor Epoxide	0.20 U	0.12	0.20 U	0.12	0.21 U	0.13	0.20 U	0.12	0.21 U	0.13	0.21 U	0.13
Hexachlorobenzene	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-
Methoxychlor	0.51 U	0.26	0.50 U	0.25	0.51 U	0.26	0.51 U	0.26	0.52 U	0.26	0.52 U	0.26
Mirex	-	-	-	-	-	-	-	-	-	-	-	-
Oxychlordane	0.20 U	0.074	0.20 U	0.073	0.21 U	0.075	0.20 U	0.074	0.21 U	0.076	0.21 U	0.076
Pentachloroanisole	-	-	-	-	-	-	-	-	-	-	-	-
Toxaphene	1.0 U	-	0.99 U	-	1.0 U	-	1.0 U	-	1.0 U	-	1.0 U	-
trans-Chlordane	0.20 U	0.15	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15
Trans-Nonachlor	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-

Table E-4. September 2009 Chlorinated Pesticides Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
2,4'-DDE	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
2,4'-DDT	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
4,4'-DDD	0.21 U	0.18	0.21 U	0.18	0.23 U	0.2	0.20 U	0.18	0.21 U	0.18	0.20 U	0.17	0.20 U	0.17	0.20 U	0.17
4,4'-DDE	0.21 U	0.17	0.21 U	0.17	0.23 U	0.19	0.20 U	0.17	0.21 U	0.17	0.20 U	0.17	0.20 U	0.17	0.20 U	0.17
4,4'-DDT	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
Aldrin	0.21 UJ	0.062	0.21 UJ	0.062	0.23 UJ	0.069	0.20 UJ	0.062	0.21 UJ	0.062	0.20 UJ	0.062	0.20 UJ	0.061	0.20 UJ	0.061
Alpha-BHC	0.21 U	0.041	0.21 U	0.041	0.23 U	0.046	0.21	0.041	0.21 U	0.041	0.20 U	0.041	0.20 U	0.041	0.20 U	0.041
Beta-BHC	0.21 U	0.15	0.21 U	0.15	0.23 U	0.16	0.32	0.15	0.21 U	0.15	0.20 U	0.15	0.20 U	0.14	0.20 U	0.14
Chlorpyriphos	14 UJ	-	0.21 U	-	0.23 U	-	1.9 UJ	-	1.1 UJ	-	3.0 UJ	-	0.93 UJ	-	1.8 UJ	-
cis-Chlordane	0.21 U	0.092	0.21 U	0.092	0.23 U	0.1	0.20 U	0.092	0.21 U	0.092	0.20 U	0.091	0.20 U	0.09	0.20 U	0.09
Cis-Nonachlor	0.21 U	0.13	0.21 U	0.13	0.23 U	0.14	0.20 U	0.13	0.21 U	0.13	0.20 U	0.13	0.20 U	0.13	0.20 U	0.13
Dacthal (DCPA)	0.21 U	-	0.21 U	-	0.23 U	-	0.24 UJ	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
DDMU	0.21 U	-	0.21 U	-	0.23 U	-	0.38 UJ	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
Delta-BHC	0.21 U	0.041	0.21 U	0.041	0.23 U	0.045	0.25 J	0.041	0.21 U	0.041	0.20 U	0.04	0.20 U	0.04	0.20 U	0.04
Dieldrin	0.51 U	0.21	0.51 U	0.21	0.57 U	0.23	0.51 U	0.21	0.51 U	0.21	0.51 U	0.2	0.50 U	0.2	0.50 U	0.2
Endosulfan I	0.21 U	0.093	0.21 U	0.093	0.23 U	0.1	0.20 U	0.092	0.21 U	0.093	0.20 U	0.092	0.20 U	0.091	0.20 U	0.091
Endosulfan II	0.21 UJ	0.076	0.21 UJ	0.076	0.31 UJ	0.084	0.20 UJ	0.075	0.21 UJ	0.076	0.20 UJ	0.075	0.20 UJ	0.074	0.20 UJ	0.074
Endosulfan Sulfate	0.21 UJ	0.16	0.21 UJ	0.16	0.23 UJ	0.18	0.20 UJ	0.16	0.21 UJ	0.16	0.20 UJ	0.16	0.20 UJ	0.16	0.20 UJ	0.16
Endrin	0.51 UJ	0.22	0.51 UJ	0.22	0.57 UJ	0.24	0.51 UJ	0.22	0.51 UJ	0.22	0.51 UJ	0.22	0.50 UJ	0.22	0.50 UJ	0.22
Endrin Aldehyde	0.38 UJ	0.15	0.49 UJ	0.15	0.68 UJ	0.17	0.37 UJ	0.15	0.40 UJ	0.15	0.32 UJ	0.15	0.46 UJ	0.15	0.42 UJ	0.15
Endrin Ketone	0.77 U	0.62	0.77 U	0.62	0.85 U	0.69	0.76 U	0.61	0.77 U	0.62	0.76 U	0.61	0.75 U	0.61	0.75 U	0.61
Gamma-BHC (Lindane)	2.4 UJ	0.051	1.3 UJ	0.051	2.5 UJ	0.057	2.4 UJ	0.051	1.9 UJ	0.051	2.0 UJ	0.051	3.5 UJ	0.05	3.3 UJ	0.05
Heptachlor	0.21 U	0.09	0.21 U	0.09	0.23 U	0.1	0.20 U	0.089	0.21 U	0.09	0.20 U	0.089	0.20 U	0.088	0.20 U	0.088
Heptachlor Epoxide	0.21 U	0.13	0.21 U	0.13	0.23 U	0.14	0.20 U	0.12	0.21 U	0.13	0.20 U	0.12	0.20 U	0.12	0.20 U	0.12
Hexachlorobenzene	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
Methoxychlor	0.51 UJ	0.26	1.1 UJ	0.26	0.57 UJ	0.29	0.51 UJ	0.26	0.51 UJ	0.26	0.51 UJ	0.26	0.50 UJ	0.25	0.50 UJ	0.25
Mirex	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
Oxychlordane	0.21 U	0.075	0.21 U	0.075	0.23 U	0.083	0.20 U	0.074	0.21 U	0.075	0.20 U	0.074	0.20 U	0.073	0.20 U	0.073
Pentachloroanisole	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-
Toxaphene	10 U	-	10 U	-	11 U	-	10 U	-	10 U	-	10 U	-	9.9 U	-	9.9 U	-
trans-Chlordane	0.21 U	0.15	0.21 U	0.15	0.23 U	0.17	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15	0.20 U	0.15	0.20 U	0.15
Trans-Nonachlor	0.21 U	-	0.21 U	-	0.23 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.20 U	-

Table E-5. September 2009 Chlorinated Pesticides Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
2,4'-DDE	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
2,4'-DDT	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
4,4'-DDD	0.21 U	0.18	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18	0.21 U	0.18	0.20 U	0.17
4,4'-DDE	0.21 U	0.18	0.20 U	0.17	0.21 U	0.18	0.21 U	0.17	0.21 U	0.18	0.20 U	0.17
4,4'-DDT	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
Aldrin	0.21 U	0.063	0.20 U	0.062	0.21 U	0.063	0.21 U	0.062	0.21 U	0.064	0.20 U	0.062
Alpha-BHC	0.21 U	0.042	0.20 U	0.041	0.21 U	0.042	0.21 U	0.041	0.21 U	0.042	0.20 U	0.041
Beta-BHC	0.21 U	0.15	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15	0.21 U	0.15	0.20 U	0.15
Chlorpyriphos	0.53 UJ	-	0.20 U	-	0.76 UJ	-	0.36 UJ	-	0.64 UJ	-	0.54 UJ	-
cis-Chlordane	0.21 U	0.093	0.20 U	0.091	0.21 U	0.094	0.21 U	0.092	0.21 U	0.094	0.20 U	0.091
Cis-Nonachlor	0.21 U	0.13	0.20 U	0.13	0.21 U	0.13	0.21 U	0.13	0.21 U	0.13	0.20 U	0.13
Dacthal (DCPA)	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
DDMU	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
Delta-BHC	0.21 U	0.041	0.20 U	0.04	0.21 U	0.041	0.21 U	0.041	0.21 U	0.042	0.20 U	0.04
Dieldrin	0.52 U	0.21	0.51 U	0.2	0.52 U	0.21	0.51 U	0.21	0.52 U	0.21	0.51 U	0.2
Endosulfan I	0.21 U	0.093	0.20 U	0.092	0.21 U	0.094	0.21 U	0.093	0.21 U	0.094	0.20 U	0.092
Endosulfan II	0.30 UJ	0.077	0.21 UJ	0.075	0.21 UJ	0.077	0.23 UJ	0.076	0.22 UJ	0.077	0.29 UJ	0.075
Endosulfan Sulfate	0.21 UJ	0.17	0.20 UJ	0.16	0.21 UJ	0.17	0.26 UJ	0.16	0.21 UJ	0.17	0.20 UJ	0.16
Endrin	0.52 UJ	0.22	0.51 UJ	0.22	0.52 UJ	0.22	0.51 UJ	0.22	0.52 UJ	0.22	0.51 UJ	0.22
Endrin Aldehyde	0.62 UJ	0.16	0.52 UJ	0.15	0.66 UJ	0.16	0.59 UJ	0.15	0.52 UJ	0.16	0.42 UJ	0.15
Endrin Ketone	0.77 U	0.62	0.76 U	0.61	0.78 U	0.63	0.77 U	0.62	0.78 U	0.63	0.76 U	0.61
Gamma-BHC (Lindane)	3.6 UJ	0.052	2.2 UJ	0.051	3.6 UJ	0.052	4.2 UJ	0.051	1.5 UJ	0.052	4.0 UJ	0.051
Heptachlor	0.21 U	0.09	0.20 U	0.089	0.21 U	0.091	0.21 U	0.09	0.21 U	0.091	0.20 U	0.089
Heptachlor Epoxide	0.21 U	0.13	0.20 U	0.12	0.21 U	0.13	0.21 U	0.13	0.21 U	0.13	0.20 U	0.12
Hexachlorobenzene	0.21 U	-	0.20 U	-	0.21	-	0.21 U	-	0.21 U	-	0.20 U	-
Methoxychlor	0.52 UJ	0.26	0.51 UJ	0.26	0.52 UJ	0.26	0.51 UJ	0.26	0.52 UJ	0.26	0.51 UJ	0.26
Mirex	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
Oxychlordane	0.21 U	0.075	0.20 U	0.074	0.21 U	0.076	0.21 U	0.075	0.21 U	0.076	0.20 U	0.074
Pentachloroanisole	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-
Toxaphene	10 U	-	10 U	-	10 U	-	10 U	-	10 U	-	10 U	-
trans-Chlordane	0.21 U	0.15	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15	0.21 U	0.15	0.20 U	0.15
Trans-Nonachlor	0.21 U	-	0.20 U	-	0.21 U	-	0.21 U	-	0.21 U	-	0.20 U	-

Table E-6. January 2010 Chlorinated Pesticides Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
2,4'-DDE	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
2,4'-DDT	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
4,4'-DDD	0.20 U	0.17	0.21 U	0.18	0.20 U	0.17	0.20 U	0.17	0.21 U	0.18	0.20 U	0.18	0.21 U	0.18	0.20 U	0.17
4,4'-DDE	0.20 U	0.17	0.21 U	0.17	0.20 U	0.17	0.20 UJ	0.17	0.21 U	0.17	0.20 U	0.17	0.21 U	0.18	0.20 U	0.17
4,4'-DDT	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
Aldrin	0.20 UJ	0.062	0.21 UJ	0.063	0.20 U	0.062	0.20 U	0.06	0.21 UJ	0.062	0.20 UJ	0.062	0.21 UJ	0.064	0.20 UJ	0.06
Alpha-BHC	0.20 UJ	0.041	0.21 UJ	0.042	0.20 U	0.041	0.20 U	0.04	0.21 UJ	0.041	0.20 UJ	0.041	0.21 UJ	0.042	0.20 UJ	0.04
Beta-BHC	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15	0.20 U	0.14	0.21 U	0.15	0.20 U	0.15	0.21 U	0.15	0.20 U	0.14
Chlorpyriphos	0.20 U	-	0.21 U	-	0.20 U	-	0.22 UJ	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
cis-Chlordane	0.20 U	0.091	0.21 U	0.093	0.20 U	0.091	0.20 U	0.089	0.21 U	0.092	0.20 U	0.092	0.21 U	0.094	0.20 U	0.089
Cis-Nonachlor	0.20 U	0.13	0.21 U	0.13	0.20 U	0.13	0.20 U	0.12	0.21 U	0.13	0.20 U	0.13	0.21 U	0.13	0.20 U	0.13
Dacthal (DCPA)	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
DDMU	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
Delta-BHC	0.20 U	0.04	0.21 U	0.041	0.20 U	0.04	0.20 U	0.039	0.21 U	0.041	0.20 U	0.041	0.21 U	0.042	0.20 U	0.039
Dieldrin	0.51 U	0.2	0.51 U	0.21	0.51 U	0.2	0.49 U	0.2	0.51 U	0.21	0.51 U	0.21	0.52 U	0.21	0.49 U	0.2
Endosulfan I	0.20 U	0.092	0.21 U	0.093	0.20 UJ	0.092	0.20 UJ	0.089	0.21 U	0.093	0.20 U	0.092	0.21 U	0.094	0.20 U	0.089
Endosulfan II	0.20 U	0.075	0.21 U	0.076	0.20 U	0.075	0.20 U	0.073	0.21 U	0.076	0.20 U	0.075	0.21 U	0.077	0.20 U	0.073
Endosulfan Sulfate	0.20 U	0.16	0.21 U	0.17	0.20 U	0.16	0.20 U	0.16	0.21 U	0.16	0.20 U	0.16	0.21 U	0.17	0.20 U	0.16
Endrin	0.51 U	0.22	0.51 U	0.22	0.51 U	0.22	0.49 U	0.21	0.51 U	0.22	0.51 U	0.22	0.52 U	0.22	0.49 U	0.21
Endrin Aldehyde	0.20 U	0.15	0.21 U	0.16	0.20 U	0.15	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15	0.21 U	0.16	0.20 U	0.15
Endrin Ketone	0.76 U	0.61	0.77 U	0.62	0.76 U	0.61	0.74 U	0.59	0.77 U	0.62	0.76 U	0.61	0.78 U	0.63	0.74 U	0.6
Gamma-BHC (Lindane)	0.43 UJ	0.051	0.21 UJ	0.052	0.40 UJ	0.051	0.31 UJ	0.049	0.21 U	0.051	0.20 U	0.051	0.21 U	0.052	0.20 U	0.05
Heptachlor	0.20 U	0.089	0.21 U	0.09	0.20 U	0.089	0.20 U	0.086	0.21 U	0.09	0.20 U	0.089	0.21 U	0.091	0.20 U	0.086
Heptachlor Epoxide	0.20 U	0.12	0.21 U	0.13	0.20 UJ	0.12	0.20 UJ	0.12	0.21 U	0.13	0.20 U	0.12	0.21 U	0.13	0.20 U	0.12
Hexachlorobenzene	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
Methoxychlor	0.51 U	0.26	0.51 U	0.26	0.51 U	0.26	0.49 UJ	0.25	0.51 U	0.26	0.51 U	0.26	0.52 U	0.26	0.49 U	0.25
Mirex	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
Oxychlordane	0.20 U	0.074	0.21 U	0.075	0.20 U	0.074	0.20 U	0.072	0.21 U	0.075	0.20 U	0.074	0.21 U	0.076	0.20 U	0.072
Pentachloroanisole	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-
Toxaphene	10 U	-	10 U	-	10 U	-	9.7 U	-	10 U	-	10 U	-	10 U	-	9.8 U	-
trans-Chlordane	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15	0.20 U	0.14	0.21 U	0.15	0.20 U	0.15	0.21 U	0.15	0.20 U	0.15
Trans-Nonachlor	0.20 U	-	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.20 U	-	0.21 U	-	0.20 U	-

Table E-7. January 2010 Chlorinated Pesticides Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.20 UJ	-
2,4'-DDE	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.25 UJ	-	0.21 UJ	-	0.20 UJ	-
2,4'-DDT	0.21 UJ	-	0.21 UJ	-	0.21 UJ	-	0.24 UJ	-	0.21 UJ	-	0.25 UJ	-
4,4'-DDD	0.21 UJ	0.18	0.21 U	0.18	0.21 UJ	0.18	0.21 U	0.18	0.21 UJ	0.18	0.20 UJ	0.17
4,4'-DDE	0.21 UJ	0.17	0.21 UJ	0.18	0.21 UJ	0.18	0.21 UJ	0.18	0.21 UJ	0.17	0.20 UJ	0.17
4,4'-DDT	0.21 UJ	-	0.21 UJ	-	0.21 UJ	-	0.21 UJ	-	0.33 UJ	-	0.20 UJ	-
Aldrin	0.21 UJ	0.062	0.28 UJ	0.063	0.23 UJ	0.064	0.27 UJ	0.064	0.23 UJ	0.062	0.20 UJ	0.061
Alpha-BHC	0.21 UJ	0.041	0.21 U	0.042	0.21 UJ	0.042	0.21 U	0.042	0.21 UJ	0.041	0.20 UJ	0.041
Beta-BHC	0.21 UJ	0.15	0.21 U	0.15	0.21 UJ	0.15	0.21 U	0.15	0.21 UJ	0.15	0.20 UJ	0.14
Chlorpyriphos	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.20 UJ	-
cis-Chlordane	0.21 UJ	0.092	0.21 U	0.094	0.21 UJ	0.094	0.21 U	0.094	0.21 UJ	0.092	0.20 UJ	0.09
Cis-Nonachlor	0.21 UJ	0.13	0.21 U	0.13	0.21 UJ	0.13	0.21 U	0.13	0.21 UJ	0.13	0.20 UJ	0.13
Dacthal (DCPA)	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.20 UJ	-
DDMU	0.36 UJ	-	0.62 UJ	-	0.21 UJ	-	0.59 UJ	-	0.21 UJ	-	0.20 UJ	-
Delta-BHC	0.21 UJ	0.041	0.21 UJ	0.041	0.21 UJ	0.042	0.21 UJ	0.042	0.21 UJ	0.041	0.20 UJ	0.04
Dieldrin	0.51 UJ	0.21	0.52 UJ	0.21	0.52 UJ	0.21	0.52 UJ	0.21	0.51 UJ	0.21	0.50 UJ	0.2
Endosulfan I	0.21 UJ	0.093	0.21 UJ	0.094	0.21 UJ	0.094	0.21 UJ	0.094	0.21 UJ	0.093	0.20 UJ	0.091
Endosulfan II	0.21 UJ	0.076	0.21 UJ	0.077	0.21 UJ	0.077	0.21 UJ	0.077	0.21 UJ	0.076	0.20 UJ	0.074
Endosulfan Sulfate	0.21 UJ	0.16	0.21 UJ	0.17	0.21 UJ	0.17	0.22 UJ	0.17	0.21 UJ	0.16	0.20 UJ	0.16
Endrin	0.51 UJ	0.22	0.52 UJ	0.22	0.52 UJ	0.22	0.52 UJ	0.22	0.51 UJ	0.22	0.50 UJ	0.22
Endrin Aldehyde	0.21 UJ	0.15	0.21 U	0.16	0.21 UJ	0.16	0.21 U	0.16	0.21 UJ	0.15	0.20 UJ	0.15
Endrin Ketone	0.77 UJ	0.62	0.78 U	0.63	0.78 UJ	0.63	0.78 U	0.63	0.77 UJ	0.62	0.75 UJ	0.61
Gamma-BHC (Lindane)	0.39 UJ	0.051	0.29 UJ	0.052	0.57 UJ	0.052	0.47 UJ	0.052	0.33 UJ	0.051	0.33 UJ	0.05
Heptachlor	0.21 UJ	0.09	0.21 UJ	0.091	0.21 UJ	0.091	0.21 UJ	0.091	0.21 UJ	0.09	0.20 UJ	0.088
Heptachlor Epoxide	0.21 UJ	0.13	0.21 UJ	0.13	0.21 UJ	0.13	0.21 UJ	0.13	0.21 UJ	0.13	0.20 UJ	0.12
Hexachlorobenzene	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.20 UJ	-
Methoxychlor	0.51 UJ	0.26	0.52 UJ	0.26	0.52 UJ	0.26	0.52 UJ	0.26	0.51 UJ	0.26	0.50 UJ	0.25
Mirex	0.49 UJ	-	0.53 UJ	-	0.51 UJ	-	0.51 UJ	-	0.49 UJ	-	0.32 UJ	-
Oxychlordane	0.21 UJ	0.075	0.21 U	0.076	0.21 UJ	0.076	0.21 U	0.076	0.21 UJ	0.075	0.20 UJ	0.073
Pentachloroanisole	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.20 UJ	-
Toxaphene	10 UJ	-	10 U	-	10 UJ	-	10 U	-	10 UJ	-	9.9 UJ	-
trans-Chlordane	0.79 UJ	0.15	1.1 UJ	0.15	1.1 UJ	0.15	1.4 UJ	0.15	0.77 UJ	0.15	0.75 UJ	0.15
Trans-Nonachlor	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.21 U	-	0.21 UJ	-	0.20 UJ	-

Table E-8. July 2009 PAH Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.010 U	0.011	0.0099 U	0.010	0.0098 U	0.010	0.010 U	0.011	0.010 U	0.010	0.010 UJ	0.010	0.0099 U	0.010	0.010 U	0.010
2-Chloronaphthalene	0.010 U	0.0096	0.0099 U	0.0092	0.0098 U	0.0091	0.010 U	0.0097	0.010 U	0.0095	0.010 UJ	0.0095	0.0099 U	0.0092	0.010 U	0.0095
2-Methylnaphthalene	0.010 U	0.0089	0.0099 U	0.0085	0.0098 U	0.0084	0.010 U	0.0090	0.010 U	0.0088	0.010 UJ	0.0088	0.0099 U	0.0085	0.010 U	0.0088
Acenaphthene	0.010 U	0.0088	0.0099 U	0.0085	0.0098 U	0.0084	0.010 U	0.0089	0.010 U	0.0088	0.010 U	0.0088	0.0099 U	0.0085	0.010 U	0.0088
Acenaphthylene	0.010 U	0.0087	0.0099 U	0.0084	0.0098 U	0.0083	0.010 U	0.0088	0.010 U	0.0086	0.010 U	0.0086	0.0099 U	0.0084	0.010 U	0.0086
Anthracene	0.010 U	0.0052	0.0099 U	0.0050	0.0098 U	0.0050	0.010 U	0.0053	0.010 U	0.0052	0.010 U	0.0052	0.0099 U	0.0050	0.010 U	0.0052
Benzo(a)anthracene	0.010 U	0.0009	0.0099 U	0.0009	0.0098 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.020 U	0.0009	0.020 U	0.0009
Benzo(a)pyrene	0.010 UJ	0.0017	0.0099 UJ	0.0016	0.0098 UJ	0.0016	0.010 UJ	0.0017	0.010 UJ	0.0017	0.010 UJ	0.0017	0.020 UJ	0.0016	0.020 UJ	0.0017
Benzo(b)fluoranthene	0.010 U	0.0011	0.0099 U	0.0010	0.0098 UJ	0.0010	0.010 UJ	0.0011	0.010 UJ	0.0010	0.010 UJ	0.0010	0.020 UJ	0.0010	0.020 UJ	0.0010
Benzo(ghi)perylene	0.010 UJ	0.0016	0.0099 UJ	0.0016	0.0098 UJ	0.0016	0.010 UJ	0.0017	0.010 UJ	0.0016	0.010 UJ	0.0016	0.020 U	0.0016	0.020 U	0.0016
Benzo(k)fluoranthene	0.010 U	0.0005	0.0099 UJ	0.0005	0.0098 U	0.0005	0.010 U	0.0006	0.010 U	0.0005	0.010 U	0.0005	0.020 UJ	0.0005	0.020 UJ	0.0005
Carbazole	0.010 U	0.0015	0.0099 U	0.0015	0.0098 U	0.0014	0.010 U	0.0015	0.010 U	0.0015	0.010 U	0.0015	0.0099 U	0.0015	0.010 U	0.0015
Chrysene	0.010 U	0.0009	0.0099 U	0.0008	0.0098 U	0.0008	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.020 U	0.0008	0.020 U	0.0009
Dibenzo(a,h)anthracene	0.010 UJ	0.0014	0.0099 UJ	0.0014	0.0098 UJ	0.0014	0.010 UJ	0.0015	0.010 UJ	0.0014	0.010 UJ	0.0014	0.020 UJ	0.0014	0.020 UJ	0.0014
Dibenzofuran	0.010 U	0.0081	0.0099 U	0.0078	0.0098 U	0.0077	0.010 U	0.0082	0.010 U	0.0081	0.010 U	0.0081	0.0099 U	0.0078	0.010 U	0.0081
Fluoranthene	0.010 U	0.0016	0.0099 U	0.0015	0.0098 U	0.0015	0.010 U	0.0016	0.010 U	0.0016	0.010 U	0.0016	0.0099 U	0.0015	0.010 U	0.0016
Fluorene	0.010 U	0.0076	0.0099 U	0.0073	0.0098 U	0.0072	0.010 U	0.0077	0.010 U	0.0076	0.010 U	0.0076	0.0099 U	0.0073	0.010 U	0.0076
Indeno(1,2,3-cd)pyrene	0.010 U	0.0020	0.0099 U	0.0020	0.0098 U	0.0019	0.010 U	0.0021	0.010 U	0.0020	0.010 UJ	0.0020	0.020 UJ	0.0020	0.020 U	0.0020
Naphthalene	0.010 U	0.032	0.0099 U	0.031	0.0098 U	0.031	0.010 U	0.033	0.010 U	0.032	0.010 UJ	0.032	0.0099 U	0.031	0.010 U	0.032
Phenanthrene	0.010 U	0.0063	0.0099 U	0.0060	0.0098 U	0.0060	0.010 U	0.0063	0.010 U	0.0062	0.010 U	0.0062	0.0099 U	0.0060	0.010 U	0.0062
Pyrene	0.010 U	0.0018	0.0099 U	0.0018	0.0098 U	0.0017	0.010 U	0.0019	0.010 U	0.0018	0.010 U	0.0018	0.020 U	0.0018	0.020 U	0.0018
Retene	0.010 U	0.0010	0.0099 U	0.0009	0.0098 U	0.0009	0.010 U	0.0010	0.010 U	0.0010	0.010 U	0.0010	0.020 U	0.0009	0.020 U	0.0010

Total PAHs																
…ND at ½ RL	0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.16 U		0.16 U	
…ND at MDL	0.12 U		0.12 U		0.12 U		0.12 U		0.12 U		0.12 U		0.12 U		0.12 U	

Total cPAHs*																
…ND at ½ RL	0.035 U		0.035 U		0.034 U		0.035 U		0.035 U		0.035 U		0.070 U		0.070 U	
…ND at MDL	0.0085 U		0.0082 U		0.0081 U		0.0088 U		0.0084 U		0.0084 U		0.0082 U		0.0084 U	

* The carcinogenic PAH compounds (cPAHs) are: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

Table E-9. July 2009 PAH Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.010 U	0.010	0.010 U	0.010	0.010 U	0.010	0.010 U	0.010	0.010 U	0.010	0.010 U	0.011
2-Chloronaphthalene	0.010 U	0.0093	0.010 U	0.0095	0.010 U	0.0093	0.010 U	0.0094	0.010 U	0.0095	0.010 U	0.0096
2-Methylnaphthalene	0.010 U	0.0086	0.010 U	0.0088	0.010 U	0.0086	0.010 U	0.0087	0.010 U	0.0088	0.010 U	0.0089
Acenaphthene	0.010 U	0.0086	0.010 U	0.0088	0.010 U	0.0086	0.010 U	0.0087	0.010 U	0.0087	0.010 U	0.0089
Acenaphthylene	0.010 U	0.0085	0.010 U	0.0086	0.010 U	0.0084	0.010 U	0.0085	0.010 U	0.0086	0.010 U	0.0087
Anthracene	0.010 U	0.0051	0.010 U	0.0052	0.010 U	0.0051	0.010 U	0.0051	0.010 U	0.0052	0.010 U	0.0053
Benzo(a)anthracene	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009
Benzo(a)pyrene	0.010 UJ	0.0016	0.010 UJ	0.0017	0.010 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0017	0.010 UJ	0.0017
Benzo(b)fluoranthene	0.010 UJ	0.0010	0.010 UJ	0.0010	0.010 UJ	0.0010	0.010 UJ	0.0010	0.010 UJ	0.0010	0.010 UJ	0.0011
Benzo(ghi)perylene	0.010 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0017
Benzo(k)fluoranthene	0.010 U	0.0005	0.010 U	0.0005	0.010 U	0.0005	0.010 U	0.0005	0.010 U	0.0005	0.010 U	0.0005
Carbazole	0.010 U	0.0015	0.010 U	0.0015	0.010 U	0.0015	0.010 U	0.0015	0.010 U	0.0015	0.010 U	0.0015
Chrysene	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009
Dibenzo(a,h)anthracene	0.010 UJ	0.0014	0.010 UJ	0.0014	0.010 UJ	0.0014	0.010 UJ	0.0014	0.010 UJ	0.0014	0.010 UJ	0.0015
Dibenzofuran	0.010 U	0.0079	0.010 U	0.0081	0.010 U	0.0079	0.010 U	0.0079	0.010 U	0.0080	0.010 U	0.0081
Fluoranthene	0.010 U	0.0015	0.010 U	0.0016	0.010 U	0.0015	0.010 U	0.0016	0.010 U	0.0016	0.010 U	0.0016
Fluorene	0.010 U	0.0074	0.010 U	0.0076	0.010 U	0.0074	0.010 U	0.0075	0.010 U	0.0075	0.010 U	0.0077
Indeno(1,2,3-cd)pyrene	0.010 U	0.0020	0.010 U	0.0020	0.010 U	0.0020	0.010 U	0.0020	0.010 U	0.0020	0.010 U	0.0020
Naphthalene	0.010 U	0.032	0.010 U	0.032	0.010 U	0.031	0.010 U	0.032	0.010 U	0.032	0.010 U	0.033
Phenanthrene	0.010 U	0.0061	0.010 U	0.0062	0.010 U	0.0061	0.010 U	0.0061	0.010 U	0.0062	0.010 U	0.0063
Pyrene	0.010 U	0.0018	0.010 U	0.0018	0.010 U	0.0018	0.010 U	0.0018	0.010 U	0.0018	0.010 U	0.0018
Retene	0.010 U	0.0010	0.010 U	0.0010	0.010 U	0.0010	0.010 U	0.0010	0.010 U	0.0010	0.010 U	0.0010

Total PAHs												
…ND at ½ RL	0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.11 U	
…ND at MDL	0.12 U		0.12 U		0.12 U		0.12 U		0.12 U		0.12 U	

Total cPAHs												
…ND at ½ RL	0.035 U		0.035 U		0.035 U		0.035 U		0.035 U		0.035 U	
…ND at MDL	0.0083 U		0.0084 U		0.0083 U		0.0083 U		0.0084 U		0.0086 U	

Table E-10. September 2009 PAH Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.010 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.0099 U	0.0010	0.0099 U	0.0010	0.0099 U	0.0010	0.010 U	0.0010	0.010 U	0.0010
2-Chloronaphthalene	0.010 U	0.0093	0.010 U	0.0093	0.0098 U	0.0092	0.0099 U	0.0092	0.0099 U	0.0092	0.0099 U	0.0092	0.010 U	0.0096	0.010 U	0.0095
2-Methylnaphthalene	0.010 U	0.0086	0.010 U	0.0086	0.0098 U	0.0085	0.0099 U	0.0085	0.0099 U	0.0085	0.0099 U	0.0086	0.010 U	0.0089	0.010 U	0.0088
Acenaphthene	0.010 U	0.0086	0.010 U	0.0086	0.0098 U	0.0084	0.0099 U	0.0085	0.0099 U	0.0085	0.0099 U	0.0085	0.010 U	0.0089	0.010 U	0.0088
Acenaphthylene	0.010 UJ	0.0085	0.010 UJ	0.0084	0.0098 UJ	0.0083	0.0099 UJ	0.0084	0.0099 UJ	0.0084	0.0099 UJ	0.0084	0.010 UJ	0.0087	0.010 UJ	0.0086
Anthracene	0.010 U	0.0051	0.010 U	0.0051	0.0098 U	0.0050	0.0099 U	0.0050	0.0099 U	0.0050	0.0099 U	0.0051	0.010 U	0.0053	0.010 U	0.0052
Benzo(a)anthracene	0.010 U	0.0009	0.010 U	0.0009	0.0098 U	0.0009	0.0099 U	0.0009	0.0099 U	0.0009	0.0099 U	0.0009	0.010 U	0.0009	0.010 U	0.0009
Benzo(a)pyrene	0.010 U	0.0016	0.010 U	0.0016	0.0098 U	0.0016	0.0099 U	0.0016	0.0099 U	0.0016	0.0099 U	0.0016	0.010 U	0.0017	0.010 U	0.0017
Benzo(b)fluoranthene	0.010 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.0099 U	0.0010	0.0099 U	0.0010	0.0099 U	0.0010	0.010 U	0.0011	0.010 U	0.0010
Benzo(ghi)perylene	0.010 U	0.0016	0.010 U	0.0016	0.0098 U	0.0016	0.0099 U	0.0016	0.0099 U	0.0016	0.0099 U	0.0016	0.010 U	0.0017	0.010 U	0.0016
Benzo(k)fluoranthene	0.010 U	0.0005	0.010 U	0.0005	0.0098 U	0.0005	0.0099 U	0.0005	0.0099 U	0.0005	0.0099 U	0.0005	0.010 U	0.0005	0.010 U	0.0005
Carbazole	0.010 UJ	0.0015	0.010 UJ	0.0015	0.0098 UJ	0.0015	0.0099 UJ	0.0015	0.0099 UJ	0.0015	0.0099 UJ	0.0015	0.010 UJ	0.0015	0.010 UJ	0.0015
Chrysene	0.010 U	0.0009	0.010 U	0.0009	0.0098 U	0.0008	0.0099 U	0.0008	0.0099 U	0.0008	0.0099 U	0.0008	0.010 U	0.0009	0.010 U	0.0009
Dibenzo(a,h)anthracene	0.010 U	0.0014	0.010 U	0.0014	0.0098 U	0.0014	0.0099 U	0.0014	0.0099 U	0.0014	0.0099 U	0.0014	0.010 U	0.0015	0.010 U	0.0014
Dibenzofuran	0.010 U	0.0079	0.010 U	0.0079	0.0098 U	0.0077	0.0099 U	0.0078	0.0099 U	0.0078	0.0099 U	0.0078	0.010 U	0.0081	0.010 U	0.0081
Fluoranthene	0.010 U	0.0015	0.010 U	0.0015	0.0098 U	0.0015	0.0099 U	0.0015	0.0099 U	0.0015	0.0099 U	0.0015	0.010 U	0.0016	0.010 U	0.0016
Fluorene	0.010 U	0.0074	0.010 U	0.0074	0.0098 U	0.0073	0.0099 U	0.0073	0.0099 U	0.0073	0.0099 U	0.0074	0.010 U	0.0077	0.010 U	0.0076
Indeno(1,2,3-cd)pyrene	0.010 U	0.0020	0.010 U	0.0020	0.0098 U	0.0019	0.0099 U	0.0020	0.0099 U	0.0020	0.0099 U	0.0020	0.010 U	0.0020	0.010 U	0.0020
Naphthalene	0.010 U	0.0011	0.010 U	0.0011	0.0098 U	0.0011	0.0099 U	0.0011	0.0099 U	0.0011	0.0099 U	0.0011	0.010 U	0.0012	0.010 U	0.0011
Phenanthrene	0.010 U	0.0061	0.010 U	0.0061	0.0098 U	0.0060	0.0099 U	0.0060	0.0099 U	0.0060	0.0099 U	0.0060	0.010 U	0.0063	0.010 U	0.0062
Pyrene	0.010 U	0.0018	0.010 U	0.0018	0.0098 U	0.0018	0.0099 U	0.0018	0.0099 U	0.0018	0.0099 U	0.0018	0.010 U	0.0018	0.010 U	0.0018
Retene	0.010 U	0.0010	0.010 U	0.0010	0.0098 U	0.0009	0.0099 U	0.0009	0.0099 U	0.0009	0.0099 U	0.0009	0.010 U	0.0010	0.010 U	0.0010

Total PAHs																
…ND at ½ RL	0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.11 U	
…ND at MDL	0.079 U		0.079 U		0.078 U		0.078 U		0.078 U		0.079 U		0.082 U		0.081 U	

Total cPAHs*																
…ND at ½ RL	0.035 U		0.035 U		0.034 U		0.035 U		0.035 U		0.035 U		0.035 U		0.035 U	
…ND at MDL	0.0083 U		0.0083 U		0.0081 U		0.0082 U		0.0082 U		0.0082 U		0.0086 U		0.0084 U	

* The carcinogenic PAH compounds (cPAHs) are: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

Table E-11. September 2009 PAH Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.0098 U	0.0010	0.010 U	0.0010	0.0099 U	0.0010	0.0099 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010
2-Chloronaphthalene	0.0098 U	0.0092	0.010 U	0.0093	0.0099 U	0.0092	0.0099 U	0.0092	0.010 U	0.0096	0.0098 U	0.0092
2-Methylnaphthalene	0.0098 U	0.0085	0.010 U	0.0086	0.0099 U	0.0085	0.0099 U	0.0086	0.010 U	0.0089	0.0098 U	0.0085
Acenaphthene	0.0098 U	0.0084	0.010 U	0.0086	0.0099 U	0.0085	0.0099 U	0.0085	0.010 U	0.0089	0.0098 U	0.0084
Acenaphthylene	0.0098 U	0.0083	0.010 U	0.0084	0.0099 U	0.0084	0.0099 U	0.0084	0.010 U	0.0087	0.0098 U	0.0083
Anthracene	0.0098 U	0.0050	0.010 U	0.0051	0.0099 U	0.0050	0.0099 U	0.0051	0.010 U	0.0053	0.0098 U	0.0050
Benzo(a)anthracene	0.0098 U	0.0009	0.010 U	0.0009	0.0099 U	0.0009	0.0099 U	0.0009	0.010 U	0.0009	0.0098 U	0.0009
Benzo(a)pyrene	0.0098 U	0.0016	0.010 U	0.0016	0.0099 U	0.0016	0.0099 U	0.0016	0.010 U	0.0017	0.0098 U	0.0016
Benzo(b)fluoranthene	0.0098 U	0.0010	0.010 U	0.0010	0.0099 U	0.0010	0.0099 U	0.0010	0.010 U	0.0011	0.0098 U	0.0010
Benzo(ghi)perylene	0.0098 U	0.0016	0.010 U	0.0016	0.0099 U	0.0016	0.0099 U	0.0016	0.010 U	0.0017	0.0098 U	0.0016
Benzo(k)fluoranthene	0.0098 U	0.0005	0.010 U	0.0005	0.0099 U	0.0005	0.0099 U	0.0005	0.010 U	0.0005	0.0098 U	0.0005
Carbazole	0.0098 UJ	0.0015	0.010 UJ	0.0015	0.0099 UJ	0.0015	0.0099 UJ	0.0015	0.010 UJ	0.0015	0.0098 UJ	0.0015
Chrysene	0.0098 U	0.0008	0.010 U	0.0009	0.0099 U	0.0008	0.0099 U	0.0008	0.010 U	0.0009	0.0098 U	0.0008
Dibenzo(a,h)anthracene	0.0098 U	0.0014	0.010 U	0.0014	0.0099 U	0.0014	0.0099 U	0.0014	0.010 U	0.0015	0.0098 U	0.0014
Dibenzofuran	0.0098 U	0.0077	0.010 U	0.0079	0.0099 U	0.0078	0.0099 U	0.0078	0.010 U	0.0081	0.0098 U	0.0077
Fluoranthene	0.0098 U	0.0015	0.010 U	0.0015	0.0099 U	0.0015	0.0099 U	0.0015	0.010 U	0.0016	0.0098 U	0.0015
Fluorene	0.0098 U	0.0073	0.010 U	0.0074	0.0099 U	0.0073	0.0099 U	0.0074	0.010 U	0.0077	0.0098 U	0.0073
Indeno(1,2,3-cd)pyrene	0.0098 U	0.0019	0.010 U	0.0020	0.0099 U	0.0020	0.0099 U	0.0020	0.010 U	0.0020	0.0098 U	0.0019
Naphthalene	0.0098 U	0.0011	0.010 U	0.0011	0.0099 U	0.0011	0.0099 U	0.0011	0.010 U	0.0012	0.0098 U	0.0011
Phenanthrene	0.0098 U	0.0060	0.010 U	0.0061	0.0099 U	0.0060	0.0099 U	0.0060	0.010 U	0.0063	0.0098 U	0.0060
Pyrene	0.0098 U	0.0018	0.010 U	0.0018	0.0099 U	0.0018	0.0099 U	0.0018	0.010 U	0.0018	0.0098 U	0.0018
Retene	0.0098 U	0.0009	0.010 U	0.0010	0.0099 U	0.0009	0.0099 U	0.0009	0.010 U	0.0010	0.0098 U	0.0009

Total PAHs												
…ND at ½ RL	0.11 U		0.11 U		0.11 U		0.11 U		0.11 U		0.11 U	
…ND at MDL	0.078 U		0.079 U		0.078 U		0.079 U		0.082 U		0.078 U	

Total cPAHs												
…ND at ½ RL	0.034 U		0.035 U		0.035 U		0.035 U		0.035 U		0.034 U	
…ND at MDL	0.0081 U		0.0083 U		0.0082 U		0.0082 U		0.0086 U		0.0081 U	

Table E-12. January 2010 PAH Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.0099 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.010 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010
2-Chloronaphthalene	0.0099 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.010 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0009	0.0099 U	0.0010
2-Methylnaphthalene	0.0099 U	0.0013	0.0099 U	0.0013	0.0097 U	0.0013	0.010 U	0.0013	0.0097 U	0.0013	0.0099 U	0.0013	0.0097 U	0.0013	0.0099 U	0.0013
Acenaphthene	0.0099 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.010 U	0.0011	0.0097 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010
Acenaphthylene	0.0099 U	0.0018	0.0099 U	0.0018	0.0097 UJ	0.0018	0.010 UJ	0.0019	0.0097 UJ	0.0018	0.0099 UJ	0.0018	0.0097 UJ	0.0018	0.0099 UJ	0.0018
Anthracene	0.0099 U	0.0023	0.0099 U	0.0023	0.0097 U	0.0022	0.010 U	0.0023	0.0097 U	0.0022	0.0099 U	0.0022	0.0097 U	0.0022	0.0099 U	0.0022
Benzo(a)anthracene	0.0099 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.010 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010
Benzo(a)pyrene	0.020 U	0.0018	0.020 U	0.0018	0.019 U	0.0018	0.020 U	0.0019	0.019 U	0.0018	0.020 U	0.0018	0.019 U	0.0018	0.020 U	0.0018
Benzo(b)fluoranthene	0.0099 U	0.0011	0.0099 U	0.0011	0.0097 U	0.0011	0.010 U	0.0011	0.0097 U	0.0011	0.0099 U	0.0011	0.0097 U	0.0011	0.0099 U	0.0011
Benzo(ghi)perylene	0.0099 U	0.0017	0.0099 U	0.0017	0.0097 UJ	0.0017	0.010 UJ	0.0017	0.0097 UJ	0.0017	0.0099 UJ	0.0017	0.0097 UJ	0.0017	0.0099 UJ	0.0017
Benzo(k)fluoranthene	0.0099 U	0.0006	0.0099 U	0.0006	0.0097 U	0.0006	0.010 U	0.0006	0.0097 U	0.0006	0.0099 U	0.0006	0.0097 U	0.0006	0.0099 U	0.0006
Carbazole	0.0099 U	0.0013	0.0099 U	0.0013	0.0097 U	0.0012	0.010 U	0.0013	0.0097 U	0.0012	0.0099 U	0.0012	0.0097 U	0.0012	0.0099 U	0.0012
Chrysene	0.0099 U	0.0009	0.0099 U	0.0009	0.0097 U	0.0009	0.010 U	0.0009	0.0097 U	0.0009	0.0099 U	0.0009	0.0097 U	0.0009	0.0099 U	0.0009
Dibenzo(a,h)anthracene	0.0099 U	0.0015	0.0099 U	0.0015	0.0097 UJ	0.0015	0.010 UJ	0.0015	0.0097 UJ	0.0015	0.0099 UJ	0.0015	0.0097 UJ	0.0015	0.0099 UJ	0.0015
Dibenzofuran	0.0099 U	0.0009	0.0099 U	0.0009	0.0097 U	0.0009	0.010 U	0.0009	0.0097 U	0.0009	0.0099 U	0.0009	0.0097 U	0.0009	0.0099 U	0.0009
Fluoranthene	0.0099 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.010 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010	0.0097 U	0.0010	0.0099 U	0.0010
Fluorene	0.0099 U	0.0007	0.0099 U	0.0007	0.0097 U	0.0007	0.010 U	0.0007	0.0097 U	0.0007	0.0099 U	0.0007	0.0097 U	0.0007	0.0099 UJ	0.0007
Indeno(1,2,3-cd)pyrene	0.0099 U	0.0020	0.0099 U	0.0020	0.0097 U	0.0020	0.010 U	0.0021	0.0097 U	0.0020	0.0099 U	0.0020	0.0097 U	0.0020	0.0099 U	0.0020
Naphthalene	0.0099 U	0.0011	0.0099 U	0.0011	0.0097 U	0.0011	0.010 U	0.0011	0.0097 U	0.0011	0.0099 U	0.0011	0.0097 U	0.0011	0.0099 U	0.0011
Phenanthrene	0.0099 U	0.0024	0.0099 U	0.0024	0.0097 U	0.0023	0.010 U	0.0025	0.0097 U	0.0023	0.0099 U	0.0024	0.0097 U	0.0023	0.0099 U	0.0024
Pyrene	0.0099 U	0.0020	0.0099 U	0.0020	0.0097 U	0.0019	0.010 U	0.0020	0.0097 U	0.0019	0.0099 U	0.0020	0.0097 U	0.0019	0.0099 U	0.0020
Retene	0.0099 U	0.0011	0.0099 U	0.0011	0.0097 U	0.0011	0.010 U	0.0011	0.0097 U	0.0011	0.0099 U	0.0011	0.0097 U	0.0010	0.0099 U	0.0011

Total PAHs																
…ND at ½ RL	0.11 U		0.11 U		0.11 U		0.12 U		0.11 U		0.11 U		0.11 U		0.11 U	
…ND at MDL	0.030 U		0.030 U		0.029 U		0.030 U		0.029 U		0.029 U		0.029 U		0.029 U	

Total cPAHs*																
…ND at ½ RL	0.040 U		0.040 U		0.039 U		0.040 U		0.039 U		0.040 U		0.039 U		0.040 U	
…ND at MDL	0.0089 U		0.0089 U		0.0089 U		0.0091 U		0.0089 U		0.0089 U		0.0089 U		0.0089 U	

* The carcinogenic PAH compounds (cPAHs) are: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

Table E-13. January 2010 PAH Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.0098 UJ	0.0010	0.011 U	0.0011	0.0099 U	0.0010	0.010 UJ	0.0010	0.0098 U	0.0010	0.0098 U	0.0010
2-Chloronaphthalene	0.0098 U	0.0010	0.011 U	0.0010	0.0099 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.0098 U	0.0010
2-Methylnaphthalene	0.0098 UJ	0.0013	0.011 U	0.0014	0.0099 U	0.0013	0.010 UJ	0.0013	0.0098 U	0.0013	0.0098 U	0.0013
Acenaphthene	0.0098 U	0.0010	0.011 U	0.0011	0.0099 U	0.0010	0.010 U	0.0011	0.0098 U	0.0010	0.0098 U	0.0010
Acenaphthylene	0.0098 U	0.0018	0.011 U	0.0019	0.0099 U	0.0018	0.010 U	0.0019	0.0098 U	0.0018	0.0098 U	0.0018
Anthracene	0.0098 U	0.0022	0.011 U	0.0024	0.0099 U	0.0023	0.010 U	0.0023	0.0098 U	0.0022	0.0098 U	0.0022
Benzo(a)anthracene	0.0098 U	0.0010	0.011 U	0.0011	0.0099 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.0098 U	0.0010
Benzo(a)pyrene	0.020 U	0.0018	0.021 U	0.0020	0.020 U	0.0018	0.021 U	0.0019	0.020 U	0.0018	0.020 U	0.0018
Benzo(b)fluoranthene	0.0098 U	0.0011	0.011 U	0.0012	0.0099 U	0.0011	0.010 U	0.0012	0.0098 U	0.0011	0.0098 U	0.0011
Benzo(ghi)perylene	0.0098 U	0.0017	0.011 U	0.0018	0.0099 U	0.0017	0.010 U	0.0018	0.0098 U	0.0017	0.0098 U	0.0017
Benzo(k)fluoranthene	0.0098 U	0.0006	0.011 U	0.0006	0.0099 U	0.0006	0.010 U	0.0006	0.0098 U	0.0006	0.0098 U	0.0006
Carbazole	0.0098 U	0.0012	0.011 U	0.0013	0.0099 U	0.0013	0.010 U	0.0013	0.0098 U	0.0012	0.0098 U	0.0012
Chrysene	0.0098 U	0.0009	0.011 U	0.0010	0.0099 U	0.0009	0.010 U	0.0009	0.0098 U	0.0009	0.0098 U	0.0009
Dibenzo(a,h)anthracene	0.0098 UJ	0.0015	0.011 UJ	0.0016	0.0099 UJ	0.0015	0.010 UJ	0.0016	0.0098 UJ	0.0015	0.0098 UJ	0.0015
Dibenzofuran	0.0098 U	0.0009	0.011 U	0.0010	0.0099 U	0.0009	0.010 U	0.0009	0.0098 U	0.0009	0.0098 U	0.0009
Fluoranthene	0.0098 U	0.0010	0.011 U	0.0011	0.0099 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.0098 U	0.0010
Fluorene	0.0098 U	0.0007	0.011 U	0.0007	0.0099 U	0.0007	0.010 U	0.0007	0.0098 U	0.0007	0.0098 U	0.0007
Indeno(1,2,3-cd)pyrene	0.0098 U	0.0020	0.011 U	0.0021	0.0099 U	0.0020	0.010 U	0.0021	0.0098 U	0.0020	0.0098 U	0.0020
Naphthalene	0.0098 UJ	0.0011	0.011 U	0.0012	0.0099 U	0.0011	0.010 UJ	0.0012	0.0098 U	0.0011	0.0098 U	0.0011
Phenanthrene	0.0098 U	0.0024	0.011 U	0.0025	0.0099 U	0.0024	0.010 U	0.0025	0.0098 U	0.0024	0.0098 U	0.0024
Pyrene	0.0098 U	0.0020	0.011 U	0.0021	0.0099 U	0.0020	0.010 U	0.0021	0.0098 U	0.0020	0.0098 U	0.0020
Retene	0.0098 U	0.0011	0.011 U	0.0011	0.0099 U	0.0011	0.010 U	0.0011	0.0098 U	0.0011	0.0098 U	0.0011

Total PAHs												
…ND at ½ RL	0.11 U		0.13 U		0.11 U		0.12 U		0.11 U		0.11 U	
…ND at MDL	0.029 U		0.031 U		0.030 U		0.031 U		0.029 U		0.029 U	

Total cPAHs												
…ND at ½ RL	0.039 U		0.044 U		0.040 U		0.041 U		0.039 U		0.039 U	
…ND at MDL	0.0089 U		0.0096 U		0.0089 U		0.0093 U		0.0089 U		0.0089 U	

Table E-14. July 2009 BNA Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
1,2-Dichlorobenzene	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
1,2-Diphenylhydrazine	0.083 U	-	0.088 UJ	-	0.089 UJ	-	0.091 UJ	-	0.086 UJ	-	0.086 UJ	-	0.090 UJ	-	0.085 UJ	-
1,3-Dichlorobenzene	0.083 UJ	-	0.088 UJ	-	0.089 UJ	-	0.091 UJ	-	0.086 UJ	-	0.086 UJ	-	0.090 UJ	-	0.085 UJ	-
1,4-Dichlorobenzene	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
2,2'-Oxybis[1-chloropropane]	0.08 U	-	0.09 U	-	0.09 U	-	0.09 U	-	0.09 U	-	0.09 U	-	0.09 U	-	0.08 U	-
2,4,5-Trichlorophenol	0.33 U	-	0.35 U	-	0.36 U	-	0.36 U	-	0.34 U	-	0.34 U	-	0.36 U	-	0.34 U	-
2,4,6-Trichlorophenol	0.33 UJ	-	0.35 UJ	-	0.36 UJ	-	0.36 UJ	-	0.34 UJ	-	0.34 UJ	-	0.36 UJ	-	0.34 UJ	-
2,4-Dichlorophenol	0.062 J	-	0.16 J	-	0.043 J	-	0.91 U	-	0.86 U	-	0.86 U	-	0.90 U	-	0.85 U	-
2,4-Dimethylphenol	0.83 U	-	0.88 U	-	0.89 U	-	0.91 U	-	0.86 U	-	0.86 U	-	0.90 U	-	0.85 U	-
2,4-Dinitrophenol	0.83 U	-	0.88 U	-	0.89 U	-	0.91 U	-	0.86 U	-	0.86 U	-	0.90 U	-	0.85 U	-
2,4-Dinitrotoluene	0.33 UJ	-	0.35 UJ	-	0.36 UJ	-	0.36 UJ	-	0.34 UJ	-	0.34 U	-	0.36 U	-	0.34 U	-
2,6-Dinitrotoluene	0.33 U	-	0.35 U	-	0.36 U	-	0.36 U	-	0.34 U	-	0.34 U	-	0.36 U	-	0.34 U	-
2-Chlorophenol	0.33 U	-	0.35 U	-	0.36 U	-	0.36 U	-	0.34 U	-	0.34 U	-	0.36 U	-	0.34 U	-
2-Methylphenol	0.011 J	-	0.037 J	-	0.010 J	-	0.91 U	-	0.86 U	-	0.86 U	-	0.90 U	-	0.85 U	-
2-Nitroaniline	1.7 U	-	1.8 U	-	1.8 U	-	1.8 U	-	1.7 U	-	1.7 U	-	1.8 U	-	1.7 U	-
2-Nitrophenol	0.17 UJ	-	0.18 UJ	-	0.18 UJ	-	0.18 UJ	-	0.17 UJ	-	0.17 UJ	-	0.18 UJ	-	0.17 UJ	-
3,3'-Dichlorobenzidine	0.17 UJ	-	0.18 UJ	-	0.18 UJ	-	0.18 UJ	-	0.17 UJ	-	0.17 U	-	0.18 U	-	0.17 U	-
3B-Coprostanol	1.2 J	-	0.88 UJ	-	0.89 UJ	-	0.91 UJ	-	0.86 UJ	-	0.86 U	-	0.90 U	-	0.85 U	-
3-Nitroaniline	0.33 U	-	0.35 U	-	0.36 U	-	0.36 U	-	0.34 U	-	0.34 U	-	0.36 U	-	0.34 U	-
4,6-Dinitro-2-Methylphenol	0.33 U	-	0.35 U	-	0.36 U	-	0.36 U	-	0.34 U	-	0.34 U	-	0.36 U	-	0.34 U	-
4-Bromophenyl phenyl ether	0.17 U	-	0.18 U	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 U	-	0.18 U	-	0.17 U	-
4-Chloro-3-Methylphenol	0.060 J	-	0.33 J	-	0.024 J	-	0.91 UJ	-	0.86 UJ	-	0.86 UJ	-	0.90 UJ	-	0.026 J	-
4-Chloroaniline	3.3 REJ	-	3.5 REJ	-	3.6 REJ	-	3.6 REJ	-	3.4 REJ	-	3.4 REJ	-	3.6 REJ	-	3.4 REJ	-
4-Chlorophenyl-Phenylether	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
4-Methylphenol	0.83 U	-	0.88 U	-	0.89 U	-	0.91 U	-	0.86 U	-	0.86 U	-	0.90 U	-	0.85 U	-
4-Nitroaniline	0.33 UJ	-	0.35 UJ	-	0.36 UJ	-	0.36 UJ	-	0.34 UJ	-	0.34 UJ	-	0.36 UJ	-	0.34 UJ	-
4-Nitrophenol	0.83 UJ	-	0.88 UJ	-	0.89 UJ	-	0.91 UJ	-	0.86 UJ	-	0.86 UJ	-	0.90 UJ	-	0.85 UJ	-
4-nonylphenol	0.33 U	0.033	0.35 U	0.035	0.36 U	0.036	0.36 U	0.036	0.34 U	0.034	0.34 U	0.034	0.36 U	0.036	0.34 U	0.034
Benzoic Acid	0.83 UJ	-	0.88 UJ	-	0.89 UJ	-	0.91 UJ	-	0.86 UJ	-	0.86 UJ	-	0.90 UJ	-	0.85 UJ	-
Benzyl Alcohol	0.83 UJ	-	0.88 UJ	-	0.89 UJ	-	0.91 UJ	-	0.86 UJ	-	0.86 UJ	-	0.90 UJ	-	0.85 UJ	-
Bis(2-chloro-1-methylethyl) ether	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
Bis(2-Chloroethoxy)Methane	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
Bis(2-Chloroethyl)Ether	0.17 U	-	0.18 U	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 U	-	0.18 U	-	0.17 U	-
Bis(2-Ethylhexyl) Phthalate	0.048 J	-	0.012 J	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 U	-	0.18 U	-	0.17 U	-
Bisphenol A	0.33 UJ	0.033	0.19 J	0.035	0.36 U	0.036	0.36 U	0.036	0.34 U	0.034	0.34 U	0.034	0.36 U	0.036	0.34 U	0.034
Butyl benzyl phthalate	0.069 UJ	0.033	0.35 UJ	0.035	0.36 U	0.036	0.36 U	0.036	0.34 U	0.034	0.34 U	0.034	0.36 U	0.036	0.34 U	0.034
Caffeine	0.17 U	-	0.18 U	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 U	-	0.029 J	-	0.17 U	-
Cholesterol	0.62 J	-	0.88 UJ	-	0.75 J	-	0.91 UJ	-	0.86 UJ	-	0.86 U	-	0.76 J	-	0.64 J	-

Table E-14, continued. July 2009 BNA Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
Diethyl phthalate	0.17 U	0.033	0.18 U	0.035	0.18 U	0.036	0.18 U	0.036	0.17 U	0.034	0.17 U	0.034	0.18 U	0.036	0.17 U	0.034
Dimethyl phthalate	0.17 U	0.033	0.18 U	0.035	0.18 U	0.036	0.18 U	0.036	0.17 U	0.034	0.17 U	0.034	0.18 U	0.036	0.17 U	0.034
Di-N-Butylphthalate	0.29 UJ	-	0.34 UJ	-	0.23 UJ	-	0.20 UJ	-	0.12 UJ	-	0.14 UJ	-	0.15 UJ	-	0.17 UJ	-
Di-N-Octyl Phthalate	0.17 UJ	-	0.18 UJ	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 U	-	0.18 U	-	0.17 U	-
Ethanol, 2-Chloro-, Phosphate (3:1)	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.099	-	0.085 U	-
Hexachlorobenzene	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
Hexachlorobutadiene	0.083 UJ	-	0.088 UJ	-	0.089 UJ	-	0.091 UJ	-	0.086 UJ	-	0.086 UJ	-	0.090 UJ	-	0.085 UJ	-
Hexachlorocyclopentadiene	0.33 UJ	-	0.35 UJ	-	0.36 UJ	-	0.36 UJ	-	0.34 UJ	-	0.34 UJ	-	0.36 UJ	-	0.34 UJ	-
Hexachloroethane	0.083 UJ	-	0.088 UJ	-	0.089 UJ	-	0.091 UJ	-	0.086 UJ	-	0.086 UJ	-	0.090 UJ	-	0.085 UJ	-
Isophorone	0.17 U	-	0.18 U	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 U	-	0.18 U	-	0.17 U	-
Nitrobenzene	0.083 U	-	0.088 U	-	0.089 U	-	0.091 U	-	0.086 U	-	0.086 U	-	0.090 U	-	0.085 U	-
N-Nitrosodi-n-propylamine	0.10 U	-	0.11 U	-	0.11 U	-	0.11 U	-	0.10 U	-	0.10 U	-	0.11 U	-	0.10 U	-
N-Nitrosodiphenylamine	0.17 U	-	0.18 U	-	0.18 U	-	0.18 U	-	0.17 U	-	0.17 UJ	-	0.18 UJ	-	0.17 UJ	-
Pentachlorophenol	0.083 UJ	-	0.088 UJ	-	0.089 UJ	-	0.091 UJ	-	0.086 UJ	-	0.086 UJ	-	0.090 UJ	-	0.085 UJ	-
Phenol	0.33 U	-	0.017 J	-	0.36 U	-	0.36 U	-	0.34 U	-	0.34 U	-	0.36 U	-	0.34 U	-
Triclosan	0.083 UJ	-	0.088 UJ	-	0.089 UJ	-	0.091 UJ	-	0.086 UJ	-	0.086 U	-	0.090 U	-	0.085 U	-
Triethyl citrate	0.33 U	0.033	0.35 U	0.035	0.36 U	0.036	0.36 U	0.036	0.34 U	0.034	0.34 U	0.034	0.36 U	0.036	0.34 U	0.034

Table E-15. July 2009 BNA Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
1,2-Dichlorobenzene	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
1,2-Diphenylhydrazine	0.085 UJ	-	0.079 UJ	-	0.090 UJ	-	0.088 UJ	-	0.082 UJ	-	0.079 UJ	-
1,3-Dichlorobenzene	0.085 UJ	-	0.079 UJ	-	0.090 UJ	-	0.088 UJ	-	0.082 UJ	-	0.079 UJ	-
1,4-Dichlorobenzene	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
2,2'-Oxybis[1-chloropropane]	0.08 U	-	0.08 U	-	0.09 U	-	0.09 U	-	0.08 U	-	0.08 U	-
2,4,5-Trichlorophenol	0.34 U	-	0.32 U	-	0.36 U	-	0.35 U	-	0.33 U	-	0.31 U	-
2,4,6-Trichlorophenol	0.34 UJ	-	0.32 UJ	-	0.36 UJ	-	0.35 UJ	-	0.33 UJ	-	0.31 UJ	-
2,4-Dichlorophenol	0.85 U	-	0.79 U	-	0.90 U	-	0.88 U	-	0.82 U	-	0.063 J	-
2,4-Dimethylphenol	0.85 U	-	0.79 U	-	0.90 U	-	0.88 U	-	0.82 U	-	0.79 U	-
2,4-Dinitrophenol	0.85 U	-	0.79 U	-	0.90 U	-	0.88 U	-	0.82 U	-	0.79 U	-
2,4-Dinitrotoluene	0.34 UJ	-	0.32 UJ	-	0.36 UJ	-	0.35 UJ	-	0.33 UJ	-	0.31 UJ	-
2,6-Dinitrotoluene	0.34 U	-	0.32 U	-	0.36 U	-	0.35 U	-	0.33 U	-	0.31 U	-
2-Chlorophenol	0.34 U	-	0.32 U	-	0.36 U	-	0.35 U	-	0.33 U	-	0.31 U	-
2-Methylphenol	0.85 U	-	0.79 U	-	0.90 U	-	0.88 U	-	0.82 U	-	0.013 J	-
2-Nitroaniline	1.7 U	-	1.6 U	-	1.8 U	-	1.8 U	-	1.6 U	-	1.6 U	-
2-Nitrophenol	0.17 UJ	-	0.16 UJ	-	0.18 UJ	-	0.18 UJ	-	0.16 UJ	-	0.16 UJ	-
3,3'-Dichlorobenzidine	0.17 UJ	-	0.16 UJ	-	0.18 UJ	-	0.18 UJ	-	0.16 UJ	-	0.16 UJ	-
3B-Coprostanol	0.85 UJ	-	0.79 UJ	-	0.90 UJ	-	0.88 UJ	-	0.82 UJ	-	0.79 UJ	-
3-Nitroaniline	0.34 U	-	0.32 U	-	0.36 U	-	0.35 U	-	0.33 U	-	0.31 U	-
4,6-Dinitro-2-Methylphenol	0.34 U	-	0.32 U	-	0.36 U	-	0.35 U	-	0.33 U	-	0.31 U	-
4-Bromophenyl phenyl ether	0.17 U	-	0.16 U	-	0.18 U	-	0.18 U	-	0.16 U	-	0.16 U	-
4-Chloro-3-Methylphenol	0.85 UJ	-	0.025 J	-	0.90 U	-	0.016 J	-	0.82 UJ	-	0.094 J	-
4-Chloroaniline	3.4 REJ	-	3.2 REJ	-	3.6 REJ	-	3.5 REJ	-	3.3 REJ	-	3.1 REJ	-
4-Chlorophenyl-Phenylether	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
4-Methylphenol	0.85 U	-	0.79 U	-	0.90 U	-	0.88 U	-	0.82 U	-	0.79 U	-
4-Nitroaniline	0.34 UJ	-	0.32 UJ	-	0.36 UJ	-	0.35 UJ	-	0.33 UJ	-	0.31 UJ	-
4-Nitrophenol	0.85 UJ	-	0.79 UJ	-	0.90 UJ	-	0.88 UJ	-	0.82 UJ	-	0.79 UJ	-
4-nonylphenol	0.34 U	0.034	0.32 U	0.032	0.36 U	0.036	0.35 U	0.035	0.33 U	0.033	0.31 U	0.031
Benzoic Acid	0.85 UJ	-	0.79 UJ	-	0.90 UJ	-	0.88 UJ	-	0.82 UJ	-	0.79 UJ	-
Benzyl Alcohol	0.85 UJ	-	0.79 UJ	-	0.90 UJ	-	0.88 UJ	-	0.82 UJ	-	0.79 UJ	-
Bis(2-chloro-1-methylethyl) ether	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
Bis(2-Chloroethoxy)Methane	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
Bis(2-Chloroethyl)Ether	0.17 U	-	0.16 U	-	0.18 U	-	0.18 U	-	0.16 U	-	0.16 U	-
Bis(2-Ethylhexyl) Phthalate	0.17 U	-	0.16 UJ	-	0.18 UJ	-	0.18 UJ	-	0.16 U	-	0.059 J	-
Bisphenol A	0.34 U	0.034	0.32 UJ	0.032	0.36 UJ	0.036	0.35 UJ	0.035	0.33 U	0.033	0.31 UJ	0.031
Butyl benzyl phthalate	0.34 U	0.034	0.32 UJ	0.032	0.36 UJ	0.036	0.35 UJ	0.035	0.33 U	0.033	0.31 UJ	0.031
Caffeine	0.17 U	-	0.16 U	-	0.18 U	-	0.18 U	-	0.16 U	-	0.16 U	-
Cholesterol	0.85 UJ	-	0.79 UJ	-	0.90 UJ	-	0.88 UJ	-	0.82 UJ	-	0.79 UJ	-
Diethyl phthalate	0.17 U	0.034	0.16 U	0.032	0.18 U	0.036	0.18 U	0.035	0.16 U	0.033	0.16 U	0.031
Dimethyl phthalate	0.17 U	0.034	0.16 U	0.032	0.18 U	0.036	0.18 U	0.035	0.16 U	0.033	0.16 U	0.031
Di-N-Butylphthalate	0.19 UJ	-	0.23 UJ	-	0.21 UJ	-	0.16 UJ	-	0.13 UJ	-	0.17 UJ	-
Di-N-Octyl Phthalate	0.17 U	-	0.16 UJ	-	0.18 UJ	-	0.18 UJ	-	0.16 U	-	0.16 UJ	-
Ethanol, 2-Chloro-, Phosphate (3:1)	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
Hexachlorobenzene	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
Hexachlorobutadiene	0.085 UJ	-	0.079 UJ	-	0.090 UJ	-	0.088 UJ	-	0.082 UJ	-	0.079 UJ	-
Hexachlorocyclopentadiene	0.34 UJ	-	0.32 UJ	-	0.36 UJ	-	0.35 UJ	-	0.33 UJ	-	0.31 UJ	-
Hexachloroethane	0.085 UJ	-	0.079 UJ	-	0.090 UJ	-	0.088 UJ	-	0.082 UJ	-	0.079 UJ	-
Isophorone	0.17 U	-	0.16 U	-	0.18 U	-	0.18 U	-	0.16 U	-	0.16 U	-
Nitrobenzene	0.085 U	-	0.079 U	-	0.090 U	-	0.088 U	-	0.082 U	-	0.079 U	-
N-Nitrosodi-n-propylamine	0.10 U	-	0.095 U	-	0.11 U	-	0.11 U	-	0.098 U	-	0.094 U	-
N-Nitrosodiphenylamine	0.17 U	-	0.16 U	-	0.18 U	-	0.18 U	-	0.16 U	-	0.16 U	-
Pentachlorophenol	0.085 UJ	-	0.079 UJ	-	0.090 UJ	-	0.088 UJ	-	0.082 UJ	-	0.079 UJ	-
Phenol	0.34 U	-	0.32 U	-	0.36 U	-	0.35 U	-	0.33 U	-	0.31 U	-
Triclosan	0.085 UJ	-	0.079 UJ	-	0.090 UJ	-	0.088 UJ	-	0.082 UJ	-	0.079 UJ	-
Triethyl citrate	0.34 U	0.034	0.32 U	0.032	0.36 U	0.036	0.35 U	0.035	0.33 U	0.033	0.31 U	0.031

Table E-16. September 2009 BNA Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
1,2-Dichlorobenzene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
1,2-Diphenylhydrazine	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
1,3-Dichlorobenzene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 UJ	-	0.079 UJ	-
1,4-Dichlorobenzene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
2,2'-Oxybis[1-chloropropane]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4,5-Trichlorophenol	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
2,4,6-Trichlorophenol	0.33 U	-	0.32 U	-	0.33 UJ	-	0.32 UJ	-	0.32 UJ	-	0.32 UJ	-	0.31 UJ	-	0.32 UJ	-
2,4-Dichlorophenol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
2,4-Dimethylphenol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
2,4-Dinitrophenol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
2,4-Dinitrotoluene	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
2,6-Dinitrotoluene	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
2-Chlorophenol	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
2-Methylphenol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
2-Nitroaniline	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-	1.5 U	-	1.6 U	-
2-Nitrophenol	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.15 U	-	0.16 U	-
3,3'-Dichlorobenzidine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.15 UJ	-	0.16 UJ	-
3B-Coprostanol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
3-Nitroaniline	0.33 UJ	-	0.32 UJ	-	0.33 UJ	-	0.32 UJ	-	0.32 UJ	-	0.32 UJ	-	0.31 UJ	-	0.32 UJ	-
4,6-Dinitro-2-Methylphenol	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
4-Bromophenyl phenyl ether	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.15 U	-	0.16 U	-
4-Chloro-3-Methylphenol	0.82 UJ	-	0.80 UJ	-	0.81 UJ	-	0.80 UJ	-	0.81 UJ	-	0.79 UJ	-	0.77 UJ	-	0.79 UJ	-
4-Chloroaniline	3.3 REJ	-	3.2 REJ	-	3.3 REJ	-	3.2 REJ	-	3.2 REJ	-	3.2 REJ	-	3.1 REJ	-	3.2 REJ	-
4-Chlorophenyl-Phenylether	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
4-Methylphenol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
4-Nitroaniline	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
4-Nitrophenol	0.82 U	-	0.80 U	-	0.81 U	-	0.80 U	-	0.81 U	-	0.79 U	-	0.77 U	-	0.79 U	-
4-nonylphenol	0.33 U	0.033	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.32 U	0.032	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032
Benzoic Acid	0.82 U	-	0.80 U	-	0.81 UJ	-	0.80 UJ	-	0.81 UJ	-	0.79 UJ	-	0.77 UJ	-	0.79 UJ	-
Benzyl Alcohol	0.82 U	-	0.80 U	-	0.81 UJ	-	0.80 UJ	-	0.81 UJ	-	0.79 UJ	-	0.77 UJ	-	0.79 UJ	-
Bis(2-chloro-1-methylethyl) ether	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
Bis(2-Chloroethoxy)Methane	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
Bis(2-Chloroethyl)Ether	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.15 U	-	0.16 U	-
Bis(2-Ethylhexyl) Phthalate	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.15 U	-	0.19 UJ	-
Bisphenol A	0.33 U	0.033	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.32 U	0.032	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032
Butyl benzyl phthalate	0.33 U	0.033	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.32 U	0.032	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032
Caffeine	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.15 U	-	0.16 U	-
Cholesterol	0.77 J	-	0.70 J	-	1.1	-	0.73 J	-	0.73 J	-	0.71 J	-	0.73 J	-	0.73 J	-

Table E-16, continued. September 2009 BNA Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
Diethyl phthalate	0.16 U	0.033	0.16 U	0.032	0.16 U	0.033	0.16 U	0.032	0.16 U	0.032	0.16 U	0.032	0.15 U	0.031	0.16 U	0.032
Dimethyl phthalate	0.16 U	0.033	0.16 U	0.032	0.16 U	0.033	0.16 U	0.032	0.16 U	0.032	0.16 U	0.032	0.15 U	0.031	0.16 U	0.032
Di-N-Butylphthalate	0.27 UJ	-	0.23 UJ	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
Di-N-Octyl Phthalate	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.15 UJ	-	0.16 UJ	-
Ethanol, 2-Chloro-, Phosphate (3:1)	0.082 UJ	-	0.080 UJ	-	0.081 UJ	-	0.080 UJ	-	0.081 UJ	-	0.079 UJ	-	0.077 UJ	-	0.079 UJ	-
Hexachlorobenzene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
Hexachlorobutadiene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 UJ	-	0.079 UJ	-
Hexachlorocyclopentadiene	0.33 UJ	-	0.32 UJ	-	0.33 UJ	-	0.32 UJ	-	0.32 UJ	-	0.32 UJ	-	0.31 UJ	-	0.32 UJ	-
Hexachloroethane	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 UJ	-	0.079 UJ	-
Isophorone	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.15 U	-	0.16 U	-
Nitrobenzene	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
N-Nitrosodi-n-propylamine	0.098 U	-	0.096 U	-	0.098 U	-	0.096 U	-	0.097 U	-	0.095 U	-	0.092 U	-	0.095 U	-
N-Nitrosodiphenylamine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.15 UJ	-	0.16 UJ	-
Pentachlorophenol	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
Phenol	0.33 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-	0.31 U	-	0.32 U	-
Triclosan	0.082 U	-	0.080 U	-	0.081 U	-	0.080 U	-	0.081 U	-	0.079 U	-	0.077 U	-	0.079 U	-
Triethyl citrate	0.33 UJ	0.033	0.32 UJ	0.032	0.33 UJ	0.033	0.32 UJ	0.032	0.32 UJ	0.032	0.32 UJ	0.032	0.31 UJ	0.031	0.32 UJ	0.032

Table E-17. September 2009 BNA Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
1,2-Dichlorobenzene	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
1,2-Diphenylhydrazine	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
1,3-Dichlorobenzene	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
1,4-Dichlorobenzene	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
2,2'-Oxybis[1-chloropropane]	-	-	-	-	-	-	-	-	-	-	-	-
2,4,5-Trichlorophenol	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
2,4,6-Trichlorophenol	0.32 UJ	-	0.32 UJ	-	0.33 UJ	-	0.32 UJ	-	0.32 UJ	-	0.32 UJ	-
2,4-Dichlorophenol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
2,4-Dimethylphenol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
2,4-Dinitrophenol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
2,4-Dinitrotoluene	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
2,6-Dinitrotoluene	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
2-Chlorophenol	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
2-Methylphenol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
2-Nitroaniline	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-
2-Nitrophenol	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
3,3'-Dichlorobenzidine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-
3B-Coprostanol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
3-Nitroaniline	0.32 UJ	-	0.32 UJ	-	0.33 UJ	-	0.32 UJ	-	0.32 UJ	-	0.32 UJ	-
4,6-Dinitro-2-Methylphenol	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
4-Bromophenyl phenyl ether	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
4-Chloro-3-Methylphenol	0.80 UJ	-	0.81 UJ	-	0.82 UJ	-	0.81 UJ	-	0.81 UJ	-	0.81 UJ	-
4-Chloroaniline	3.2 REJ	-	3.2 REJ	-	3.3 REJ	-	3.2 REJ	-	3.2 REJ	-	3.2 REJ	-
4-Chlorophenyl-Phenylether	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
4-Methylphenol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
4-Nitroaniline	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
4-Nitrophenol	0.80 U	-	0.81 U	-	0.82 U	-	0.81 U	-	0.81 U	-	0.81 U	-
4-nonylphenol	0.32 U	0.032	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.32 U	0.032	0.32 U	0.032
Benzoic Acid	0.80 UJ	-	0.81 UJ	-	0.82 UJ	-	0.81 UJ	-	0.81 UJ	-	0.81 UJ	-
Benzyl Alcohol	0.80 UJ	-	0.81 UJ	-	0.82 UJ	-	0.81 UJ	-	0.81 UJ	-	0.81 UJ	-
Bis(2-chloro-1-methylethyl) ether	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
Bis(2-Chloroethoxy)Methane	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
Bis(2-Chloroethyl)Ether	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Bis(2-Ethylhexyl) Phthalate	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Bisphenol A	0.32 U	0.032	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.32 U	0.032	0.32 U	0.032
Butyl benzyl phthalate	0.32 U	0.032	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.32 U	0.032	0.32 U	0.032
Caffeine	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Cholesterol	0.73 J	-	0.71 J	-	0.73 J	-	0.72 J	-	0.81 U	-	0.74 J	-
Diethyl phthalate	0.16 U	0.032	0.16 U	0.032	0.16 U	0.033	0.16 U	0.032	0.16 U	0.032	0.16 U	0.032
Dimethyl phthalate	0.16 U	0.032	0.16 U	0.032	0.16 U	0.033	0.16 U	0.032	0.16 U	0.032	0.16 U	0.032
Di-N-Butylphthalate	0.080 U	-	0.081 U	-	0.082 U	-	0.30 UJ	-	0.081 U	-	0.081 U	-
Di-N-Octyl Phthalate	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-
Ethanol, 2-Chloro-, Phosphate (3:1)	0.080 UJ	-	0.081 UJ	-	0.082 UJ	-	0.081 UJ	-	0.081 UJ	-	0.081 UJ	-
Hexachlorobenzene	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
Hexachlorobutadiene	0.080 UJ	-	0.081 UJ	-	0.082 UJ	-	0.081 UJ	-	0.081 UJ	-	0.081 UJ	-
Hexachlorocyclopentadiene	0.32 UJ	-	0.32 UJ	-	0.33 UJ	-	0.32 UJ	-	0.32 UJ	-	0.32 UJ	-
Hexachloroethane	0.080 UJ	-	0.081 UJ	-	0.082 UJ	-	0.081 UJ	-	0.081 UJ	-	0.081 UJ	-
Isophorone	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Nitrobenzene	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
N-Nitrosodi-n-propylamine	0.096 U	-	0.097 U	-	0.098 U	-	0.097 U	-	0.097 U	-	0.097 U	-
N-Nitrosodiphenylamine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-
Pentachlorophenol	0.080 U	-	0.081 U	-	0.082 U	-	0.081 U	-	0.081 U	-	0.081 U	-
Phenol	0.32 U	-	0.32 U	-	0.33 U	-	0.32 U	-	0.32 U	-	0.32 U	-
Triclosan	0.048 J	-	0.048 J	-	0.051 J	-	0.050 J	-	0.047 J	-	0.051 J	-
Triethyl citrate	0.32 UJ	0.032	0.32 UJ	0.032	0.33 UJ	0.033	0.32 UJ	0.032	0.32 UJ	0.032	0.32 UJ	0.032

Table E-18. January 2010 BNA Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.079 U	0.020	0.082 U	0.020	0.079 U	0.020	0.079 U	0.019	0.079 U	0.020	0.079 U	0.019	0.080 U	0.020	0.081 U	0.020
1,2-Dichlorobenzene	0.079 U	0.019	0.082 U	0.019	0.079 U	0.019	0.079 U	0.019	0.079 U	0.019	0.079 U	0.019	0.080 U	0.019	0.081 U	0.019
1,2-Diphenylhydrazine	0.079 U	0.051	0.082 U	0.052	0.079 U	0.051	0.079 U	0.050	0.079 U	0.050	0.079 U	0.050	0.080 U	0.051	0.081 U	0.051
1,3-Dichlorobenzene	0.079 UJ	0.016	0.082 UJ	0.017	0.079 U	0.016	0.079 U	0.016	0.079 UJ	0.016	0.079 UJ	0.016	0.080 UJ	0.016	0.081 UJ	0.016
1,4-Dichlorobenzene	0.079 U	0.017	0.082 U	0.018	0.079 U	0.017	0.079 U	0.017	0.079 U	0.017	0.079 U	0.017	0.080 U	0.017	0.081 U	0.018
2,2'-Oxybis[1-chloropropane]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4,5-Trichlorophenol	0.32 U	0.063	0.33 U	0.065	0.32 U	0.063	0.31 U	0.062	0.32 U	0.063	0.31 U	0.062	0.32 U	0.063	0.32 U	0.064
2,4,6-Trichlorophenol	0.32 U	0.048	0.33 U	0.050	0.32 U	0.048	0.31 U	0.048	0.32 U	0.048	0.31 U	0.048	0.32 U	0.048	0.32 U	0.049
2,4-Dichlorophenol	0.79 U	0.042	0.82 U	0.043	0.79 U	0.042	0.79 U	0.041	0.79 U	0.041	0.79 U	0.041	0.80 U	0.042	0.81 U	0.042
2,4-Dimethylphenol	0.79 U	0.047	0.82 U	0.048	0.79 U	0.047	0.79 U	0.046	0.79 U	0.047	0.79 U	0.046	0.80 U	0.047	0.81 U	0.048
2,4-Dinitrophenol	0.79 U	-	0.82 U	-	0.79 U	-	0.79 U	-	0.79 U	-	0.79 U	-	0.80 U	-	0.81 U	-
2,4-Dinitrotoluene	0.32 U	0.045	0.33 U	0.046	0.32 U	0.045	0.31 U	0.044	0.32 U	0.045	0.31 U	0.044	0.32 U	0.045	0.32 U	0.046
2,6-Dinitrotoluene	0.32 U	0.054	0.33 U	0.056	0.32 U	0.054	0.31 U	0.054	0.32 U	0.054	0.31 U	0.054	0.32 U	0.054	0.32 U	0.055
2-Chlorophenol	0.32 U	0.041	0.33 U	0.043	0.32 U	0.041	0.31 U	0.041	0.32 U	0.041	0.31 U	0.041	0.32 U	0.042	0.32 U	0.042
2-Methylphenol	0.79 U	0.040	0.82 U	0.041	0.79 U	0.040	0.79 U	0.040	0.79 U	0.040	0.79 U	0.040	0.80 U	0.040	0.81 U	0.041
2-Nitroaniline	1.6 UJ	0.053	1.6 UJ	0.055	1.6 UJ	0.053	1.6 UJ	0.053	1.6 UJ	0.053	1.6 UJ	0.053	1.6 UJ	0.053	1.6 UJ	0.054
2-Nitrophenol	0.16 UJ	0.036	0.16 UJ	0.037	0.16 UJ	0.036	0.16 UJ	0.035	0.16 UJ	0.036	0.16 UJ	0.035	0.16 UJ	0.036	0.16 UJ	0.036
3,3'-Dichlorobenzidine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-
3B-Coprostanol	0.79 UJ	-	0.82 UJ	-	0.79 UJ	-	0.79 UJ	-	0.79 UJ	-	0.79 UJ	-	0.80 UJ	-	0.81 UJ	-
3-Nitroaniline	0.32 REJ	0.046	0.33 REJ	0.047	0.32 REJ	0.046	0.31 REJ	0.045	0.32 REJ	0.045	0.31 REJ	0.045	0.32 REJ	0.046	0.32 REJ	0.046
4,6-Dinitro-2-Methylphenol	1.6 U	0.53	1.6 U	0.55	1.6 U	0.53	1.6 U	0.53	1.6 U	0.53	1.6 U	0.53	1.6 U	0.53	1.6 U	0.54
4-Bromophenyl phenyl ether	0.16 U	0.071	0.16 U	0.074	0.16 U	0.071	0.16 U	0.071	0.16 U	0.071	0.16 U	0.071	0.16 U	0.072	0.16 U	0.072
4-Chloro-3-Methylphenol	0.79 UJ	0.063	0.82 UJ	0.065	0.79 UJ	0.063	0.79 UJ	0.062	0.79 UJ	0.063	0.79 UJ	0.062	0.80 UJ	0.063	0.81 UJ	0.064
4-Chloroaniline	3.2 REJ	0.13	3.3 REJ	0.13	3.2 REJ	0.13	3.1 REJ	0.13	3.2 REJ	0.13	3.1 REJ	0.13	3.2 REJ	0.13	3.2 REJ	0.13
4-Chlorophenyl-Phenylether	0.079 U	0.071	0.082 U	0.073	0.079 U	0.071	0.079 U	0.070	0.079 U	0.071	0.079 U	0.070	0.080 U	0.071	0.081 U	0.072
4-Methylphenol	0.79 U	0.039	0.82 U	0.041	0.79 U	0.039	0.79 U	0.039	0.79 U	0.039	0.79 U	0.039	0.80 U	0.040	0.81 U	0.040
4-Nitroaniline	0.32 UJ	-	0.33 UJ	-	0.32 UJ	-	0.31 UJ	-	0.32 UJ	-	0.31 UJ	-	0.32 UJ	-	0.32 UJ	-
4-Nitrophenol	0.79 U	-	0.82 U	-	0.79 U	-	0.79 U	-	0.79 U	-	0.79 U	-	0.80 U	-	0.81 U	-
4-nonylphenol	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032	0.32 U	0.032
Benzoic Acid	0.79 UJ	-	0.82 UJ	-	0.79 UJ	-	0.79 UJ	-	0.79 UJ	-	0.79 UJ	-	0.80 UJ	-	0.81 UJ	-
Benzyl Alcohol	0.79 UJ	0.028	0.82 UJ	0.029	0.79 UJ	0.028	0.79 UJ	0.028	0.79 UJ	0.028	0.79 UJ	0.028	0.80 UJ	0.028	0.81 UJ	0.028
Bis(2-chloro-1-methylethyl) ether	0.079 U	0.053	0.082 U	0.055	0.079 U	0.053	0.079 U	0.053	0.079 U	0.053	0.079 U	0.053	0.080 U	0.053	0.081 U	0.054
Bis(2-Chloroethoxy)Methane	0.079 U	0.066	0.082 U	0.068	0.079 U	0.066	0.079 U	0.065	0.079 U	0.066	0.079 U	0.065	0.080 U	0.066	0.081 U	0.067
Bis(2-Chloroethyl)Ether	0.16 U	0.046	0.16 U	0.047	0.16 U	0.046	0.16 U	0.045	0.16 U	0.045	0.16 U	0.045	0.16 U	0.046	0.16 U	0.046
Bis(2-Ethylhexyl) Phthalate	0.16 U	0.048	0.16 U	0.049	0.16 U	0.048	0.16 U	0.047	0.16 U	0.048	0.16 U	0.047	0.16 U	0.048	0.16 U	0.048
Bisphenol A	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032	0.32 U	0.032
Butyl benzyl phthalate	0.32 UJ	0.037	0.33 UJ	0.038	0.32 UJ	0.037	0.31 UJ	0.037	0.32 UJ	0.037	0.31 UJ	0.037	0.32 UJ	0.037	0.32 UJ	0.038
Caffeine	0.16 U	0.062	0.16 U	0.064	0.16 U	0.062	0.16 U	0.061	0.16 U	0.061	0.16 U	0.061	0.16 U	0.062	0.16 U	0.063
Cholesterol	0.79 UJ	0.075	0.82 UJ	0.078	0.79 UJ	0.075	0.79 UJ	0.075	0.79 UJ	0.075	0.79 UJ	0.075	0.80 UJ	0.076	0.81 UJ	0.077

Table E-18, continued. January 2010 BNA Results for Marine Water Samples from Puget Sound Basin Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Hood Canal				Whidbey Basin				Main Basin				South Sound			
	Surface		Deep		Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
Diethyl phthalate	0.16 U	0.078	0.16 U	0.081	0.16 U	0.078	0.16 U	0.078	0.16 U	0.078	0.16 U	0.078	0.16 U	0.079	0.16 U	0.080
Dimethyl phthalate	0.16 U	0.069	0.16 U	0.071	0.16 U	0.069	0.16 U	0.068	0.16 U	0.068	0.16 U	0.068	0.16 U	0.069	0.16 U	0.070
Di-N-Butylphthalate	0.11 UJ	0.058	0.19 UJ	0.060	0.13 UJ	0.058	0.15 UJ	0.058	0.23 UJ	0.058	0.21 UJ	0.058	0.17 UJ	0.058	0.25 UJ	0.059
Di-N-Octyl Phthalate	0.16 U	0.071	0.16 U	0.073	0.16 U	0.071	0.16 U	0.070	0.16 U	0.070	0.16 U	0.070	0.16 U	0.071	0.16 U	0.072
Ethanol, 2-Chloro-, Phosphate (3:1)	0.079 U	0.032	0.082 U	0.033	0.079 U	0.032	0.079 U	0.031	0.079 U	0.032	0.079 U	0.031	0.080 U	0.032	0.081 U	0.032
Hexachlorobenzene	0.079 U	0.039	0.082 U	0.040	0.079 U	0.039	0.079 U	0.039	0.079 U	0.039	0.079 U	0.039	0.080 U	0.039	0.081 U	0.040
Hexachlorobutadiene	0.079 UJ	0.012	0.082 UJ	0.012	0.079 U	0.012	0.079 U	0.012	0.079 UJ	0.012	0.079 UJ	0.012	0.080 UJ	0.012	0.081 UJ	0.012
Hexachlorocyclopentadiene	0.32 UJ	0.010	0.33 UJ	0.010	0.32 UJ	0.010	0.31 UJ	0.0099	0.32 UJ	0.0099	0.31 UJ	0.0099	0.32 UJ	0.010	0.32 UJ	0.010
Hexachloroethane	0.079 UJ	-	0.082 UJ	-	0.079 U	-	0.079 U	-	0.079 UJ	-	0.079 UJ	-	0.080 UJ	-	0.081 UJ	-
Isophorone	0.16 U	0.073	0.16 U	0.076	0.16 U	0.073	0.16 U	0.073	0.16 U	0.073	0.16 U	0.073	0.16 U	0.074	0.16 U	0.075
Nitrobenzene	0.079 U	0.066	0.082 U	0.068	0.079 U	0.066	0.079 U	0.065	0.079 U	0.065	0.079 U	0.065	0.080 U	0.066	0.081 U	0.067
N-Nitrosodi-n-propylamine	0.095 U	0.070	0.098 U	0.073	0.095 U	0.070	0.094 U	0.070	0.095 U	0.070	0.094 U	0.070	0.096 U	0.071	0.097 U	0.071
N-Nitrosodiphenylamine	0.16 U	0.033	0.16 U	0.034	0.16 U	0.033	0.16 U	0.033	0.16 U	0.033	0.16 U	0.033	0.16 U	0.033	0.16 U	0.034
Pentachlorophenol	0.079 UJ	-	0.082 UJ	-	0.079 UJ	-	0.079 UJ	-	0.079 UJ	-	0.079 UJ	-	0.080 UJ	-	0.081 UJ	-
Phenol	0.32 U	0.025	0.33 U	0.026	0.32 U	0.025	0.31 U	0.025	0.32 U	0.025	0.31 U	0.025	0.32 U	0.025	0.32 U	0.026
Triclosan	0.079 U	0.032	0.082 U	0.033	0.079 U	0.032	0.079 U	0.031	0.079 U	0.032	0.079 U	0.031	0.080 U	0.032	0.081 U	0.032
Triethyl citrate	0.32 U	0.032	0.33 U	0.033	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032	0.31 U	0.031	0.32 U	0.032	0.32 U	0.032

Table E-19. January 2010 BNA Results for Marine Water Samples from Boundary Water Sites.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	SJdF at Sill				SJdF North				Haro Strait			
	Surface		Deep		Surface		Deep		Surface		Deep	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.082 U	0.020	0.087 U	0.021	0.083 U	0.020	0.084 U	0.021	0.081 U	0.020	0.082 U	0.020
1,2-Dichlorobenzene	0.082 U	0.019	0.087 U	0.021	0.083 U	0.020	0.084 U	0.020	0.081 U	0.019	0.082 U	0.019
1,2-Diphenylhydrazine	0.082 U	0.052	0.087 U	0.055	0.083 U	0.053	0.084 U	0.053	0.081 U	0.052	0.082 U	0.052
1,3-Dichlorobenzene	0.082 U	0.017	0.087 U	0.018	0.083 U	0.017	0.084 U	0.017	0.081 U	0.017	0.082 U	0.017
1,4-Dichlorobenzene	0.082 U	0.018	0.087 U	0.019	0.083 U	0.018	0.084 U	0.018	0.081 U	0.018	0.082 U	0.018
2,2'-Oxybis[1-chloropropane]	-	-	-	-	-	-	-	-	-	-	-	-
2,4,5-Trichlorophenol	0.33 U	0.065	0.35 U	0.069	0.33 U	0.066	0.33 U	0.066	0.32 U	0.064	0.33 U	0.065
2,4,6-Trichlorophenol	0.33 U	0.050	0.35 U	0.053	0.33 U	0.050	0.33 U	0.051	0.32 U	0.049	0.33 U	0.050
2,4-Dichlorophenol	0.82 U	0.043	0.87 U	0.045	0.83 U	0.043	0.84 U	0.044	0.81 U	0.042	0.82 U	0.043
2,4-Dimethylphenol	0.82 U	0.048	0.87 U	0.051	0.83 U	0.049	0.84 U	0.049	0.81 U	0.048	0.82 U	0.049
2,4-Dinitrophenol	0.82 U	-	0.87 U	-	0.83 U	-	0.84 U	-	0.81 U	-	0.82 U	-
2,4-Dinitrotoluene	0.33 U	0.046	0.35 U	0.049	0.33 U	0.047	0.33 U	0.047	0.32 U	0.046	0.33 U	0.046
2,6-Dinitrotoluene	0.33 U	0.056	0.35 U	0.059	0.33 U	0.057	0.33 U	0.057	0.32 U	0.055	0.33 U	0.056
2-Chlorophenol	0.33 U	0.043	0.35 U	0.045	0.33 U	0.043	0.33 U	0.044	0.32 U	0.042	0.33 U	0.043
2-Methylphenol	0.82 U	0.041	0.87 U	0.044	0.83 U	0.042	0.84 U	0.042	0.81 U	0.041	0.82 U	0.042
2-Nitroaniline	1.6 UJ	0.055	1.7 UJ	0.058	1.7 UJ	0.055	1.7 UJ	0.056	1.6 UJ	0.054	1.6 UJ	0.055
2-Nitrophenol	0.16 UJ	0.037	0.17 UJ	0.039	0.17 UJ	0.037	0.17 UJ	0.038	0.16 UJ	0.036	0.16 UJ	0.037
3,3'-Dichlorobenzidine	0.16 UJ	-	0.17 UJ	-	0.17 UJ	-	0.17 UJ	-	0.16 UJ	-	0.16 UJ	-
3B-Coprostanol	0.82 UJ	-	0.87 UJ	-	0.83 UJ	-	0.84 UJ	-	0.81 UJ	-	0.82 UJ	-
3-Nitroaniline	0.33 REJ	0.047	0.35 REJ	0.050	0.33 REJ	0.048	0.33 REJ	0.048	0.32 REJ	0.047	0.33 REJ	0.047
4,6-Dinitro-2-Methylphenol	1.6 U	0.55	1.7 U	0.58	1.7 U	0.55	1.7 U	0.56	1.6 U	0.54	1.6 U	0.55
4-Bromophenyl phenyl ether	0.16 U	0.074	0.17 U	0.078	0.17 U	0.075	0.17 U	0.075	0.16 U	0.073	0.16 U	0.074
4-Chloro-3-Methylphenol	0.82 UJ	0.065	0.87 UJ	0.069	0.83 UJ	0.066	0.84 UJ	0.066	0.81 UJ	0.064	0.82 UJ	0.065
4-Chloroaniline	3.3 REJ	0.13	3.5 REJ	0.14	3.3 REJ	0.13	3.3 REJ	0.13	3.2 REJ	0.13	3.3 REJ	0.13
4-Chlorophenyl-Phenylether	0.082 U	0.073	0.087 U	0.078	0.083 U	0.074	0.084 U	0.075	0.081 U	0.073	0.082 U	0.073
4-Methylphenol	0.82 U	0.041	0.87 U	0.043	0.83 U	0.041	0.84 U	0.041	0.81 U	0.040	0.82 U	0.041
4-Nitroaniline	0.33 UJ	-	0.35 UJ	-	0.33 UJ	-	0.33 UJ	-	0.32 UJ	-	0.33 UJ	-
4-Nitrophenol	0.82 U	-	0.87 U	-	0.83 U	-	0.84 U	-	0.81 U	-	0.82 U	-
4-nonylphenol	0.33 U	0.033	0.35 U	0.035	0.33 U	0.033	0.33 U	0.033	0.32 U	0.032	0.33 U	0.033
Benzoic Acid	0.82 UJ	-	0.87 UJ	-	0.83 UJ	-	0.84 UJ	-	0.81 UJ	-	0.82 UJ	-
Benzyl Alcohol	0.82 UJ	0.029	0.87 UJ	0.031	0.83 UJ	0.029	0.84 UJ	0.029	0.81 UJ	0.029	0.82 UJ	0.029
Bis(2-chloro-1-methylethyl) ether	0.082 U	0.055	0.087 U	0.058	0.083 U	0.055	0.084 U	0.056	0.081 U	0.054	0.082 U	0.055
Bis(2-Chloroethoxy)Methane	0.082 U	0.068	0.087 U	0.072	0.083 U	0.069	0.084 U	0.069	0.081 U	0.067	0.082 U	0.068
Bis(2-Chloroethyl)Ether	0.16 U	0.047	0.17 U	0.050	0.17 U	0.048	0.17 U	0.048	0.16 U	0.047	0.16 U	0.047
Bis(2-Ethylhexyl) Phthalate	0.16 U	0.049	0.17 U	0.052	0.17 U	0.050	0.17 U	0.050	0.16 U	0.049	0.16 U	0.049
Bisphenol A	0.33 U	0.033	0.35 U	0.035	0.33 U	0.033	0.33 U	0.033	0.32 U	0.032	0.33 U	0.033
Butyl benzyl phthalate	0.33 UJ	0.038	0.35 UJ	0.041	0.33 UJ	0.039	0.33 UJ	0.039	0.32 UJ	0.038	0.33 UJ	0.038
Caffeine	0.16 U	0.064	0.17 U	0.067	0.17 U	0.064	0.17 U	0.065	0.16 U	0.063	0.16 U	0.064
Cholesterol	0.82 UJ	0.078	0.87 UJ	0.083	0.83 UJ	0.079	0.84 UJ	0.079	0.81 UJ	0.077	0.82 UJ	0.078
Diethyl phthalate	0.16 U	0.081	0.17 U	0.086	0.17 U	0.082	0.17 U	0.082	0.16 U	0.080	0.16 U	0.081
Dimethyl phthalate	0.16 U	0.071	0.17 U	0.075	0.17 U	0.072	0.17 U	0.072	0.16 U	0.070	0.16 U	0.071
Di-N-Butylphthalate	0.29 UJ	0.060	0.26 UJ	0.064	0.21 UJ	0.061	0.24 UJ	0.061	0.30 UJ	0.059	0.28 UJ	0.060
Di-N-Octyl Phthalate	0.16 U	0.073	0.17 U	0.077	0.17 U	0.074	0.17 U	0.074	0.16 U	0.072	0.16 U	0.073
Ethanol, 2-Chloro-, Phosphate (3:1)	0.082 U	0.033	0.087 U	0.035	0.083 U	0.033	0.084 U	0.033	0.081 U	0.032	0.082 U	0.033
Hexachlorobenzene	0.082 U	0.040	0.087 U	0.043	0.083 U	0.041	0.084 U	0.041	0.081 U	0.040	0.082 U	0.041
Hexachlorobutadiene	0.082 U	0.012	0.087 U	0.013	0.083 U	0.013	0.084 U	0.013	0.081 U	0.012	0.082 U	0.012
Hexachlorocyclopentadiene	0.33 UJ	0.010	0.35 UJ	0.011	0.33 UJ	0.010	0.33 UJ	0.011	0.32 UJ	0.010	0.33 UJ	0.010
Hexachloroethane	0.082 UJ	-	0.087 UJ	-	0.083 UJ	-	0.084 UJ	-	0.081 UJ	-	0.082 UJ	-
Isophorone	0.16 U	0.076	0.17 U	0.080	0.17 U	0.077	0.17 U	0.077	0.16 U	0.075	0.16 U	0.076
Nitrobenzene	0.082 U	0.068	0.087 U	0.072	0.083 U	0.069	0.084 U	0.069	0.081 U	0.067	0.082 U	0.068
N-Nitrosodi-n-propylamine	0.098 U	0.073	0.10 U	0.077	0.10 U	0.074	0.10 U	0.074	0.097 U	0.072	0.099 U	0.073
N-Nitrosodiphenylamine	0.16 U	0.034	0.17 U	0.036	0.17 U	0.035	0.17 U	0.035	0.16 U	0.034	0.16 U	0.034
Pentachlorophenol	0.082 U	-	0.087 U	-	0.083 U	-	0.084 U	-	0.081 U	-	0.082 U	-
Phenol	0.33 U	0.026	0.35 U	0.028	0.33 U	0.026	0.33 U	0.027	0.32 U	0.026	0.33 U	0.026
Triclosan	0.082 U	0.033	0.087 U	0.035	0.083 U	0.033	0.084 U	0.033	0.081 U	0.032	0.082 U	0.033
Triethyl citrate	0.33 U	0.033	0.35 U	0.035	0.33 U	0.033	0.33 U	0.033	0.32 U	0.032	0.33 U	0.033

Table E-20. July 2009 Detected PCB Congeners for Marine Water Samples.

PCB Congener (pg/L)	Homolog	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
		Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
PCB-001	mono-									3.07 NJ	1.3 NJ				
PCB-002	mono-										1.4 NJ				
PCB-003	mono-									3.19 NJ	1.82 NJ				
PCB-004	di-		3 J								2.27 J	1.72 J			2.9 J
PCB-008	di-		3.22 J					1.03 J			1.82 J	1.84 J	1.44 J		2.52 J
PCB-017	tri-		2.41 J								2.43 J				
PCB-018/030	tri-		2.69 NJ								2.44 J			2.12 J	
PCB-020/028	tri-		1.79 NJ											1.16 J	
PCB-031	tri-		1.78 NJ									1.96 J		1.06 J	
PCB-040/071	tetra-										0.731 J				
PCB-044/047/065	tetra-	5.82 J	10.8	6.68 J	4.99 J	6.63	4.66 J	5.02 J	7.58	6.81 N	6.5	5.94	6.29	6.09	13.6
PCB-049/069	tetra-		1.22 NJ								1.26 J	1.07 NJ	0.935 J	0.946 J	
PCB-051	tetra-	2.7 NJ	9.14 J	3.91 J	3.3 J	5.45	3.71 J	3.34 J	5.87	6.72	3.74 J	3.77 J	4.04 J	3.58 J	10.6
PCB-052	tetra-	2.6 J	4.02 J			1.23 NJ	1.15 J	0.838 J	1.17 J	2.01 J	2.51 J	2.63 J	1.95 J	2.06 J	2.52 J
PCB-061/070/074/076	tetra-		2.24 NJ			0.933 NJ	0.967 J				1.54 J			1 J	
PCB-066	tetra-										0.867 J				
PCB-068	tetra-		1.66 NJ			1.74 J	1.45 J	1.42 J	1.87 NJ	2.43 NJ	1.6 J		1.57 J	1.12 J	4.57 J
PCB-086/087/097/108/119/125	penta-		2.4 NJ								1.29 NJ	1.16 NJ			
PCB-090/101/113	penta-	2.29 NJ	4.37 J			0.91 J		1.02 J	1.04 NJ	2.03 NJ	3.01 J	2.34 J	1.59 J	2.04 J	2.48 J
PCB-095	penta-		4.55 J			0.864 NJ			1 NJ		2.35 J	1.97 NJ	1.18 NJ	2.01 J	1.55 NJ
PCB-099	penta-										0.974 NJ				0.883 NJ
PCB-105	penta-										0.932 J				
PCB-110	penta-	2.14 J	2.56 NJ			0.675 NJ	0.677 NJ	0.698 NJ	0.767 NJ		2.53 J	1.42 NJ	1.72 J	1.38 J	1.5 NJ
PCB-118	penta-	1.65 J	1.97 NJ			0.679 J		0.817 J			1.42 NJ	1.47 J	0.909 NJ	1.14 NJ	1.57 J
PCB-128/166	hexa-						0.532 J								
PCB-129/138/163	hexa-		2.13 J				1.74 J				2.98 J	1.52 J	1.51 NJ	1.04 J	
PCB-147/149	hexa-		1.53 NJ				0.539 NJ				1.94 J	1.03 NJ	1.29 NJ	0.944 J	1.49 J
PCB-153/168	hexa-		1.25 J								2.47 J	1.3 J	0.99 NJ	1.07 NJ	1.23 J
PCB-156/157	hexa-						0.715 NJ								
PCB-194	octa-								0.763 NJ						

Total PCBs														
…including N,NJ	17.2 J	64.73 J	10.59 J	8.29 J	19.111 J	16.14 J	14.183 J	20.06 J	26.26 J	52.124 J	31.14 J	25.414 J	28.76 J	47.413 J
…excluding N,NJ	12.21 J	44.89 J	10.59 J	8.29 J	15.409 J	14.209 J	13.485 J	14.62	8.73 J	43.92 J	24.49 J	19.535 J	26.55 J	43.48 J

Table E-21. September 2009 Detected PCB Congeners for Marine Water Samples.

PCB Congener (pg/L)	Homolog	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
		Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
PCB-001	mono-	2.46 NJ	0.403 J		0.81 J	0.387 J	0.407 J		1.3 NJ	2.38 J					
PCB-002	mono-	0.336 NJ	1.21 J		0.498 J				0.958 J	7.17					
PCB-003	mono-	0.399 J	1.18 J		1.05 J	0.569 J	0.455 J		1.9 J	4.87 J					
PCB-004	di-	1.62 J	1.65 J	1.08 J	1.36 J	1.32 J	1.93 J	0.977 J	1.87 J	4.05 J	3.08 J	2.67 J	4.05 J	2.25 J	2.51 J
PCB-006	di-	0.397 J	0.386 J			0.404 J	0.411 J	0.299 J		0.826 J	5 U		1.37 J		
PCB-008	di-	1.41 J	1.16 J		1.03 J	0.857 J	1.28 J	0.78 J	1.36 J	2.43 J	1.44 J	1.19 J	1.75 J	1.34 J	1.48 J
PCB-015	di-		0.587 J												
PCB-016	tri-	0.503 J					0.475 J	0.301 NJ							
PCB-017	tri-	0.687 NJ	0.849 J	0.625 J	0.934 J	0.614 J	0.895 J	0.555 J	0.913 NJ	1.74 J	2.46 J	1.54 J	1.52 J	5 U	1.22 J
PCB-018/030	tri-	1.12 J	1.16 J	0.941 J	1.12 J	0.734 J	1.07 J	0.745 J	1.02 NJ	2.6 J	2.1 J	1.75 J	2.23 J	1.2 NJ	1.71 J
PCB-019	tri-	0.348 J					0.315 J	0.405 J		1.02 J					
PCB-020/028	tri-	1.06 J	0.993 J	0.723 J	0.676 NJ	0.656 J	0.757 J	0.506 NJ	0.709 J	1.1 J	1.14 NJ	0.995 NJ	1.16 J	5 U	0.976 J
PCB-021/033	tri-	0.595 J	0.563 J		0.579 J		0.478 NJ	0.348 J		0.963 J					
PCB-022	tri-	0.35 J													
PCB-031	tri-	0.822 J	0.868 J		0.713 NJ	0.535 J	0.685 J	0.519 NJ	0.758 J	1.37 J	1.06 NJ	0.891 J	1.11 J		
PCB-032	tri-	0.34 NJ	0.381 J				0.302 J			0.629 NJ	1.04 J	5 U			
PCB-039	tri-						0.308 J	0.199 NJ				5 U			
PCB-044/047/065	tetra-	5.48 J	6.12 J	5.93 J	12.6	5.73 J	9.7 J	4.94 J	9.55 J	14.5 J	17.1	6.76 J	13 J	6.32 J	8.25 J
PCB-049/069	tetra-	0.482 NJ	0.631 NJ		0.874 J		0.54 J	0.438 J		1.21 J	1.34 J	5 U		0.909 J	1.34 J
PCB-051	tetra-	4.01 J	4.2	3.54 J	9.76	4.1	6.71	3.33 J	8.62	11.7	12.4	4.84 J	10.4	4.44 J	6.61
PCB-052	tetra-	1.24 J	1.45 J	0.984 J	1.56 J	1.1 J	1.14 J	0.972 J	1.95 J	2.86 J	2.55 NJ	1.85 J	2.43 J	1.6 J	2.12 J
PCB-061/070/074/076	tetra-	1.05 J	1.07 J	0.656 J			0.837 J	0.728 J		1.58 NJ		1.41 NJ			
PCB-068	tetra-	0.96 J	1.43 J	1.11 J	2.79 J	1.07 J	2.16 J	0.93 J	2.29 J	2.45 J	6.26	1.78 NJ	2.77 J	1.13 NJ	2.45 J
PCB-086/087/097/108/119/125	penta-	0.903 J	1.28 J		1.14 J		0.808 J	0.723 J		2.1 J				2.4 J	
PCB-090/101/113	penta-	1.09 J	1.67 J	0.883 J		0.816 NJ	0.897 J	0.733 J	1.38 J	2.28 NJ	1.82 NJ	2.6 NJ	3.28 NJ		2.11 J
PCB-095	penta-	0.933 J	1.65 J	0.976 J		0.979 J	0.986 NJ	0.598 J	1.06 NJ	2.43 J	2.55 J	1.8 NJ	2.19 NJ	2.04 J	2.09 NJ
PCB-099	penta-						0.358 J								
PCB-105	penta-	0.371 NJ						0.413 NJ		0.935 NJ	1.31 NJ		1.06 NJ		
PCB-110	penta-	0.841 J	1.2 J	0.711 J	1.22 J	0.635 NJ	0.847 J	0.454 NJ	1.19 J	2.11 J	2.1 NJ	1.24 NJ	2.34 J	1.39 J	1.39 J
PCB-118	penta-	0.573 J	0.823 J	0.505 J	0.935 J		0.61 J	0.473 J		1.44 NJ	1.59 J	0.862 NJ	1.64 NJ	1.44 J	1.12 NJ
PCB-129/138/163	hexa-	0.609 J	1.3 J		1.14 J		0.44 J	0.473 J		1.04 NJ	1.44 J	1.75 J	2.01 J		1.9 J
PCB-147/149	hexa-	0.366 NJ	4.13 U				0.434 J	0.254 J		1.2 J	1.68 J	1.18 NJ	2.17 J	1.26 J	1.48 J
PCB-153/168	hexa-	0.383 J	0.542 NJ		0.732 NJ		0.366 J	0.302 J		1.02 J	1.29 NJ	0.865 J	1.86 J		1.26 J
PCB-169	hexa-	0.337 J													
PCB-177	hepta-												2.06 J		
PCB-187	hepta-									3.04 J	1.63 J				
PCB-194	octa-							0.287 J				1.27 J			1.53 NJ

Total PCBs														
…including N,NJ	32.075 J	34.756 J	18.664 J	41.521 J	20.506 J	36.882 J	21.682 J	36.828 J	83.043 J	68.83 J	37.243 J	60.4 J	27.719 J	41.546 J
…excluding N,NJ	27.033 J	33.583 J	18.664 J	39.4 J	19.055 J	35.418 J	19.29 J	32.535 J	75.139 J	57.56 J	25.376 J	52.23 J	25.389 J	36.806 J

Table E-22. January 2010 Detected PCB Congeners for Marine Water Samples.

PCB Congener (pg/L)	Homolog	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
		Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
PCB-001	mono-				0.818 J								4.22		1.04 NJ
PCB-002	mono-												7.82	1.07 J	0.973 J
PCB-003	mono-				0.916 J								6.65	1.41 NJ	1.21 NJ
PCB-004	di-				1.67 J						2.15 J				
PCB-008	di-				1.28 J						0.858 J				
PCB-017	tri-				0.975 NJ						1.17 J			0.883 NJ	
PCB-018/030	tri-	1.14 J		0.939 J	0.808 NJ	1.03 NJ	1.39 J	1.11 J	0.958 NJ	1.22 NJ	1.5 J	1.68 NJ	1.26 NJ	1.42 NJ	1.22 J
PCB-020/028	tri-	0.629 NJ		0.62 J	0.67 J	0.855 J	0.908 J	0.644 J			1.05 J		1.24 J	1.24 J	
PCB-021/033	tri-			0.444 NJ	0.443 NJ										
PCB-031	tri-			0.53 NJ	0.521 NJ			0.587 NJ			0.883 NJ		1.11 J	1.11 NJ	
PCB-032	tri-										0.843 J				
PCB-040/071	tetra-										0.576 NJ				
PCB-044/047/065	tetra-	4.32 NJ	9.42 J	4.83 J	14.4	4.66 NJ	11.6 J	5.87 J	11.5 J	14.6	6.49 J	7.32 J	7.28 J	6.25 J	7.08 J
PCB-049/069	tetra-			0.714 NJ		1.04 NJ		0.569 NJ		1.36 J	1.09 J	1.58 J	1.35 J	0.982 NJ	
PCB-051	tetra-	3 NJ	6.82	3.3 J	9.99	3.61 J	8.36	3.78 J	8.01	8.69 NJ	3.9 J	4.36	4.65	2.53 NJ	4.93
PCB-052	tetra-	2.84 J	2.67 J	1.95 J	2.1 J	1.88 J	1.75 J	1.77 J	1.72 J	2.28 NJ	2.76 J	2.86 NJ	3.33 J	3.18 J	2.45 NJ
PCB-061/070/074/076	tetra-										1.35 NJ				
PCB-068	tetra-		1.27 NJ	0.696 NJ	2.89 J		2.4 J	0.983 J	2.36 J	2.71 NJ	0.923 J		0.916 NJ		0.856 J
PCB-084	penta-										0.818 J				
PCB-086/087/097/108/119/125	penta-										1.42 J				
PCB-090/101/113	penta-	2.11 J		1.42 J	1.12 J			0.944 J		2.43 J	2.81 J		1.95 NJ	2.86 J	2.57 J
PCB-095	penta-				1.44 NJ		1.4 NJ	1.3 J			2.76 NJ		1.82 NJ	1.84 NJ	2.65 J
PCB-099	penta-										0.969 J				
PCB-105	penta-				0.384 J						0.665 J				
PCB-110	penta-			1.15 J	0.935 J			0.803 NJ		1.52 NJ	2.13 J		1.29 NJ	2.07 J	1.47 NJ
PCB-118	penta-				0.649 J						1.56 NJ		1.33 J	1.37 J	
PCB-129/138/163	hexa-			0.595 NJ	0.872 J						2.68 J		1.6 NJ		2.48 J
PCB-132	hexa-										0.851 J				
PCB-135/151	hexa-										0.978 J				
PCB-147/149	hexa-	0.783 NJ						0.675 J			1.59 NJ		1.49 NJ	1.59 J	1.92 J
PCB-153/168	hexa-			0.545 NJ				0.582 J		1.11 NJ	1.83 J		1.04 NJ	1.54 NJ	1.63 J
PCB-169	hexa-				0.457 NJ										
PCB-180/193	hepta-										0.526 NJ				
PCB-187	hepta-										0.739 NJ				

Total PCBs														
…including N,NJ	14.822 J	20.18 J	17.733 J	43.338 J	13.075 J	27.808 J	19.617 J	24.548 J	35.92 J	47.869 J	17.8 J	50.346 J	31.345 J	32.479 J
…excluding N,NJ	6.09 J	18.91 J	14.209 J	38.694 J	6.345 J	26.408 J	17.658 J	23.59 J	18.39 J	37.885 J	13.26 J	38.98 J	19.63 J	26.309 J

Table E-23. PCB Homolog Totals for Marine Water Samples.

Results qualified as N or NJ were not included in homolog sums or Total PCB calculations.

Sampling Date	PCB Homolog (pg/L)	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
		Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
July 2009	Mono-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Di-CBs	0	6.22 J	0	0	0	0	1.03 J	0	0	4.09 J	3.56 J	1.44 J	0	5.42 J
	Tri-CBs	0	2.41 J	0	0	0	0	0	0	0	4.87 J	1.96 J	0	4.34 J	0
	Tetra-CBs	8.42 J	23.96 J	10.59 J	8.29 J	13.82 J	11.937 J	10.618 J	14.62	8.73 J	18.748 J	12.34 J	14.785 J	14.796 J	31.29 J
	Penta-CBs	3.79 J	8.92 J	0	0	1.589 J	0	1.837 J	0	0	8.822 J	3.81 J	3.31 J	5.43 J	4.05 J
	Hexa-CBs	0	3.38 J	0	0	0	2.272 J	0	0	0	7.39 J	2.82 J	0	1.984 J	2.72 J
	Hepta-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Octa-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nona-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PCB-209	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total PCBs	12.21 J	44.89 J	10.59 J	8.29 J	15.409 J	14.209 J	13.485 J	14.62	8.73 J	43.92 J	24.49 J	19.535 J	26.55 J	43.48 J
September 2009	Mono-CBs	0.399 J	2.793 J	0	2.358 J	0.956 J	0.862 J	0	2.858 J	14.42 J	0	0	0	0	0
	Di-CBs	3.427 J	3.783 J	1.08 J	2.39 J	2.581 J	3.621 J	2.056 J	3.23 J	7.306 J	4.52 J	3.86 J	7.17 J	3.59 J	3.99 J
	Tri-CBs	4.798 J	4.814 J	2.289 J	2.633 J	2.539 J	4.807 J	2.053 J	1.467 J	8.793 J	7.05 J	4.181 J	6.02 J	0	3.906 J
	Tetra-CBs	12.74 J	14.27 J	12.22 J	27.584 J	12 J	21.368 J	11.338 J	22.41 J	32.72 J	37.1	13.45 J	28.6 J	13.269 J	20.77 J
	Penta-CBs	4.34 J	6.623 J	3.075 J	3.295 J	0.979 J	3.52 J	2.527 J	2.57 J	6.64 J	4.14 J	0	2.34 J	7.27 J	3.5 J
	Hexa-CBs	1.329 J	1.3 J	0	1.14 J	0	1.24 J	1.029 J	0	2.22 J	3.12 J	2.615 J	6.04 J	1.26 J	4.64 J
	Hepta-CBs	0	0	0	0	0	0	0	0	3.04 J	1.63 J	0	2.06 J	0	0
	Octa-CBs	0	0	0	0	0	0	0.287 J	0	0	0	1.27 J	0	0	0
	Nona-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PCB-209	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total PCBs	27.033 J	33.583 J	18.664 J	39.4 J	19.055 J	35.418 J	19.29 J	32.535 J	75.139 J	57.56 J	25.376 J	52.23 J	25.389 J	36.806 J
January 2010	Mono-CBs	0	0	0	1.734 J	0	0	0	0	0	0	0	18.69	1.07 J	0.973 J
	Di-CBs	0	0	0	2.95 J	0	0	0	0	0	3.008 J	0	0	0	0
	Tri-CBs	1.14 J	0	1.559 J	0.67 J	0.855 J	2.298 J	1.754 J	0	0	4.563 J	0	2.35 J	1.24 J	1.22 J
	Tetra-CBs	2.84 J	18.91 J	10.08 J	29.38 J	5.49 J	24.11 J	12.403 J	23.59 J	15.96	15.163 J	13.26 J	16.61 J	9.43 J	12.866 J
	Penta-CBs	2.11 J	0	2.57 J	3.088 J	0	0	2.244 J	0	2.43 J	8.812 J	0	1.33 J	6.3 J	5.22 J
	Hexa-CBs	0	0	0	0.872 J	0	0	1.257 J	0	0	6.339 J	0	0	1.59 J	6.03 J
	Hepta-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Octa-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nona-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PCB-209	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total PCBs	6.09 J	18.91 J	14.209 J	38.694 J	6.345 J	26.408 J	17.658 J	23.59 J	18.39 J	37.885 J	13.26 J	38.98 J	19.63 J	26.309 J

Table E-24. Detected PBDE Congeners for Marine Water Samples.

Samples for which all congener results were nondetects (U- or UJ-qualified) were assigned a total PBDE value equal to the highest congener reporting limit (RL).

Sampling Date	PBDE Homolog [1]	PBDE Congener (pg/L)	Hood Canal		SJdF at Sill		SJdF North		Haro Strait		Whidbey Basin		Main Basin		South Sound	
			Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
July 2009	Tetra-	PBDE-047				163 J										
	Penta-	PBDE-085				25.6										
	Penta-	PBDE-099				184										
	Penta-	PBDE-100				50 N										
	Total PBDEs															
	…including N, NJ		120.2 U	120.2 U	128.9 U	422.6 J	122.5 U	134.4 U	125 U	129.5 U	135.9 U	127.6 U	120.2 U	121.4 U	130.2 U	128.9 U
	…excluding N, NJ		120.2 U	120.2 U	128.9 U	372.6 J	122.5 U	134.4 U	125 U	129.5 U	135.9 U	127.6 U	120.2 U	121.4 U	130.2 U	128.9 U
September 2009	Tri-	PBDE-028													10.7 J	
	Tetra-	PBDE-047					87.5 J		556							
	Tetra-	PBDE-049							29.7							
	Penta-	PBDE-085							56.9				28.3		23 J	
	Penta-	PBDE-099					152	51 J	1080						424 J	
	Penta-	PBDE-100					26.4		238				63.2 J		74.3 J	
	Hexa-	PBDE-139							21.5 J				12.3 J			
	Hexa-	PBDE-153							115				32.6		33.1	
	Hexa-	PBDE-154							87.6				49.3		28	
	Octa-	PBDE-201							43 J							
	Deca-	PBDE-209							959							
	Total PBDEs															
	…including N, NJ		123 U	122.5 U	123.8 U	122.5 U	265.9 J	51 J	3186.7	134 U	121.4 U	120.2 U	185.7 J	121.4 U	593.1 J	127.6 U
	…excluding N, NJ		123 U	122.5 U	123.8 U	122.5 U	265.9 J	51 J	3186.7	134 U	121.4 U	120.2 U	185.7 J	121.4 U	593.1 J	127.6 U
January 2010	Tetra-	PBDE-066		12.8 NJ												
	Octa-	PBDE-196								40.8 J						
	Octa-	PBDE-201								50.3 J						
	Octa-	PBDE-203								108						
	Nona-	PBDE-206				80 J				822						
	Nona-	PBDE-207				166 J				1240						
	Nona-	PBDE-208				153 J				1270	101 NJ					
	Deca-	PBDE-209				2700				15200 J	1300 J				904	
	Total PBDEs															
	…including N, NJ		245 U	12.8 NJ	243 U	3099 J	253 U	253 U	255 U	18691 J	1401 J	245 U	240 U	245 U	904	238 U
	…excluding N, NJ		245 U	240 U	243 U	3099 J	253 U	253 U	255 U	18691 J	1300 J	245 U	240 U	245 U	904	238 U

[1] The following 36 congeners were measured (listed by homolog group):
Di-brominated congeners = PBDEs 007, 010, and 015; tri-brominated congeners = PBDEs 017, 028, and 030; tetra-brominated congeners = PBDEs 047, 049, 066, 071, and 077; penta-brominated congeners = PBDEs 085, 099, 100, 119, and 126; hexa-brominated congeners are PBDEs 138-140, 153, 154, and 156/169; hepta-brominated congeners are PBDEs 171, 180, 183, 184, and 191; octa-brominated congeners are PBDEs 196, 197/204, 201, 203, and 205; nona-brominated congeners are PBDEs 206-208; the deca-brominated congener is PBDE 209.

Appendix F. Analytical Results - Marine SPM

Table F-1. Summary of Results for Marine Particulate Samples.

All results for the Case+Carr Inlet sample were J-qualified due to analysis beyond holding time. PBDE results show only detected congeners.

Parameter	Hood Canal (Deep)	Case+Carr (Mid-water)
Conventional Parameters (%)		
TOC	2.75	n/a
Total Recoverable Metals (mg/Kg dry)		
Arsenic	7.53	5.72 J
Cadmium	0.87	1.04 J
Copper	82.0	18.5 J
Lead	9.13	8.78 J
Zinc	90.0	72.0 J
PBDE s (ng/Kg dry)		
BDE-017		28.6 J
BDE-028	10.2 J	40.1 J
BDE-047	120	438 J
BDE-049	17.8 J	59.6 J
BDE-099	104	184 J
BDE-100	27.1 J	84.8 J
BDE-139		10.4 J
BDE-153	29.6	18.2 J
BDE-154	14 J	29.8 J
BDE-183	54.1 J	41.2 J
BDE-197/204	36.7 J	28.4 J
BDE-203	20.6 J	
BDE-206		92.1 J
BDE-207	103 J	
BDE-208	167	
BDE-209	879	
Total PBDEs	1583.1 J	1055.2 J

Table F-2. Summary of Detected PCB Congeners in Marine Particulate Samples.

All detected results for the Case+Carr sample were J-qualified due to analysis beyond holding time.

PCB Congener (ng/Kg dry)	Hood Canal (Deep)	Case+Carr (Mid-water)
PCB-001		19 NJ
PCB-002		13.3 J
PCB-003		22 J
PCB-004		18.8 NJ
PCB-005/008	71.9	165 J
PCB-006		12.4 NJ
PCB-007	10.1 NJ	
PCB-011	305	571 J
PCB-012/013		58.5 N
PCB-015	52.5	104 J
PCB-016	13.5 NJ	60.7 J
PCB-017	22.9	61.5 J
PCB-018	42.6	143 J
PCB-020/033	34.9	172 J
PCB-022	26.4	111 J
PCB-025		28 J
PCB-026		34.5 J
PCB-027		11.7 J
PCB-028	56.6	381 J
PCB-031	52.5	243 J
PCB-032		47.1 J
PCB-037	44.2	57.5 N
PCB-042	20.5 J	21.4 NJ
PCB-043/049	43.7	150 J
PCB-044	53.1	97.8 J
PCB-045		15.8 NJ
PCB-046	31.8 N	
PCB-047/048	32.8	87.1J
PCB-050		
PCB-051		12.6 NJ
PCB-052/069		187 J
PCB-053		18.3 J
PCB-056	12.3 NJ	65.8 J
PCB-060		39.9 J
PCB-064/072	20.1 J	30 J
PCB-066	55.2	186 J
PCB-070	73	218 J
PCB-071	11.9 J	16.4 J
PCB-074	32.3	102 J
PCB-076		11.8 NJ
PCB-077		33.8 J
PCB-081	12.9 NJ	
PCB-082		32.1 N
PCB-083		19.1 NJ
PCB-084		75.7 J
PCB-085		72.5 J
PCB-086/097/117	54.1	86.3 J
PCB-087/115	50.6 N	103 J
PCB-090		15.8 J
PCB-091		50.2 J
PCB-092	39.7	72 J
PCB-093/095/098/102	134	283 J
PCB-099	124	214 J
PCB-101	171	365 J
PCB-105	61.9	133 J
PCB-107/108		42.7 J
PCB-110	201	368 J
PCB-112/119		13.3 J
PCB-118	128	384 J
PCB-121	22 J	
PCB-123	12.5 J	11.7 J
PCB-124	11.5 NJ	
PCB-128	22.9 N	72.4 J
PCB-129		12.1 NJ
PCB-130		49.5 N
PCB-132	45.4	158 J
PCB-134		27.1 J
PCB-135	36	97.1 J
PCB-136	24.1 N	93.9 J
PCB-137		20 J
PCB-138	147	534 J
PCB-139/149	176	535 J
PCB-141		61.8 J
PCB-144		41.2 J
PCB-146	25 N	127 J
PCB-151	20.9 NJ	145 J
PCB-153	170	690 J
PCB-154		11.9 NJ
PCB-156	13.1 J	35.4 J
PCB-157		11.6 J
PCB-158	10.6 J	37.6 J
PCB-163/164	44.3	206 J
PCB-167		25.7 J
PCB-170	38.1	85 J
PCB-171		39.4 J
PCB-172		11.8 J
PCB-174	31.5 N	52.9 J
PCB-176		12 J
PCB-177	31.2	85.1 J
PCB-178		55.5 J
PCB-179	27.4	63.3 J
PCB-180	92.4	202 J
PCB-182/187	94.8	254 J
PCB-183	21.4 NJ	47.7 J
PCB-190		13.8 NJ
PCB-194		37.6 J
PCB-195		25.8 J
PCB-196		25.1 J
PCB-199	26.4 N	92.2 J
PCB-201		15.4 NJ
PCB-202		28.7 J
PCB-203	11.6 J	39.7 J
PCB-206	20.3 NJ	53.4 J
PCB-208	23.2 N	21.1 NJ
PCB-209	27.8	32.3 J
Total PCBs		
…including N,NJ	3324.4 J	10256.2 J
…excluding N,NJ	2966	9853.4 J

Appendix G. Analytical Results - Rivers

Table G-1. Conventionals and Metals Results for River Water Samples.

Non-detect values are given at the method detection limit (MDL).

Parameter	Nooksack			Skagit			Stillaguamish			Snohomish			Puyallup		
	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec
Conventional Parameters (mg/L)															
TSS	10.9	3.7	76.3 J	7.2	6.4	60.8 J	2.6	41.3	3.7	4.7	13.6	54.5	233	38.7	11.9
TOC	0.6 J	0.8 J	2.8	0.6 J	0.6 J	1.7	0.8 J	3.3	1.1	0.6 J	2.1	2.1	0.5 J	1.1	1.3
DOC	0.8 J	1	2.9	0.6 J	0.9 J	1.6	0.9 J	4	1	0.7 J	2.2	2.1	0.8 J	1.4	1.2
Ammonia	0.002 U	0.002 U	0.022	0.002 U	0.046	0.002 U	0.011	0.039	0.007 J	0.002 U	0.079	0.008 J	0.01	0.162	0.027
Nitrate+Nitrite	0.087	0.344	0.544	0.045	0.084	0.126	0.088	0.341	0.301	0.077	0.281	0.276	0.11	0.309	0.301
Total Nitrogen	0.106	0.376	0.656	0.057	0.163	0.157	0.147	0.418	0.332	0.102	0.389	0.321	0.137	0.545	0.37
Total Phosphorus	0.0212	0.0257	0.0904	0.0073 J	0.0059	0.0855	0.0172	0.0718	0.0155	0.0092 J	0.0324	0.0532	0.25	0.0795	0.0437
Ortho-phosphate	0.0082 J	0.0209	0.0099	0.0042	0.0032	0.0045	0.0141	0.0112 J	0.0075	0.0047	0.0144	0.0041	0.0287	0.0478	0.0211
Hardness	38.1	62.0 J	38.5	21.8	29.9 J	27.6	31.9	19.2	29.9	17.4	15.7	13.2	27.7	40.8	33.2
Metals (µg/L)															
Arsenic, total	0.37	0.26	1.01	0.57	0.43	1.24	0.73	1.12	0.52	0.92	0.94	1.14	0.92	0.6	0.52
Arsenic, dissolved	0.31	0.37	0.3	0.5	0.47	0.5	0.75	0.51	0.48	0.86	0.71	0.52	0.46	0.62	0.5
Cadmium, total	0.005 J	0.005 J	0.04 J	0.009 J	0.006 J	0.02 J	0.005 J	0.02 J	0.007 J	0.005 J	0.01 J	0.03 J	0.01 J	0.006 J	0.005 J
Cadmium, dissolved	0.002 U	0.007 J	0.006 UJ	0.002 U	0.006 J	0.035	0.002 U	0.003 J	0.005 J	0.002 U	0.003 J	0.010 J	0.003 J	0.003 J	0.002 U
Copper, total	2.08	0.75 J	4.41	0.77	0.86	4.56	1.16	6.58	1.12	1.35	2.36	4.08	11.6	1.81	1.32
Copper, dissolved	0.38	0.41	2.09	0.52	0.35	1.04	1.22	1.69	0.68	1.71	1.17	1	4.19	0.91	0.63
Lead, total	0.10 J	0.05 J	0.82	0.11 J	0.05 J	0.78	0.03 UJ	0.79	0.37 J	0.09 J	0.3	0.63	1.42	0.2	0.11 UJ
Lead, dissolved	0.006 U	0.018 J	0.281	0.006 U	0.014 J	0.046	0.006 U	0.052	0.04	0.048	0.037	0.054	0.006 U	0.035	0.024
Zinc, total	5.1	3.2 J	9.7	2.4 J	2.4 J	10.6	4.0 J	17.7	5.2 J	2.5 J	3.3 J	8.3 J	11.6	3.7 J	2.7 UJ
Zinc, dissolved	1.4	1	3.4	1.5	0.7 J	0.9 J	2.2	0.7 J	3.2	4.4	3.7	0.9 J	2	1.2	1

Table G-2. Petroleum-Related Products Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Sampling Date	Parameter (mg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
		Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
July 2009	Oil and Grease	1.4 J	0.5	1.4 J	0.5	1.4 J	0.5	2.8	0.5	0.9 J	0.5
	TPH-D #2 Diesel	0.05 U	0.002	0.05 U	0.002	0.05 U	0.002	0.05 U	0.002	0.05 U	0.002
	TPH-D Lube Oil	0.12 U	0.004	0.13 U	0.004	0.13 U	0.004	0.13 U	0.004	0.13 U	0.004
	TPH-G [1]	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014
October 2009	Oil and Grease	1.8 U	0.5	1.9 U	0.5	1.8 U	0.5	1.8 U	0.5	1.8 U	0.5
	TPH-D #2 Diesel	0.05 U	0.002	0.05 U	0.002	0.05 U	0.002	0.05 U	0.002	0.05 U	0.002
	TPH-D Lube Oil	0.12 U	0.004	0.12 U	0.004	0.13 U	0.004	0.12 U	0.004	0.12 U	0.004
	TPH-G	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014
December 2009	Oil and Grease	5.5 U	1.5	5.4 U	1.5	5.4 U	1.5	1.6 J	1.5	5.5 U	1.5
	TPH-D #2 Diesel	0.02 U	0.0005	0.02 U	0.0006	0.05 U	0.002	0.02 U	0.0006	0.02 U	0.0006
	TPH-D Lube Oil	0.04 U	0.001	0.04 U	0.001	0.12 U	0.004	0.04 U	0.001	0.04 U	0.004
	TPH-G	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014	0.14 U	0.014

[1] TPH-G results for July represent the average of three quarter point samples (none were detected).

Table G-3. July 2009 Chlorinated Pesticides Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	-	-	-	-	-	-	-	-	-	-
2,4'-DDE	-	-	-	-	-	-	-	-	-	-
2,4'-DDT	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18	0.20 U	0.17	0.21 UJ	0.18
4,4'-DDE	0.28 UJ	0.17	0.21 U	0.18	0.26 UJ	0.17	0.21 UJ	0.17	0.21 UJ	0.17
4,4'-DDT	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 UJ	-
Aldrin	0.20 UJ	0.061	0.21 UJ	0.065	0.21 UJ	0.062	0.20 UJ	0.061	0.21 UJ	0.063
Alpha-BHC	0.20 U	0.041	0.21 U	0.043	0.21 U	0.041	0.20 U	0.040	0.21 UJ	0.042
Beta-BHC	0.20 U	0.14	0.21 U	0.15	0.21 U	0.15	0.20 U	0.14	0.21 UJ	0.15
Chlorpyriphos	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
cis-Chlordane	0.20 U	0.090	0.21 U	0.096	0.21 U	0.092	0.20 U	0.090	0.21 UJ	0.093
Cis-Nonachlor	0.20 U	0.13	0.21 U	0.14	0.21 U	0.13	0.20 U	0.13	0.21 UJ	0.13
Dacthal (DCPA)	-	-	-	-	-	-	-	-	-	-
DDMU	-	-	-	-	-	-	-	-	-	-
Delta-BHC	0.20 UJ	0.040	0.21 UJ	0.043	0.21 UJ	0.041	0.20 UJ	0.040	0.21 UJ	0.041
Dieldrin	0.50 U	0.20	0.53 U	0.21	0.51 U	0.21	0.50 U	0.20	0.51 U	0.21
Endosulfan I	0.20 U	0.091	0.21 U	0.096	0.21 U	0.093	0.20 U	0.090	0.21 U	0.093
Endosulfan II	0.20 U	0.074	0.21 U	0.079	0.21 U	0.076	0.20 U	0.074	0.21 U	0.076
Endosulfan Sulfate	0.20 U	0.16	0.21 U	0.17	0.21 U	0.16	0.20 U	0.16	0.21 U	0.17
Endrin	0.50 U	0.22	0.53 U	0.23	0.51 U	0.22	0.50 U	0.21	0.51 U	0.22
Endrin Aldehyde	0.20 U	0.15	0.21 U	0.16	0.21 U	0.15	0.20 U	0.15	0.21 U	0.16
Endrin Ketone	0.75 U	0.61	0.80 U	0.64	0.77 U	0.62	0.75 U	0.60	0.77 U	0.62
Gamma-BHC (Lindane)	1.0 UJ	0.050	1.2 UJ	0.054	0.87 UJ	0.051	1.2 UJ	0.050	2.1 UJ	0.052
Heptachlor	0.20 UJ	0.088	0.21 UJ	0.093	0.21 UJ	0.090	0.20 UJ	0.087	0.21 UJ	0.090
Heptachlor Epoxide	0.20 U	0.12	0.21 U	0.13	0.21 U	0.13	0.20 U	0.12	0.21 U	0.13
Hexachlorobenzene	0.20 UJ	-	0.21 UJ	-	0.21 UJ	-	0.20 UJ	-	0.21 UJ	-
Methoxychlor	0.50 U	0.25	0.53 U	0.27	0.51 U	0.26	0.50 U	0.25	0.51 U	0.26
Mirex	-	-	-	-	-	-	-	-	-	-
Oxychlordane	0.20 U	0.073	0.21 U	0.078	0.21 U	0.075	0.20 U	0.073	0.21 UJ	0.075
Pentachloroanisole	-	-	-	-	-	-	-	-	-	-
Toxaphene	9.9 U	-	11 U	-	10 U	-	9.9 U	-	10 UJ	-
trans-Chlordane	0.20 U	0.15	0.21 U	0.16	0.21 U	0.15	0.20 U	0.15	0.21 UJ	0.15
Trans-Nonachlor	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 UJ	-

Table G-4. October 2009 Chlorinated Pesticides Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
2,4'-DDE	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
2,4'-DDT	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
4,4'-DDD	0.21 U	0.18	0.20 U	0.17	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18
4,4'-DDE	0.21 U	0.17	0.20 U	0.17	0.20 U	0.17	0.21 U	0.17	0.21 U	0.18
4,4'-DDT	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
Aldrin	0.21 UJ	0.062	0.20 UJ	0.062	0.20 UJ	0.061	0.21 UJ	0.063	0.21 UJ	0.063
Alpha-BHC	0.21 U	0.041	0.20 U	0.041	0.20 UJ	0.041	0.21 UJ	0.042	0.21 U	0.042
Beta-BHC	0.21 U	0.15	0.20 U	0.15	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15
Chlorpyriphos	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
cis-Chlordane	0.21 U	0.092	0.20 U	0.091	0.20 U	0.091	0.21 U	0.093	0.21 U	0.093
Cis-Nonachlor	0.21 U	0.13	0.20 U	0.13	0.20 U	0.13	0.21 U	0.13	0.21 U	0.13
Dacthal (DCPA)	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
DDMU	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
Delta-BHC	0.21 U	0.041	0.20 U	0.040	0.20 U	0.040	0.21 U	0.041	0.21 U	0.041
Dieldrin	0.51 U	0.21	0.51 U	0.20	0.50 U	0.20	0.51 U	0.21	0.52 U	0.21
Endosulfan I	0.21 U	0.093	0.20 U	0.092	0.20 U	0.091	0.21 U	0.093	0.21 U	0.093
Endosulfan II	0.21 U	0.076	0.20 U	0.075	0.20 U	0.075	0.21 U	0.076	0.21 U	0.077
Endosulfan Sulfate	0.21 U	0.16	0.25 UJ	0.16	0.20 U	0.16	0.23 UJ	0.17	0.32 UJ	0.17
Endrin	0.51 U	0.22	0.51 U	0.22	0.50 U	0.22	0.51 U	0.22	0.52 U	0.22
Endrin Aldehyde	0.44 UJ	0.15	0.36 UJ	0.15	0.36 UJ	0.15	0.52 UJ	0.16	0.46 UJ	0.16
Endrin Ketone	0.77 U	0.62	0.76 U	0.61	0.75 U	0.61	0.77 U	0.62	0.77 U	0.62
Gamma-BHC (Lindane)	8.6 UJ	0.051	5.6 UJ	0.051	4.4 UJ	0.051	5.2 UJ	0.052	26 UJ	0.26
Heptachlor	0.21 U	0.090	0.20 U	0.089	0.20 U	0.088	0.21 U	0.090	0.21 U	0.090
Heptachlor Epoxide	0.21 U	0.13	0.20 U	0.12	0.20 U	0.12	0.21 U	0.13	0.21 U	0.13
Hexachlorobenzene	0.21 U	-	0.20 U	-	1.6	-	0.21 U	-	0.21 U	-
Methoxychlor	0.51 U	0.26	0.51 U	0.26	0.50 U	0.25	0.51 U	0.26	0.52 U	0.26
Mirex	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
Oxychlordane	0.21 U	0.075	0.20 U	0.074	0.20 U	0.073	0.21 U	0.075	0.21 U	0.075
Pentachloroanisole	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-
Toxaphene	10 U	-	10 U	-	9.9 U	-	10 U	-	10 U	-
trans-Chlordane	0.21 U	0.15	0.20 U	0.15	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15
Trans-Nonachlor	0.21 U	-	0.20 U	-	0.20 U	-	0.21 U	-	0.21 U	-

Table G-5. December 2009 Chlorinated Pesticides Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (ng/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
2,4'-DDE	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
2,4'-DDT	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
4,4'-DDD	0.20 U	0.17	0.21 U	0.18	0.21 U	0.18	0.20 U	0.17	0.21 U	0.18
4,4'-DDE	0.20 U	0.17	0.21 U	0.17	0.21 U	0.18	0.20 U	0.17	0.21 U	0.18
4,4'-DDT	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
Aldrin	0.20 U	0.061	0.21 UJ	0.062	0.21 U	0.065	0.20 U	0.061	0.21 UJ	0.064
Alpha-BHC	0.20 U	0.041	0.21 U	0.041	0.21 U	0.043	0.20 U	0.041	0.21 U	0.042
Beta-BHC	0.20 U	0.15	0.21 U	0.15	0.21 U	0.15	0.20 U	0.14	0.21 U	0.15
Chlorpyriphos	0.21 UJ	-	0.23 UJ	-	0.21 U	-	0.20 U	-	0.21 UJ	-
cis-Chlordane	0.20 U	0.091	0.21 U	0.092	0.21 U	0.096	0.20 U	0.090	0.21 U	0.094
Cis-Nonachlor	0.20 U	0.13	0.21 U	0.13	0.21 U	0.14	0.20 U	0.13	0.21 U	0.13
Dacthal (DCPA)	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
DDMU	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
Delta-BHC	0.20 U	0.040	0.21 U	0.041	0.21 U	0.043	0.20 U	0.040	0.21 U	0.042
Dieldrin	0.50 U	0.20	0.51 U	0.21	0.53 U	0.21	0.50 U	0.20	0.52 U	0.21
Endosulfan I	0.20 U	0.091	0.21 U	0.093	0.21 U	0.096	0.20 U	0.091	0.21 U	0.094
Endosulfan II	0.20 U	0.075	0.21 U	0.076	0.21 U	0.079	0.20 U	0.074	0.21 U	0.077
Endosulfan Sulfate	0.42	0.16	0.21 U	0.16	0.21 U	0.17	0.20 U	0.16	0.21 U	0.17
Endrin	0.50 U	0.22	0.51 U	0.22	0.53 U	0.23	0.50 U	0.22	0.52 U	0.22
Endrin Aldehyde	0.20 U	0.15	0.21 U	0.15	0.21 U	0.16	0.20 U	0.15	0.21 U	0.16
Endrin Ketone	0.75 U	0.61	0.77 U	0.62	0.80 U	0.64	0.75 U	0.61	0.78 U	0.63
Gamma-BHC (Lindane)	0.20 U	0.051	0.40 UJ	0.051	0.56 UJ	0.054	0.47 UJ	0.050	0.42 UJ	0.052
Heptachlor	0.20 U	0.088	0.21 U	0.090	0.21 U	0.093	0.20 U	0.088	0.21 U	0.091
Heptachlor Epoxide	0.20 U	0.12	0.21 U	0.13	0.21 U	0.13	0.20 U	0.12	0.21 U	0.13
Hexachlorobenzene	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
Methoxychlor	0.50 U	0.25	0.51 U	0.26	0.53 U	0.27	0.50 U	0.25	0.52 U	0.26
Mirex	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
Oxychlordane	0.20 U	0.073	0.21 U	0.075	0.21 U	0.078	0.20 U	0.073	0.21 U	0.076
Pentachloroanisole	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-
Toxaphene	9.9 U	-	10 U	-	11 U	-	9.9 U	-	10 U	-
trans-Chlordane	0.20 U	0.15	0.21 U	0.15	0.21 U	0.16	0.20 U	0.15	0.21 U	0.15
Trans-Nonachlor	0.20 U	-	0.21 U	-	0.21 U	-	0.20 U	-	0.21 U	-

Table G-6. July 2009 PAH Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.011 U	0.011	0.011 U	0.011	0.0099 U	0.010	0.010 U	0.010	0.010 UJ	0.010
2-Chloronaphthalene	0.011 U	0.010	0.011 U	0.010	0.0099 U	0.0092	0.010 U	0.0094	0.010 UJ	0.0093
2-Methylnaphthalene	0.011 U	0.0095	0.011 U	0.0095	0.0099 U	0.0085	0.010 U	0.0087	0.010 UJ	0.0086
Acenaphthene	0.011 U	0.0095	0.011 U	0.0095	0.0099 U	0.0085	0.010 U	0.0087	0.010 UJ	0.0086
Acenaphthylene	0.011 U	0.0094	0.011 U	0.0094	0.0099 U	0.0084	0.010 U	0.0085	0.010 UJ	0.0084
Anthracene	0.011 U	0.0056	0.011 U	0.0056	0.0099 U	0.0051	0.010 U	0.0051	0.010 UJ	0.0051
Benzo(a)anthracene	0.018 UJ	0.0010	0.018 UJ	0.0010	0.016 UJ	0.0009	0.016 UJ	0.0009	0.016 UJ	0.0009
Benzo(a)pyrene	0.011 UJ	0.0018	0.011 UJ	0.0018	0.0099 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0016
Benzo(b)fluoranthene	0.011 U	0.0011	0.011 U	0.0011	0.0099 U	0.0010	0.010 U	0.0010	0.010 UJ	0.0010
Benzo(ghi)perylene	0.011 UJ	0.0018	0.011 UJ	0.0018	0.0099 UJ	0.0016	0.010 UJ	0.0016	0.010 UJ	0.0016
Benzo(k)fluoranthene	0.011 U	0.0006	0.011 U	0.0006	0.0099 U	0.0005	0.010 U	0.0005	0.012 UJ	0.0005
Carbazole	0.011 U	0.0016	0.011 U	0.0016	0.0099 U	0.0015	0.010 U	0.0015	0.010 UJ	0.0015
Chrysene	0.011 UJ	0.0009	0.011 UJ	0.0009	0.0099 UJ	0.0008	0.010 UJ	0.0009	0.010 UJ	0.0009
Dibenzo(a,h)anthracene	0.011 U	0.0016	0.011 U	0.0016	0.0099 U	0.0014	0.010 U	0.0014	0.010 UJ	0.0014
Dibenzofuran	0.011 U	0.0087	0.011 U	0.0087	0.0099 U	0.0078	0.010 U	0.0079	0.010 UJ	0.0079
Fluoranthene	0.011 U	0.0017	0.011 U	0.0017	0.0099 U	0.0015	0.010 U	0.0016	0.010 UJ	0.0015
Fluorene	0.011 U	0.0082	0.011 U	0.0082	0.0099 U	0.0074	0.010 U	0.0075	0.010 UJ	0.0074
Indeno(1,2,3-cd)pyrene	0.011 U	0.0022	0.011 U	0.0022	0.0099 U	0.0020	0.010 U	0.0020	0.010 UJ	0.0020
Naphthalene	0.011 U	0.035	0.011 U	0.035	0.0099 U	0.031	0.010	0.032	0.010 UJ	0.031
Phenanthrene	0.011 U	0.0067	0.011 U	0.0067	0.0099 U	0.0060	0.010 U	0.0061	0.010 UJ	0.0061
Pyrene	0.011 U	0.0020	0.011 U	0.0020	0.0099 U	0.0018	0.010 U	0.0018	0.010 UJ	0.0018
Retene	0.011 U	0.0011	0.011 U	0.0011	0.0099 U	0.0009	0.010 U	0.0010	0.010 UJ	0.0010

Table G-7. October 2009 PAH Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.0039 J	0.0010	0.0049 J	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.010 U	0.0010
2-Chloronaphthalene	0.010 UJ	0.0093	0.010 U	0.0095	0.010 U	0.0093	0.0098 U	0.0091	0.010 U	0.0093
2-Methylnaphthalene	0.010 UJ	0.0086	0.0089 J	0.0087	0.010 U	0.0086	0.0098 U	0.0084	0.010 U	0.0086
Acenaphthene	0.010 UJ	0.0086	0.010 U	0.0087	0.010 U	0.0086	0.0098 U	0.0084	0.010 U	0.0086
Acenaphthylene	0.010 UJ	0.0085	0.010 U	0.0086	0.010 U	0.0085	0.0098 U	0.0083	0.010 U	0.0084
Anthracene	0.010 UJ	0.0051	0.010 U	0.0052	0.010 U	0.0051	0.0098 U	0.0050	0.010 U	0.0051
Benzo(a)anthracene	0.010 UJ	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.0098 U	0.0009	0.010 U	0.0009
Benzo(a)pyrene	0.020 UJ	0.0016	0.020 UJ	0.0017	0.020 UJ	0.0016	0.020 UJ	0.0016	0.020 UJ	0.0016
Benzo(b)fluoranthene	0.010 UJ	0.0010	0.010 U	0.0010	0.010 U	0.0010	0.0098 U	0.0010	0.010 U	0.0010
Benzo(ghi)perylene	0.010 UJ	0.0016	0.010 U	0.0016	0.010 U	0.0016	0.0098 U	0.0016	0.010 U	0.0016
Benzo(k)fluoranthene	0.010 UJ	0.0005	0.010 U	0.0005	0.010 U	0.0005	0.0098 U	0.0005	0.010 U	0.0005
Carbazole	0.010 UJ	0.0015	0.010 U	0.0015	0.010 U	0.0015	0.0098 U	0.0014	0.010 U	0.0015
Chrysene	0.010 UJ	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.0098 U	0.0008	0.010 U	0.0009
Dibenzo(a,h)anthracene	0.010 UJ	0.0014	0.010 U	0.0014	0.010 U	0.0014	0.0098 U	0.0014	0.010 U	0.0014
Dibenzofuran	0.010 UJ	0.0079	0.010 U	0.0080	0.010 U	0.0079	0.0098 U	0.0077	0.010 U	0.0079
Fluoranthene	0.010 UJ	0.0015	0.010 U	0.0016	0.010 U	0.0015	0.0098 U	0.0015	0.010 U	0.0015
Fluorene	0.010 UJ	0.0074	0.010 U	0.0075	0.010 U	0.0074	0.0098 U	0.0072	0.010 U	0.0074
Indeno(1,2,3-cd)pyrene	0.010 UJ	0.0020	0.010 U	0.0020	0.010 U	0.0020	0.0098 U	0.0019	0.010 U	0.0020
Naphthalene	0.012 UJ	0.0011	0.015 UJ	0.0011	0.010 U	0.0011	0.010 UJ	0.0011	0.012 UJ	0.0011
Phenanthrene	0.010 UJ	0.0061	0.010 U	0.0062	0.010 U	0.0061	0.0098 U	0.0060	0.010 U	0.0061
Pyrene	0.010 UJ	0.0018	0.010 U	0.0018	0.010 U	0.0018	0.0098 U	0.0017	0.010 U	0.0018
Retene	0.010 UJ	0.0010	0.010 U	0.0010	0.010 U	0.0010	0.0098 U	0.0009	0.010 U	0.0010

Table G-8. December 2009 PAH Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	0.010 U	0.010	0.010 U	0.011	0.010 U	0.0010	0.010 U	0.010	0.011 U	0.011
2-Chloronaphthalene	0.010 REJ	0.0094	0.010 REJ	0.0096	0.010 U	0.0010	0.010 REJ	0.0093	0.011 U	0.0098
2-Methylnaphthalene	0.010 U	0.0087	0.010 U	0.0089	0.010 U	0.0011	0.010 U	0.0086	0.011 U	0.0091
Acenaphthene	0.010 U	0.0087	0.010 U	0.0089	0.010 U	0.0011	0.010 U	0.0086	0.011 U	0.0091
Acenaphthylene	0.010 U	0.0086	0.010 U	0.0087	0.010 U	0.0018	0.010 U	0.0085	0.011 REJ	0.0089
Anthracene	0.010 U	0.0052	0.010 U	0.0053	0.010 U	0.0023	0.010 U	0.0051	0.011 U	0.0054
Benzo(a)anthracene	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0010	0.0009 J	0.0009	0.011 U	0.0009
Benzo(a)pyrene	0.010 U	0.0016	0.010 U	0.0017	0.010 U	0.0018	0.010 U	0.0016	0.011 U	0.0017
Benzo(b)fluoranthene	0.010 U	0.0010	0.010 U	0.0011	0.010 U	0.0011	0.010 U	0.0010	0.011 U	0.0011
Benzo(ghi)perylene	0.010 U	0.0016	0.010 U	0.0017	0.010 U	0.0017	0.010 U	0.0016	0.011 U	0.0017
Benzo(k)fluoranthene	0.010 U	0.0005	0.010 U	0.0005	0.010 U	0.0006	0.010 U	0.0005	0.011 U	0.0006
Carbazole	0.010 U	0.0015	0.010 U	0.0015	0.010 U	0.0013	0.010 U	0.0015	0.011 U	0.0016
Chrysene	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.010 U	0.0009	0.011 U	0.0009
Dibenzo(a,h)anthracene	0.010 UJ	0.0014	0.010 U	0.0015	0.010 UJ	0.0015	0.010 U	0.0014	0.011 UJ	0.0015
Dibenzofuran	0.010 U	0.0080	0.010 U	0.0081	0.010 U	0.0009	0.010 U	0.0079	0.011 U	0.0083
Fluoranthene	0.010 U	0.0016	0.010 U	0.0016	0.010 U	0.0010	0.010 U	0.0015	0.011 U	0.0016
Fluorene	0.010 U	0.0075	0.010 U	0.0077	0.010 U	0.0007	0.010 U	0.0074	0.011 U	0.0078
Indeno(1,2,3-cd)pyrene	0.010 U	0.0020	0.010 U	0.0020	0.010 U	0.0020	0.010 U	0.0020	0.011 U	0.0021
Naphthalene	0.010 U	0.0081	0.010 U	0.0082	0.010 U	0.0011	0.010 U	0.0080	0.024	0.0084
Phenanthrene	0.010 U	0.0062	0.010 U	0.0063	0.010 U	0.0024	0.010 U	0.0061	0.011 U	0.0064
Pyrene	0.010 U	0.0018	0.010 U	0.0018	0.010 U	0.0020	0.010 U	0.0018	0.011 U	0.0019
Retene	0.0097 J	0.0010	0.11	0.0010	0.010 U	0.0011	0.0030 J	0.0010	0.0015 J	0.0010

Table G-9. Total PAH and Total cPAH Results for River Water Samples.

Sampling Date	Parameter (µg/L)	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
July 2009	Total PAHs					
	…ND at ½ RL	0.12 U	0.12 U	0.11 U	0.010	0.11 UJ
	…ND at MDL	0.13 U	0.13 U	0.12 U	0.010	0.12 UJ
	Total cPAHs					
	…ND at ½ RL	0.039 U	0.039 U	0.035 U	0.035 U	0.035 UJ
	…ND at MDL	0.0092 U	0.0092 U	0.0082 U	0.0083 U	0.0083 UJ
October 2009	Total PAHs					
	…ND at ½ RL	0.0039 J	0.014 J	0.12 U	0.11 U	0.12 U
	…ND at MDL	0.0039 J	0.014 J	0.079 U	0.077 U	0.079 U
	Total cPAHs					
	…ND at ½ RL	0.040 UJ	0.040 U	0.040 U	0.039 U	0.040 U
	…ND at MDL	0.0083 UJ	0.0084 U	0.0083 U	0.0081 U	0.0083 U
December 2009	Total PAHs					
	…ND at ½ RL	0.0097 J	0.11	0.11 U	0.0039 J	0.026
	…ND at MDL	0.0097 J	0.11	0.029 U	0.0039 J	0.026
	Total cPAHs					
	…ND at ½ RL	0.035 U	0.035 U	0.035 U	0.0009 J	0.039 U
	…ND at MDL	0.0083 U	0.0086 U	0.0089 U	0.0009 J	0.0088 U

Table G-10. Summary of July 2009 BNA Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
1,2-Dichlorobenzene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
1,2-Diphenylhydrazine	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
1,3-Dichlorobenzene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
1,4-Dichlorobenzene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
2,4,5-Trichlorophenol	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
2,4,6-Trichlorophenol	0.32 UJ	-	0.31 UJ	-	0.31 UJ	-	0.33 UJ	-	0.31 UJ	-
2,4-Dichlorophenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
2,4-Dimethylphenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
2,4-Dinitrophenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
2,4-Dinitrotoluene	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
2,6-Dinitrotoluene	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
2-Chlorophenol	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
2-Methylphenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.0058 J	-
2-Nitroaniline	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-	1.6 U	-
2-Nitrophenol	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
3,3'-Dichlorobenzidine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-
3B-Coprostanol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
3-Nitroaniline	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
4,6-Dinitro-2-Methylphenol	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
4-Bromophenyl phenyl ether	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
4-Chloro-3-Methylphenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
4-Chloroaniline	3.2 REJ	-	3.1 REJ	-	3.1 REJ	-	3.3 REJ	-	3.1 REJ	-
4-Chlorophenyl-Phenylether	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
4-Methylphenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
4-Nitroaniline	0.32 UJ	-	0.31 UJ	-	0.31 UJ	-	0.33 UJ	-	0.31 UJ	-
4-Nitrophenol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
4-nonylphenol	0.32 U	0.032	0.31 U	0.031	0.31 U	0.031	0.33 U	0.033	0.31 U	0.031
Benzoic Acid	0.81 UJ	-	0.79 UJ	-	0.78 UJ	-	0.81 UJ	-	0.79 UJ	-
Benzyl Alcohol	0.81 UJ	-	0.79 UJ	-	0.78 UJ	-	0.81 UJ	-	0.79 UJ	-
Bis(2-chloro-1-methylethyl) ether	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Bis(2-Chloroethoxy)Methane	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Bis(2-Chloroethyl)Ether	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Bis(2-Ethylhexyl) Phthalate	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Bisphenol A	0.32 U	0.032	0.31 U	0.031	0.31 U	0.031	0.33 U	0.033	0.31 U	0.031
Butyl benzyl phthalate	0.32 U	0.032	0.31 U	0.031	0.31 U	0.031	0.33 U	0.033	0.31 U	0.031
Caffeine	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Cholesterol	0.81 U	-	0.79 U	-	0.78 U	-	0.81 U	-	0.79 U	-
Diethyl phthalate	0.16 U	0.032	0.16 U	0.031	0.16 U	0.031	0.16 U	0.033	0.16 U	0.031
Dimethyl phthalate	0.16 U	0.032	0.16 U	0.031	0.16 U	0.031	0.16 U	0.033	0.16 U	0.031
Di-N-Butylphthalate	0.12 UJ	-	0.18 UJ	-	0.19 UJ	-	0.16 UJ	-	0.17 UJ	-
Di-N-Octyl Phthalate	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Ethanol, 2-Chloro-, Phosphate (3:1)	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Hexachlorobenzene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Hexachlorobutadiene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Hexachlorocyclopentadiene	0.32 UJ	-	0.31 UJ	-	0.31 UJ	-	0.33 UJ	-	0.31 UJ	-
Hexachloroethane	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Isophorone	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Nitrobenzene	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
N-Nitrosodi-n-propylamine	0.097 U	-	0.094 U	-	0.094 U	-	0.098 U	-	0.094 U	-
N-Nitrosodiphenylamine	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-	0.16 U	-
Pentachlorophenol	0.081 UJ	-	0.079 UJ	-	0.078 UJ	-	0.081 UJ	-	0.079 UJ	-
Phenol	0.32 U	-	0.31 U	-	0.31 U	-	0.33 U	-	0.31 U	-
Triclosan	0.081 U	-	0.079 U	-	0.078 U	-	0.081 U	-	0.079 U	-
Triethyl citrate	0.32 U	0.032	0.31 U	0.031	0.31 U	0.031	0.33 U	0.033	0.31 U	0.031

Table G-11. Summary of October 2009 BNA Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.079 U	0.020	0.080 U	0.020	0.079 U	0.019	0.083 U	0.020	0.080 U	0.020
1,2-Dichlorobenzene	0.079 U	0.019	0.080 U	0.019	0.079 U	0.019	0.083 U	0.020	0.080 U	0.019
1,2-Diphenylhydrazine	0.079 U	0.051	0.080 U	0.051	0.079 U	0.050	0.083 U	0.053	0.080 U	0.051
1,3-Dichlorobenzene	0.079 U	0.016	0.080 U	0.016	0.079 U	0.016	0.083 U	0.017	0.080 U	0.016
1,4-Dichlorobenzene	0.079 U	0.017	0.080 U	0.018	0.079 U	0.017	0.083 U	0.018	0.080 U	0.018
2,4,5-Trichlorophenol	-	-	-	-	-	-	-	-	-	-
2,4,6-Trichlorophenol	-	-	-	-	-	-	-	-	-	-
2,4-Dichlorophenol	0.79 U	0.042	0.80 U	0.042	0.79 U	0.041	0.83 U	0.043	0.80 U	0.042
2,4-Dimethylphenol	0.79 U	0.047	0.80 U	0.047	0.79 U	0.046	0.83 U	0.049	0.80 U	0.047
2,4-Dinitrophenol	0.79 U	-	0.80 U	-	0.79 U	-	0.83 U	-	0.80 U	-
2,4-Dinitrotoluene	0.32 U	0.045	0.32 U	0.045	0.31 U	0.044	0.33 U	0.047	0.32 U	0.045
2,6-Dinitrotoluene	0.32 U	0.054	0.32 U	0.054	0.31 U	0.054	0.33 U	0.056	0.32 U	0.054
2-Chlorophenol	0.32 U	0.041	0.32 U	0.042	0.31 U	0.041	0.33 U	0.043	0.32 U	0.042
2-Methylphenol	0.79 U	0.040	0.80 U	0.040	0.79 U	0.040	0.83 U	0.042	0.80 U	0.040
2-Nitroaniline	1.6 U	0.053	1.6 U	0.053	1.6 U	0.053	1.7 U	0.055	1.6 U	0.053
2-Nitrophenol	0.16 U	0.036	0.16 U	0.036	0.16 U	0.035	0.17 U	0.037	0.16 U	0.036
3,3'-Dichlorobenzidine	0.16 UJ	-	0.16 UJ	-	0.16 UJ	-	0.17 UJ	-	0.16 UJ	-
3B-Coprostanol	-	-	-	-	-	-	-	-	-	-
3-Nitroaniline	0.32 UJ	0.046	0.32 UJ	0.046	0.31 UJ	0.045	0.33 UJ	0.047	0.32 UJ	0.046
4,6-Dinitro-2-Methylphenol	1.6 U	0.53	1.6 U	0.53	1.6 U	0.53	1.7 U	0.55	1.6 U	0.53
4-Bromophenyl phenyl ether	0.16 U	0.071	0.16 U	0.072	0.16 U	0.071	0.17 U	0.074	0.16 U	0.072
4-Chloro-3-Methylphenol	0.79 U	0.063	0.80 U	0.063	0.79 U	0.062	0.83 U	0.065	0.80 U	0.063
4-Chloroaniline	3.2 U	0.13	3.2 U	0.13	3.1 UJ	0.13	3.3 UJ	0.13	3.2 U	0.13
4-Chlorophenyl-Phenylether	0.079 U	0.071	0.080 U	0.071	0.079 U	0.070	0.083 U	0.074	0.080 U	0.071
4-Methylphenol	0.79 U	0.039	0.80 U	0.040	0.050 J	0.039	0.093 J	0.041	0.80 U	0.040
4-Nitroaniline	0.32 U	-	0.32 U	-	0.31 U	-	0.33 U	-	0.32 U	-
4-Nitrophenol	-	-	-	-	-	-	-	-	-	-
4-nonylphenol	0.32 U	0.032	0.32 U	0.032	0.31 U	0.031	0.33 U	0.033	0.32 U	0.032
Benzoic Acid	-	-	-	-	-	-	-	-	-	-
Benzyl Alcohol	-	-	-	-	-	-	-	-	-	-
Bis(2-chloro-1-methylethyl) ether	-	-	-	-	-	-	-	-	-	-
Bis(2-Chloroethoxy)Methane	0.079 U	0.066	0.080 U	0.066	0.079 U	0.065	0.083 U	0.069	0.080 U	0.066
Bis(2-Chloroethyl)Ether	0.16 U	0.046	0.16 U	0.046	0.16 U	0.045	0.17 U	0.047	0.16 U	0.046
Bis(2-Ethylhexyl) Phthalate	0.16 U	0.048	0.16 U	0.048	0.16 U	0.047	0.17 U	0.050	0.16 U	0.048
Bisphenol A	0.32 U	0.032	0.32 U	0.032	0.072 J	0.031	0.33 U	0.033	0.32 U	0.032
Butyl benzyl phthalate	0.32 U	0.037	0.32 U	0.037	0.31 U	0.037	0.33 U	0.039	0.32 U	0.037
Caffeine	0.16 U	0.062	0.16 U	0.062	0.16 U	0.061	0.17 U	0.064	0.16 U	0.062
Cholesterol	0.13 NJ	0.075	0.63 J	0.076	0.49 J	0.075	0.73 J	0.078	1.4	0.076
Diethyl phthalate	0.16 U	0.078	0.16 U	0.079	0.16 U	0.078	0.17 U	0.081	0.16 U	0.079
Dimethyl phthalate	0.16 U	0.069	0.16 U	0.069	0.16 U	0.068	0.17 U	0.071	0.16 U	0.069
Di-N-Butylphthalate	0.13 UJ	0.058	0.12 UJ	0.058	0.079 U	0.058	0.083 U	0.060	0.14 UJ	0.058
Di-N-Octyl Phthalate	0.16 U	0.071	0.16 U	0.071	0.16 U	0.070	0.17 U	0.074	0.16 U	0.071
Ethanol, 2-Chloro-, Phosphate (3:1)	-	-	-	-	-	-	-	-	-	-
Hexachlorobenzene	0.079 U	0.039	0.080 U	0.039	0.079 U	0.039	0.083 U	0.041	0.080 U	0.039
Hexachlorobutadiene	0.079 U	0.012	0.080 U	0.012	0.079 UJ	0.012	0.083 UJ	0.013	0.080 U	0.012
Hexachlorocyclopentadiene	0.32 UJ	0.010	0.32 UJ	0.010	0.31 UJ	0.0099	0.33 UJ	0.010	0.32 UJ	0.010
Hexachloroethane	0.079 UJ	-	0.080 UJ	-	0.079 UJ	-	0.083 UJ	-	0.080 UJ	-
Isophorone	0.16 U	0.073	0.16 U	0.074	0.16 U	0.073	0.17 U	0.076	0.16 U	0.074
Nitrobenzene	0.079 U	0.066	0.080 U	0.066	-	-	0.083 U	0.068	0.080 U	0.066
N-Nitrosodi-n-propylamine	0.095 U	0.070	0.096 U	0.071	0.094 U	0.070	0.099 U	0.073	0.096 U	0.071
N-Nitrosodiphenylamine	0.16 UJ	0.033	0.16 UJ	0.034	0.16 UJ	0.033	0.17 UJ	0.035	0.16 UJ	0.034
Pentachlorophenol	0.079 U	-	0.080 U	-	0.079 U	-	0.083 U	-	0.083 NJ	-
Phenol	0.32 U	0.025	0.32 U	0.025	0.31 U	0.025	0.33 U	0.026	0.32 U	0.025
Triclosan	0.079 U	0.032	0.080 U	0.032	0.079 U	0.031	0.083 U	0.033	0.080 U	0.032
Triethyl citrate	0.060 J	0.032	0.058 J	0.032	0.31 U	0.031	0.33 U	0.033	0.32 U	0.032

Table G-12. Summary of December 2009 BNA Results for River Water Samples.

Non-detect values are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/L)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	0.078 UJ	0.019	0.084 U	0.021	0.079 UJ	0.019	0.084 U	0.021	0.076 UJ	0.019
1,2-Dichlorobenzene	0.078 UJ	0.018	0.084 U	0.020	0.079 U	0.019	0.084 U	0.020	0.076 UJ	0.018
1,2-Diphenylhydrazine	0.078 U	0.049	0.084 U	0.053	0.079 U	0.050	0.084 U	0.053	0.076 U	0.049
1,3-Dichlorobenzene	0.078 UJ	0.016	0.084 U	0.017	0.079 UJ	0.016	0.084 U	0.017	0.076 UJ	0.016
1,4-Dichlorobenzene	0.078 UJ	0.017	0.084 U	0.018	0.079 UJ	0.017	0.084 U	0.018	0.076 UJ	0.017
2,4,5-Trichlorophenol	0.31 U	0.061	0.34 U	0.066	0.31 U	0.062	0.34 U	0.066	-	-
2,4,6-Trichlorophenol	0.31 UJ	0.047	0.34 UJ	0.051	0.31 UJ	0.048	0.34 UJ	0.051	-	-
2,4-Dichlorophenol	0.78 U	0.041	0.84 U	0.044	0.79 U	0.041	0.84 U	0.044	0.76 U	0.040
2,4-Dimethylphenol	-	-	0.84 U	0.049	0.79 U	0.046	0.84 U	0.049	0.76 U	0.045
2,4-Dinitrophenol	0.78 U	-	0.84 U	-	0.79 U	-	0.84 U	-	0.76 U	-
2,4-Dinitrotoluene	0.31 U	0.044	0.34 U	0.047	0.31 UJ	0.044	0.34 U	0.047	0.31 UJ	0.043
2,6-Dinitrotoluene	0.31 U	0.053	0.34 U	0.057	0.31 U	0.054	0.34 U	0.057	0.31 U	0.052
2-Chlorophenol	0.31 U	0.040	0.34 U	0.044	0.31 U	0.041	0.34 U	0.044	0.31 U	0.040
2-Methylphenol	0.78 U	0.039	0.84 U	0.042	0.79 U	0.040	0.84 U	0.042	0.76 U	0.039
2-Nitroaniline	1.6 UJ	0.052	1.7 UJ	0.056	1.6 UJ	0.053	1.7 UJ	0.056	1.5 UJ	0.051
2-Nitrophenol	0.16 U	0.035	0.17 U	0.038	0.16 UJ	0.035	0.17 UJ	0.038	0.15 UJ	0.034
3,3'-Dichlorobenzidine	0.16 UJ	-	0.17 UJ	-	0.16 UJ	-	0.17 UJ	-	0.15 UJ	-
3B-Coprostanol	0.78 UJ	-	0.84 UJ	-	0.79 UJ	-	0.84 UJ	-	0.76 UJ	-
3-Nitroaniline	0.31 REJ	0.045	0.34 REJ	0.048	0.31 REJ	0.045	0.34 REJ	0.048	0.31 REJ	0.044
4,6-Dinitro-2-Methylphenol	1.6 U	0.52	1.7 U	0.56	1.6 U	0.53	1.7 U	0.56	1.5 U	0.51
4-Bromophenyl phenyl ether	0.16 U	0.070	0.17 U	0.075	0.16 U	0.071	0.17 U	0.075	0.15 U	0.069
4-Chloro-3-Methylphenol	0.78 UJ	0.061	0.84 UJ	0.066	0.79 UJ	0.062	0.84 UJ	0.066	0.76 UJ	0.060
4-Chloroaniline	3.1 REJ	0.12	3.4 REJ	0.13	3.1 REJ	0.13	3.4 REJ	0.13	3.1 REJ	0.12
4-Chlorophenyl-Phenylether	0.078 U	0.069	0.084 U	0.075	0.079 U	0.070	0.084 U	0.075	0.076 U	0.068
4-Methylphenol	0.78 U	0.038	0.84 U	0.042	0.13 J	0.039	0.84 U	0.042	0.76 U	0.038
4-Nitroaniline	0.31 UJ	-	0.34 UJ	-	0.31 UJ	-	0.34 UJ	-	0.31 UJ	-
4-Nitrophenol	0.78 U	-	0.84 U	-	0.79 U	-	0.84 U	-	0.76 U	-
4-nonylphenol	0.31 U	0.031	0.052 J	0.034	0.31 U	0.031	0.34 U	0.034	0.31 U	0.031
Benzoic Acid	0.78 REJ	-	0.84 UJ	-	0.79 U	-	0.84 UJ	-	0.76 UJ	-
Benzyl Alcohol	0.78 UJ	0.027	0.84 UJ	0.030	0.79 UJ	0.028	0.84 UJ	0.030	0.76 UJ	0.027
Bis(2-chloro-1-methylethyl) ether	0.078 U	0.052	0.084 U	0.056	0.079 U	0.053	0.084 U	0.056	0.076 U	0.051
Bis(2-Chloroethoxy)Methane	0.078 U	0.064	0.084 U	0.070	0.079 U	0.065	0.084 U	0.070	0.076 U	0.063
Bis(2-Chloroethyl)Ether	0.16 U	0.044	0.17 U	0.048	0.16 U	0.045	0.17 U	0.048	0.15 U	0.044
Bis(2-Ethylhexyl) Phthalate	0.16 U	0.047	0.17 U	0.050	0.16 U	0.047	0.17 U	0.050	0.074 J	0.046
Bisphenol A	0.31 U	0.031	0.34 UJ	0.034	0.31 UJ	0.031	0.34 U	0.034	0.31 UJ	0.031
Butyl benzyl phthalate	0.31 U	0.036	0.34 UJ	0.039	0.31 UJ	0.037	0.34 UJ	0.039	0.31 U	0.036
Caffeine	0.16 U	0.060	0.17 U	0.065	0.16 U	0.061	0.17 U	0.065	0.15 U	0.059
Cholesterol	0.78 UJ	0.074	0.56 J	0.079	0.51 J	0.075	0.84 UJ	0.079	0.57 J	0.072
Diethyl phthalate	0.16 U	0.076	0.17 U	0.083	0.16 U	0.078	0.17 U	0.083	0.15 U	0.075
Dimethyl phthalate	0.16 U	0.067	0.17 U	0.072	0.16 U	0.068	0.17 U	0.072	0.15 U	0.066
Di-N-Butylphthalate	0.41 UJ	0.057	0.27 UJ	0.061	0.12 UJ	0.058	0.084 U	0.061	0.18 UJ	0.056
Di-N-Octyl Phthalate	0.16 U	0.069	0.17 U	0.075	0.16 U	0.070	0.17 U	0.075	0.15 U	0.068
Ethanol, 2-Chloro-, Phosphate (3:1)	0.078 U	0.031	0.084 U	0.034	0.079 U	0.031	0.084 U	0.034	0.076 U	0.031
Hexachlorobenzene	0.078 U	0.038	0.084 U	0.041	0.079 U	0.039	0.084 U	0.041	0.076 U	0.038
Hexachlorobutadiene	0.078 UJ	0.012	0.084 UJ	0.013	0.079 UJ	0.012	0.084 UJ	0.013	0.076 UJ	0.012
Hexachlorocyclopentadiene	0.31 UJ	0.0097	0.34 UJ	0.011	0.31 UJ	0.0099	0.34 UJ	0.011	0.31 UJ	0.0096
Hexachloroethane	0.078 UJ	-	0.084 UJ	-	0.079 UJ	-	0.084 UJ	-	0.076 UJ	-
Isophorone	0.16 U	0.072	0.17 U	0.077	0.16 U	0.073	0.17 U	0.077	0.15 U	0.071
Nitrobenzene	0.078 U	0.064	0.084 U	0.069	0.079 U	0.065	0.084 U	0.069	0.076 U	0.063
N-Nitrosodi-n-propylamine	0.093 U	0.069	0.10 U	0.074	0.094 U	0.070	0.10 U	0.074	0.092 U	0.068
N-Nitrosodiphenylamine	0.16 UJ	0.032	0.17 UJ	0.035	0.16 UJ	0.033	0.17 UJ	0.035	0.15 REJ	0.032
Pentachlorophenol	0.078 UJ	-	0.084 U	-	0.079 U	-	0.084 UJ	-	0.076 U	-
Phenol	0.31 U	0.025	0.34 U	0.027	0.31 U	0.025	0.34 U	0.027	0.31 U	0.024
Triclosan	0.078 UJ	0.031	0.084 U	0.034	0.079 U	0.031	0.084 U	0.034	0.076 U	0.031
Triethyl citrate	0.31 U	0.031	0.34 U	0.034	0.31 U	0.031	0.34 U	0.034	0.31 U	0.031

Table G-13. Detected PCB Congeners for River Water Samples.

PCB Congener (pg/L)	Nooksack			Skagit			Stillaguamish			Snohomish			Puyallup		
	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec
PCB-001		0.861 NJ						0.86 NJ							0.976 J
PCB-002		1.46 NJ		1.71 J		0.595 NJ		1.26 NJ							1.73 NJ
PCB-003	11.4 NJ	2.14 J		10.5 NJ		0.677 NJ		1.75 J						1.8 J	1.75 J
PCB-006		0.391 J													
PCB-008	3.18 J	0.878 J		1.94 J		0.842 J	2.98 J	1.55 J		2.45 J				2.04 J	
PCB-015		0.513 J			0.709 J	0.532 J		0.948 J		3.69 J					
PCB-017					0.463 J	0.561 NJ									
PCB-018/030		0.742 J	0.688 NJ	2.17 J	0.902 J	1.16 J	3.17 J	1.28 J	1.11 J	2.84 J	1.02 NJ	0.801 J		1.69 J	1.49 J
PCB-020/028		0.666 NJ	0.756 NJ	1.51 J	1.04 J	0.988 J	2.19 J	1.59 J	0.625 J	2.54 J	1.29 J	0.5 NJ	10.3 NJ	1.77 J	1.04 NJ
PCB-021/033		0.286 J				0.496 J	1.63 J	0.651 NJ							0.897 J
PCB-022						0.297 J									
PCB-031	2.11 J	0.629 NJ			0.964 J	0.971 J	2.69 J	1.37 NJ		2.38 J	1.12 J		10.3 NJ	1.74 J	1.17 J
PCB-037		0.32 J													
PCB-039		0.255 NJ													
PCB-044/047/065		0.78 J	0.64 NJ		0.763 J	1.08 J		2.67 J	1.628 J	1.64 J		0.902 J			1.57 J
PCB-049/069		0.317 NJ	0.539 J			0.519 J		1.36 J				0.448 J		1.27 NJ	0.751 J
PCB-052		1.15 J			1.08 J		10.5 NJ	4.31 J			1.35 J		1.45 J	2.76 J	
PCB-056						0.217 J									
PCB-061/070/074/076		0.952 J	0.692 NJ		0.702 J	1.01 J		5.63 J				0.656 NJ		3.13 J	1.72 J
PCB-064						0.298 J		1.04 J							0.585 J
PCB-066						0.397 NJ		1.45 J							0.841 J
PCB-084								2.19 J							
PCB-085/116								0.806 NJ							
PCB-086/087/097/108/119/125		1.28 J			0.733 J	0.592 J		4.45 NJ							
PCB-090/101/113		1.39 J	1.39 NJ		0.847 J	0.974 J	1.87 J	7.03 J	0.821 J	11 NJ		1 NJ	10.3 NJ	3.04 J	1.76 J
PCB-095		1.11 J	0.685 NJ		0.688 NJ	0.848 NJ	1.18 J	5.87				1.19 J		3.37 J	1.4 J
PCB-099		0.39 J	0.382 NJ			0.355 J		2.32 J						1.63 J	0.497 J
PCB-105		0.566 J			0.469 NJ	0.294 J		2.45 NJ						1.86 J	
PCB-110	1.12 J	1 J	0.806 J		0.721 J	0.811 J	10.5 NJ	6.69		1.19 J		0.796 J	1.16 J	2.66 J	1.58 J
PCB-118		1.03 J	0.691 NJ		0.44 J	0.674 J	1.21 J	4.62 J				0.572 NJ		2.55 J	1.25 J
PCB-129/138/163		0.868 J	1.95 J		0.597 J	1.3 J	1.07 J	3.21 J	0.807 J	1.09 J	1.17 J	1.33 J		3.19 J	1.85 J
PCB-132						0.332 NJ		1.12 NJ							
PCB-135/151						0.55 J									
PCB-146						0.24 J									
PCB-147/149		0.69 J	0.979 J			0.656 NJ		2.03 NJ				0.829 J		2.43 J	1.41 J
PCB-153/168	11.4 NJ	0.704 J	1.52 J		0.405 NJ	0.974 J		2.33 J				0.997 J		3.01 J	1.17 NJ
PCB-169										0.961 J					
PCB-180/193						0.717 J						0.647 NJ			
PCB-187						0.523 NJ								1.51 J	
PCB-194						0.272 NJ	1.28 J	1.14 J							
PCB-198/199						0.292 NJ									
PCB-209						1.09 J									

Table G-14. Total PCBs for River Water Samples.

Total concentrations were calculated by summing the congener detects, as described in Appendix D.

Total PCBs (pg/L)	Nooksack			Skagit			Stillaguamish			Snohomish			Puyallup		
	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec
…including N,NJ	29.21 J	21.37 J	11.72 J	17.83 J	11.52 J	22.13 J	40.27 J	73.98 J	4.99 J	29.78 J	5.95 J	10.67 J	35.31 J	41.45 J	25.44 J
…excluding N,NJ	6.41 J	17.18 J	5.79 J	7.33 J	9.96 J	16.98 J	19.27 J	58.98 J	4/99 J	18.78 J	4.93 J	7.29 J	2.61 J	40.18 J	21.5 J

Table G-15. PCB Homolog Totals for River Water Samples.

Results qualified as N or NJ were not included when summing homologs to calculate total PCBs.

PCB Homolog (pg/L)	Nooksack			Skagit			Stillaguamish			Snohomish			Puyallup		
	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec
Mono-CBs	0	2.14 J	0	1.71 J	0	0	0	1.75 J	0	0	0	0	0	1.8 J	2.726 J
Di-CBs	3.18 J	1.782 J	0	1.94 J	0.709 J	1.374 J	2.98 J	2.498 J	0	6.14 J	0	0	0	2.04 J	0
Tri-CBs	2.11 J	1.348 J	0	3.68 J	3.369 J	3.912 J	9.68 J	2.87 J	1.735 J	7.76 J	2.41 J	0.801 J	0	5.2 J	3.557 J
Tetra-CBs	0	2.882 J	0.539 J	0	2.545 J	3.124 J	0	16.46 J	1.628 J	1.64 J	1.35 J	1.35 J	1.45 J	5.89 J	5.467 J
Penta-CBs	1.12 J	6.766 J	0.806 J	0	2.741 J	3.7 J	4.26 J	28.72 J	0.821 J	1.19 J	0	1.986 J	1.16 J	15.11 J	6.487 J
Hexa-CBs	0	2.262 J	4.449 J	0	0.597 J	3.064 J	1.07 J	5.54 J	0.807 J	2.051 J	1.17 J	3.156 J	0	8.63 J	3.26 J
Hepta-CBs	0	0	0	0	0	0.717 J	0	0	0	0	0	0	0	1.51 J	0
Octa-CBs	0	0	0	0	0	0	1.28 J	1.14 J	0	0	0	0	0	0	0
Nona-CBs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PCB-209	0	0	0	0	0	1.09 J	0	0	0	0	0	0	0	0	0
Total PCBs	6.41 J	17.18 J	5.794 J	7.33 J	9.961 J	16.98 J	19.27 J	58.98 J	4.991 J	18.78 J	4.93 J	7.293 J	2.61 J	40.18 J	21.50 J

Table G-16. Detected PBDE Congeners for River Water Samples.

Samples for which all congener results were nondetects (U- or UJ-qualified) were assigned a total PBDE value equal to the highest congener reporting limit (RL).

PBDE Congener (pg/L)	Nooksack			Skagit			Stillaguamish			Snohomish			Puyallup		
	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec	July	Oct	Dec
BDE-017		5.19 J													
BDE-028		7.32 J		13.3 J			10.7 J			5.7 NJ				5.18 J	
BDE-030							5.2 NJ								
BDE-049		17 J													
BDE-100	34.2 J						11.6 J			13.7 J			10.9 J		
BDE-209														260	

Total PBDEs															
…including N, NJ	34.2 J	29.51 J	250 U	13.3 J	250 U	250 U	27.5 J	250 U	250 UJ	19.4 J	250 U	250 U	10.9 J	265.18	250 U
…excluding N,NJ	34.2 J	29.51 J	250 U	13.3 J	250 U	250 U	22.3 J	250 U	250 UJ	13.7 J	250 U	250 U	10.9 J	265.18	250 U

Appendix H. Analytical Results - River SPM

Table H-1. Results for Conventionals, Metals, and Petroleum-Related Products in River Particulate Samples.

All samples were collected in December 2009. Non-detect petroleum results are given at the reporting limit (RL).

Parameter	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
Conventional Parameters (%)					
Percent Solids	69.0	60.6	43.9	56.7	73.3
TOC	0.96	1.46	1.88	1.49	0.36
Metals (mg/Kg dry)					
Arsenic	6.62	6.46	11.1	13.3	1.45
Cadmium	0.17	0.13	0.24	0.20	0.04 J
Copper	33.0	27.1	53.5	51.6	17.2
Lead	5.35	4.46	9.55	8.36	1.57
Zinc	77.4	53.8	106	86.0	20.3
Petroleum-Related Products (mg/Kg dry)					
TPH-D #2 Diesel	14 U	16 U	23 U	17 U	13 U
TPH-D Lube Oil	36 U	41 U	57 U	44 U	33 U

Table H-2. December 2009 Chlorinated Pesticides Results for River Particulate Samples.

Non-detect results are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter (µg/Kg dry)	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
2,4'-DDD	0.13 U	0.027	0.13 U	0.027	0.32 U	0.069	0.13 U	0.027	0.12 U	0.027
2,4'-DDE	0.13 U	0.068	0.13 U	0.068	0.32 U	0.17	0.13 U	0.069	0.12 U	0.067
2,4'-DDT	0.13 U	0.051	0.13 U	0.051	0.32 U	0.13	0.13 U	0.051	0.12 U	0.050
4,4'-DDD	0.13 U	0.032	0.13 U	0.032	0.32 U	0.082	0.13 U	0.032	0.12 U	0.032
4,4'-DDE	0.38	0.069	0.13 U	0.069	0.32 U	0.18	0.13 U	0.070	0.12 U	0.068
4,4'-DDT	0.39	0.053	0.13 U	0.054	0.32 U	0.14	0.13 U	0.054	0.12 U	0.053
Aldrin	0.13 U	0.057	0.13 U	0.057	0.32 U	0.15	0.13 U	0.058	0.12 U	0.056
Alpha-BHC	0.13 U	0.033	0.13 U	0.033	0.32 U	0.084	0.13 U	0.033	0.12 U	0.032
Beta-BHC	0.13 U	0.027	0.13 U	0.027	0.32 U	0.068	0.13 U	0.027	0.12 U	0.026
Chlordane, technical	1.3 U	-	1.3 U	-	3.2 U	-	1.3 U	-	1.2 U	-
Chlorpyriphos	0.13 U	0.029	0.13 U	0.029	0.32 U	0.073	0.13 U	0.029	0.12 U	0.028
cis-Chlordane	0.13 U	0.041	0.13 U	0.041	0.32 U	0.10	0.13 U	0.041	0.12 U	0.040
Cis-Nonachlor	0.13 U	0.046	0.13 U	0.046	0.32 U	0.12	0.13 U	0.047	0.12 U	0.045
Dacthal	0.13 U	0.021	0.13 U	0.021	0.32 U	0.053	0.13 U	0.021	0.12 U	0.020
DDMU	0.13 U	0.032	0.13 U	0.032	0.32 U	0.082	0.13 U	0.033	0.12 U	0.032
Delta-BHC	0.13 U	0.029	0.13 U	0.029	0.32 U	0.075	0.13 U	0.030	0.12 U	0.029
Dieldrin	0.13 U	0.0052	0.13 U	0.0052	0.32 U	0.013	0.13 U	0.0052	0.12 U	0.0051
Endosulfan I	0.13 U	0.056	0.13 U	0.056	0.32 U	0.14	0.13 U	0.057	0.12 U	0.055
Endosulfan II	0.13 U	0.010	0.13 U	0.010	0.32 U	0.026	0.13 U	0.010	0.12 U	0.0099
Endosulfan Sulfate	0.72 UJ	0.045	0.26 UJ	0.045	0.32 U	0.11	0.30 UJ	0.045	0.32 UJ	0.044
Endrin	0.13 U	0.0056	0.13 U	0.0056	0.32 U	0.014	0.13 U	0.0057	0.12 U	0.0055
Endrin Aldehyde	0.13 UJ	0.083	0.13 UJ	0.083	0.32 UJ	0.21	0.13 UJ	0.084	0.12 UJ	0.082
Endrin Ketone	0.13 U	0.029	0.13 U	0.029	0.32 U	0.074	0.13 U	0.029	0.12 U	0.029
Gamma-BHC	0.52 UJ	0.028	0.58 UJ	0.029	2.0 UJ	0.073	0.47 UJ	0.029	0.72 UJ	0.028
Heptachlor	0.13 U	0.034	0.13 U	0.034	0.32 U	0.086	0.13 U	0.034	0.12 U	0.033
Heptachlor Epoxide	0.13 U	0.060	0.13 U	0.061	0.32 U	0.15	0.13 U	0.061	0.12 U	0.060
Hexachlorobenzene	0.41	0.065	0.13 U	0.065	0.32 U	0.17	0.13 U	0.066	0.12 U	0.064
Methoxychlor	0.13 U	0.066	0.13 U	0.066	0.32 U	0.17	0.13 U	0.066	0.12 U	0.065
Mirex	0.13 U	0.067	0.13 U	0.067	0.32 U	0.17	0.13 U	0.068	0.12 U	0.066
Oxychlordane	0.13 U	0.037	0.13 U	0.037	0.32 U	0.095	0.13 U	0.037	0.12 U	0.037
Pentachloroanisole	0.17	0.120	0.13 U	0.12	0.32 U	0.31	0.13 U	0.12	0.12 U	0.12
Toxaphene	1.3 U	0.043	1.3 U	0.043	3.2 U	0.11	1.3 U	0.043	1.2 U	0.042
trans-Chlordane	0.13 U	0.037	0.13 U	0.037	0.32 U	0.095	0.13 U	0.037	0.12 U	0.037
Trans-Nonachlor	0.13 U	0.060	0.13 U	0.060	0.32 U	0.15	0.13 U	0.061	0.12 U	0.059

Table H-3. December 2009 PAH Results for River Particulate Samples.

Non-detect results are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
(µg/Kg dry)	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1-Methylnaphthalene	13	0.81	3.6	0.93	18	3.2	6.4	0.99	5.3	0.77
2-Chloronaphthalene	3.6 U	2.4	4.1 U	2.7	14 U	9.3	4.4 U	2.9	3.4 U	2.3
2-Methylnaphthalene	21		6.1		30		11		7.8	
Acenaphthene	1.4 U	2.1	1.6 U	2.4	5.6 U	8.0	1.7 U	2.5	1.4 U	2.0
Acenaphthylene	1.4 U	0.74	1.6 U	0.85	5.6 U	2.9	1.7 U	0.90	1.4 U	0.70
Anthracene	1.5	1.4	1.6 U	1.6	6.6	5.3	2.6	1.7	1.5	1.3
Benzo(a)anthracene	3.6	0.80	1.6 U	0.92	6.9	3.1	4.6	0.97	1.6	0.76
Benzo(a)pyrene	2.8 J	1.6	3.3 U	1.8	6.9 J	6.1	3.7	1.9	2.7 U	1.5
Benzo(b)fluoranthene	8.0	1.9	1.6 U	2.2	14	7.3	11	2.3	2.0	1.8
Benzo(ghi)perylene	5.2 J	1.2	1.8 J	1.3	12 J	4.5	7.7 J	1.4	2.0 J	1.1
Benzo(k)fluoranthene	2.1	2.0	1.6 U	2.2	5.6 U	7.6	1.7	2.4	1.4 U	1.8
Carbazole	3.6 U	4.1	4.1 U	4.6	14 U	16	4.4 U	4.9	3.4 U	3.8
Chrysene	12	1.3	2.3	1.5	15	4.9	9.6	1.5	2.8	1.2
Dibenzo(a,h)anthracene	0.94 J	0.78	1.6 U	0.89	5.6 U	3.0	1.1 J	0.94	1.4 U	0.73
Dibenzofuran	4.3		1.4 J		8.8		3.2		1.6	
Fluoranthene	18	0.94	2.1	1.1	13	3.6	8.9	1.1	3.2	0.88
Fluorene	3.9 J	0.89	1.1 J	1.0	7.6	3.5	4.3	1.1	1.4 U	0.84
Indeno(1,2,3-cd)pyrene	3.1 J	0.73	0.92 J	0.84	7.5 J	2.8	5.0 J	0.89	1.3 J	0.69
Naphthalene	11	1.7	3.4	2.0	19	6.7	8.8	2.1	2.7	1.6
Phenanthrene	28	0.77	6.7	0.88	36	3.0	22	0.94	6.7	0.73
Pyrene	18	2.1	3.5	2.4	18	8.2	11	2.6	4.4	2.0
Retene	100	2.3	280 J	5.2	310	8.8	400 J	11	60	2.1

Total PAHs	260		310 J		530		520 J		100	
Total cPAHs*	33 J		3.2 J		50 J		37 J		7.7 J	

*The carcinogenic PAH compounds (cPAHs) are: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

Table H-4. December 2009 BNA Results for River Particulate Samples.

Non-detect results are given at the reporting limit (RL). The method detection limit (MDL) is presented for comparison.

Parameter	Nooksack		Skagit		Stillaguamish		Snohomish		Puyallup	
(µg/Kg dry)	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
1,2,4-Trichlorobenzene	47 U	39	53 U	44	74 U	61	57 U	47	43 U	35
1,2-Dichlorobenzene	94 U	41	110 U	46	150 U	64	110 U	49	85 U	37
1,2-Diphenylhydrazine	23 U	17	27 U	20	37 U	27	28 U	21	21 U	16
1,3-Dichlorobenzene	94 U	39	110 U	45	150 U	62	110 U	48	85 U	36
1,4-Dichlorobenzene	94 U	39	110 U	44	150 U	61	110 U	47	85 U	35
2,4,5-Trichlorophenol	94 U	15	110 U	17	150 U	23	110 U	18	85 U	13
2,4,6-Trichlorophenol	94 U	11	110 U	13	150 U	17	110 U	13	85 U	10
2,4-Dichlorophenol	230 U	16	270 U	18	370 U	25	280 U	19	210 U	15
2,4-Dimethylphenol	230 U	16	270 U	18	370 U	25	280 U	19	210 U	15
2,4-Dinitrophenol	230 REJ		270 REJ		370 REJ		280 REJ		210 REJ	
2,4-Dinitrotoluene	94 UJ	8.9	110 UJ	10	150 UJ	14	110 UJ	11	85 UJ	8.0
2,6-Dinitrotoluene	94 U	8.5	110 U	9.7	150 U	13	110 U	10	85 U	7.7
2-Chlorophenol	94 U	19	110 U	21	150 U	29	110 U	23	85 U	17
2-Methylphenol	230 U	17	270 U	19	370 U	26	280 U	20	210 U	15
2-Nitroaniline	470 UJ	22	530 UJ	25	740 UJ	34	570 UJ	26	430 UJ	20
2-Nitrophenol	47 UJ	15	53 UJ	17	74 UJ	23	57 UJ	18	43 UJ	14
3,3'-Dichlorobenzidine	94 UJ	5.2	110 UJ	5.9	150 UJ	8.1	110 UJ	6.2	85 UJ	4.7
3B-Coprostanol	260 J	12	220 J	13	670 J	18	240 J	14	310 J	11
3-Nitroaniline	94 REJ	23	110 REJ	26	150 REJ	36	110 REJ	28	85 REJ	21
4,6-Dinitro-2-Methylphenol	94 REJ		110 REJ		150 REJ		110 REJ		85 REJ	
4-Bromophenyl phenyl ether	47 U	9.8	53 U	11	74 U	15	57 U	12	43 U	8.9
4-Chloro-3-Methylphenol	230 U	14	270 U	16	370 U	22	280 U	17	210 U	13
4-Chloroaniline	940 REJ	23	1100 REJ	27	1500 REJ	37	1100 REJ	28	850 REJ	21
4-Chlorophenyl-Phenylether	23 U	12	27 U	14	37 U	19	28 U	15	21 U	11
4-Methylphenol	230 U	30	78 J	34	52 J	47	43 J	36	210 U	27
4-Nitroaniline	94 UJ	9.1	110 UJ	10	150 UJ	14	110 UJ	11	85 UJ	8.2
4-Nitrophenol	230 UJ	9.0	270 UJ	10	370 UJ	14	280 UJ	11	210 UJ	8.2
4-nonylphenol	15 J	2.3	27 U	2.7	37 U	3.7	28 U	2.8	21 U	2.1
Benzoic Acid	230 UJ	9.1	270 UJ	10	370 UJ	14	310 J	11	210 UJ	8.3
Benzyl Alcohol	230 UJ	39	270 UJ	44	370 UJ	61	280 UJ	47	210 UJ	35
Bis(2-chloro-1-methylethyl) ether	23 U	21	27 U	24	37 U	33	28 U	25	21 U	19
Bis(2-Chloroethoxy)Methane	23 U	16	27 U	18	37 U	24	28 U	19	21 U	14
Bis(2-Chloroethyl)Ether	47 U	16	53 U	18	74 U	25	57 U	19	43 U	14
Bis(2-Ethylhexyl) Phthalate	540	5.9	510	6.7	230 J	9.2	170 J	7.1	1000	5.3
Bisphenol A	20 J	2.3	27 U	2.7	37 U	3.7	28 U	2.8	21 U	2.1
Butyl benzyl phthalate	47 UJ	4.4	53 UJ	5.0	74 UJ	7.0	57 UJ	5.4	43 UJ	4.0
Caffeine	47 UJ	24	53 UJ	27	74 UJ	38	57 UJ	29	43 UJ	22
Cholesterol	410 J	2.3	1100 J	2.7	8600 J	3.7	1300 J	2.8	1400 J	2.1
Diethyl phthalate	23 U	8.6	27 U	9.8	37 U	13	28 U	10	21 U	7.8
Dimethyl phthalate	23 U	11	27 U	12	37 U	17	28 U	13	21 U	9.7
Di-N-Butylphthalate	58 UJ	6.0	54 UJ	6.8	70 UJ	9.4	40 UJ	7.2	33 UJ	5.4
Di-N-Octyl Phthalate	47 U	3.8	53 U	4.3	74 U	6.0	57 U	4.6	43 U	3.5
Ethanol, 2-Chloro-, Phosphate (3:1)	23 U	2.3	27 U	2.7	37 U	3.7	28 U	2.8	21 U	2.1
Hexachlorobenzene	23 U	8.3	27 U	9.4	37 U	13	28 U	10	21 U	7.5
Hexachlorobutadiene	94 U	42	110 U	47	150 U	65	110 U	50	85 U	38
Hexachlorocyclopentadiene	94 UJ		110 UJ		150 UJ		110 UJ		85 UJ	
Hexachloroethane	23 U	15	27 U	17	37 U	23	28 U	18	21 U	14
Isophorone	47 U	13	53 U	15	74 U	21	57 U	16	43 U	12
Nitrobenzene	23 U	20	27 U	23	37 U	32	28 U	24	21 U	18
N-Nitrosodi-n-propylamine	23 U	15	27 U	17	37 U	24	28 U	18	21 U	14
N-Nitrosodiphenylamine	47 UJ	9.4	53 UJ	11	74 UJ	15	57 UJ	11	43 UJ	8.5
Pentachlorophenol	230 UJ	4.8	270 UJ	5.4	370 UJ	7.5	280 UJ	5.8	210 UJ	4.3
Phenol	94 U	20	26 NJ	23	150 U	32	110 U	25	26 J	18
Triclosan	23 UJ	2.3	27 UJ	2.7	37 UJ	3.7	28 UJ	2.8	21 UJ	2.1
Triethyl citrate	23 REJ	2.3	27 REJ	2.7	37 REJ	3.7	28 REJ	2.8	21 REJ	2.1

Table H-5. Detected PCB Congeners for River Particulate Samples Collected in December 2009.

PCB Congener (ng/Kg dry)	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
PCB-003		3.52 J	5.34 J		
PCB-005/008	15.8	11.7	25.7	20.8	8.59
PCB-006			8.23		
PCB-007				5.96	
PCB-011	86.8	35.5	121	86.4	26.1
PCB-015	5.69	9.91	13.3	10.2	4.63
PCB-016	3.44 J		4.86 NJ		
PCB-017	5.6	4.06	5.54 J	5.02	
PCB-018	12.1	8.76	16.9	11.5	5.51
PCB-020/033	8.02	6.86	15.2	7.85	3.63 J
PCB-022	4.83	5.54	9.99	4.06 N	
PCB-028	11.3	10.9	18.6	11.3	6.56
PCB-031	9.56	8.32	18	10	4.15
PCB-037	4.76	7.95	15.7	6.6	4.63 N
PCB-042			5.63 J		
PCB-043/049	5.33		9.36	5.21	
PCB-044	5.7		13.1	3.97 NJ	
PCB-047/048	4.97		5.35 J	3.36 J	
PCB-052/069	8.56	4.64	18.4	10.2	3.93 J
PCB-056			3.81 J	3.33 J	
PCB-060			3.95 NJ		
PCB-064/072	3.1 J		5.22 J		
PCB-066	7.21	4.42	12.5	7.01	
PCB-070	11.6	4.36 N	19.5	10.4	5.58
PCB-074	4.38		7.67	4.78	
PCB-082			4.22 NJ		
PCB-084			3.79 J		
PCB-085		3.42 J	8.49		
PCB-086/097/117	4.57		13.6	5.95	3.08 J
PCB-087/115	6.43 N	3.75 J	19.3	6.07	6.16
PCB-092	5.16		6.18 N	3.07 J	
PCB-093/095/098/102	21.1	6.91 N	36.3	20.7	7.17
PCB-099	6.99		17.6	7.99	
PCB-101	16.9 N	7.05	39.2	19	8.03
PCB-105	5.22	5.49	15.4	5.74	3.43 J
PCB-110	22	12.7	45.3	22.4	12.3
PCB-118	10.1	11.1	33.4	13.2	7.84
PCB-128			7.15 N	4.37	
PCB-132			7 N	4.55 N	
PCB-135			6.48		
PCB-136	4.22		8.88	5.25	
PCB-138	9.8	8.7	34.6	20.4	6.96
PCB-139/149	18.1	10.5	37.7	24.3	9.74 N
PCB-141			7.13	3.26 NJ	
PCB-146			3.67 NJ	3.45 J	
PCB-151	6.66		14.6	6.57	
PCB-153	13.2	8.6	29.4	20.2	6.36
PCB-156			3.69 J		
PCB-158			3.2 J		
PCB-163/164			9.18 N	7.85	
PCB-170		4.91	10.8	3.58 NJ	
PCB-174	3.15 J		15.2	7.43	4.33
PCB-177			9.02	5.04	
PCB-179			3.37 NJ		

PCB Congener (ng/Kg dry)	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
PCB-180	6.72	7.94	29.9	12.3	6.89
PCB-182/187	4.58	4.88	16	10.4	4.13
PCB-183			4.89 J		
PCB-190			3.67 J		
PCB-199		4.7	8.52	7.25	
PCB-203			7.05	3.42 J	
PCB-206			8.31 N	5.81 N	
PCB-209		5.12	7.46	4.32	
Total PCBs					
…including N,NJ	383.65	232.21	922.5 J	491.82	162.73 J
…excluding N,NJ	360.32	220.94	864.61	466.59	145.36

Table H-6. PCB Homolog Totals for River Particulate Samples Collected in December 2009.

Results qualified as N or NJ were not included in homolog sums or Total PCB calculations.

PCB Homolog (ng/Kg dry)	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
Mono-CBs	0	3.52 J	5.34 J	0	0
Di-CBs	108.29	57.11	168.23	123.36	39.32
Tri-CBs	59.61	52.39	99.93	52.27	19.85 J
Tetra-CBs	50.85	9.06	100.54 J	44.29 J	9.51 J
Penta-CBs	75.14	43.51 J	232.38	104.12	48.01 J
Hexa-CBs	51.98	27.8	145.68	92.39	13.32
Hepta-CBs	14.45 J	17.73	89.48	35.17	15.35
Octa-CBs	0	4.7	15.57	10.67 J	0
Nona-CBs	0	0	0	0	0
Deca-CBs (PCB-209)	0	5.12	7.46	4.32	0
Total PCBs	360.32	220.94	864.61	466.59	145.36

Table H-7. Detected PBDE Congeners for River Particulate Samples Collected in December 2009.

PBDE Congener (ng/Kg dry)	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
BDE-017	6.02		4.69 J		
BDE-028	5.62	3.51	18.9	2.28 J	4.08
BDE-047	126	18.9 J	442	53.4	77.5
BDE-049	24.8		24	4.94 J	5.96
BDE-066	6.15		25.3	3.09 J	3.57 J
BDE-071	2.2 J		5.01 J		
BDE-085	6.05		20.4	2.86 J	4.87
BDE-099	155	19	499	60	84.4
BDE-100	40.5		114	15.8	19.9
BDE-119			6.17 J		
BDE-138	3.73 J		3.19 J		
BDE-139	2.64 J		4.01 NJ		
BDE-140			3.62 J		
BDE-153	17.9		46.2	7.3	9.33
BDE-154	18.7	3.41 J	51.5	5.02 J	4.87
BDE-156/169			2.97 J		
BDE-183	5 J		9.74 J		
BDE-196	9.18	4.24 J	31.4		8.2 J
BDE-197/204	6.56 J		29.3 J		5.58 NJ
BDE-201	8.01 J	7.08 J	38.6	6.31 J	8.9 J
BDE-203	12.9	10.6	66.9	6.63 J	13.9
BDE-206	84	14.3 J	268	52.5	69.4
BDE-207	88.2	68.7	308	55.7	115
BDE-208	96.2	50.1	397	69.9	133
BDE-209	683	322	2280	375	470
Total PBDEs					
…including N,NJ	1408.36	521.84	4699.9	720.73	1038.46
…excluding N,NJ	1408.36	521.84	4695.89	720.73	1032.88

Table H-8. PBDE Homolog Totals for River Particulate Samples Collected in December 2009.

Results qualified as N or NJ were not included in homolog sums or total PBDE calculations.

PBDE Homolog (ng/Kg dry)	Nooksack	Skagit	Stillaguamish	Snohomish	Puyallup
Mono-BDEs	-	-	-	-	-
Di-BDEs	0	0	0	0	0
Tri-BDEs	11.64	3.51	23.59 J	2.28	4.08
Tetra-BDEs	159.2	18.9 J	496.3	61.43 J	87.03
Penta-BDEs	201.6	19	639.6	78.66	109.2
Hexa-BDEs	42.97 J	3.41 J	107.5 J	12.32 J	14.2
Hepta-BDEs	5 J	0	9.74 J	0	0
Octa-BDEs	36.65 J	21.92 J	166.2 J	12.94 J	31 J
Nona-BDEs	268.4	133.1 J	973	178.1	317.4
Deca-BDEs (PBDE-209)	683	322	2280	375	470
Total PBDEs	1408.36	521.84	4695.89	720.73	1032.88

Appendix I. 2009-2010 Results Compared to Historical Data

Table I-1. Marine water column results for conventional parameters compared to historical data.

Parameter (mg/L)	Number	Median	Mean	Stdev	Low	High	Data Source*
TSS	42	1.6	1.75	1.05	0.8	6.0	Present Study
	18	4.5	4.9	1.6	2	9	Johnson (2009)
	19185	~2.5	~3.0	~2.47	0.0	64.1	Pelletier and Mohamedali (2009)
POC	28	0.059	0.133	0.326	0.028	1.780	Present Study
	~472	~0.08	~0.11	~0.03	~0.01	~0.36	Johannessen et al. (2008)
	(calc'd)	~2.84	~5.12	-	-	-	Pelletier and Mohamedali (2009)
DOC	28	0.754	0.757	0.089	0.611	0.969	Present Study
	~472	~0.64	~0.66	~0.02	~0.44	~0.91	Johannessen et al. (2008)
	24	1.06	1.23	-	0.70	2.16	Pelletier and Mohamedali (2009)
TOC	28	0.807	0.891	0.379	0.660	2.749	Present Study
	~472	~0.71	~0.77	~0.03	~0.48	~1.2	Johannessen et al. (2008)
	348	4.00	~6.35	-	0.85	79.0	Pelletier and Mohamedali (2009)

* Data sources:
Johannessen et al. (2008) data from Straits of Juan de Fuca and Georgia, 2003.
Johnson (2009) data from Strait of Juan de Fuca, Guemes Channel, and Commencement Bay, 2008-2009.
Pelletier and Mohamedali (2009) summary of EIM data for various Box Model regions; POC calculated as the difference of TOC and DOC.

Table I-2. Marine water column results for PCBs and PBDEs compared to historical data.

Parameter (pg/L)	Number	Median	Mean	Stdev	Low	High	Data Source*
Total PCBs	42	24.0	26.3	14.9	6.09	75.1	Present Study
	~14	-	~42	-	40.3	43.5	Dangerfield (2007)
Total PBDEs	10	749	2865	5678	51	18691	Present Study
	~14	-	~19	-	14.8	23.4	Dangerfield (2007)

* Data source:
Dangerfield et al. (2007) data from Boundary Pass and Rosario Strait, Strait of Georgia.

Table I-3 (presented on the following page). Marine water column metals results compared to historical data.

* Data sources:
Crecelius (1998) data from Cherry Point, Strait of Georgia and from March Point, Strait of Juan de Fuca, 1997.
Johnson (2009) data from Strait of Juan de Fuca, Guemes Channel, and Commencement Bay, 2008-2009.
Johnson (2009) summary of KCDNR data from Strait of Juan de Fuca, 1997-2000 (King County, 2001).
Johnson (2009) summary of Johnson and Summers (1999) data from Commencement Bay, 1997-1998.
Serdar (2008) summary of KCDNR data from Puget Sound region, 1996-2002; summary of EIM data from Puget Sound, 1995-2007.

Table I-3. Marine water column metals results compared to historical data.

Parameter (µg/L)	Number	Median	Mean	Stdev	Low	High	Data Source
Arsenic Total	42	1.41	1.42	0.091	1.16	1.56	Present Study
	10	0.457	0.468	0.044	0.410	0.567	Crecelius (1998) – Cherry Point
	10	1.03	1.03	0.081	0.856	1.16	Crecelius (1998) – March Point
	1927	~1.1	-	-	-	-	Serdar (2008) – KCDNR
	~130	~1	-	-	0.5	2.0	Serdar (2008) – EIM
Arsenic Dissolved	42	1.42	1.42	0.089	1.26	1.70	Present Study
	10	0.444	0.464	0.057	0.417	0.579	Crecelius (1998) – Cherry Point
	10	1.06	1.06	0.682	0.965	1.18	Crecelius (1998) – March Point
	1927	~1.1	-	-	-	-	Serdar (2008) – KCDNR
	~125	~1	-	-	0.5	2.0	Serdar (2008) – EIM
Cadmium Total	42	0.084	0.085	0.0097	0.059	0.112	Present Study
	10	0.0455	0.0451	0.0026	0.040	0.0480	Crecelius (1998) – Cherry Point
	10	0.0713	0.0703	0.0041	0.0616	0.0746	Crecelius (1998) – March Point
	~2227	~0.06	-	-	-	-	Serdar (2008) – KCDNR & EIM
Cadmium Dissolved	42	0.081	0.083	0.0105	0.067	0.111	Present Study
	10	0.0373	0.0365	0.0033	0.0306	0.0408	Crecelius (1998) – Cherry Point
	10	0.0696	0.0694	0.0047	0.0626	0.0759	Crecelius (1998) – March Point
	~2227	~0.06	-	-	-	-	Serdar (2008) – KCDNR & EIM
Copper Total	42	0.38	0.41	0.212	0.19	1.37	Present Study
	10	0.673	0.666	0.051	0.556	0.733	Crecelius (1998) – Cherry Point
	10	0.508	0.500	0.029	0.444	0.535	Crecelius (1998) – March Point
	17	0.45	0.53	0.30	0.19	1.3	Johnson (2009) /King County (2001)
	3 to 5	-	0.45	-	-	-	Johnson (2009)/King County (2001)
	1935	0.55	-	-	-	-	Serdar (2008) – KCDNR
	340	0.8	-	-	-	-	Serdar (2008) – EIM
Copper Dissolved	42	0.30	0.31	0.079	0.16	0.51	Present Study
	10	0.606	0.594	0.034	0.525	0.637	Crecelius (1998) – Cherry Point
	10	0.425	0.425	0.022	0.387	0.451	Crecelius (1998) – March Point
	12	0.38	0.48	0.21	0.31	1.0	Johnson (2009) /King County (2001)
	3 to 5	-	0.37	-	-	-	Johnson (2009) /King County (2001)
	3	-	0.61	-	-	-	Johnson and Summers (1999)
	1935	~0.39	-	-	-	-	Serdar (2008) – KCDNR
Lead Total	37	0.070	0.085	0.0541	0.015	0.230	Present Study
	10	0.0146	0.0144	0.0025	0.0101	0.0189	Crecelius (1998) – Cherry Point
	10	0.0380	0.0389	0.0057	0.0309	0.0507	Crecelius (1998) – March Point
	18	0.039	0.034	0.021	< 0.006	0.069	Johnson (2009)
	7 to 14	-	0.015	-	-	-	Johnson (2009) /King County (2001)
	1953	~0.045	-	-	-	-	Serdar (2008) – KCDNR
	< 274	~0.08	-	-	-	-	Serdar (2008) – EIM
Lead Dissolved	39	0.048	0.056	0.0464	0.006	0.235	Present Study
	10	0.0061	0.0083	0.0070	0.0061	0.0281	Crecelius (1998) – Cherry Point
	10	0.0089	0.0096	0.0032	0.0061	0.0182	Crecelius (1998) – March Point
	16	< 0.006	< 0.008	0.007	< 0.006	0.033	Johnson (2009)
	7 to 14	-	< 0.005	-	-	-	Johnson (2009)/King County (2001)
	3	-	0.018	-	-	-	Johnson and Summers (1999)
	1953	~0.008	-	-	-	-	Serdar (2008) – KCDNR
	< 274	~0.03	-	-	-	-	Serdar (2008) – EIM
Zinc Total	42	0.69	0.86	1.060	0.41	7.44	Present Study
	10	0.832	0.846	0.194	0.574	1.30	Crecelius (1998) – Cherry Point
	10	0.336	0.447	0.218	0.336	1.01	Crecelius (1998) – March Point
	18	0.75	0.90	0.64	0.20	2.9	Johnson (2009)/King County (2001)
	7 to 24	-	0.42	-	-	-	Johnson (2009) – KCDNR
	1954	0.87	-	-	-	-	Serdar (2008) – KCDNR
Zinc Dissolved	39	0.65	0.71	0.388	0.36	2.30	Present Study
	10	0.500	0.552	0.150	0.336	0.836	Crecelius (1998) – Cherry Point
	10	0.336	0.581	0.776	0.336	2.79	Crecelius (1998) – March Point
	14	0.60	0.80	0.59	0.31	2.6	Johnson (2009)/King County (2001)
	3	-	2.0	-	-	-	Johnson and Summers (1999)
	1954	0.73	0.73	-	-	-	Serdar (2008) – KCDNR
	< 574	2	-	-	-	-	Serdar (2008) – EIM

Table I-4. Concentrations of conventional parameters and nutrients in major rivers discharging to Puget Sound compared to historical data.

River	Study/ Data Source	TSS	TOC	DOC	Total N	Nitrite/ Nitrate - N	Ammonia - N	Total P	Ortho-P
Skagit	Present Study Mean (n=3 except as noted) and Range	24.8 6.4 - 60.8	1.0 0.6-1.7	1.0 0.6-1.6	0.13 0.057-0.163	0.08 0.045-0.126	0.046 (1) --	0.033 0.006-0.086	0.004 0.003-0.005
	EIM Mean (n) and Range [1]	42.4 (401) 1.0-1230	2.1 (42) 0.5-7.0	--	0.140 (209) 0.033-0.48	0.097 (64) 0.020-0.200	0.041 (252) 0.010-2.65	0.032 (359) 0.003-0.737	0.007 (105) 0.001-0.030
	Wise et al., 2007 Range for annual mean [2]	13.6 - 78.5	--	--	0.13 - 0.17	--	--	0.02 -0.05	--
Snohomish	Present Study	24.3 4.7-54.5	1.6 0.6-2.1	1.7 0.7-2.2	0.271 0.102-0.389	0.211 0.077-0.281	0.044 0.008-0.079	0.032 0.009-0.053	0.008 0.004-0.014
	EIM	15.2 (392) 1.0-260	1.85 (21) 0.8-6.1	--	0.304 (205) 0.030-0.840	0.219 (21) 0.073-0.368	0.040 (306) 0.010-0.780	0.025 (429) 0.005-0.160	0.011 (207) 0.002-0.100
	Wise et al., 2007	9.7 - 42.4	--	--	0.32 - 0.34	--	--	0.02 - 0.03	--
Nooksack	Present Study	30.3 3.7-76.3	1.4 0.6-2.8	1.6 0.8-2.9	0.379 0.106-0.656	0.325 0.087-0.544	0.022 (1) --	0.046 0.021-0.090	0.013 0.009-0.021
	EIM	97.5 (382) 1.0-2600	--	--	0.437 (233) 0.097-1.22	0.331 (20) 0.076-0.684	0.057 (408) 0.010-0.510	0.066 (562) 0.009-0.132	0.013 (324) 0.004-0.121
	Embrey & Frans, 2003 [3] *Median* and range	70 8-2,890	2.2 0.7-6.8	--	--	0.35 0.13-0.94	0.03 <0.02-0.08	0.04 <0.01-.3	0.008 <0.01 - 0.02
	Wise et al., 2007	48 - 301	--	--	0.49 -0.55	--	--	0.05 - 0.20	--
Stillaguamish	Present Study	15.9 2.6-41.3	1.7 0.8-3.3	2.0 0.9-4.0	0.299 0.147-0.418	0.243 0.088-0.341	0.019 0.007-0.039	0.035 0.016-0.072	0.011 0.008-0.014
	EIM	73.1 (758) 0.1-2700	1.7 (2) 1.4-2.0	--	0.275 (389) 0.054-0.767	0.208 (410) 0.010-0.728	0.044 (500) 0.010-0.760	0.046 (615) 0.008-0.698	0.010 (393) 0.002-0.110
Puyallup	Present Study	94.5 11.9-233	1.0 0.5-1.3	1.1 0.8-1.4	0.351 0.137-0.545	0.240 0.110-0.309	0.066 0.010-0.162	0.124 0.044-0.250	0.033 0.021-0.048
	EIM	138 (483) 1.0-2890	3.0 (63) 0.9-9.1	1.7 (16) 1.1-3.2	0.305 (274) 0.074-0.826	0.225 (21) 0.056-0.399	0.064 (542) 0.004-0.580	0.104 (585) 0.010-1.66	0.018 (526) 0.007-0.120
	Wise et al., 2007	77.1 - 407	--	--	0.27 - 0.41	--	--	0.09 - 0.15	--

[1] Derived from EIM data representing similar locations in each river and equivalent and analytical methods.

[2] Flow-weighted annual mean concentrations for 1997, 2000, and 2001 based on LOADEST model annual loads and annual flows.

[3] Based on approximately 40 samples collected near Brennan, Washington, in 1996-1998.

Table I-5. Hardness and concentrations of metals in major rivers discharging to Puget Sound compared to historical data.

River	Study/ Data Source	Hardness	Total Arsenic	Total Cadmium	Total Copper	Total Lead	Total Zinc
		mg/L	µg/L				
Skagit	Present Study Mean (n=3 except as noted) and Range	26.4 21.8-29.9	0.75 0.43 - 1.24	0.012 0.006-0.020	2.06 0.77-4.56	0.31 0.05-0.78	5.1 2.4-10.6
	EIM Mean (n) and Range [1]	22.6 (218) 13-48	0.65 (12) 0.45-1.09	--	1.39 (19) 0.280-12.0	0.165 (9) 0.023-0.47	3.09 (8) 0.55-9.34
Snohomish	Present Study	15.4 13.2-17.4	1.00 0.92-1.14	0.015 0.005-0.030	2.60 1.35-4.08	0.34 0.09-0.63	4.7 2.5-8.3
	EIM	18.2 (368) 3.0-52.0	0.82 (23) 0.48-1.9	0.03 (1) --	1.06 (42) 0.39-5.9	0.271 (29) 0.020-1.50	5.49 (30) 0.61-33.9
Nooksack	Present Study	46.2 38.1-62.0	0.55 0.26-1.01	0.017 0.005-0.040	2.41 0.75-4.41	0.32 0.05-0.82	6.0 3.2-9.7
	EIM	39.8 (306) 10.0-71.0	0.725 (18) 0.23-5.22	--	2.03 (29) 0.27-21	0.368 (22) 0.020-3.86	5.0 (24) 0.34-35.3
Stillaguamish	Present Study	27.0 19.2-31.9	0.79 0.52-1.12	0.011 0.005-0.020	2.95 1.16-6.58	0.58 (2) 0.37-0.79	9.0 4.0-17.7
	EIM	22.3 (178) 11.0-43.0	0.90 (18) 0.37-2.65	0.102 (1) --	2.15 (18) 0.50-18.0	0.08 (12) 0.020-0.450	4.2 (10) 0.45-20
Puyallup	Present Study	33.9 27.7-40.8	0.68 0.52-0.92	0.007 0.005-0.010	4.91 1.32-11.6	0.81 (2) 0.20-1.42	7.7 (2) 3.7-11.6
	EIM	25.5 (273) 14.0-60.4	0.68 (38) 0.33-1.16	0.073 (22) 0.003-0.200	4.82 (73) 0.45-41.4	0.77 (45) 0.022-6.30	7.5 (57) 0.21-43.5
Green/Duwamish	King County (2007) [1,2] Mean (n) and range	--	0.71 (11) 0.34-2.4	--	13.1	--	21.3
Surface Runoff	PSTLA (Ecology, 2010) [3] Range for 5% - 95% probability of exceedance concentrations	--	0.2 -14.9	0.0002 - 9.2	0.1 - 110	0.02 - 309	0.28 - 527

[1] King County, personal communication, April 2009. Arsenic data from 2006-2008.

[2] Mean copper and zinc concentrations derived from 2003-2005 total annual loads and discharges listed in King County (2007), Table 5-9.

[3] Range of values from Ecology (2010), Table 2: Probability of exceedance concentrations applied to major land-use types and highways.

Table I-6. Comparison of concentration ranges for organic compounds measured for the present study and others.

River	Study/ Data Source	Oil and Grease		Total PAH	cPAH *	Total PCBs	Total PBDEs
		Including ND=MDL/2	Detects only	Including ND = MDL/2			
		µg/L				pg/L	
Skagit, Snohomish, Nooksack, Stillaguamish, and Puyallup	Present Study Mean (n) and Range	920 (15) 250-2800	1600 (6) 900-2800	0.032 (15) 0.012 - 0.055	0.011 (15) 0.009 - 0.014	16.1 (15) 2.6 - 59.0	55.6 (7) 10.9 - 265
Green/Duwamish	Williston (2009) [1] Mean (n) and Range	--		0.026 (11) 0.015 - 0.05	0.001 (18) <0.001 - 0.003	410 (22) 38 - 2360	--
	Gries and Sloan (2009) [2] Est. range for annual mean	--		--	1.2-14.3	140 - 1,600	--
Total Surface Runoff	PSTLA (Ecology 2010) [3] Concentration Range	3.7 - 26,400		0.001- 56.6	0.0002 - 11.8	16 - 810,000	0.30 - 810

* Carcinogenic PAH compounds (cPAH) include benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene

[1] King County, personal communication, April 2009. PAH data from 2008.

[2] Estimated range for annual flow-weighted mean concentrations.

[3] Range of values from Ecology (2010), Table 2: Probability of exceedance concentrations applied to major land uses types and highways.

Appendix J. Statistical Results

Marine Water Column Statistics

River Water Statistics

Table J-1. Data distributions and potential outliers for marine water column sample results.

Parentheses indicate that some distributions change when outliers are removed from the data set.

Parameter	Normal Distribution	Log Normal Distribution	Gamma Distribution	Statistical Outliers
TSS	x (Y)	x (Y)	x (Y)	6.0, 5.5, 3.5
DOC	Y	Y	Y	--
POC	x (x)	x (Y)	x (Y)	1.78, 0.22, 0.18
Arsenic, Total	x	x	Y	--
Arsenic, Dissolved	x (Y)	x (Y)	Y	1.704
Cadmium, Total	x	x	Y	--
Cadmium, Dissolved	x	x	Y	--
Copper, Total	x (Y)	x (Y)	x (Y)	1.37, 1.03, 0.72
Copper, Dissolved	x	x	Y	--
Lead, Total	x	Y	Y	--
Lead, Dissolved	x (x)	Y	Y	0.235
Zinc, Total	x (Y)	x (Y)	x (Y)	7.44, 1.44
Zinc, Dissolved	x (x)	x (x)	x (Y)	2.3, 1.78, 1.42, 1.25, 1.06
Mono-chlorinated PCBs	x	Y	X	18.7, 0.399
Di-chlorinated PCBs	Y	Y	Y	7.31, 1.03
Tri-chlorinated PCBs	x	Y	Y	--
Tetra-chlorinated PCBs	x	x	Y	--
Penta-chlorinated PCBs	x	Y	Y	--
Hexa-chlorinated PCBs	x	Y	Y	7.39, 0.872
Total PCBs *	x (Y)	x	Y	75.1
Total PBDEs *	x	Y	Y	18700, 51

* Insufficient number of detected results (n<8) to evaluate distributions for PCB homologs with more than 6 chlorines or any PBDE homologs.

Table J-2. Results of nonparametric ANOVA (Kruskal Wallis Test and Test of Means) for all marine water column results.

Independent Categorical Variable →	Puget Sound (PS) Vs. Ocean Boundary (OB)	Summer, Fall, Winter: Kruskal Wallis Test & Test of Medians	Stations Kruskal Wallis Test & Test of Medians	Surface vs. Deep Layer Kruskal Wallis Test & Test of Medians
Chemical Name ↓				
TSS		$p<0.002$, TSS lowest in Fall		
DOC	$p<0.001$, PS>OB	$p<0.024$*, Fall > Winter	$p<0.014$, greatest at Whidbey Basin & South Sound stations	
POC		$p<0.004$, Fall > Winter		
TOC	$p<0.001$, PS>OB	$p<0.031$, Fall > Winter	$p<0.034$, see DOC	
Arsenic, Total		$p<0.020$, lowest in Fall		$p<0.031$, Surface < Deep
Arsenic, Dissolved				$p<0.001$, Surface < Deep
Cadmium, Total	$p<0.001$, PS<OB		$p<0.003$, greatest at Juan de Fuca & Hood Canal stations	($p<0.13$, Surface < Deep)
Cadmium, Dissolved	$p<0.001$, PS<OB		$p<0.002$, see total cadmium	
Copper, Total	$p<0.005$, PS>OB	$p<0.003$, lowest in Fall		
Copper, Dissolved	$p<0.001$, PS>OB	$p<0.042$, lowest in Fall	$p<0.001$, lowest at Juan de Fuca & Hood Canal stations	
Lead, Total				$p<0.005$, Surface < Deep
Di-chlorinated PCBs	$p<0.001$, PS>OB			
Tri-chlorinated PCBs		$p<0.002$, lowest in Winter		
Tetra-chlorinated PCBs				$P<0.001$, Surface < Deep
Penta-chlorinated PCBs	$p<0.002$, PS>OB		$p<0.015$, greatest at Haro Strait, Whidbey Basin, and South Sound stations	
Hexa-chlorinated PCBs			$p<0.044$, greatest at Main and Whidbey basin stations	
Total PCBs	$p<0.027$, PS>OB	$p<0.020$, greatest in fall		$p<0.001$, Surface < Deep
Total PBDEs		$p<0.034$*, greatest in winter		

* Identified as significant only by Test of Medians.

Table J-3. Spearman rank correlation coefficients between pairs of parameters measured in marine water column samples.

Units of measure are mg/L for conventionals, μ/L for metals, and pg/L for total PCBs and PBDEs.
Values in bold are significant at p<0.05. The 3 italicized values are significant only at p<0.10.

	TSS	DOC	POC	TOC	Arsenic , Total	Arsenic , Dissolved	Cadmium , Total	Cadmium , Dissolved	Copper , Total	Copper , Dissolved	Lead , Total	Lead , Dissolved	Zinc , Total	Zinc , Dissolved	Total PCBs	Total PBDEs
TSS	1.00															
DOC	**-0.67**	1.00														
POC	**-0.49**	*0.32*	1.00													
TOC	**-0.76**	**0.96**	*0.36*	1.00												
Arsenic, Total	0.20	**-0.57**	0.11	**-0.61**	1.00											
Arsenic, Dissolved	0.27	**-0.70**	0.02	**-0.76**	**0.88**	1.00										
Cadmium, Total	0.27	**-0.54**	-0.07	**-0.50**	**0.39**	**0.63**	1.00									
Cadmium, Dissolved	**0.45**	**-0.88**	-0.13	**-0.78**	**0.52**	**0.66**	**0.79**	1.00								
Copper, Total	0.16	**-0.46**	**0.36**	**-0.57**	**0.75**	**0.88**	**0.43**	**0.40**	1.00							
Copper, Dissolved	**-0.45**	**0.64**	**0.50**	**0.54**	0.14	-0.16	**-0.61**	**-0.72**	0.11	1.00						
Lead, Total	**0.83**	**-0.93**	**-0.39**	**-0.89**	**0.43**	**0.51**	**0.54**	**0.85**	0.25	**-0.68**	1.00					
Lead, Dissolved	**0.54**	**-0.88**	**-0.56**	**-0.78**	0.31	**0.39**	**0.36**	**0.78**	0.04	**-0.76**	**0.85**	1.00				
Zinc, Total	-0.02	0.25	0.21	0.04	**0.32**	0.20	**-0.46**	**-0.54**	**0.46**	**0.79**	**-0.36**	**-0.51**	1.00			
Zinc, Dissolved	**-0.99**	**0.61**	**0.46**	**0.71**	-0.18	-0.27	**-0.32**	**-0.41**	-0.18	**0.43**	**-0.79**	**-0.45**	0.00	1.00		
Total PCBs	**0.70**	**-0.54**	0.14	**-0.57**	0.04	0.16	0.11	**0.38**	**0.32**	**-0.32**	**0.61**	**0.31**	0.00	**-0.68**	1.00	
Total PBDEs	0.29	-0.07	-0.46	-0.11	0.14	-0.18	*-0.61*	-0.25	-0.32	0.29	0.14	0.25	0.32	-0.21	-0.07	1.00

Table J-4. Data distributions and potential outliers for river water sample results.

Chemical	Normal Distribution	Log Normal Distribution	Gamma Distribution	Statistical Outliers
TSS	x (x)	Y	Y	233
TOC	x	Y	Y	--
DOC	x (x)	Y	Y	0.56
Total Nitrogen	Y	Y	Y	--
Nitrate+Nitrite Nitrogen	x	Y	x	--
Ammonia Nitrogen	x (Y)	Y	Y	0.162
Total Phosphorus	x (Y)	Y	Y	0.250
Ortho-phosphate	x (Y)	Y	Y	0.0478
Hardness	Y	Y	Y	62
Arsenic, Total	Y	Y	Y	--
Arsenic, Dissolved	Y	Y	Y	--
Cadmium, Total	x	x	x (Y)	0.04
Cadmium, Dissolved	x (Y)	x (Y)	Y	0.035 *
Copper, Total	x (x)	Y	Y	11.6
Copper, Dissolved	x (x)	Y	Y	4.19
Lead, Total	x	Y	Y	--
Lead, Dissolved	x (Y)	Y	x (Y)	0.281
Zinc, Total	x	Y	Y	--
Zinc, Dissolved	x	Y	Y	--
Oil & Grease	Y	Y	Y	2.8
Mono-chlorinated PCBs	Y	Y	Y	--
Di-chlorinated PCBs	Y	Y	Y	6.14
Tri-chlorinated PCBs	Y	Y	Y	9.68
Tetra-chlorinated PCBs	x (x)	Y	Y	16.5
Penta-chlorinated PCBs	x (x)	Y	Y	28.7
Hexa-chlorinated PCBs	Y	Y	Y	--
Total PCBs	x (x)	Y	Y	59.0
Tri-brominated PBDEs	--	--	--	--
Penta-brominated PBDEs	--	--	--	34.2
Total PBDEs	x (Y)	x (Y)	x (Y)	265.2

* Outlier removed for analysis because dissolved cadmium >> total cadmium.

Table J-5. Results of nonparametric ANOVA (Kruskal Wallis Test and Test of Medians) for all river water results.

Independent Categorical Variable → Chemical Name ↓	Season: Summer vs. Fall vs. Winter	River/Station	Flow Regime: Baseflow vs. Runoff Event
TSS	--	--	--
DOC	p<0.011; summer low	--	--
TOC	p<0.019; summer low	--	--
Total Nitrogen	p<0.008; summer low	--	--
Ammonia Nitrogen	p<0.038; fall high	--	--
Nitrate+Nitrite Nitrogen	p<0.026; summer low	--	--
Total Phosphorus	--	--	--
Ortho-phosphate	--	P<0.034; Skagit lowest, Puyallup highest	--
Hardness	--	P<0.026; Snohomish lowest, Nooksack/Puyallup highest	--
Arsenic, Total	--	--	--
Arsenic, Dissolved	--	P<0.041; Nooksack lowest	--
Cadmium, Total	--	--	--
Cadmium, Dissolved	--	--	--
Copper, Total	--	--	--
Copper, Dissolved	--	--	--
Lead, Total	p<0.034*; summer/fall low, winter high	--	--
Lead, Dissolved	--	--	--
Zinc, Total	p<0.050*; fall low, winter high	--	--
Zinc, Dissolved	--	--	--
Oil and Grease	--	--	--
Total PCBs	--	--	(p<0.094; baseflow higher)
Total PBDEs	--	--	--

* Identified as significant only by Test of Medians.

Table J-6. Results of nonparametric ANOVA (Kruskal Wallis Test and Test of Medians) excluding summer Puyallup River results.

Independent Categorical Variable → Chemical Name ↓	Season: Summer vs. Fall vs. Winter	River/Station	Flow Regime: Baseflow vs. Runoff Event
TSS	p<0.050*; summer low, winter high	--	--
DOC	p<0.022; summer low, winter high	--	--
TOC	p<0.038; summer low, winter high	--	--
Total Nitrogen	p<0.015; summer low, fall high	--	--
Ammonia Nitrogen	p<0.050, fall high, winter low	--	--
Nitrate+Nitrite Nitrogen	p<0.039; summer low, fall high	--	--
Total Phosphorus	0.050*; summer low, winter high	--	--
Ortho-phosphate	--	--	--
Hardness	--	p<0.022, Nooksack/Puyallup high, Skagit/Snohomish low	--
Arsenic, Total	--	--	--
Arsenic, Dissolved	--	P<0.044, Nooksack/Skagit low, Snohomish high	--
Cadmium, Total	--	--	--
Cadmium, Dissolved	--	--	--
Copper, Total	--	--	--
Copper, Dissolved	--	--	--
Lead, Total	0.027*; summer low, winter high	--	--
Lead, Dissolved	--	--	--
Zinc, Total	p<0.050*; winter high, summer/fall low	--	--
Zinc, Dissolved	p<0.034*; summer high, fall low	--	--
Oil and Grease	--	--	--
Total PCBs	--	--	--
Total PBDEs	--	--	--

* Identified as significant only by Test of Medians.

Table J-7. Spearman rank correlation coefficients between paired parameters measured in river water samples.

Units of measure are mg/L for conventionals, nutrients, and hardness; μg/L for all metals; mg/L for oil and grease, and pg/L for PCBs. Values in bold are significant at $p<0.05$.

Flow (cfs)	1.00																			
TSS	0.50	1.00																		
TOC	0.28	0.39	1.00																	
DOC	0.22	0.50	**0.95**	1.00																
Total Nitrogen	-0.11	0.29	**0.76**	**0.85**	1.00															
Nitrate+Nitrite Nitrogen	-0.22	0.28	**0.71**	**0.78**	**0.92**	1.00														
Ammonia Nitrogen	-0.09	-0.04	0.14	0.31	0.49	0.17	1.00													
Total Phosphorus	0.09	**0.85**	0.47	**0.59**	0.49	**0.59**	0.02	1.00												
Ortho-phosphate	**-0.70**	0.13	0.05	0.17	0.44	0.52	0.36	0.50	1.00											
Hardness	**-0.64**	-0.02	-0.17	-0.08	0.29	0.30	0.30	0.25	0.50	1.00										
Arsenic, Total	**0.61**	**0.67**	**0.59**	**0.56**	0.17	0.13	-0.16	**0.58**	-0.14	**-0.52**	1.00									
Arsenic, Dissolved	0.00	-0.20	0.16	0.06	-0.08	-0.24	0.29	-0.18	0.02	-0.46	0.39	1.00								
Cadmium, Total	**0.74**	**0.76**	**0.59**	**0.62**	0.34	0.30	-0.21	**0.57**	-0.24	-0.32	**0.77**	-0.11	1.00							
Cadmium, Dissolved	0.51	0.01	0.01	-0.03	-0.33	-0.10	-0.47	-0.14	**-0.65**	-0.15	0.22	-0.31	0.19	1.00						
Copper, Total	0.33	**0.86**	0.41	0.50	0.20	0.22	-0.07	**0.81**	0.17	-0.16	**0.77**	0.01	**0.66**	-0.21	1.00					
Copper, Dissolved	0.15	0.48	0.28	0.28	0.13	0.18	-0.20	**0.57**	0.27	-0.20	**0.74**	0.30	0.46	-0.36	**0.69**	1.00				
Lead, Total	0.47	**0.86**	0.48	**0.53**	0.34	0.41	-0.35	**0.78**	0.11	-0.10	**0.67**	-0.21	**0.85**	-0.14	**0.81**	**0.57**	1.00			
Lead, Dissolved	0.56	**0.64**	**0.66**	0.58	0.12	0.11	-0.55	0.54	-0.28	-0.32	**0.81**	0.16	**0.74**	0.17	**0.77**	**0.85**	**0.83**	1.00		
Zinc, Total	0.10	**0.63**	0.45	0.52	0.28	0.43	-0.47	**0.76**	0.17	0.02	**0.60**	-0.19	**0.62**	-0.13	**0.82**	**0.57**	**0.78**	**0.70**	1.00	
Zinc, Dissolved	-0.13	-0.19	-0.17	-0.26	-0.14	-0.11	-0.13	-0.11	0.20	0.01	0.02	0.17	-0.13	-0.34	-0.04	0.44	-0.01	0.17	-0.12	1.00
	Flow	TSS	TOC	DOC	Total Nitrogen (N)	Nitrate+Nitrite N	Ammonia N	Total Phosphorus	Ortho-phosphate	Hardness	Arsenic , Total	Arsenic , Dissolved	Cadmium , Total	Cadmium , Dissolved	Copper , Total	Copper , Dissolved	Lead , Total	Lead , Dissolved	Zinc , Total	Zinc , Dissolved

Table J-7 (continued). Spearman rank correlation coefficients between paired parameters measured in river water samples.

Units of measure are mg/L for conventionals, nutrients, and hardness; µg/L for all metals; mg/L for oil and grease; pg/L for all summed PCBs. There were no significant correlations involving PBDE results for river water. Values in bold are significant at p<0.05.

	Flow	TSS	TOC	DOC	Total Nitrogen (N)	Nitrate+Nitrite N	Ammonia N	Total Phosphorus	Ortho-phosphate	Hardness	Arsenic , Total	Arsenic , Dissolved	Cadmium , Total	Cadmium , Dissolved	Copper , Total	Copper , Dissolved	Lead , Total	Lead , Dissolved	Zinc , Total	Zinc , Dissolved	Oil & Grease	1-Cl PCBs	2-Cl PCBs	3-Cl PCBs	4-Cl PCBs	5-Cl PCBs	6-Cl PCBs	Total PCBs
Oil & Grease	0.46	-0.40	0.55	0.03	-0.03	-0.15	-0.50	-0.40	-0.70	-0.64	0.37	0.70	-0.16	**1.00**	-0.21	-0.09	-0.40	**-1.00**	-0.40	0.09	1.00							
Mono-chlorinated PCBs	**-0.70**	-0.20	0.30	0.10	0.10	0.30	-0.50	0.20	**0.70**	**0.60**	**-0.60**	-0.31	**-0.87**	**0.87**	-0.20	-0.20	-0.41	**-0.80**	0.00	-0.36	.	1.00						
Di-chlorinated PCBs	-0.40	-0.20	-0.18	-0.34	-0.35	-0.18	**-0.80**	-0.05	0.33	-0.18	0.15	0.45	-0.50	**-0.67**	0.30	**0.53**	-0.05	**0.77**	0.24	**0.70**	**0.78**	-0.40	1.00					
Tri-chlorinated PCBs	-0.15	-0.11	-0.28	-0.32	-0.30	-0.39	0.41	-0.06	0.12	0.28	0.25	**0.55**	-0.29	-0.27	-0.02	0.41	-0.28	-0.08	-0.27	0.25	-0.11	-0.30	0.30	1.00				
Tetra-chlorinated PCBs	-0.49	-0.24	-0.03	-0.02	0.07	0.13	0.34	-0.07	0.26	0.22	-0.21	0.16	-0.45	-0.12	-0.14	-0.39	-0.30	-0.39	-0.06	**-0.54**	0.50	-0.40	0.09	0.45	1.00			
Penta-chlorinated PCBs	-0.35	-0.15	0.24	0.31	0.34	0.26	**0.67**	0.06	0.39	-0.11	-0.03	0.46	-0.24	-0.15	-0.12	-0.18	-0.26	-0.38	-0.14	**-0.60**	0.31	**-1.00**	-0.29	0.21	**0.89**	1.00		
Hexa-chlorinated PCBs	0.04	**0.67**	**0.60**	**0.65**	**0.63**	**0.61**	0.37	**0.83**	0.43	0.37	0.40	-0.03	0.34	-0.20	**0.64**	0.29	**0.54**	0.39	0.46	-0.17	0.50	**-0.60**	0.07	0.03	0.40	0.44	1.00	
Total PCBs	-0.34	-0.24	0.17	0.12	0.17	0.14	0.43	-0.07	0.17	0.14	-0.04	0.43	-0.37	0.14	-0.19	-0.10	-0.37	-0.14	-0.18	-0.44	0.52	0.10	0.23	**0.54**	**0.84**	**0.88**	0.51	1.00

THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

DEC - 1 2014

MEMORANDUM

SUBJECT: Commemorating the 30th Anniversary of the EPA's Indian Policy

FROM: Gina McCarthy

TO: All EPA Employees

I am proud to recognize the U.S. Environmental Protection Agency's 30th anniversary of its Indian policy, and I want to thank everyone who has worked diligently to establish and sustain the agency's Indian program. As we mark this milestone, I also want to convey gratitude to our tribal-government partners for all their time, expertise and effort in building this important partnership with the EPA.

On November 8, 1984, the EPA issued its *Policy for the Administration of Environmental Programs on Indian Reservations*. In doing so, the EPA became the first federal agency to adopt a formal Indian policy to guide its relations with tribal governments in the administration of its programs. The 1984 Indian Policy represented – and continues to represent – a bold statement on the EPA's commitment to our partnership with federally recognized Indian tribes and to tribal self-governance in implementing environmental-protection programs.

The underlying principles of the 1984 Indian policy continue to guide our unique relationship with, and the federal trust responsibility to, federally recognized Indian tribes as expressed in treaties, statutes, executive orders and court decisions. The agency remains fully committed to engaging tribes as sovereign governments with a right to self-governance, which is a commitment the EPA made and has kept since our agency's founding.

Tribal Treaty Rights

Under the U.S. Constitution, treaties have the same legal force as federal statutes. And the United States' government-to-government relationship with and trust responsibility to federally recognized Indian tribes reinforces the importance of honoring these treaty rights. As such, the EPA has an obligation to honor and respect tribal rights and resources protected by treaties. While treaties do not expand the EPA's authority, the EPA must ensure its actions do not conflict with tribal treaty rights. In addition, EPA programs should be implemented to enhance protection of tribal treaty rights and treaty-covered resources when we have discretion to do so. To help guide the agency's decisions when treaty rights should be considered, the Office of General Counsel and the American Indian Environmental Office will develop an analytical framework, with input and consultation from other EPA offices and tribal governments.

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Intergovernmental Cooperation

Good governance demands that the EPA increase our efforts to work in concert with other federal agencies, tribes, states and local governments to protect human health and the environment. Coming together to set priorities and define mutual roles and responsibilities regarding the administration of environmental-protection programs will build stronger, more efficient and effective partnerships. The EPA remains committed to continue building on the following notable Indian program efforts:

- engaging tribal-elected officials on key environmental and public-health issues through an annual tribal leaders' listening session;
- coordinating with the Environmental Council of the States to include tribal governments in key discussions as co-regulators;
- using the Council for the Commission for Environmental Cooperation to ensure that the U.S., Canada and Mexico continue to work with indigenous communities across North America and recognize the importance of the traditional ecological knowledge and practices of indigenous communities; and
- working with the Department of the Interior to build tribal resiliency regarding the impacts of climate change.

The EPA this year also celebrates the 20th anniversary of the Indian Environmental General Assistance Program. Through this program, the EPA has provided more than $1 billion in direct funding to federally recognized tribes and intertribal consortia to build strong, sustainable tribal environmental-protection program capacity.

Thank you all once more for your hard work and your commitment. I look forward to working with you to achieve much more in the months ahead.

DEPARTMENT OF
ECOLOGY
State of Washington

Fish Consumption Rates

Technical Support Document

A Review of Data and Information about Fish Consumption in Washington

Version 2.0

Final

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For more information contact:

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Fish Consumption Rates

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Toxics Cleanup Program
Washington State Department of Ecology
Olympia, Washington

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Acronyms and Abbreviations

API	Asian and Pacific Islander
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	bioaccumulation factor
BCF	bioconcentration factor
bw	body weight
BRFSS	Behavioral Risk Factor Surveillance System
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRITFC	Columbia River Inter-Tribal Fish Commission
CSFII	Continuing Survey of Food Intakes by Individuals
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
g/day	grams per day
g/kg	grams per kilogram
IHS	Indian Health Service
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µg/mg	micrograms per milligram
MTCA	Model Toxics Control Act
NCI	National Cancer Institute
NHANES	National Health and Nutrition Examination Survey
NOAA	National Oceanic and Atmospheric Administration
Oregon DEQ	Oregon Department of Environmental Quality
OFM	Office of Financial Management
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PBT	persistent bioaccumulative toxic
PCB	polychlorinated biphenyl
POP	persistent organic pollutant
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RME	reasonable maximum exposure
SaSI	Salmonid Stock Inventory
SMS	Sediment Management Standards
U.S.	United States

USDA	U.S. Department of Agriculture
WAC	Washington Administrative Code
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

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The Washington State Department of Ecology wishes to thank the many people who have participated in the ongoing dialogue on fish consumption rates. There have been many conversations through the years, with a great many people providing insight and input, answering questions, reviewing draft documents, and clarifying various issues. In particular, Ecology wishes to acknowledge the following people. Persons listed here provided constructive input and feedback; they were not, however, asked to endorse the final product, and did not see the final report before its release.

University of Washington

- Dr. William (Bill) Daniell, Associate Professor, Environmental and Occupational Health Sciences
- Dr. Elaine Faustman, Professor, Environmental Health
- Dr. William (Bill) Griffith, Principal Research Scientist and Director of the Risk Assessment Core of the Institute for Risk Analysis and Risk Communication
- Alison Scherer, Research Scientist, Environmental and Occupational Health Sciences
- Anna Schmidt, Graduate Student, Environmental and Occupational Health Sciences
- Dr. Thomas M. Burbacher, Professor, Environmental Health
- Dr. Vincent F. Gallucci, Professor, Aquatic and Fishery Sciences
- Verna Blackhurst, School of Aquatic and Fishery Sciences

Seattle University School of Law

- Catherine A. O’Neill, Professor of Law
- Doug Nash, Professor of Law and member of Nez Perce Tribe

Washington State Department of Health (DOH)

- Maria C. Gardipee
- Dr. Joan Hardy
- David McBride
- Dr. Jim W. White

Selected Tribal Representatives

- Larry Dunn, Lower Elwha Klallam Tribe
- Don Hurst and Patti Bailey, Confederated Tribes of the Colville Reservation
- Fran Wilshusen, Northwest Indian Fisheries Commission
- Denice Taylor, Suquamish Tribe

- Dianne C. Barton and Aja DeCoteau, Columbia River Inter-Tribal Fish Commission (CRITFC)

Washington State Office of Financial Management

- Yi Zhao, Chief Demographer

Washington Department of Fish and Wildlife

- James E. West

National Oceanic and Atmospheric Administration

- Thomas Hooper
- Sandra O'Neill

U.S. Environmental Protection Agency, Headquarters, Washington, D.C.

- Dr. Jacqueline Moya
- David J. Miller
- David Hardy
- Bayazid Sarkar
- Aaron Niman

U.S. Environmental Protection Agency, Region 10, Seattle

- Lon Kissinger, Senior Toxicologist

Selected members of the Human Health Focus Group, Oregon Dept of Environmental Quality

- Dr. Patricia Cirone (Affiliate Professor, University of Washington)
- Dr. Bruce Hope, Senior Toxicologist
- DOH personnel identified above

Statisticians

- Dr. Nayak Polissar, The Mountain-Whisper-Light Statistics
- Dr. Moni Blazej Neradilek, The Mountain-Whisper-Light Statistics
- Dr. Sasha Aravkin, The Mountain-Whisper-Light Statistics
- Dr. Shiquan Liao, King County

Preface to Version 2.0

Washington's marine and fresh waters are home to rich stocks of finfish and shellfish, and these resources are vital to the well-being of the peoples of our state.[1] Several years ago the Washington State Department of Ecology (Ecology) began work reviewing fish consumption rates as part of updating environmental cleanup regulations, and subsequently produced a draft Technical Support Document. The evaluations presented in that document followed similar evaluations done in Oregon. Ecology received several hundred comments on the draft document and has made revisions based on input received. Additional analyses were performed and supplemental information was gathered to support preparation of this revised version.

Regulatory context plays a role in this topic, and Ecology will be addressing both the scientific and policy questions associated with fish consumption rates. This Technical Support Document, however, does not address the policy questions. It focuses quite specifically on the issue of how much and what types of fish are consumed by the people of Washington, and what data are available about fish consumption rates.

It is appropriate and necessary to review and, if needed, update exposure parameters used in various regulatory contexts, and this document is offered as one part of the effort to consider fish consumption rates. Readers may notice that this document has evolved. Ecology produced the *Fish Consumption Rates Technical Support Document: A Review of Data and Information about Fish Consumption in Washington, Version 1.0* to support dialogue related to updating the default fish consumption rates used in Washington environmental regulations. At that time, Ecology was focused on updating the Sediment Management Standards, with updates to water quality standards to follow at a later time. It was a draft document that posed several questions and was distributed for public review and input in October 2011. Although scheduled to end December 31, 2011, the comment period was extended until January 18, 2012.[2]

In Version 1.0 of the Technical Support Document, Ecology collected data about fish consumers in Washington and looked at national data about fish consumption in the United States. We reviewed this information as a first step in addressing how to establish a fish consumption rate for use in Washington. Ecology then considered how to systematically and scientifically determine a default rate appropriate for use in a regulatory context. Multiple questions arose, including: How should the data be combined in a statistically correct manner? Is it appropriate to establish a single default rate for use in multiple settings? How should salmon be included in the default fish consumption rate?

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[1] In most places in this document, unless noted otherwise, fish refers to both finfish and shellfish.

[2] Due to a winter storm that caused statewide power outages during that week, Ecology accepted all late comments.

Ecology received over 300 comments on Version 1.0 of the Technical Support Document. Comments were posted on the Ecology website in the order in which they were received. Ecology announced that a response to comments would be prepared.

In order to respond to comments and to update the document based on public input, Ecology performed a number of additional analyses. The additional work in response to comments falls generally into the following categories:

- Technical analyses to more accurately characterize fish-consuming populations, including statistical review of data and methodologies.
- Research of relevant supporting information (for example, regarding recreational fish consumption, health benefits and risks from eating finfish and shellfish, and life strategies for different fish species).

Purpose

The purpose of this Technical Support Document (Version 2.0) is to compile and evaluate available information on fish consumption in Washington State. It is a technical document, and is not designed to resolve policy issues associated with using that information to make regulatory decisions. Those issues will be dealt with in separate rulemaking documents and processes. However, in order to assist readers, this document does provide a certain amount of context and identifies some of the policy questions that are relevant to the topic of fish consumption rates.

This document is narrower in scope than Version 1.0 of the Technical Support Document (distributed in October 2011). At that time, Ecology planned to adopt a default fish consumption rate in the Sediment Management Standards (SMS) rule. One purpose of the Technical Support Document (Version 1.0) was to identify a recommended range of fish consumption rates for consideration in the SMS rule revision process. Since that time, Ecology has decided not to propose a default fish consumption rate in the SMS rule. Instead Ecology is proposing to use a *reasonable maximum exposure* as the sediment cleanup standard for protecting fish consumers. Ecology is also beginning the process to revise the Water Quality Standards for Surface Waters and adopt human health criteria.

Instead of identifying a fish consumption rate appropriate for use in a particular regulatory context, this document compiles relevant data and information. Ecology acknowledges the complexity of this topic and offers this Technical Support Document to provide a thorough, rigorous, and comprehensive review of the available technical information about fish and fish consumers in Washington.

Executive Summary

Problem statement

Washington's aquatic resources provide tremendous benefit to the people of the state. Large quantities of finfish and shellfish are caught each year, both recreationally and commercially, and many residents eat seafood harvested from our waters. In addition, tribal populations enjoy treaty fishing rights, and harvesting and eating seafood plays a significant role in their cultures. Finfish and shellfish are important parts of a healthy diet.

Polychlorinated biphenyls (PCBs), dioxins, mercury, and other persistent chemicals can accumulate in fish tissue and harm the health of people who consume fish. Those who may be particularly vulnerable include adults who eat large amounts of finfish or shellfish, as well as children and other sensitive populations. Current fish consumption rates used by Ecology to make regulatory decisions are not consistent with data about fish consumption by Washington populations for which fish consumption survey information is available.[3]

Ecology currently identifies two separate default fish consumption rates that have been used to establish regulatory requirements:

- Washington's Model Toxics Control Act (MTCA) Cleanup Regulation includes a default fish consumption rate of 54 grams (1.9 ounces) per day. This value was established in 1991. It is based on information from a survey of Washington recreational anglers in Commencement Bay (Pierce et al., 1981).
- Washington is covered under a federal regulation – the National Toxics Rule. Washington's Water Quality Standards for Surface Waters currently rely on the 1992 National Toxics Rule (57 Fed. Reg. 60848-60923 codified at 40 CFR 131.36), which includes Water Quality Standards for human health protection based on a fish consumption rate of 6.5 grams (0.22 ounce) per day.

There have been many scientific and regulatory developments related to fish consumption rates over the past 20 years. The review of Washington fish consumption in this Technical Support Document is offered to provide data and information pertinent to ongoing public dialogue concerning regulatory issues. This report reviews recent scientific data, noting the uncertainty and variability associated with those data.

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[3] Ecology has the ability to make site-specific decisions and use site-specific information, including fish consumption rates protective of tribal populations.

The aquatic environment challenge

Many different species of finfish and shellfish are harvested from Washington waters. Each species has a unique life history and preferred habitat. Some finfish and shellfish are exposed to contaminants, but determining how much or where that exposure occurs is difficult. In an aquatic environment, contaminants move between water and sediment and from one location to another. In addition, the various salmon species, like other anadromous fish, migrate between river and open ocean environments, spending only a portion of their life cycle near shore.

The issues surrounding salmon life history are particularly complex. Most salmon leave freshwater streams when they are juveniles, only a couple of inches long, and spend varying amounts of time in coastal waters. Salmon spend most of their life cycle in the open ocean, and return to Washington waters at the end of their life cycle. Salmon are the most frequently consumed fish in Washington, but how to account for the complexity they present when considering questions related to water and sediment quality is a challenge. This document does not resolve these questions. Instead it offers information that will be useful as readers think through various options.

Washington fish resources

A large variety of fish and shellfish are available for harvesting in Washington, including more than 50 species of edible freshwater fish and almost as many in marine waters (WDFW, 2010).

Commercial fish landings from Washington non-treaty fisheries totaled over 109 million pounds of finfish and shellfish in 2006, including over 25 million pounds of shellfish and over 11 million pounds of salmon.

Recreationally caught finfish in Washington include albacore, bottomfish, Pacific halibut, salmon, steelhead, and sturgeon, with the 2006 catch totaling over 840,000 fish. Over 113,000 pounds of shellfish were collected from Washington waters in 2006, primarily Dungeness crab and razor clams.

Washington fish consumers

Ecology estimates that between 1.4 and 3.8 million Washington adults and 290,000 children consume some amount of fish as part of their diet.[4]

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[4] The term *fish* in this document may refer to finfish or to both finfish and shellfish. The term *fish consumption* usually refers to consumption of both finfish and shellfish. The intent should be clear from the context; where appropriate the distinction is noted.

Recreational fishers may consume more fish than the general Washington population. Some population groups consume especially large amounts of finfish and shellfish as part of traditionally influenced diets. These include Native Americans and Asian and Pacific Islanders.

Fish consumption surveys

Information about fish consumption can be collected in a variety of ways. This document describes the different methodologies used to collect information about fish consumption. To identify robust and defensible surveys relevant to Washington, Ecology reviewed survey methodologies and survey results by considering measures of technical defensibility.

Ecology reviewed general population data from national surveys. Statistical methodology used by the National Cancer Institute (NCI) was applied to the national survey data to better estimate long-term consumption rates using short-term dietary records.

Ecology reviewed available information on fish consumption in Washington. Certain dietary recall surveys are identified as well-designed and well-conducted. The following studies meet measures of technical defensibility and contain data directly applicable to Washington population groups:

- *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (CRITFC, 1994).
- *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region* (Toy et al., 1996).
- *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations, Puget Sound Region* (The Suquamish Tribe, 2000).

The *Asian and Pacific Islander Seafood Consumption Study* (Sechena et al., 1999, including EPA’s 2005 re-evaluation) is a well-designed and conducted study, but it represents a very small sample of each of the Asian and Pacific Islander populations surveyed, and statewide populations may differ.

Data on recreational fishing provide another piece of information about fish consumers in Washington. However, this information is collected from creel surveys and is therefore less useful than dietary recall surveys for estimating consumption rates for a population. (The data are included with the table below for convenience only.)

Survey information for the general population, Pacific Northwest populations, and recreational fishers is summarized in Table 1.

Table 1. Summary of Fish Consumption Data, All Finfish and Shellfish (g/day)

Population	Source of Fish	Number of Adults Surveyed	Mean	Percentiles		
				50th	90th	95th
General population (consumers only)	All sources: EPA method	2,853	56	38	128	168
	All sources: NCI method	6,465	19	13	43	57
Columbia River Tribes	All sources	464	63	41	130	194
	Columbia River	–	56	36	114	171
Tulalip Tribes	All sources	73	82	45	193	268
	Puget Sound	71	60	30	139	237
Squaxin Island Tribe	All sources	117	84	45	206	280
	Puget Sound	–	56	30	139	189
Suquamish Tribe	All sources	92	214	132	489	797
	Puget Sound	91	165	58	397	767
Recreational Fishers (compilation of multiple studies)	Marine waters, WA State	–	11–53	1.0–21	13–246	
	Freshwater, WA State	–	6.0–22	–	42–67	

Sources: Adapted from Polissar et al., 2012, Table E-1. Data for recreational fishers is from Table 3, Technical Issue Paper: *Recreational Fish Consumption Rates* (Ecology, 2012). General population data are for consumers only, as opposed to per capita. See Chapters 4 and 6.

Key technical findings

Key findings of this Technical Support Document include the following:

- Significant numbers of people in Washington consume finfish and shellfish. Ecology estimates that between 1.4 and 3.8 million adults in Washington eat finfish or shellfish at least occasionally.
- No survey data currently exist about fish consumption rates specific to the general population in Washington. Statistical evaluation of national fish consumption data may provide useful information about fish consumption among the general population. For estimates based on national data, the methodology developed by the National Cancer Institute provides improved accuracy for episodically consumed foods.
- Regional-specific fish dietary surveys provide technically defensible information about high fish-consuming populations in the Pacific Northwest.

In response to public review comments received by Ecology on Version 1.0 of this Technical Support Document, supplementary information (provided as separate Technical Issue Papers) has been prepared to provide additional detail on topics of specific relevance to the evaluation of fish consumption rates. These topics include:

- Estimating annual fish consumption rates using data from short-term surveys.
- Recreational fish consumption rates.
- Health benefits and risks of consuming finfish and shellfish.
- Chemical contaminants in dietary protein sources.
- Salmon life history and body burdens.

These Technical Issue Papers are provided in Ecology, 2012 (*Supplemental Information to Support the Fish Consumption Rates Technical Support Document*).

Supporting information

In addition to the key findings, this document includes information that allows a more comprehensive understanding of fish consumption patterns in Washington. This information, taken collectively, provides multiple lines of evidence about fish consumption in Washington. For example, water body-specific evaluations, predominantly creel surveys, do provide additional information about fish consumption.

In addition, this document looks at identifying species that are locally harvested[5] and consumed.

- About 68 percent of total fish consumed by the Squaxin Island tribal population is locally harvested. The percentage of total fish consumed that is locally harvested is somewhat higher for the other tribal populations surveyed: approximately 88 percent for the Columbia River Tribes, 72 to 88 percent for the Tulalip Tribes, and 81 to 96 percent for the Suquamish tribe.
- Where possible, data on types of fish consumed and where the fish were obtained are provided, allowing a regional look at fish consumption patterns.
- About 62 percent of shellfish consumed by Squaxin Island tribal populations are locally harvested. The percentage of shellfish that is locally harvested is somewhat higher for the Suquamish Tribe (81 percent), and highest for the Tulalip Tribes (98 percent or higher).

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[5] The term *locally harvested* is used to identify the source of fish. It is used to distinguish fish harvested locally from fish purchased and coming from unknown and potentially non-local (out of state) sources.

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Chapter 1: Introduction and Purpose

1.1 Introduction

This report addresses fish consumption among Washington fish consumers, including the general population, tribal populations, and other groups, such as Asian and Pacific Islanders and recreational anglers, who are known to eat large amounts of fish.[6]

The Washington State Department of Ecology (Ecology) currently recognizes two separate default fish consumption rates used to establish regulatory requirements:

- Washington's Model Toxics Control Act (MTCA) Cleanup Regulation includes a default fish consumption rate of 54 grams (1.9 ounces) per day. This value was established in 1991. It is based on information from a survey of Washington recreational anglers in Commencement Bay (Pierce et al., 1981).
- Washington is covered under a federal regulation – the National Toxics Rule. Washington's Water Quality Standards for Surface Waters currently rely on the 1992 National Toxics Rule (57 Fed. Reg. 60848-60923 codified at 40 CFR 131.36), which includes Water Quality Standards for human health protection based on a fish consumption rate of 6.5 grams (0.22 ounce) per day.[7] This value is based on technical evaluations completed by the U.S. Environmental Protection Agency (EPA) in the mid-1980s. It represents the low estimate of national average per capita consumption of fish and shellfish from estuarine and fresh waters (45 Fed. Reg. 79348; U.S. EPA, 1980).[8]

The methods used to develop these two rates included a number of differing assumptions about exposures. The MTCA fish consumption rate of 54 grams per day (g/day) is a recreational rate based on a creel survey from Commencement Bay. The Water Quality Standards default fish consumption rate of 6.5 g/day is the average per capita consumption rate of all (contaminated and non-contaminated) freshwater and estuarine fish for the U.S. population (57 Fed. Reg. 60848-60923 codified at 40 CFR 131.36). This average includes people who never eat fish.

To estimate the average per capita intake of a pollutant due to consumption of contaminated fish and shellfish, the results of an early 1980s seafood dietary survey (U.S. EPA, 1980) were analyzed to calculate the average consumption of freshwater and estuarine fish and shellfish (45

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[6] For the purposes of this report, *fish consumers* include all people in Washington who eat finfish or shellfish. While there is variability among how much fish is consumed by—both within and among—various population groups, some people never include fish in their diets. These people are considered non-consumers.

[7] The 6.5 grams per day contaminated fish consumption value is equivalent to the average per-capita consumption rate of all (contaminated and non-contaminated) freshwater and estuarine fish for the U.S. population (57 Fed. Reg. 60863).

[8] Moderate and high average fish consumption estimates for the U.S. national population were based on the consumption of fish and shellfish from fresh, estuarine, and marine waters (U.S. EPA, 1989a).

Fed. Reg. 79348). In the absence of estimates of fish dietary information from local fish-consuming populations, an EPA companion guidance document to the National Toxics Rule proposed the following average consumption rates:

- 6.5 g/day to represent a low estimate of average consumption of fish and shellfish from estuarine and fresh waters by the U.S. population.
- 20 g/day to represent a moderate estimate of the average consumption of fish and shellfish from marine, estuarine, and fresh waters by the U.S. population.
- 165 g/day to represent a high estimate of the average consumption of fish and shellfish from marine, estuarine, and fresh waters by the 99.9th percentile of the U.S. population.

In contrast to the low average estimate, the moderate and high average fish consumption estimates for the U.S. population is based on the consumption of fish and shellfish not only from fresh and estuarine waters but also from marine waters (U.S. EPA, 1989a, page 58 and Table 7, page 71).

There have been many scientific and regulatory developments related to fish consumption rates over the past 20 years. These include:

- Acquisition of recent scientific data on finfish and shellfish consumption rates for different population groups.
- Updated approaches used by other state and federal agencies.
- Analysis of uncertainty and variability in finfish and shellfish consumption rates for different population groups and individuals within those groups.
- Analysis of current and potential future exposures resulting from finfish and shellfish consumption.
- Revision of state laws and policies, including MTCA and the Water Pollution Control Act.
- Assertion of tribal fishing rights by tribes.

1.2 Intended audience

Ecology will use this document to engage multiple audiences in discussions on issues related to fish consumption rates.[9] This report is meant to facilitate discussions with interested parties and persons throughout Washington.

To facilitate these discussions, it is important to understand the different ways we express fish consumption rates in this Technical Support Document. In general, a fish consumption rate is presented as grams of fish consumed per day (g/day). For many readers, it is easier to understand a fish consumption rate expressed in ounces per day, or number of 8-ounce meals per week. (An

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[9] The term *fish* includes all types of finfish and shellfish. When discussing the species that are consumed, fish are categorized by species groupings.

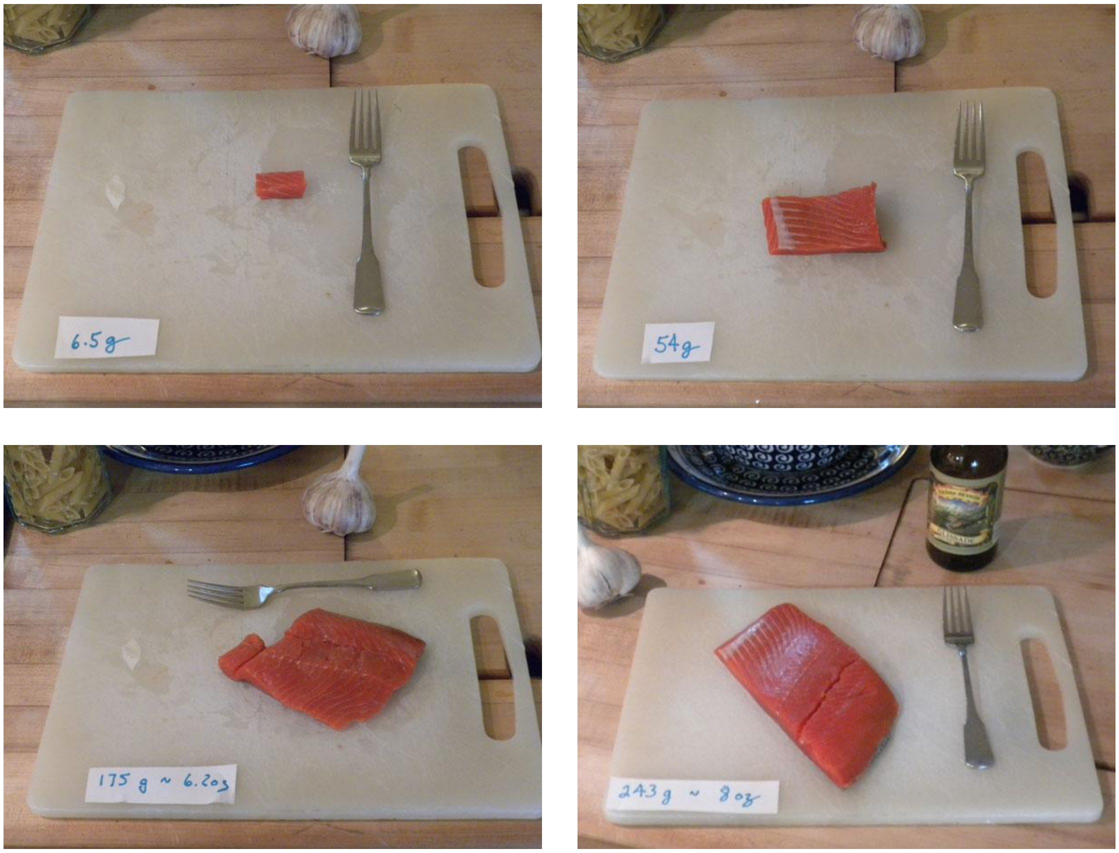
8-ounce meal corresponds to approximately 227 grams.) Another way to express fish consumption is in terms of the frequency of an 8-ounce meal (e.g., once per month, three times per week), or as total pounds of fish per year. Table 2 summarizes the different metrics that are used to describe fish consumption rates.

Table 2. Different Metrics Used to Describe Fish Consumption Rates

Consumption Rate Metric	Examples of Consumption Rates For Each Metric						
Grams per day	6.5	17.5	50	100	260	500	620
Ounces per day	0.23	0.62	1.8	3.5	10	18	22
Number of 8-ounce meals per week	0.2	0.5	1.5	3	8	15	17
Frequency of 8-ounce meals	< one 8-ounce meal per month	Two 8-ounce meals per month	One to two 8-ounce meals per week	Three 8-ounce meals per week	Every day or ½ pound per day	Twice per day or 1 pound per day	1 pound per day plus other forms and uses
Pounds per year	5	15	40	80	200	400	500

Source: Adapted from Swinomish Tribe, 2006, Table 30.

In the absence of population-specific fish dietary information, the U.S. EPA suggest using a default value of 8 ounces (227 grams) as an average meal size for the general adult population (72-kilogram person) for exposure assessments and fish advisories (U.S. EPA, 2000d).



Fish portion sizes (6.5, 54, 175, and 243 grams)

1.3 Purpose of this document

The purpose of this Technical Support Document (Version 2.0) is to compile and evaluate existing data on fish consumption in Washington State. It is a technical document, and is not designed to resolve policy issues associated with using that information to make regulatory decisions. Those issues will be dealt with in separate rulemaking documents and processes.

This Technical Support Document provides useful background information for discussions related to finfish and shellfish consumption rates. The primary question addressed in this document is:

- What is currently known about fish consumption habits and rates for people in Washington?

Specifically, what types of data are available, how much fish do people in various population groups eat, what kinds of fish do they eat, and where do they obtain the fish?

Ecology recognizes that many other considerations factor into calculating protective standards, including acceptable risk levels and exposure parameters (such as exposure duration). These considerations may be relevant to various regulatory discussions. This particular document, however, focuses primarily on technical information related to fish consumption rates.

1.4 Document history

Ecology distributed the *Fish Consumption Rates Technical Support Document, Version 1.0*, for public review in September 2011. The document was prepared to support discussion on whether and how to revise the fish consumption rates in the Sediment Management Standards (SMS) rule. Ecology held several public workshops to discuss the draft report and regulatory implications.

Ecology received several hundred written comments on the draft report. Ecology has reviewed those comments and prepared written responses that are compiled in a separate document. As part of that review, Ecology also performed additional technical analyses to address several issues raised during the public comment period.

Ecology has considered the comments and analyses when revising this Technical Support Document. Significant revisions include the following:

- *General population studies.* Several people recommended that Ecology provide information on fish consumption rates for the general population. Ecology has worked with the University of Washington to review national dietary surveys that provide information on fish consumption rates for the general population, and has included the results of that review in the revised document.
- *Recreational fisher studies.* Several people recommended that Ecology provide information on fish consumption rates for recreational fishers. Ecology reviewed available studies on recreational fishers. Based on that review, Ecology has conducted an

independent assessment, provided in a separate Technical Issue Paper (Ecology, 2012), that details recreational fish consumption studies conducted in Washington. Ecology has incorporated the results of that review into this revised Technical Support Document.

- *Asian Pacific Islander (API) studies.* Several people recommended that Ecology consider additional information on the fish dietary habits of API populations. Ecology has incorporated additional information on API populations into this revised Technical Support Document.
- *Estimating long-term consumption rates.* Several people expressed concerns about using the results from short-term episodic dietary studies to estimate long-term upper percentile fish consumption rates. Ecology has reviewed and evaluated methods for adjusting short-term episodic dietary information to provide fish consumption estimates and percentiles. These statistical corrections were used to estimate annual fish consumption rates for the general population from 2-day national survey data.
- *Salmon.* Ecology received a wide range of comments on salmon, their life cycles and survival strategies, and salmon contaminant body burdens. This document provides fish consumption estimates with and without salmon from several fish dietary surveys of Pacific Northwest populations. Where available, fish consumption estimates are tabulated for anadromous and non-anadromous species. Additional information on salmon contaminant body burdens is provided in Appendix C and in the Technical Issue Paper, *Salmon Life History and Contaminant Body Burdens* (Ecology, 2012).
- *Analysis of regional fish dietary information.* In Version 1.0 of this Technical Support Document, Ecology provided the results of a statistical evaluation from fish dietary surveys of Pacific Northwest populations. Ecology's evaluation provided fish consumption estimates between the 80th and 95th percentiles of the fish consumption distribution. Several people provided comments regarding policy choices embedded in this evaluation. Ecology has reviewed these comments, and in order to facilitate broad consideration in the process of revising the Water Quality Standards for Surface Waters, this version of the Technical Support Document does not provide a recommended range for fish consumption rates. Discussion is provided in Chapter 4.
- *Policy statements and recommendations.* This Technical Support Document is focused on finfish and shellfish resources in the Pacific Northwest, and Washington State fish-consuming populations. It includes information from fish dietary surveys of Pacific Northwest populations and national general population data. Ecology acknowledges that there are many policy decisions associated with estimating fish consumption rates for Washington State fish-consuming populations. Some of these policy issues are noted in Chapter 6. This document, however, does not provide a thorough discussion of policy choices. The issues are identified only to assist readers in a broader understanding of the context in which fish consumption rates are considered.

1.5 Organization of this document

The remainder of this document is organized as follows.

Chapter 2: Washington Fish Resources and Fish-Consuming Populations

Available information indicates that some Washington residents consume locally harvested finfish and/or shellfish. In addition, several population subgroups (including Native Americans and Asian and Pacific Islanders) consume large amounts of finfish and shellfish. This chapter summarizes available information on state water resources that support fishing practices. Regional differences are acknowledged and the size and demographic characteristics of Washington finfish and shellfish consumers and consuming populations are identified.

Chapter 3: Methodology for Assessing Fish Consumption Rate Information

Several approaches are available for developing estimates of finfish and shellfish consumption. Although surveys are generally considered to be the best approach for developing these estimates, a number of design features determine whether a particular survey provides a technically defensible basis for agency decision making. This chapter reviews those design features and outlines the factors considered when evaluating studies.

Chapter 4: Fish Consumption Survey Data that Apply to Washington Fish Consumers

This chapter reviews and analyzes available fish consumption survey data for the general population, Pacific Northwest Native American tribes, Asian and Pacific Islanders, and recreational fishers. It includes a discussion of variability and uncertainty in the survey data, and summarizes key findings.

Chapter 5: Sources of Uncertainty and Variability

When making regulatory decisions, it is important to consider the uncertainties associated with available data and the variability across individuals, fish species, and geographic areas. This chapter provides a high-level summary of important sources of uncertainty and variability in fish consumption surveys used to estimate finfish and shellfish consumption rates.

Chapter 6: Using Scientific Data to Support Regulatory Decisions

This chapter highlights some of the policy choices that will be needed when using fish consumption rates to support regulatory decisions. The discussion includes brief descriptions of particular regulatory issues and a range of examples to illustrate how agencies have resolved each issue.

Appendices

Included here is other fish consumption information used for regulatory decision making including fish species found in Washington, information on additional tribal studies, correspondence from the Columbia River Inter-Tribal Fish Commission and University of Washington, further discussion on the challenges of risk assessment and salmon consumption, a glossary of terms, and a complete list of reference citations presented alphabetically by author.

Chapter 2: Washington Fish Resources and Fish-Consuming Populations

2.1 Introduction

Washington is home to a wide range of water resources that support commercial, recreational, and subsistence fishing and harvesting. Many Washington residents consume some local finfish or shellfish. Several population groups consume larger amounts of finfish and shellfish than the general population. These include members of Native American tribal nations, Asian and Pacific Islanders, and people who fish recreationally (recreational fishers).

Ecology's review of available data on fish harvests identified the commercial, tribal, and recreational harvesting of multiple species, including groundfish, Pacific halibut, coastal pelagic species, highly migratory species, salmon, other anadromous species and eggs, and shellfish. Similarly, recreational sport fishing is structured around a multispecies fishery, and hundreds of thousands of sport anglers harvest fish throughout Washington.

Salmon are of particular importance in Washington, and questions about salmon are discussed at several points in this report. Salmon are harvested from both fresh and marine waters. The Puget Sound basin and the Columbia River basin dominate the areas of harvest. Steelhead and salmon (from both fresh and marine waters) accounted for about half of the recreational sport harvest (close to 400,000 fish) in 2006.

This chapter is organized into the following sections:

- *Fish resources*. A summary of finfish and shellfish resources in Washington.
- *Estimated number of Washington fish consumers.* This section provides rough estimates on the number of adults and children in Washington who regularly eat finfish and/or shellfish.
- *High fish-consuming populations.* This section defines *high fish consumers* and identifies and describes subpopulations in Washington generally known to be high fish consumers.

Washington waters support large finfish and shellfish populations and commercial, tribal, and recreational harvests.

2.2 Washington fish resources

Washington has more than 500 miles of Pacific coast shoreline and over 2,000 combined miles of Puget Sound, San Juan Islands, Strait of Juan de Fuca, and Hood Canal shoreline. This shoreline provides habitat for marine finfish and shellfish. In addition, the state has 4,000 rivers and streams, stretching over 50,000 miles. Many streams and rivers have seasonal salmon and steelhead runs. State waters also include more than 7,000 lakes, with over 2,500 lakes at alpine elevations, and more than 200 reservoirs that provide additional fishing opportunities. Many freshwater areas are open for fishing year-round (WDFW, 2010).

A large variety of finfish and shellfish are available for harvesting in Washington (WDFW, 2010, p. 17–30). The Washington Department of Fish and Wildlife (WDFW) has identified more than 50 species of edible freshwater fish and almost as many in marine waters (WDFW, 2010, p. 17–30). (See Appendix C for information on finfish and shellfish species harvested in Washington.)

A study to summarize the economic benefits of Washington's non-treaty commercial and recreational fisheries provides information on the valuation and numbers of commercial and recreational finfish and shellfish harvested throughout Washington. In 2006, commercial fish landings from non-treaty fisheries totaled more than 109 million pounds. The Washington coastal area is the largest contributor to commercial fish harvesting, accounting for 85 percent of total pounds landed (WDFW, 2008a).

The fish consumption rate tabulations in this technical support document are derived from national fish dietary data and from fish dietary surveys from the Pacific Northwest. The tribal fish dietary surveys from the Pacific Northwest document fish locally harvested and consumed. Independent and separate documentation from three different Washington State agencies (WDFW, Washington State Department of Health [DOH], and Ecology) document the harvest and consumption of local aquatic resources, including finfish and shellfish. However, data gaps remain regarding the exact locations of where fish and shellfish are harvested in Washington and how the fish are then made commercially available for consumption.

2.2.1 Washington's commercial fisheries

Washington's commercial fisheries include harvest of groundfish, Pacific halibut, coastal pelagic species, highly migratory species, salmon (including eggs), other anadromous species, and shellfish. In 2006, nontribal commercial fish landings from Washington fisheries totaled approximately 109.4 million pounds.

In 2006, groundfish (bottom-dwelling fish or bottomfish) composed the state's largest commercial fishery. Groundfish accounted for 54 percent of the commercial catch from Washington waters, with approximately 59.2 million pounds landed. Shellfish landings represented the state's second-largest commercial fishery, accounting for almost 25 percent of the commercial catch, with approximately 25.8 million pounds landed in 2006.

Salmon is a major contributor to Washington’s commercial fishing industry. Salmon landings from Washington waters totaled about 11 million pounds, accounting for about 10 percent of the commercial catch in 2006.

Table 3 illustrates the extent of Washington’s commercial fisheries, showing pounds of fish harvested from Washington non-treaty fisheries in 2006.

Table 3. Commercial Fish Landings from Washington Non-treaty Fisheries in 2006

Species	Pounds Landed
Groundfish (excluding halibut)	59,217,924
Total shellfish	25,789,641
Salmon	11,020,228
Coastal pelagic species	8,233,078
Highly migratory species	4,802,666
Other anadromous fish and eggs	158,621
Pacific halibut	135,868
Total commercial pounds landed of finfish/shellfish	109,358,026

Source: Adapted from WDFW, 2008a, Table 1, p. 6.

2.2.2 Washington’s recreational fisheries

Traditionally, Washington’s most intense freshwater fishing activity begins during the last weekend in April. Based on estimates from WDFW, over 300,000 anglers fish during opening weekend of the lowland lakes season. To meet this demand, WDFW stocks about 19 million trout and kokanee fry annually. Another 3 million catchable trout are planted in lakes and streams. In addition, many lakes receive additional sterile rainbow trout. Most rivers and streams throughout Washington are managed to produce wild trout, coastal and west slope cutthroat, salmon, and steelhead (WDFW, 2010).

An estimated total of 824,000 people fished in Washington in 2006, including both finfishing and shellfishing. Of these, an estimated 725,000 anglers (88 percent of the total) were state residents who fished a combined total of about 8.5 million days that year. This equals 93 percent of all fishing days available for licensed recreational sport fishing (WDFW, 2008a).

Marine recreational fishing and shellfishing occurs along more than 500 miles of the Pacific Coast shoreline and more than 2,000 combined miles of shoreline throughout Puget Sound, the San Juan Islands, the Strait of Juan de Fuca, and Hood Canal (WDFW, 2008a). As previously noted, freshwater recreational fish inhabit more than 4,000 rivers and streams extending over 50,000 miles, 7,000 lakes, and 200 reservoirs (WDFW, 2010, 2012). The following are selected highlights of recreational sport fishing and shellfishing that identify the species available for recreational anglers across Washington:

- Recreational fishing for shad on the Columbia River with several million shad passing through Bonneville Dam annually.
- WDFW lists state record catches for more than 50 freshwater species of fish (e.g., rainbow trout, Beardslee rainbow trout, brown trout, and numerous other trout species).
- Recreational sturgeon fishing on the Columbia River.
- Marine recreational seasonal fishing for lingcod, halibut, and rockfish as well as other marine bottomfish.
- Recreational shellfishing for oysters, clams, shrimp, and crab throughout Puget Sound, Hood Canal, the San Juan Islands, and the Strait of Juan de Fuca.

Recreational sport fishers harvest finfish in fresh and marine waters and shellfish along marine shorelines. Approximately 22 million trout and kokanee are stocked annually in lakes and inland streams and are available to recreational anglers. Tables 4 and 5 list information on the 2006 sport finfish and shellfish harvests, respectively. These numbers demonstrate the extent of recreational fishing in Washington.

Approximately two-thirds of the 2006 catch for bottomfish was harvested in coastal waters, with the remaining one-third harvested from the marine waters of Puget Sound.[10] Approximately 74 percent of the steelhead and 95 percent of the sturgeon harvested from Washington waters in 2006 were from the Columbia River and its tributaries.

Table 4. Number of Recreational Finfish Caught in Washington Waters in 2006 by Species and Region

Species/Group	Number of Finfish Harvested from each Catch Region				
	Puget Sound	Coast	Columbia River*	Unknown	Total
Bottomfish	112,457	295,151	---	---	407,608
Salmon – freshwater	98,576	7,186	65,817	1,227	172,806
Steelhead	12,709	15,415	80,294	477	108,895
Salmon – marine	65,423	43,027	---	---	108,450
Albacore	---	18,941	---	---	18,941
Sturgeon	203	456	15,695	182	16,536
Pacific halibut	2,727	6,977	692	---	10,400
Total	292,095	387,153	162,498	1,886	843,636

Source: Adapted from WDFW, 2008a, Table 6, p. 17.

* Columbia River region includes the Columbia River and all tributaries and the Snake River.

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[10] The term *coastal waters* refers to waters having a coastline that forms the boundary between land and freshwaters and marine and/or estuarine waters. This term encompasses all freshwaters of statewide significance (lakes, rivers, streams, etc.) and those marine and/or estuarine waters extending from the landward edge of a barrier beach or shoreline of coastal bay to the outer extent of the continental shelf.

Table 5. Pounds of Shellfish Taken Recreationally From Washington Waters in 2006, by Species and Region

Species/Group	Pounds of Shellfish Harvested from each Catch Region					
	North Puget Sound	South Puget Sound	Strait	Coast	Columbia River	Totals
Dungeness crab	3,330,004	271,167	261,540	---	---	3,862,711
Razor clams	---	---	---	3,601,000		3,601,000
Oysters	19,129	632,966	---	---	---	652,095
Other clams	93,038	252,628	---	---	---	345,666
Shrimp	23,520	87,996	1,950	---	---	113,466

Source: Adapted from WDFW, 2008a, Table 7, p. 17.

All values are in pounds except oysters, which are in number of oysters harvested.

Salmon were harvested in both fresh and marine waters, with approximately 60 percent of the salmon harvest occurring in marine waters. Puget Sound salmon accounted for approximately 60 percent of all salmon harvested in marine waters. In fresh water, approximately 57 percent of salmon are harvested in Puget Sound streams and 38 percent are from the Columbia River and its tributaries.

Dungeness crab taken from north Puget Sound waters accounted for more than 85 percent of the 2006 statewide harvest. Razor clams are only harvested from coastal beaches. Tens of thousands of recreational sport clammers harvest razor clams on weekends during clamming season (WDFW, 2008a).

2.3 Washington fish-consuming population

Washington is home to a culturally and ethnically diverse population that is projected to become more diversified over the next 20 years. The Washington Office of Financial Management (OFM) provides the following demographic information (U.S. Census Bureau, 2000, 2010)[11]:

• Total Washington Population as of April 1, 2010	6.72 million
Adults (74 percent of the population is estimated at over 18)	5.14 million
Children (between 0 and 18 years of age)	1.71 million

OFM projects that the Washington population will increase by 1.8 million people in the next 20 years: [12]

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[11] Population estimates are based on census data, and may vary depending on the census accounting procedures used to generate estimates for specific subpopulations. Therefore, subpopulation estimates and totals may not align perfectly.

[12] Population projections are provided for illustrative purposes; they are not intended as precise estimates. Population projections presented in this document do not reflect 2012 redistricting updates.

- Projected Total Washington Population, 2030	8.54 million
Projected children (between 0 and 18 years of age) 2030	2.06 million

2.3.1 Estimated number of fish consumers in Washington

The general population is made up of people with a variety of dietary preferences. Some consume fish frequently, some infrequently, and some potentially never. (However, even people who report they don't eat fish may consume some fish in processed foods like salad dressing, Worcestershire sauce, and cheese spread.) Per capita rates that take into account the entire population will differ from rates derived from consideration of so-called *consumer only* data. For protection of people who eat fish, the population of interest is generally considered to be fish consumers (CalEPA 2001, page 13; Oregon DEQ 2008; U.S.EPA 2002b).

People consume finfish and shellfish obtained from a variety of sources. Information about fish consumed by the general Washington population is available only through estimates.[13] While there are uncertainties associated with these estimates, they are useful in providing context to the discussion about fish consumption rates.

First, the total number of fish consumers was estimated. A *fish consumer* is someone who eats finfish or shellfish at least occasionally. Then a definition of *high fish consumer* was used to suggest the number of people in the general population at the high end of the exposure distribution. These estimates provide only a rough number of fish consumers and no information about the source of the fish. Ecology also reviewed available information on certain ethnic groups that consume fish from local waters.

To estimate the number of fish consumers in Washington, and how much fish they consume, Ecology considered multiple estimation methods. This is consistent with the approach taken by the Oregon Department of Environmental Quality (Oregon DEQ) Human Health Focus Group.

Using 2010 demographic information provided by the Washington OFM, Ecology estimates that between 1.4 and 3.8 million Washington adults (and approximately 290,000 Washington children 0 to 18 years old) are fish consumers. These upper and lower estimates were developed using two different methods, as described below:

- *Low Estimate: Based on national survey data.* The first approach resulted in the lower of the two estimates. It was developed using Washington population data and information on the percentage of fish consumers reported in *Estimated Per Capita Fish Consumption*

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[13] These estimates use the EPA 2002 data and are consistent with the methodology used by the Oregon Human Health Focus Group. They do not use the National Health and Nutrition Examination Survey (NHANES) results because these estimates were developed before that work was complete.

in the United States (U.S. EPA, 2002a).[14] For this estimate of fish consumers in Washington, Ecology assumed that Washington dietary habits are similar to those for the United States as a whole. The Oregon DEQ Human Health Focus Group used this approach to prepare estimates of fish consumers in Oregon.[15] (See Chapter 4 for additional information on estimated United States per capita fish consumption.)

  - *Adults.* EPA found that 28 percent of adults interviewed in the national survey were fish consumers (U.S. EPA, 2002a, Section 5.1.1.1, Table 4). Assuming that a similar percentage of Washington's 5.1 million adults also consume fish, Ecology estimates that approximately 1.4 million adults in Washington currently eat some amount of fish.
  - *Children.* EPA found that 16 to 19 percent of children (ages 0 to 18) included in the national survey were fish consumers (Moya, 2011, personal communication).[16] Assuming that 17 percent of Washington's 1.7 million children also consume fish, Ecology estimates that there are approximately 290,000 children in Washington who currently eat some amount of fish.

- *High Estimate: Based on Washington State Department of Health survey.* The second approach resulted in the higher estimate. It was developed using Washington population data and information compiled by the DOH. DOH used the Behavioral Risk Factor Surveillance System (BRFSS) to compile information on fish consumption habits of randomly selected Washington residents.[17] This work was done over a 4-year period; it was designed to improve DOH's understanding of the percent of the Washington population that consumes fish.

Washington State Behavioral Risk Factor Surveillance System

The BRFSS telephone survey is a valuable health management tool used by DOH to collect health-based information and monitor the public's behavioral risk factors that may contribute to a person's health. The BRFSS primarily collects data on chronic diseases, injuries, infectious illnesses, and the behavioral factors underlying these conditions.

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[14] This percent value may underestimate the fraction of fish consumers in Washington State because other parts of the United States do not have the fisheries resources available in Washington State.

[15] Ecology acknowledges the limitations of the national fish dietary data; this approach employed a 2-day dietary recall survey methodology where respondents who did not report eating fish on one of the two survey days were counted as non-consumers and averaged with consumers as a zero. As noted by the EPA 2011 *Exposure Factors Handbook*, p. 10-16, "… short-term consumption data may not accurately reflect long-term eating patterns and may under-represent infrequent consumers of a given fish species. This is particularly true for the tails (extremes) of the distribution of food intake. Because these are 2-day averages, consumption estimates at the upper end of the intake distribution may be underestimated are used to assess acute (i.e., short-term) exposures."

[16] Approximately 18 percent of the U.S. general population ages 16 – 21 are fish consumers; approximately 31 percent of the U.S. general population ages 20 – 50 are fish consumers. Information is based on EPA's reexamination of the National Health and Nutrition Examination Survey (NHANES) and the 2002 per capita fish consumption report.

[17] The BRFSS is sponsored by the U.S. Centers for Disease Control and Prevention (CDC) and is a probability-based telephone survey of non-institutionalized adults, ages 18 years and over.

- DOH found that in 2002 and 2004, 78 percent and 74 percent, respectively, of adults in Washington consumed store-bought fish. In 2005, 57 percent of the adults surveyed reported eating fresh fish purchased at a local grocery store or fish market (frozen fish excluded). Among Washington fish consumers, 44 percent consumed salmon, 20 percent consumed halibut, 13 percent consumed cod, and 6 percent consumed tuna.
- Although these data were intended for use by DOH in developing fish consumption advisory programs, Ecology, after consultation with DOH, determined that the information is appropriate for estimating the total number of fish consumers in Washington as needed for this report.
- Working with DOH, Ecology estimated that between 2.9 and 3.8 million Washington adults currently consume some amount of finfish and/or shellfish. Table 6 provides estimates of Washington fish consumers calculated by Ecology using the DOH data.

Table 6. Estimated Washington Fish Consumers Based on Washington DOH Survey Data

Years for Projected Population Estimates	Estimated number of Washington adults who consume:		
	Store-bought fish	Fish from local stores or markets	Salmon
2010	3.80 million [a]	2.93 million [b]	1.67 million
2030	4.88 million	3.76 million	2.90 million

a. This estimate assumes 74 percent of the total adult population consuming store-bought fish, per the DOH 2004 data.

b. This estimate assumes 57 percent of the total adult population consuming fresh fish from local stores or markets, per the DOH 2005 data.

Population projections are included to illustrate that estimates of total fish consumers in Washington are expected to increase as the population grows.

2.3.2 Estimated number of high fish-consuming adults

Pacific Northwest fish dietary information shows that certain populations—Native American tribes, Asian Pacific Islanders, and recreational fishers—consume fish at much higher rates than the average U.S. consumer and at higher rates than those used to establish surface water cleanup standards. Because these populations consume fish at higher rates than the national rates used in Ecology's regulations, their exposure to contaminants in fish may be underestimated and these populations may therefore be at a higher risk. For this reason, Ecology has estimated the number of high fish consumers in the general population. The estimate is intended only to provide

Fish consumption-related BRFSS telephone survey questions

BRFSS telephone survey questions related to fish dietary habits provide DOH with information on:

- Types and frequency of finfish consumption.
- Perceptions about the benefits of eating fish (are fish healthy to eat).
- How, where, or in what form the public receives information about fish health advisories that limit fish consumption based on mercury contamination.
- Whether people are following the fish advisories.
- Regional differences regarding frequency and types of fish consumed.

context; it does not provide information on where these consumers obtain their fish and shellfish. Specifically, it does not address the question of whether this is locally harvested.[18]

Information elsewhere in this report notes that many people in Washington consume fish from local waters—for example, recreational anglers.

For purposes of this estimate, *high fish consumers* are persons who consume fish at or above the 90th percentile of the national per capita fish consumption rate. The fish consumption rate that corresponds to the 90th percentile national per capita consumption depends on the dataset and statistical method used. The choice for defining high fish consumers this way was made for illustrative purposes. It is consistent with EPA regulatory policy and procedures and is the definition used by the Oregon Human Health Focus Group.

Selected results from BRFSS telephone survey

- In 2005, about 44 percent of all adults surveyed consumed salmon in the past 30 days.
- In 2005, about 20 percent of all adults surveyed consumed halibut in the past 30 days.
- In 2005, about 13 percent of all adults surveyed consumed cod in the past 30 days. All other species were consumed by <10 percent of survey participants.
- In 2004, about 74 percent of all adults surveyed followed fish advisories when they thought the fish advice applied to them. However, only about 44 percent of all adults surveyed thought the fish advisory applied to them.
- In 2004, about 98 percent of the pregnant women surveyed followed fish advisories when they thought the fish advice applied to them. However, only about 48 percent of the pregnant women surveyed thought the fish advisory applied to them.
- In 2004, about 35 percent of all adults surveyed reported eating sport fish in the past year harvested from Washington State waters. Among different races, about 47 percent of adult American Indians, 38 percent of Pacific Islanders, 23 percent of Asians, and 19 percent of Blacks reported eating sport fish in the past year.
- In 2004, about 35 percent of adults living in Western Washington counties (Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, King, Kitsap, Lewis, Mason, Pacific, Pierce, San Juan, Skagit, Skamania, Snohomish, Thurston, Wahkiakum, and Whatcom) reported eating any sport fish in the past year. About 40 percent of adults living in counties along the Columbia River reported eating any sport fish in the past year, while 34 percent of adults living in Puget Sound counties and 57 percent of adults living in outer coastal counties reported eating sport fish in the past year.

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[18] The term *locally harvested* is used to identify the source of fish. It is used to distinguish fish harvested locally from fish purchased and coming from unknown and potentially non-local (out of state) sources.

Based on EPA's *Estimated Per Capita Fish Consumption in the United States*, the 90th percentile of the estimated national fish consumption rate for adult fish consumers only corresponds to 250 g/day (U.S. EPA, 2002a).[19] (250 grams is approximately 0.55 pound or 8.8 ounces.) This value is used to define high fish-consuming adults in this Technical Support Document. (See Chapter 6 for a discussion of per capita vs. consumer-only fish consumption rates.)

Ecology has also evaluated national fish dietary information using data from the U.S. Department of Agriculture's National Health and Nutrition Examination Survey (NHANES), 2003–2006. This analysis is discussed in Chapter 4. Based on this evaluation, the 90th percentile of the estimated national per capita fish consumption for adult consumers is in the range of 42.5 g/day to 128 g/day, depending on the statistical method used.

Ecology estimates that between approximately 140,000 and 380,000 Washington adults are high fish consumers (Table 7). Based on OFM population projections, this number could increase by 27 percent over the next 20 years.

2.3.3 Assumptions

This estimate is based on a number of assumptions that Ecology believes to be reasonable:

- Between approximately 1.4 million and 3.8 million Washington adults consume some amount of fish on a regular basis. As described in the previous sections, this range is based on current population data and estimates indicating that between 28 and 74 percent of Washington adults regularly consume fish.[20]
- *High fish consumers* are defined as people who consume more than the 90th percentile estimate of finfish and/or shellfish per day.[21] The 90th percentile of the fish consumption distribution may be based on national data as evaluated by EPA in 2002 or by Ecology in 2012 using the 2003–2006 NHANES data. Estimates of adult fish consumption rates vary depending on the statistical methodology used to evaluate the data.
- The dietary habits and patterns for Washington fish consumers are similar to those reported for the United States fish consumers.[22]

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[19] Corresponds to the 90th percentile intake of finfish and shellfish for adult consumers only, based on uncooked fish weight. See U.S. EPA, 2002a, Section 5.2.1.1, Table 4.

[20] The 2003 – 2006 NHANES dietary information provides reasonably comparable low end percent estimates of fish consumers as evaluated in EPA, 2002, and Polissar et al., 2012.

[21] Unless otherwise noted, in this document the term *fish consumption rate* refers to consumption of both finfish and shellfish.

[22] This assumption is discussed further in the conclusions to this chapter.

Table 7. Estimated Number of Fish Consumers among the General Washington Adult Population

Year	Total Population of Washington Adults	Estimated Number of Washington Adult Fish Consumers		Estimated Number of Washington Adults who are High Fish Consumers (90th percentile or above)	
		Low Estimate	High Estimate	Low Estimate	High Estimate
2010	5.14 million	1.44 million	3.81 million	144,000	381,000
2030	6.59 million	1.85 million	4.88 million	185,000	488,000

As noted, estimates of fish consumption that correspond to the 90th percentile of the distribution may vary depending on the statistical methods used to evaluate the national data. Regardless of the national dataset used and the statistical methodology used to evaluate the national data, population estimates for Washington State fish-consuming adults based on the 90th percentile of the fish consumption distribution indicate that there are a large number of adults in Washington who consume fish (for adult low and high estimates approximating 30 to 75 percent of the total Washington State population). Note that the information used for estimates of fish consumption among the general adult population is for total fish consumed from all sources.

2.3.4 Estimated number of high fish-consuming children

For purposes of this report, Ecology defines children as high fish consumers if they consume fish at or above the 90th percentile of the estimated national per capita fish consumption rate for children. As discussed above, the fish consumption rate that corresponds to the 90th percentile depends on the dataset and statistical method used to evaluate the data. Based on EPA's *Estimated Per Capita Fish Consumption in the United States*, the 90th percentile of the estimated national per capita fish consumption rate for children who eat fish corresponds to 190 g/day (U.S. EPA, 2002a).[23] (190 grams is approximately 0.42 pound or 6.7 ounces.) Ecology's evaluation of the NHANES 2003–2006 data, as described in Section 4.2.2, did not include estimation of fish consumption rates for children.

Ecology estimates that there are approximately 29,000 Washington children who are high fish consumers (Table 8). Based on OFM population projections, this number could increase by 83 percent over the next 20 years.

This estimate is based on the following assumptions that Ecology believes to be reasonable:

- Approximately 290,000 Washington children eat some amount of fish on a regular basis. As discussed in an earlier section, this estimate is based on current population estimates and national survey results that indicate that 16 to 19 percent of children reported eating some amount of finfish or shellfish.

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[23] Corresponds to the 90th percentile intake of finfish and shellfish for consumers only, age 14 and under. Based on uncooked fish weight.

- Children are defined as high fish consumers when they consume more than the 90th percentile estimate of finfish and/or shellfish per day. The 90th percentile of the fish consumption distribution to define a high fish consumer may be applied to the national data as evaluated by the EPA (U.S. EPA, 2002a, Section 5.2.1.1, Table 4) or to the 2003–2006 NHANES data. Estimates of children's fish consumption will vary depending on the statistical methodology used to evaluate the data. The information in Table 8 suggests that about 20 percent of the total children in Washington State are fish consumers.
- The dietary habits and patterns for Washington fish consumers are similar to those reported for the United States fish consumers.

Table 8. Estimated Number of Child Fish Consumers among the General Washington Population

(Children Younger Than 18 Years Consuming Large Amounts of Finfish or Shellfish)

Year	Total Population of Children (18 and younger)	Estimated Number of Washington Child Fish Consumers	Estimated Number of Washington Children who are High Fish Consumers (90th percentile or above)
2010	1.71 million	290,000	29,000
2030	2.06 million	350,000	35,000

2.4 High fish-consuming populations

Some population groups consume especially large amounts of finfish and shellfish as part of traditionally influenced diets. These include Native Americans and Asian, Pacific Islanders, and subsistence and recreational fishers.

2.4.1 Washington Native American Tribes

Washington is home to 29 federally recognized and seven non-federally recognized Native American tribes (Governor's Office of Indian Affairs, 2010). Traditional fishing areas for tribes cover essentially all of Washington.

The Washington OFM estimates there are approximately 104,000 American Indian and Alaska natives in Washington. Approximately 70 percent of the American Indian and Alaska native population is 18 years of age or older (73,500 adults) (U.S. Census Bureau, 2000, Table 2). OFM estimates there are 33,600 American Indian and Alaska natives between the ages of 0 and 18 years.

OFM projects that the total number of Native Americans in Washington will increase from 104,000 in 2010 to approximately 146,000 by the year 2030:[24]

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[24] 2010 population numbers are based on the 2010 Census redistricting data. 2030 estimates are as of the OFM 2006 Population Projections by Age, Sex, and Race.

• Population of American Indian and Alaska natives in Washington	104,000
Adults (70 percent of population is estimated at over 18)	73,500
Children (between 0 and 18 years of age)	33,600
• 2030 Population Projection	146,000

2.4.2 Asian and Pacific Islanders

Asian and Pacific Islander (API) populations include Native Hawaiians and peoples from other Pacific islands. The Washington OFM estimates there are approximately 522,000 Asian and Pacific Islanders currently residing in Washington (U.S. Census Bureau, 2000, Table 2). Finfish and shellfish consumption among this population in Washington has been documented. Approximately 75 percent of the current API population is 18 years of age or older (405,000 adults) (Sechena et al., 1999). There are 138,000 Asian and Pacific Islanders between the ages of 0 and 18 years.

OFM projects that the total number of Asian and Pacific Islanders in Washington will increase from 522,000 in 2010 to approximately 825,000 by the year 2030:[25]

• Population of Asian and Pacific Islanders in Washington	522,000
Adults (75 percent of the population is estimated at over 18)	405,000
Children (between 0 and 18 years of age)	138,000
• 2030 API Population Projection	825,000

2.4.3 Subsistence and recreational fishers

Approximately 824,000 people fished in Washington State during 2006; of these, 725,000 were Washington residents and 99,000 were nonresidents. Washington residents fished a total of 8.5 million days in 2006, an average of 12 days per angler (U.S. Department of the Interior and U.S. Department of Commerce, 2008).

Washington is home to some number of persons engaged in a subsistence lifestyle. Considerations related to subsistence fishing for Native American tribes in the Pacific Northwest have been identified (Donatuto and Harper, 2008; Harper and Harris, 2008). However, due to a lack of data, at this time Ecology is unable to estimate the number of subsistence fishers in Washington.

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[25] 2010 population numbers are based on the 2010 Census redistricting data. 2030 estimates are as of the OFM 2006 Population Projections by Age, Sex, and Race.

2.5 Sources of Fish Consumed

Fish consumption rate tabulations in this technical support document are derived from national fish dietary data and fish dietary surveys from the Pacific Northwest. The tribal fish dietary surveys from the Pacific Northwest provide information about the types of fish that are locally harvested and consumed. These tribal fish dietary surveys document locally harvested fish from usual and accustomed tribal treaty areas throughout the Columbia River basin and throughout Puget Sound.

For example, the 1994 Columbia River Inter-Tribal Fish Consumption Survey reflects fish harvest rates throughout the Columbia River basin for over 80% of the respondents.

Independent and separate documentation from three different Washington State agencies (WDFW, DOH, and Ecology) document the harvest and consumption of local abundant aquatic resources, including finfish and shellfish. For example, WDFW has documented the amounts of different shellfish harvested from various regions in Washington State (see Table 5).

Data gaps remain regarding exact locations where fish and shellfish are harvested in Washington State, and information about their commercial availability in state-wide grocery stores and local food markets.

2.6 Summary

From current demographic information, Ecology has estimated the total number of Washington fish consumers. Ecology reached its estimate after working with OFM to use census data and applying national and Washington fish consumption rate estimates to the general Washington population. There may be some variation in the adult and child fish-consuming population estimates for Washington State depending on the dataset and statistical methods used to evaluate national fish dietary information. Adult and child fish-consuming population estimates presented in this report are based on a similar analysis conducted by the 2008 Oregon DEQ Human Health Focus Group Report (Oregon DEQ, 2008).

Ecology believes that the population estimates for Washington State adult and child fish consumers provided in this report are reasonable estimates that help gauge and approximate the number of fish consumers. There are a large number of adults and children in Washington State who routinely consume finfish and shellfish.

According to Ecology's analysis, there are between 1.4 and 3.8 million Washington adults (18 years of age or older) who are fish consumers.[26] The number of adult fish consumers is

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[26] This includes a large number of recreational anglers. For example, the Washington Department of Fish and Wildlife estimates there were 824,000 recreational anglers (both finfishing and shellfishing) in Washington in 2006.

projected to increase by up to 27 percent as Washington's population grows over the next 20 years.

Ecology estimates that approximately 290,000 Washington children (0 to 18 years of age) consume fish. It should be noted that this estimate was developed using national survey data for the general population. Studies have shown that people living in coastal states tend to consume finfish and shellfish at a higher frequency and higher rates than inland states (Moya, 2004).[27] Ecology is not aware of Washington surveys that have examined child fish consumption frequency for the general population. The number of Washington children who eat some type of fish is also projected to increase as Washington's population grows over the next 20 years.

For this report, Ecology defined *high fish consumers* as all Washington adults and children who consume finfish and/or shellfish at or above the 90th percentile estimates from surveys of national per capita consumption. Based on data presented by the EPA (U.S. EPA, 2002a), these estimates correspond to 250 g/day and 190 g/day for adults and children, respectively.

- Ecology estimates that there are between 140,000 and 380,000 Washington adults who are high fish consumers. Ecology believes that the high end of this range provides a reasonable estimate of the number of high fish consumers in Washington. The high end of the range is based on information collected by the Department of Health on fish consumption habits of Washington residents.
- Ecology estimates that there are approximately 29,000 Washington children who are high fish consumers.

Certain population groups, including Native Americans and Asian and Pacific Islanders, consume large amounts of finfish and shellfish.[28]

- According to OFM estimates, there are approximately 104,000 Native American and Alaska natives in Washington.
- According to OFM estimates, approximately 522,000 Asian and Pacific Islanders live in Washington.

In summary, considerable quantities of finfish and shellfish are harvested for consumption in Washington, both recreationally and commercially. Many Washington residents harvest and presumably consume finfish and shellfish from local waters (WDFW, 2008a, 2012). High fish consumers include several population groups known to consume larger amounts of finfish and shellfish than the general population.

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[27] National fish consumption studies are typically carried out over a broad geographical area, including multiple states. Consequently, national studies may underestimate the rates and frequencies for states like Washington.

[28] Chapter 4 discusses further the consumption rates, patterns, and species consumed by Native Americans and Asian and Pacific Islanders.

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Chapter 3: Methodology for Assessing Fish Consumption Rate Information

3.1 Introduction

Researchers use a variety of methods for estimating the amount of finfish and shellfish consumed. Surveys are generally considered to be the best approach for collecting data; however, a number of design features determine whether a particular survey will provide a technically defensible basis for agency decision making. *Technical defensibility* means that the survey stands up to technical and scientific scrutiny and provides a solid technical basis for regulatory decisions. Among other factors, a survey that is technically defensible: (1) uses sound scientific methods and survey methods that have been peer reviewed and tested; (2) employs interviewers who are trained and/or questionnaires that follow accepted guidance; (3) presents clear reporting and conclusions that are supported by the data; (4) studies sample populations that represent the population of concern and consider temporal, geographic, and cultural aspects of fish consumption; (5) uses current information; and (6) provides results that can be used to support regulatory decision making. The measures of technical defensibility are described in more detail at the end of this chapter.

Different surveys are designed for different purposes. This chapter reviews the design features of various methods for collecting information about finfish and shellfish consumption. The purpose of this review is to identify the specific factors that Ecology considered when evaluating fish consumption surveys.

Regional-specific dietary information about people who eat finfish and shellfish is useful in providing a weight of evidence for evaluating the fish-consuming habits and patterns of fish consumers in Washington. Fish dietary information from the Pacific Northwest indicates that Washington State's fish-consuming populations eat more fish than what is reflected in the rates used to establish regulatory standards.

To provide more information when making risk management decisions, Ecology understands that it would be desirable to have *statewide* fish dietary data and information regarding the fish consumption habits and patterns of *all* Washington State fish consumers. However, in the absence of a statewide fish dietary survey, Ecology believes that the fish dietary information from Pacific Northwest fish-consuming populations such as tribal populations is useful and relevant for making sound risk management decisions that protect Washington State's residents. Ecology believes that there is sufficient credible fish dietary information to provide fish consumption estimates for fish-consuming populations in Washington State. If the assumption is made that the fish consumption habits and patterns among the Washington State general fish-consuming population are similar to those of the U.S. general population of fish consumers, then the fish dietary estimates for the U.S. general population may be used to provide estimates for the Washington general population. Ecology notes that differences between the Washington population and the U.S. general population do exist: for example, status as a coastal state has the possibility of affecting fish consumption patterns.

The Pacific Northwest surveys have all followed a similar design: dietary recall complemented by food frequency questionnaires; they have been scientifically peer-reviewed (CRITFC, 2012; University of Washington, 2012), and have included reviews of study design and analysis of the results of the dietary surveys. The surveys have been considered and utilized by EPA on both a regional and national basis for environmental regulation as well as by the State of Oregon. These fish dietary surveys, together with other dietary information, provide a reasonable and technically sound basis to estimate the fish consumption habits and patterns for Washington State fish consumers.

This chapter is organized into three sections:

- *Surveys and other approaches used to estimate fish consumption.* This section reviews the various methods that have been used or are available for collecting data about dietary habits and patterns surrounding fish consumption.
- *Factors to consider when evaluating survey results.* This section identifies key design or implementation features that impact the quality of individual surveys.
- *Establishing technical defensibility*. This section describes the methodology Ecology used in assessing the technical defensibility of fish consumption survey information and results. The methodology explained here is then applied in the next chapter to surveys pertinent to Washington.

3.2 Surveys and other approaches used to estimate fish consumption

The various approaches to collecting information on finfish/shellfish dietary habits and patterns include telephone surveys, mail surveys, food diaries, personal interviews, and creel surveys (U.S. EPA, 1992). Each method has certain limitations, including bias, error, and variability (U.S. EPA, 1992; Moya et al., 2008). Ecology thoroughly examined the methodology used in fish consumption surveys. To determine quality and ensure utility for each survey examined, Ecology evaluated experimental design, target population, sample size, location, and potential bias (Ecology, 1999). This analysis aids general understanding and identifies the limitations and utility of the available data.

Fish dietary survey methodologies and limitations, as described in this report, are consistent with EPA guidance for conducting fish consumption surveys (U.S. EPA, 1992, 1998). Another approach, a dietary *market basket* survey, is used by EPA's Office of Pesticide Programs to evaluate aggregate exposure to pesticide residues in food to which consumers may be exposed. This is a different approach that analyzes exposure to a single chemical by multiple pathways and routes of exposure. Market basket surveys conducted by EPA's Office of Pesticide Programs are statistically designed and executed on a single-serving basis at the point of sale to the consumer (U.S. EPA, 2000a).

Five fish consumption survey methods, and the strengths and weaknesses of each approach, are briefly described below.

3.2.1 Creel surveys

Creel surveys estimate fish consumption by interviewing anglers[29] on site. Using the number of fish caught at a given location divided by the number of people who will consume the catch, creel surveys can determine a fish consumption rate (Moya, 2004). The Technical Issue Paper entitled *Recreational Fish Consumption Rates* (Ecology, 2012) provides a more detailed review and analysis of fish consumption rates for recreational fishers.

A number of creel surveys have been conducted in Washington. Examples are:

- Landolt, M.L., Hafer, F.R., Nevissi, A., Van Belle, G., Van Ness, K., and Rockwell, C. 1985. Potential toxicant exposure among consumers of recreationally caught fish from urban embayments of Puget Sound. NOAA Technical Memorandum NOS OMA 23. November 1985.
- Landolt, M.L., Kalman, D.L., Nevissi, A., Van Belle, G., Van Ness, K., and Hafer, F.R. 1987. Potential toxicant exposure among consumers of recreationally caught fish from urban embayments of Puget Sound. NOAA Technical Memorandum NOS OMA 33. As cited in Tetra Tech 1988.
- Mayfield, D.B., Robinson, S., and Simmonds, J. 2007. Survey of fish consumption patterns of King County (Washington) recreational anglers. *Journal of Exposure Analysis and Environmental Epidemiology*, 17:604-612.
- McCallum, M. 1985. Recreational and subsistence catch and consumption of seafood from three urban industrial bays of Puget Sound: Port Gardner, Elliott Bay and Sinclair Inlet. Washington State Division of Health, Epidemiology Section. January 1985.
- Parametrix. 2003. Results of a human use survey for shoreline areas of Lake Union, Lake Washington, and Lake Sammamish. Sammamish-Washington Analysis and Modeling Program (SWAMP). Prepared for King County Department of Natural Resources. September 2003.

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[29] The term *fisher* denotes a person who fishes for any type of seafood by any method, including finfish and shellfish. The term *angler* refers to a person who fishes with hook and line.

- Pierce, D., Noviello, D.T., and Rogers, S.H. 1981. Commencement Bay seafood consumption study. Preliminary Report. Tacoma-Pierce County Health Department, Tacoma, Washington. December 1981.
- Price, P., Su, S., and Gray, M. 1994. The effects of sampling bias on estimates of angler consumption rates in creel surveys. *Journal of Exposure Analysis and Environmental Epidemiology* 4:355-371. As cited in U.S. EPA, 2011.

As with any type of survey, creel surveys have both strengths and weaknesses (see Table 9) (U.S. EPA, 1992).

Table 9. Strengths and Weaknesses of Creel Surveys

Strengths	Weaknesses
∗ Can assess site-specific consumption rates. ∗ Can target specific at-risk populations who fish at contaminated sites. ∗ The interviewer can observe the participant's fishing behaviors and catch as well as the condition of the interview site. ∗ Recall bias is minimized by using visual aids and by having the interviewer refer to the fish caught around the time of the interview as a reference. ∗ Results can be verified by looking at the daily catch of the participant. ∗ Response rate is high. ∗ More information can be gained by using visual aids and probing questions. ∗ Creel surveys are routinely done for fishery management purposes; adding fish consumption questions to the surveys can be done with little added cost.	∗ Only a limited number and types of questions are used to minimize survey time. ∗ Language barriers may exist between participants and interviewers. ∗ Surveys require well-trained staff that must be monitored for quality control. ∗ If interviews are occurring at fishing sites, answers about consumption are hypothetical because the fish have not yet been consumed. ∗ Participants who fish more frequently are more likely to be interviewed than those who fish less frequently. [a] ∗ Survey results cannot be generalized to the entire population. ∗ May miss anglers if not all fishing locations and times are surveyed. ∗ May under- or overestimate yearly consumption if survey is not conducted throughout the year. ∗ Pilot testing for a target population is not as effective as is the case with personal interview surveys. ∗ Anglers may not be as receptive to engaging in interviews as preselected personal interview survey interviewees. ∗ Fears of contact with government officials may inhibit responses of minority groups. ∗ Anglers in the field may not be as inclined or ready to respond as individuals that have been contacted and readied to participate in a personal interview survey. ∗ Visual aids for unique seafood preparations are difficult to develop without knowledge of the target population. ∗ If the water body is known to have chemical contamination, rates may be impacted by a suppression effect (i.e., the suppression of the harvest and consumption of fish), and hence may not result in protective risk estimates or cleanup levels. ∗ It may difficult to know who actually consumes the fish.

a. Moya et al., 2008.

3.2.2 Personal interviews

Personal interviews can be used to estimate fish consumption rates by asking participants questions about their dietary patterns, particularly about how much fish they consume over a given amount of time (Table 10). A useful type of personal interview survey considers 24-hour dietary recall. In this type of interview, participants are asked by a trained interviewer to report what they ate during the previous 24 hours. Although the 24-hour dietary recall format avoids recall bias, the short time period of recall is unable to show consumption variation over the course of a year (U.S. EPA, 1992). Some survey designs have addressed this by interviewing the same individual multiple times or by staggering interviews of the survey population over the course of a year. Other personal interviews may ask a participant to provide information about their consumption of finfish and shellfish over longer time periods, such as 2 weeks, a month, a season, or a year. Examples of personal interview surveys include the Native American fish consumption surveys conducted for tribes residing along the Columbia River basin and throughout Puget Sound (see Chapter 4).

Table 10. Strengths and Weaknesses of Personal Interviews

Strengths	Weaknesses
∗ Can assess site-specific consumption rates. ∗ Can identify and get information from vulnerable subpopulations (those populations at a disproportionate risk) by collecting data from participants who are close to contaminated sites and by asking community agencies who should be interviewed. ∗ Responses can be validated and supported with information gathered by the interviewer. ∗ Literacy and language barriers are minimized by face-to-face interaction. ∗ Visual aids can be used to estimate meal size or fish species, reducing recall bias. ∗ High response rate. ∗ Interviewer can clarify questions for respondents. ∗ Possible to select a random sample that is representative of the population. ∗ Pilot testing of interview with target population is possible. ∗ Possible to incorporate culturally unique seafood preparations and considerations into the dietary survey. ∗ Possible to tailor survey to specific groups. ∗ Avoids issues associated with missing fishing locations or times that are encountered in creel surveys.	∗ Only a limited number and types of questions are used to minimize survey time. ∗ Requires coordinated and supervised interviewers. ∗ If interviews are occurring at fishing sites, answers about consumption are hypothetical because the fish have not yet been consumed. ∗ Responses may be biased by fishing practices at the time the interview is being administered. ∗ Uncertainty introduced when individuals are asked to recall consumption throughout the year.

3.2.3 Diary surveys

Diary surveys use questionnaires, in the form of logbooks, diaries, or catch cards, to record fish consumption over time. Information is filled out by the participant ideally at the end of a fishing day or at the time of consumption, to minimize possible recall bias (Table 11).

The Connecticut Department of Environmental Protection used diary surveys to find out about fish meals and portion sizes eaten by Connecticut families. The families received the surveys in the mail (U.S. EPA, 1992; Moya et al., 2008).

Table 11. Strengths and Weaknesses of the Diary Method

Strengths	Weaknesses
∗ Can assess site-specific consumption rates. ∗ Information collected over long periods of time. ∗ Less expensive than personal interviews. ∗ Large numbers of participants possible. ∗ Recall bias is reduced. ∗ Visual aids can be used to improve accuracy of answers.	∗ Respondents must be taught how to complete the survey by a trained interviewer. ∗ Participants must be literate. ∗ Participants must be monitored during the study to maintain consistency. ∗ Keeping a dietary record may change a participant's dietary practices. ∗ Participants may not maintain daily record keeping. ∗ Language barriers may affect how participants are recruited and how their diary responses are interpreted. ∗ Questionnaire design is more complicated than other types of surveys.

3.2.4 Telephone surveys

Telephone interview surveys estimate recent fish consumption or information about recent fishing trips. Answers are recorded on preprinted questionnaires (Table 12) (U.S. EPA, 1992).

Table 12. Strengths and Weaknesses of Telephone Surveys

Strengths	Weaknesses
∗ Can assess region-specific consumption rates. ∗ Can target and identify specific subpopulations of concern. ∗ Less expensive and time-consuming than personal interviews. ∗ High rate of success for completion of interviews. ∗ Sensitive information may be obtained more easily. ∗ Provides immediate response to questions.	∗ Interviewers cannot reach people who do not have phones. ∗ Interviews are limited in scope and length. ∗ Difficult to verify information. ∗ Cannot use visual aids. ∗ Inability to reach people by phone may be of concern for low-income individuals who harvest more fish than more affluent people. ∗ Language barriers may pose limitations.

3.2.5 Recall mail surveys

Recall mail surveys are self-administered questionnaires used to estimate fish consumption. Most commonly they are used to obtain information from recreational anglers (Table 13) (U.S. EPA, 1992).

Table 13. Strengths and Weaknesses of Recall Mail Surveys

Strengths	Weaknesses
∗ Can assess region-specific consumption rates. ∗ Can target and identify specific subpopulations of concern. ∗ Least expensive since no interviewers are required. ∗ Large numbers of respondents may be contacted over a large area. ∗ Most likely to provide honest answers. ∗ Complex technical data may be obtained if respondent takes the time to consider the questions and/or consult other sources. ∗ Survey can cover broad areas of inquiry.	∗ Cannot reach people without mailing addresses. ∗ Questions must be carefully designed to compensate for lack of personal interaction. ∗ Questions should be limited in scope and complexity. ∗ Requires substantial follow-up efforts or incentives to achieve reasonable response rate. ∗ Higher number of inaccurate and incomplete responses. ∗ May miss respondents who are illiterate, or have difficulty in understanding questions, or who cannot read the language.

3.3 Survey selection criteria

Both dietary recall interviews and creel surveys have been used in Washington in various contexts to estimate fish consumption rates (see Chapter 4, Table 14).

Certain criteria are useful for comparing survey methodologies, and key factors influence the selection of a particular survey type (U.S. EPA, 1998). These selection criteria assist in discriminating between different survey approaches. In addition, how different survey methodologies compare based on these criteria highlights the various strengths and weaknesses.

Consistent with this approach, Ecology established key considerations for selection criteria: time frame, resources, target populations, subpopulations, accuracy, and harvest characteristics. Although many of these considerations are discussed separately, Table 14 provides a useful tool for comparing different survey methodologies.

Table 14. Comparison of Five Consumption Survey Methodologies Using EPA's Selection Criteria

Survey Type Selection Criteria	Telephone	Mail	Diary	Interview	Creel
Time Frame					
Immediate data from respondent	Yes	No	No	Yes	Yes
Resources					
Interviewer burden	Moderate	Low	Low	High	High
Respondent burden	Low	Moderate	High	Low	Low
Relative cost	Moderate	Low/moderate	Low	High	High
Target Populations/Subpopulations					
Survey sample known prior to conducting survey	Yes/no [a]	Yes	Yes	Yes/no [b]	Yes/no [c]
Can be used with low literacy populations	Yes	No	No	Yes	Yes
Accuracy [d, e]					
Reliability: Potential for response reliability	Moderate/high	Low/moderate	Low/moderate	Moderate/high	Moderate/high
Validity: Validity of consumption estimates	Low	Low/high [f]	Moderate	Moderate [g]	Low/moderate [g]
Validity: Validity of species identification	Low	Moderate	Moderate	Moderate/high [h]	High
Bias: Potential to minimize recall bias	Moderate	Low/high [f]	Moderate	Moderate/high [h]	Not applicable [i]
Bias: Potential to minimize prestige bias	Moderate	Low	Low	Moderate	Moderate
Measurement error: opportunity for respondent to ask for clarification	Moderate/high	Low	Low	High	High
Measurement error: potential for respondent participation	Moderate	Moderate	Low	High	High
Harvest Characteristics					
Many access points	Yes	Yes	Yes	Yes/no [b]	Yes/no [j]
High fishing or hunting pressure	Yes/no [k]	Yes	No	Yes	Yes/no [l]
Large geographic area	Yes	Yes	Yes	Yes [m]	No
Account for seasons and times	Yes	Yes	Yes	Yes	No [n]

Source: U.S. EPA, 1998, Table 3, p. 3-3.

a. Yes if phone numbers are obtained after sample population has been preselected; no if random digit dialing.
b. No for interviews conducted at fish/hunting access points; yes for off-site interviews.
c. Depends on ability to estimate total site usage using random sampling of all access points.
d. Given sufficient resources, all five survey approaches can generate accurate data.
e. For minority and tribal populations a sense of trust and cultural identity between interviewer and interviewee is particularly important.
f. Dependent on the recall method employed.
g. On-site interviews result in valid catch estimates, but consumption estimates are hypothetical because they measure only the intent to consume. Off-site interviews result in catch and consumption estimates with potentially low validity depending on the period of recall.
h. Moderate for off-site interviews; high for on-site interviews. Administering the survey at regular intervals can reduce bias associated with the availability of different seafood resources throughout the year.
i. Creel surveys may minimize recall bias but the responses only represent the point of time the individual starts fishing to the time the individual is interviewed.
j. Yes for roving creel survey; no for access point survey.
k. Yes for random telephone numbers; no for known telephone numbers.
l. Yes for access point survey; no for roving creel survey.
m. Yes when interviewees are preselected so they can tell interviewer where they have fished.
n. A creel survey may be designed to account for seasons and times; however, creel surveys seeking to develop health protective estimates of fish consumption may only be conducted during high harvest time periods.

3.4 Evaluating survey vehicles

Large differences in survey objectives combined with the high variability in fish consumption patterns make it difficult to make generalizations about surveys. To compare and evaluate both the survey vehicle (that is, the questionnaire or interview process) and the data obtained, a number of factors should be considered. Also, to establish whether a particular survey is appropriate to use, each factor needs to be evaluated and documented. Moya, 2004, and U.S. EPA, 1992 and 1998, identify important elements of survey design.

Also of significance is whether a survey is designed to look at short-term or long-term behaviors. This is especially relevant when comparing results of different surveys.

3.4.1 General survey design

Survey design is fundamental to the accuracy and success of a survey, and identifying the target population is important both when both choosing a survey method and effectively executing the survey (Table 15). The design establishes the type of information collected and the level of detail provided (Moya, 2004). Survey accuracy improves when the following factors are considered during the design phase. Ecology considered these as essential in a well-designed survey.

Table 15. Survey Design Evaluation Criteria

Criteria	Description
1. Timing of interviews	For a survey to adequately capture fish consumption, an appropriate time frame must have been chosen that minimizes the effect of recall bias yet captures the dietary variations.[a] (Additional discussion on survey recall error and bias are provided in the Glossary, Appendix D.)
2. Training of interviewers	Interviewers should be trained for the study protocol to avoid potential interviewer bias. Interviewers must adhere to the questionnaire wording and format and be culturally sensitive when interacting with the study participants. If possible, interviews should be conducted by members of the target population to avoid adverse impacts associated with cultural differences, language barriers, and participation refusals. [a]
3. Consideration of all fish species	The types of fish consumed can be highly variable depending on seasonal and geographic availability, market prices, and cultural preferences. Surveys should identify and record each type of fish consumed and any unique preparation methods. [a]
4. Identification of the source	If known, either the water body where the fish was caught or the purchase location (for example, grocery store or fish market) should be identified. To improve exposure assessment, both locally caught fish and store bought fish should be included in fish consumption rate estimates. This distinction allows the risk assessor to better account for regional and seasonal variations in fish consumption estimates. [b]
5. Random selection of participants, sample size, and statistical analysis	During the planning phase, statistical analysis helps identify the ideal sample size and how to randomly select participants. This analysis helps minimize bias and sampling error and ensures statistical rigor. After the data have been collected, sound descriptive statistical analysis should ensure that the data are presented accurately. The range of data should be presented with confidence intervals and appropriate distribution values. Weighting schemes should be clearly described in order to apply survey results to populations of interest. Statistical treatment of perceived outliers should be discussed.

Criteria	Description
6. Appropriate quality assurance and quality control	The study design should include appropriate quality assurance and quality controls into the planning and execution of the survey. For example, types of quality control measures would include checking questionnaires for completeness and proper entry of recorded responses, verifying correct data entry, and checking the manual coding operations and comparisons of results and error rates. This reduces bias and random error, improving accuracy. [c]
7. Accuracy and precision	The study design can affect the overall accuracy of the study. Accuracy can be split into five components. Reliability (the variability or repeatability of the response), validity (the ability of the respondent to provide the correct answer), measurement errors (which are associated with the interviewer, the respondent, the questionnaire, and the mode of data collection), bias (the consistent overestimation or underestimation due to survey design and sample selection), and random errors. [c]

Sources:

a. Ecology, 1999.

b. Ebert et al., 1994.

c. U.S. EPA, 1998.

3.4.2 Survey questions

The following information should be collected from study respondents and is necessary for understanding what they eat (Strauss, 2004).[30]

- Frequency and quantity (how much fish is consumed per day, week, or month).
- Parts of the fish consumed.
- Species consumed.
- Source of the fish.
- Seafood preparation and cooking methods.
- Respondent’s body weight.
- Exposure duration.
- Approximate age (child or adult).

Survey questions should be clearly worded, unambiguous, and well understood to obtain clear and correct answers from respondents.

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[30] See this 2004 article by Strauss for details regarding complexities and variability.

3.4.3 Population surveyed

The sample population must represent the target population. This is particularly important because fish consumption rates may be affected by the socio-demographic characteristics of a population. Furthermore, the type of survey used may influence or determine a number of things, including what population will respond to the survey, the response rates, and the level of detail obtained (Moya, 2004).

3.4.4 Description of water body

The survey must identify and understand the characteristics of all relevant water bodies, including location, size, species inhabiting the water, and fish advisory status. These characteristics influence the quantity of fish available. In addition, this information is critical to producing results that can be used to compare with or extrapolate to other populations (Moya, 2004).

3.4.5 Survey results

Ecology considered it important to evaluate how the survey results are presented and what they are meant to represent. This included identifying and considering goals of the survey.

Estimating the size of a meal is subject to error, especially when a survey vehicle (questionnaire or interview) does not include visual aids. Also, quantities of seafood may be part of stews, soups, and other recipes that may or may not be accounted for in fish dietary survey design.

Sound descriptive statistical analysis is required to ensure that the data are presented accurately. The range of data should be presented with confidence intervals and appropriate distribution values (Moya, 2004). Weighting schemes should be clearly described in order to apply survey results to populations of interest. Statistical treatment of perceived outliers should be discussed.

3.4.6 Factors to consider

Ecology identified the following factors as appropriate and necessary when evaluating survey results:

- *Cultural factors.* Does the population group of interest (for example, Native Americans or Asian and Pacific Islanders) have cultural characteristics that should be considered when designing a fish consumption survey? Native American ways of life may influence fish consumption habits and patterns; salmon is of particular significance in the diet of Northwest Pacific Native American tribal peoples. Asian and Pacific Islanders may consume parts of organisms that differ from those preferred by other populations. Also, is the survey designed to identify subsistence fishing practices?

- *Fish diet fraction (the portion of fish consumed that comes from the site).* Have sources of fish tissue contamination been considered in the design and/or evaluation of the survey? Are the fish consumed harvested from local waters? Does the survey distinguish between store-bought fish or fish consumed in restaurants and fish harvested from local waters?
- *Types of seafood (finfish and shellfish) consumed from marine, freshwater, and estuarine habitats.* This information may be useful in characterizing risks for consumption of aquatic biota that have different contaminant levels as a result of their feeding behaviors (for example, bottom feeding fish or top predator species). Has the fish consumption survey considered both the range of types of finfish/shellfish consumed and where they are harvested?
- *Cooking methods.* Use of cooked weights or uncooked weights to measure fish consumed must be standardized. Generally, uncooked weights are preferred because environmental contaminants are usually analytically determined for wet weight. Cooking fish can reduce the weight of a fillet by 20 percent or more (U.S. EPA, 1998). Have the methods of food preparation and cooking been considered in the fish consumption survey design and/or evaluating the survey?
- *Are there historical and traditional fishing areas and practices that should be identified?*
- *Environmental justice.* How have historically underrepresented populations and disproportionately impacted communities been considered in the design and evaluation of fish consumption surveys?

3.5 Measures of technical defensibility

For purposes of this report, Ecology developed several *measures of technical defensibility* to help guide the evaluation of individual surveys. These measures of technical defensibility ensure that a survey can stand up to technical and scientific scrutiny and are described in Table 16. They represent an expansion of the two selection criterion used by the June 2008 Oregon Human Health Focus Group-Oregon Fish and Shellfish Consumption Rate Project

Collectively, these measures of technical defensibility provide an assessment of overall technical suitability to support regulatory decision making (for example, they provide information about whether the survey results are suitable and appropriate in a regulatory context for establishing risk-based standards).

The measures of technical defensibility are based on:

- EPA *Exposure Factors Handbook*, 2009 Update (U.S. EPA, 2009a).
- EPA *Exposure Factors Handbook*, 2011 Edition (U.S. EPA, 2011a).
- EPA *Guidance for Conducting Fish and Wildlife Consumption Surveys* (U.S. EPA, 1992, 1998).
- Consultations with the University of Washington, Environmental and Occupational Health Sciences.[31]

Ecology applied these measures of technical defensibility to selected fish dietary surveys performed in Washington State. Ecology has not applied these measures of technical defensibility to all surveys conducted in Washington; many of these surveys were conducted for specific water bodies to help support fish advisories, or were used to assess risks to specific ethnic populations.

Water body-specific fish dietary surveys are limited in scope because they evaluate very specific populations, usually recreational anglers and specific ethnic groups, which harvest and consume fish from a particular water body within a specific county or jurisdiction in Washington State. Each serves a useful purpose to help evaluate and assess potential health risks from consuming contaminated finfish and shellfish; however, their methodology does not allow for the projection of longer term estimates of fish consumption.

The additional fish dietary information provided in Table 32 and Appendix B, although not meeting the measures of technical defensibility described in this chapter, provides support, using a weight-of-evidence approach, to the idea that people in Washington State harvest and consume considerable amounts of fish.

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[31] Ecology acknowledges input from the University of Washington, Seattle, Environmental and Occupational Health Sciences and Departments of Medicine and Internal Medicine.

Table 16. Measures of Technical Defensibility

Measure	Description
1. Survey Method Development	∗ Was the survey design based on sound scientific survey methods recognized either in guidance or other technical publications? ∗ For surveys dealing with unique populations (for example, tribes or ethnic minorities), was the survey vehicle reviewed by tribal staff and tribal governments? Did it include review and collaboration with state and federal agencies? ∗ Was the survey tested and modified before it was conducted? ∗ Did the survey design evaluate the essential elements provided in Table 15?
2. Survey Execution	∗ Was the execution of the survey based on sound survey methods recognized either in guidance or other technical publications? ∗ Were the personnel conducting interviews provided adequate training? ∗ Were finfish/shellfish models used as visual aids to help participants estimate approximate amounts and types of fish consumed?
3. Publication of Results	∗ Was the publication of survey results based on sound survey methods recognized either in guidance or other technical publications? ∗ Was the study methodology clearly defined and reported? ∗ Is there a discussion of the consistency of the survey's methodology with accepted practices? ∗ Was the study methodology consistent with sound survey practices? ∗ Were the survey results tabulated and reported clearly? ∗ Were statistical approaches (including weighting and treatment of outliers) clearly explained? ∗ Were the study conclusions clearly reported and supported by study findings? ∗ Were variability and uncertainty recognized? ∗ Were uncertainties identified and reported? ∗ Did the survey design take into account and/or discuss factors that might contribute to bias in the study results?
4. Applicability and Utility for Regulatory Decision Making	∗ Is the sample population representative of the population of concern, and does the survey provide sufficient information about the sample population to characterize the population being studied? ∗ Is it reasonable to apply the results of the surveyed population to populations of concern? ∗ Are the water bodies/fisheries resources upon which the surveyed population relies similar to the water bodies being regulated? ∗ Is the information current and is suppression effects on fish dietary habits recognized and accounted for? ∗ Are fish consumption rate statistics commonly used for regulatory purposes presented and supported? ∗ Are data sufficient for descriptive statistics to define statistical fish consumption rate distributions?

3.6 Custody of fish dietary survey data

Most fish dietary surveys that address the habits and patterns of ethnic groups (Asian and Pacific Islanders, Native American populations) are funded either through state or federal cooperative agreements or grants. Survey questionnaires are generally developed in close collaboration with an organization that represents the ethnic group or technical personnel associated with the tribal governments or tribal natural resource offices. Surveys are conducted by trained tribal personnel or people representative of the ethnic population being surveyed. The resulting data may be owned by the tribal government or the ethnic group that collaborated on the survey. The survey design and methodology are generally reviewed by the funding organization (federal or state) and technical personnel or representatives from the tribe or ethnic group.

The custody of survey data by tribal governments is related to their concerns with maintaining and sustaining tribal sovereignty and honoring confidentiality agreements with individual participants surveyed. The tribal governments have employed various methods to establish data quality without releasing individual response data to entities other than tribal governments. Ecology acknowledges that further evaluations would be possible using individual level response data.

Pacific Northwest Native American fish consumption surveys are designed and executed as government-to-government collaboration with state and federal governments. They are generally published under the authority of the tribal governments.

There are a number of ways to establish the defensibility of data. Scientific journals use peer review to establish scientific defensibility of reported results. A recent *Science Magazine* editorial (Hanson et al., 2011) noted the importance of making data available for scrutiny so that other researchers can verify results and test conclusions. Using independent statisticians for review and analysis may circumvent the need to release the raw data.

Many Pacific Northwest tribal organizations or tribal governments do not provide their raw seafood dietary data to researchers outside of their sovereign tribal government or organizations. They may consider survey data as confidential and not allow independent evaluations. Data evaluation typically occurs through government-to-government agreements or tribal technical personnel.

For example, the fish consumption survey of the four tribes that reside throughout the Columbia River basin was initiated through a cooperative agreement between EPA and the CRITFC. The development, design, and execution of the CRITFC fish consumption survey vehicle were conducted through the respective tribal governments that compose CRITFC. The fish consumption data were collected and evaluated by tribal members and technical staff and are retained by CRITFC. Other Pacific Northwest Indian tribes follow a similar pattern where the data are retained by tribal governments or Pacific Northwest Indian commissions.

Ecology evaluated the Native American fish consumption surveys, as well as other available surveys conducted in the Pacific Northwest, based on the measures of technical defensibility discussed above. That evaluation is described in the following chapter.

Chapter 4: Fish Consumption Survey Data that Apply to Washington Fish Consumers

4.1 Introduction

Over the last several years, Ecology has evaluated available fish consumption surveys to support site-specific regulatory decisions.

Fish consumption survey data are identified, discussed, and evaluated against the measures of technical defensibility presented in Chapter 3. The purpose of this chapter is to identify those surveys that are most appropriate for assessing fish consumption rates in Washington. A word of caution is appropriate. Many sources of data are available and provide information that may be appropriate for answering particular questions. The question being considered in this chapter is identification of data appropriate for use in a regulatory context to characterize fish-consuming populations across Washington State.

Ecology considered a range of information that describes fish consumption rates and patterns for fish consumers in Washington. In general, Ecology examined:

- General population surveys conducted at the national level.
- Dietary surveys of Washington Native American populations.
- A dietary survey of Asian and Pacific Islander populations in King County.
- Washington water body-specific evaluations, assessments, or health advisories issued by DOH.[32]
- Technical publications, assessments, and/or evaluations of fish consumption specific to the Pacific Northwest.
- Various evaluations or assessments used to make regulatory decisions. For example, the baseline human health risk assessment performed for the Lower Duwamish Waterway, which refers to the EPA Region 10 Framework and Kissinger re-evaluation (Windward Environmental, 2007; U.S. EPA, 2007b; Kissinger, 2005).[33]

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[32] Washington State Department of Health fish consumption advisories by water body located at the following web link: http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx, and Port Angeles: http://www.ecy.wa.gov/news/2012/052.html

[33] Besides the Lower Duwamish Waterway Remedial Investigation Report, Ecology also considered the Port Angeles and Port Gamble sediment cleanup:

Port Angeles: http://www.ecy.wa.gov/programs/tcp/sites_brochure/portAngelesHarborSed/paSed_hp.htm

Port Gamble: http://www.ecy.wa.gov/programs/tcp/sites_brochure/psi/portGamble/psi_portGamble.html

These data were examined and assessed to identify technically defensible studies appropriate for use in characterizing fish-consuming populations in Washington.

To provide a more detailed look at fish consumption patterns across the state, where possible, fish consumption data and descriptive statistics have been tabulated for both locally harvested fish, and for fish consumed from all sources including stores and restaurants. Where available, additional fish consumption estimates from Pacific Northwest fish dietary surveys are included for groups of fish species, such as finfish, shellfish, anadromous finish, and non-anadromous finfish.

4.2 General population data

Currently, there are no fish dietary data available for the general fish-consuming populations in Washington State. That is, there is not a survey of fish consumption of the entire population of Washington State. Ecology examined information on fish consumption among the U.S. national general population.

Ecology notes that national data show that people who live in coastal areas consume fish at higher rates than those living in other areas (Moya, 2004) and that EPA recommends using regional-specific data, when available (U.S. EPA, 2000b, 2007b, 2011a).

4.2.1 Continuing Survey of Food Intakes by Individuals

In 2000, the EPA developed national estimates of fish consumption based on an analysis of the U.S. Department of Agriculture's (USDA) 1994–1996 *Continuing Survey of Food Intakes by Individuals* (CSFII) and its 1998 *Children's Supplement* (U.S. EPA, 2002a). (These USDA reports are collectively referred to as CSFII 1994–1996, 1998).

The USDA surveys were designed to provide estimates of food consumption across the United States and were conducted in all 50 states and Washington, D.C. They include fish consumers and non-consumers, and provide data for federal activities related to the nutritional status of the U.S. population.[34] The national fish dietary information is not representative of some Washington State fish-consuming populations, such as Asian-Pacific Islanders and Native Americans.

Over 20,000 survey participants each provided dietary information during two non-consecutive 24-hour periods. The survey was designed so that the second interview occurred 3 to 10 days after the first interview but not on the same day of the week. The dietary recall surveys were administered over a period of 4 years.

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[34] By definition, per capita fish consumption includes consumers and non-consumers of fish. The per capita survey methodology is different than the Pacific Northwest fish dietary recall studies and is discussed below.

The CSFII was conducted by interviewing respondents according to a stratified design that accounted for geographic location, degree of urbanization, and socioeconomics. Eligibility for the survey was limited to households with gross incomes at or less than 130 percent of the federal poverty guidelines. Survey weights were assigned to this dataset to make it representative of the U.S. population.

The CSFII is the primary source of food consumption data used in dietary risk assessments. It is well suited to national-level dietary risk assessments, because it is statistically designed to sample individuals of all ages and major ethnic subgroups to reflect various demographics. The CSFII is statistically designed so that the national estimate of consumption is not biased by seasons of the year or regions of the country (U.S. EPA, 2001). The CSFII may be considered a variation of the dietary market basket survey approach but on a larger-scale with a more sophisticated design and execution.

Ecology notes, however, that the survey methodology limits its use. In particular, participants who did not eat fish on either of the two days surveyed would be considered non-consumers. The rate of fish consumption (or non-consumption) for individual consumers during the two days surveyed was assumed to represent their consumption rate for the entire year. In other words, someone who did not eat fish during the two days of the survey was assumed to consume no fish at all during the year. The resulting values may not be representative of long-term consumption rates that have been averaged over time and presented as a daily rate.

By definition, per capita fish consumption rates reflect fish dietary habits averaged over the general U.S. population, including people who never eat fish. Hence, per capita fish consumption rates do not necessarily describe actual fish consumption by consumers of finfish and shellfish.

Although fish consumption rates derived for consumers would be preferable to per capita rates in describing the consumption of finfish and shellfish in the United States, there are limitations when “consumer only” rates are derived from national per capita surveys:

- During the two non-consecutive days of the survey period, the amount of fish and shellfish that a respondent ate on a given day would not be equivalent to the gram per day value obtained when the amount of fish consumed over a longer survey period is divided by the number of survey-period days for a more comprehensive fish dietary recall survey.
- People who typically consume finfish and shellfish, but did not do so during one of the two non-consecutive days of the survey period, were not captured by the survey and therefore are not included in national fish consumption estimates for consumers.
- It is not possible to determine the percentage of the finfish- and shellfish-consuming population that was missed, or whether the respondents who did consume finfish or shellfish during the survey’s two-non-consecutive-day reporting period are adequately representative of the U.S. fish-consuming population.

Ecology acknowledges the difficulty in evaluating the data from the EPA 2002 per capita estimates. We have considered this information in helping to estimate the number of fish consumers in Washington but not in estimating a fish consumption rate. We have also used the per capita data to define high fish consumers in order to approximate the number of high fish consumers among the general population.

Table 17. General Population: Adult Respondents, Consumers Only, Based on CSFII 1994 to 1996

Population	Number of Adults Surveyed	Descriptive Statistics (g/day)					
		Mean	Median	Percentiles			
				75th	90th	95th	99th
U.S General Population (consumers only)	2585	127	99	-	248	334	519

Source: Adapted from Oregon DEQ, 2008, Table 3, based on EPA 2002 and CSFII dietary data. Persons interested in further details on the CSFII are referred to U.S. EPA, 2002.

4.2.2 National Health and Nutrition Examination Survey, 2003 to 2006

The EPA 2011 national estimates for fish consumption are based on analysis of the USDA National Health and Nutrition Examination Survey (NHANES) from 2003 to 2006. The fish consumption estimates from the NHANES 2003–2006 data are available in Chapter 10 of EPA's Exposure Factors Handbook, 2011 (U.S. EPA, 2011a).

Designed to assess the health and nutritional status of adults and children in the United States, starting in 1999, NHANES is a continuous program that interviews nationally representative samples of about 7,000 people annually. The survey is administered for two non-consecutive 24-hour periods of dietary intake. Data for the first day is collected in-person, while data for the second day is collected by telephone about 3 to 10 days later. Using the 2000 U.S. population census estimates to develop the sampling frame, the NHANES 2003–2006 surveys are probability-based and county-based population samples from across the United States.

The EPA's Office of Pesticide Programs used NHANES 2003–2006 data to update the CSFII 1994–1996, 1998 study (as presented in EPA's 2002 *Estimated Per Capita Fish Consumption in the United States*). Summary statistics were developed for fish consumers only and on a per capita basis. Dietary rates were derived for finfish, shellfish, and finfish and shellfish combined (shown for consumers only in Table 18 and Figure 1 below). Two-day average dietary fish consumption rates were calculated for all respondents who provided dietary information for two days of the survey. If a respondent reported consuming fish on one of the two days of the survey, then their 2-day average would be half the amount reported for the one day of consumption.

The EPA 2011 *Exposure Factors Handbook* (U.S. EPA, 2011a, p. 10–16) qualifies the fish dietary estimates as follows:

> *…it should be noted that the distribution of average daily intake rates generated using short-term data (e.g., 2-day) does not necessarily reflect the long-term distribution of average daily intake rates. The distributions generated from short-term and long-term data will differ to the extent that each individual's intake varies from day to day…*
>
> *…Short-term consumption data may not accurately reflect long-term eating patterns and may under-represent infrequent consumers of a given fish species. This is particularly true for the tails (extremes) of the distribution of food intake.*

Table 18. General Population: Adult Respondents, Consumers Only, Based on NHANES 2003–2006, Using Standard Statistical Survey Methodology

Population	Species Group	Descriptive Statistics (g/day)				
		50th Percentile	Mean	75th Percentile	90th Percentile	95th Percentile
National Estimates from NHANES 2003–2006 (consumers only)	All Fish	37.9	56.0	78.8	128	168
	Finfish	34.6	49.9	68.9	115	150
	Shellfish	25.7	43.0	54.4	101	147

See Polissar et al., 2012. Estimates based on statistical methodology defining *fish consumers* as those who consumed fish on at least one of the two dietary recall days.

Ecology reevaluated the NHANES fish dietary data using the National Cancer Institute's (NCI) statistical methodology (Polissar et al., 2012). The NCI method estimates usual intake of episodically consumed foods by accounting for day-to-day variations (Tooze et al., 2006). The national dietary information (CSFII and NHANES) consists of two detailed 24-hour dietary recalls conducted for a large, randomly selected U.S. population. Although 24-hour dietary recall surveys capture detailed information on a person's food consumption, this dietary assessment method does not adequately measure the usual intake of foods that are not consumed nearly every day (i.e., episodically consumed foods such as fish). The NCI method uses statistical modeling to combine food frequency questionnaire data with 24-hour dietary recall data to project long-term food consumption estimates. Results are shown in Table 19 and Figure 2 below.

Table 19. General Population: Adult Respondents, Consumers Only, Based on NHANES 2003–2006, Using NCI Statistical Survey Methodology

Population	Species Group	Descriptive Statistics (g/day)				
		50th Percentile	Mean	75th Percentile	90th Percentile	95th Percentile
National Estimates from NHANES 2003–2006 (consumers only)	All Fish	12.7	18.8	24.8	43.3	56.6
	Finfish	9.0	14.0	18.1	31.8	43.3
	Shellfish	2.4	5.4	6.0	13.2	20.5

See Polissar et al., 2012. Estimates based on NCI statistical methodology (Tooze et al., 2006) that models two days of fish consumption from 24-hour episodic dietary recall and fish dietary information from the food frequency questionnaire.

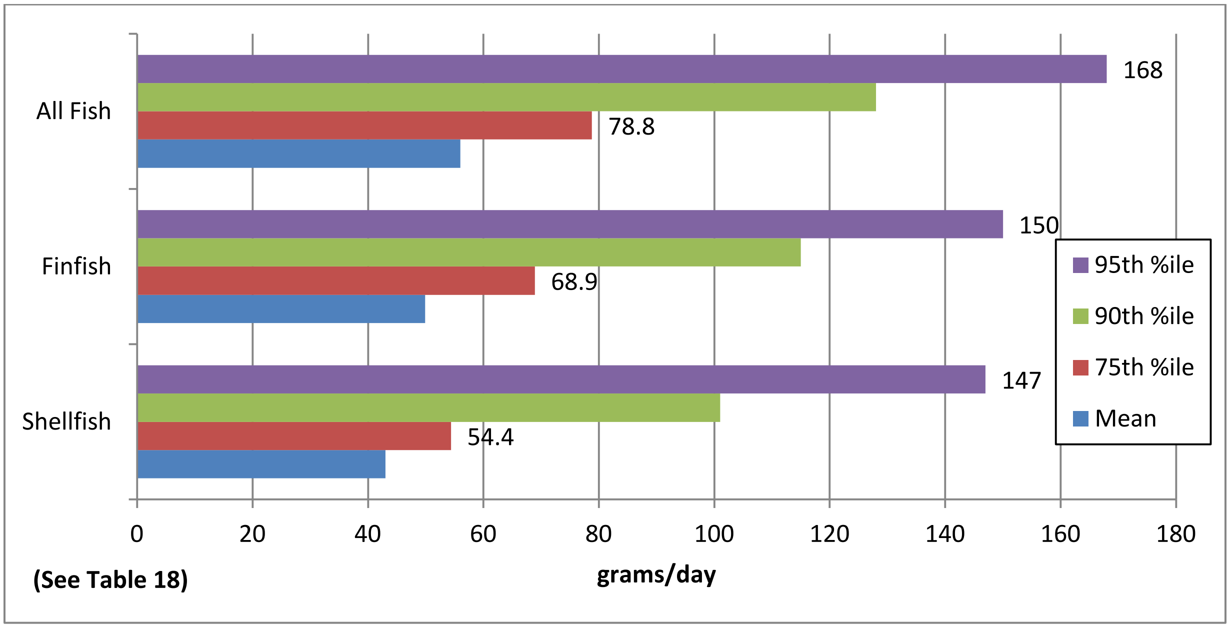

Figure 1. General Population Adult Fish Consumption Rates, Consumers Only, NHANES 2003–2006, Using Standard Statistical Survey Methodology

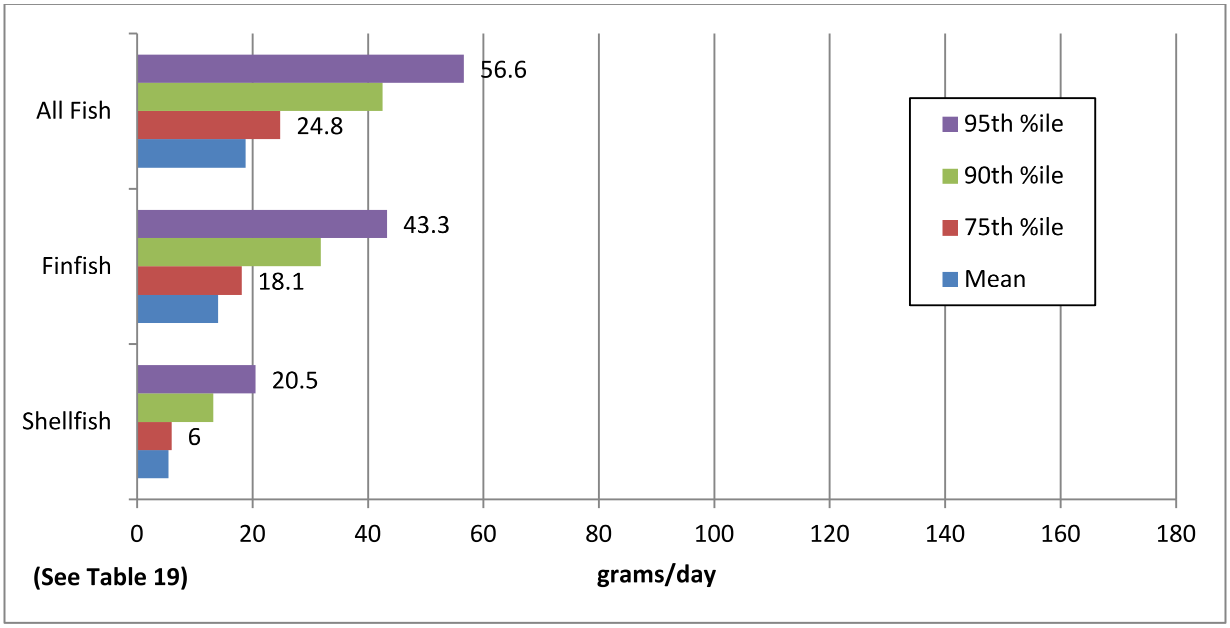

Figure 2. General Population Adult Fish Consumption Rates, Consumers Only, NHANES 2003–2006, Using NCI Statistical Survey Methodology

Technical defensibility

As summarized in Table 20 below, Ecology has determined that the national surveys of the general population are relevant to Washington and satisfy measures of technical defensibility.

Table 20. Technical Defensibility of National (General Population) Fish Dietary Information

Metric	Observations and Comments	Evaluation
1. Survey Method Development		
Description of survey vehicle	Survey methodology and analysis of survey data independently conducted by two federal agencies	Survey methodology, design and analysis described in detail; sample size very large to provide good dietary information for the general U.S. population
Description of sample population	Large sample size, randomly selected, and sample geographically representative of national general population	
2. Survey execution		
Survey method	Survey data based on recent 2-day dietary recall; data collected over short duration and independent collection periods	Nationwide survey with sample selection based on randomized selection; two non-consecutive-day recall supports development of per capita consumption estimates; high level of peer review on methodology design and execution
Bias	Good response rate (> 70%)	
Review and evaluations	Quality assurance/quality control (QA/QC) standards are high and documented	
Review and evaluations	National Center for Health Statistics	

Metric	Observations and Comments	Evaluation
3. Publication of results		
Where published and clear information	Published by USDA, EPA, and other agencies	Accessible through large number of venues and publications
Survey methodology	Two non-consecutive-day dietary recall	
Applicability for regulatory decision making		
Currency of information	CSFII 1994–1996 and 1998 2003–2006 NHANES	Suitable for average intake rates of general population; not intended to substitute for regional-specific fish dietary information [a]
Representative of target population	Representative of the general U.S. population	
4. Overall technical suitability for regulatory decision making		
Range of technical defensibility	Survey method designed to provide average intake rates for general populations	Not designed to capture long-term dietary intake
Appropriateness for use in risk-based standards	Designed to provide average dietary intake rates	Not a substitute for regional-specific dietary information

Sources: U.S. EPA, 2011a; USDA CSFII 1994–1996, 1998.

a. Study design may bias high upper percentile consumer only fish consumption estimate; however, use of national fish dietary information underestimates fish consumption estimates for areas with more fisheries and resources (i.e., Washington State).

4.3 Pacific Northwest Native American fish consumption data

As of the writing of this report, results of three tribal-specific finfish/shellfish dietary surveys of tribes along the Columbia River basin and in the Puget Sound area of Washington were available for review.

In addition, several technical publications provide information on tribal fish consumption (Harper et al., 2002, p. 513–526; Harris and Harper, 1997, 2001). These publications have been used to define a tribal reasonable maximum exposure (RME) for various regulatory decisions.[35]

Although these technical publications provide useful information for specific regulatory decisions, it is the published tribal fish consumption surveys that provide the relevant information on fish consumption. The surveys employed a well-defined, standardized, dietary survey methodology, data analysis, and reporting of results.

Tribal fish dietary surveys provide relevant fish dietary information for Washington State fish consumers because these surveys include: (1) respondents that are fish consumers from Washington State; (2) locally harvested and consumed finfish and shellfish; (3) well-defined, standardized, dietary survey methodology, data analysis, defined measures of quality assurance and quality control, and reporting of results; (4) close collaboration with and support from academia and state and federal health and resource agencies; (5) minimized recall bias in the

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[35] In Harper et al., 2002, Table 11, p. 521 notes 885 – 1,000 g/day for those with a high fish diet (fish consumers) and 175 g/day for shellfish consumption for fish consumers and non-consumers of fish.

surveys due to dietary and culturally based dependence on fish consumption; and (6) the well-supported assumption that *locally harvested fish* includes fish from large freshwater, estuarine, and marine water areas of Washington State because tribal reserved rights include harvesting fish and consuming fish from all watersheds throughout the state.

Ecology reviewed and analyzed the data from these surveys, looking specifically at species consumed and where the fish were obtained (Polissar et al., 2012). The fish dietary surveys provide credible information on the types and amounts of fish consumed by Native American populations in Washington State. Generally, the fish dietary surveys indicate that these populations consume large amounts of finfish and shellfish harvested from marine and freshwater environments throughout Washington.

This section describes the surveys, along with an evaluation of technical defensibility.

4.3.1 Columbia River Inter-Tribal Fish Commission survey: the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin

The Columbia River Inter-Tribal Fish Commission (CRITFC) surveyed fish consumption among four Native American tribes that reside along the Columbia River basin (CRITFC, 1994). The survey of adult tribal members who lived on or near the Yakama, Warm Springs, Umatilla, or Nez Perce Reservations was conducted during the fall and winter of 1991–1992.[36]

The survey identified individual tribal members’ consumption rates, habits, and food preparation methods for anadromous and resident fish species caught from the Columbia River basin. A random sampling was taken based on respondents selected from patient registration files of the Indian Health Service. The survey questionnaire included a 24-hour dietary recall and questions regarding seasonal and annual fish consumption. Food models were used to help respondents estimate the amounts of fish consumed.

Information obtained included age-specific fish consumption rates, the fish species and parts of the fish consumed, and the methods used to prepare the fish for consumption.

Personal interviews conducted on the four tribal reservations achieved an overall response rate of 69 percent from a sample size of 513 tribal members 18 years of age or older. Tribal adult respondents provided information for 204 children 5 years of age or younger. Since tribal population sizes were unequal, demographic weighting factors were applied to the pooled data in proportion to tribal population size, so that survey results would reflect the overall population of adult members of the four tribes. An unweighted analysis was performed for children, since the sample size was small. To derive consumption rates that represented the adult tribal population as a whole, the survey averaged the fish consumption for both consumers and non-consumers.

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[36] As noted in the survey, conducting interviews over this period of time biased the consumption estimates low because of low availability of fish to harvest during that seasonal period of time.

All interviews were conducted at tribal offices, which could potentially select against individuals with mobility problems. It is possible that tribal elders, who may be more likely to practice subsistence consumption, were omitted from the survey. Since adults answered questions regarding children's fish consumption, the adult respondents may have mistakenly answered questions as if they were providing their own survey responses. Selected outliers were removed from the datasets.

CRITFC consumption rates represent consumption from all sources. Salmon and steelhead were consumed by the largest number of adult respondents, followed by trout, lamprey, and smelt. A seasonal variation in fish consumption was observed, with the most fish consumed April through July. The mean fish consumption rate was 108 g/day. There was a large seasonal variation in fish consumption. The reported mean rate of consumption during the high months (April–July) was three times the mean rate of consumption in low months (November–February).

The mean fish consumption rate for all surveyed tribal adults (consumers and non-consumers) throughout the year was 58.7 g/day. Seven percent of survey respondents did not consume fish. Excluding non-consumers of fish, the mean fish consumption rate for surveyed tribal adult fish consumers was 63.2 g/day. The average consumption rate for children (5 years old and younger) was 24.8 g/day. About 83 percent of the 204 children consumed fish. The 99th percentile fish consumption rates of adults and children (5 and younger) who consume fish were 389 g/day and 162 g/day, respectively.

Reanalysis of the CRITFC survey report by Ecology provides estimates of anadromous, non-anadromous, all finfish consumption estimates, and source of harvest (Table 21, Figures 3 and 4). Slight variations between can be attributed to procedures used to estimate rates and percentiles (Polissar et al., 2012).

Table 21. CRITFC Adult Fish Consumption Rates by Species Group and Source, Consumers Only

Population Tribal	Species Group	Harvest Source of Fish	Descriptive Statistics (g/day)				
			50th Percentile	Mean	75th Percentile	90th Percentile	95th Percentile
The 4 Tribes Affiliated With The Columbia River Inter-Tribal Fish Commission	All finfish	all	40.5	63.2	64.8	130.0	194.0
	Non-anadromous	all	20.9	32.6	33.4	67.0	99.9
	Anadromous	all	19.6	30.6	31.4	63.1	94.1
	All finfish	Columbia River Basin	35.6	55.6	57.0	114	171
	Non-anadromous	Columbia River Basin	18.4	28.6	29.4	58.9	87.9
	Anadromous	Columbia River Basin	17.3	27.0	27.7	55.5	82.8

See Polissar et al., 2012, Table E-1.

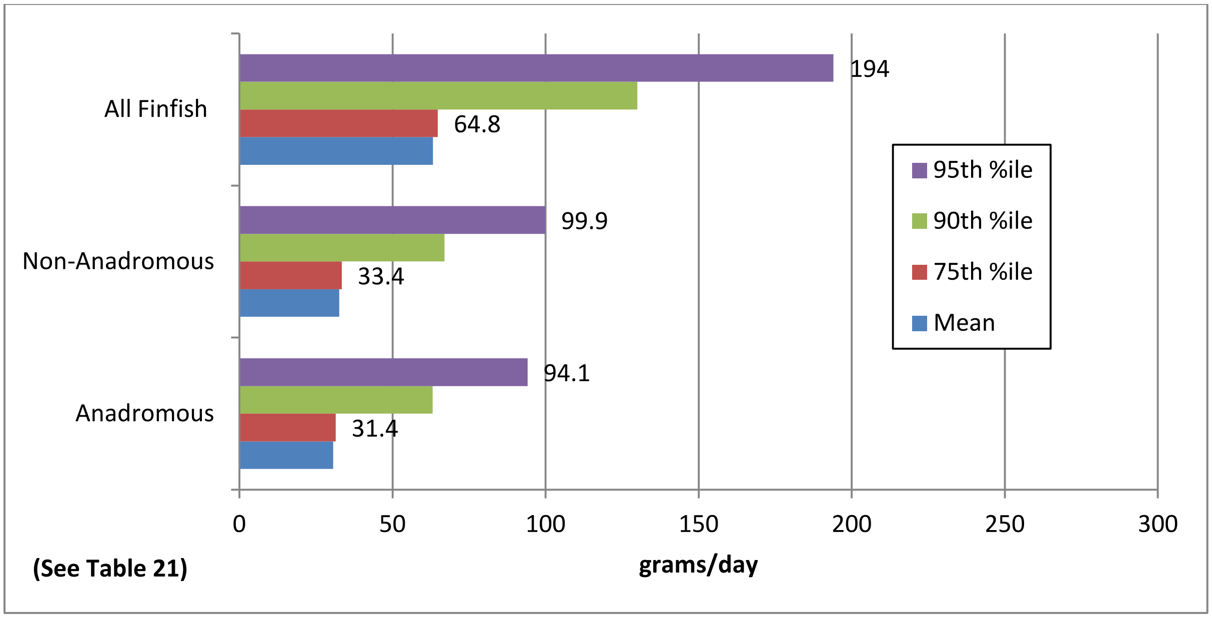


Figure 3. CRITFC Adult Fish Consumption Rates, Harvested from All Sources

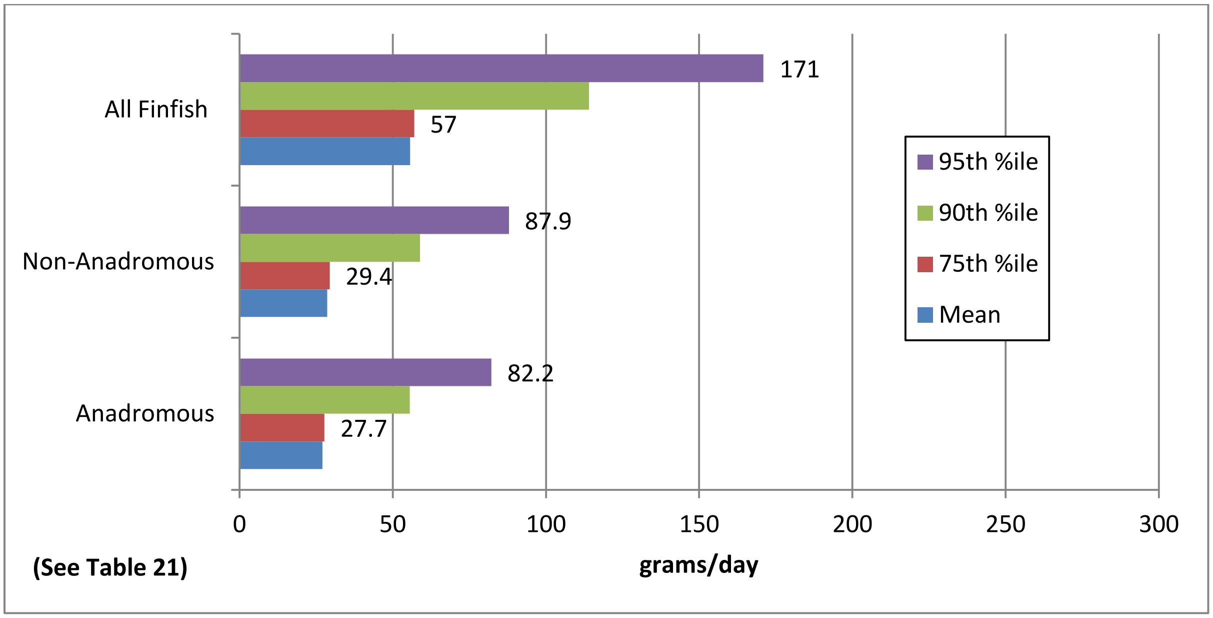


Figure 4. CRITFC Adult Fish Consumption Rates, Harvested from Columbia River Basin

Technical defensibility

As summarized in Table 22 below, Ecology has determined that the 1994 CRITFC survey is relevant to Washington and satisfies measures of technical defensibility.

Table 22. Columbia River Inter-Tribal Fish Commission Consumption Survey

Metric	Observations and Comments	Evaluation
1. Survey Method Development		
a. Type and description of survey vehicle	24-hour and seasonal dietary recall personal interview survey; respondents were randomly selected from Indian Health Service records; a large range of fish was considered in the survey (salmon, lamprey, smelt.)	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	CRITFC staff developed the survey in collaboration with Washington DOH, EPA HQ & Region 10 staff, Indian Health Service staff; it was reviewed by tribal governments of the CRITFC member tribes (Nez Perce Tribe, Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Warm Springs and Umatilla Indian Reservations).	
c. Beta testing	The survey was tested by tribal staff in consultation with EPA.	
2. Survey execution		
a. Establish and document execution standards	Execution of survey vehicle by native population documented; data gathered on adult respondents 18 years or older and children 5 years or younger.	The survey vehicle was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Native staff trained personnel in collaboration with and with technical oversight provided by state/federal agencies.	
c. Finish/shellfish models used	Fish models were employed to aid in identifying the amount of finfish and shellfish consumed.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Results were published in a CRITFC tribal government publication. The population surveyed, method used, conclusions, and tabulations were well-defined, presented, and documented. The highest fish consumers were considered outliers and were dropped from the survey data and, therefore, were not statistically evaluated.	The data presented are sufficient to develop consumption distributions with percentiles.
b. Methodology reported	The methodology used is clearly described and documented.	
c. Results tabulated and stated	Survey results are reported and summarized in a tabular format suitable for distributional descriptive statistics; the report documents an acceptable response rate (69%).	
d. Conclusions clearly reported	Conclusions are stated and correspond to data tabulated.	
e. Variability and uncertainty	Variability and uncertainty were qualitatively recognized and noted.	
f. How is the potential for bias addressed?	Different types of bias were identified and discussed in the survey.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	The survey provides a reasonable estimate of fish consumption for CRITFC member Native populations within the Columbia River Basin (Nez Perce Tribe, Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Warm Springs & Umatilla Indian Reservations).	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making. Rigorous
b. Currency of information	Surveys were conducted in the early to mid-1990s; more recently, the CRITFC estimates were used by Oregon DEQ for developing water quality standards (2011).	

Metric	Observations and Comments	Evaluation
c. Sufficiency of data	The fish consumption estimates are sufficient to provide descriptive statistics for defined distributions and percentiles for risk-based decision making. However, it is unclear what portion of seafood consumed is harvested from local sources. CRITFC fish consumption rates are for seafood from all sources and include anadromous (migratory) species.	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Survey design, development of methodology, execution of survey, data interpretation, and conclusions for fish consumption provide a reasonable quantitative exposure estimate of fish consumption rates for target populations.	Ecology concludes survey is technically defensible.
b. Appropriateness for use in risk-based standards	The data are sufficient to provide distribution, average, and percentile estimates of fish consumption as required for risk-based decision making.	

Source: CRITFC, 1994.

The CRITFC fish dietary survey was one of the first tribal dietary surveys conducted in the Pacific Northwest. The technical rigor applied to the design and conduct of this survey has been mirrored by other regional-specific surveys conducted in Washington State. The March 19, 2012, correspondence from Babtist Paul Lumley, Executive Director of CRITFC, to Ted Sturdevant, Director, Washington State Department of Ecology, summarizes the efforts that support the scientific defensibility of the CRITFC fish dietary survey (CRITFC, 2012). As described in this correspondence, the salient features of the 1994 CRITFC survey design and analysis are provided below:

- A technical panel was established to assist in designing and implementing the survey. The panel consisted of 17 members and included technical staff from CRITFC, as well as toxicologists, epidemiologists, health scientists, and environmental scientists from the Indian Health Service (IHS), the Centers for Disease Control and Prevention (CDC), Washington and Oregon State health departments, EPA Region 10, and EPA Headquarters.
- During a three-day session, the CDC trained interviewers and instructed them in procedures and techniques for conducting surveys. The instructors reviewed each question on the questionnaire with the interviewers and helped them practice conducting interviews. Models of finfish and shellfish were used as visual aids to help identify types and amounts of fish consumed.
- A total of 513 tribal members at least 18 years old were directly surveyed. These respondents provided information for 204 children age 5 or younger (one child per household). The CDC used a systematic probability sampling method to randomly select respondents from Indian Health Service client lists of tribal members. Stratified systematic sampling was used to collect survey data, with each of the four tribes considered an independent stratum.

- Survey data were transferred from the questionnaires to an electronic database, and all data entries were reviewed for missing answers or mistakes. The CDC's statistical database package for analysis of epidemiological data was used to analyze the survey data. A private consulting firm conducted a second complete audit of the database, which involved a question-by-question review of each survey. Appropriate statistical tests were used to evaluate the data. The Shapiro-Wilk test was used because the sample size was less than 2,000 and indicated that the dataset was not a purely random distribution, but rather reflected meaningful trends. In the 1994 CRITFC analysis, outliers whose data points seemed unreasonably high due to discontinuity in distribution were ignored on all calculations. For highly positively skewed distributions, removing statistical outliers from the dataset may bias the upper percentile fish consumption estimates low.
- The study design, implementation strategy, and analyses were submitted to an independent peer review panel. The peer review panel consisted of the following members: Dr. Patrick West, Ph.D., University of Michigan; Dr. Douglas Robeson, Ph.D., Ottawa, Ontario; Dr. Clayton Stunkard, Silver Spring, MD; Dr. H. Joseph Sekerke, Jr., State of Florida Department of Health and Rehabilitation Services; Dr. Mary Yoshiko Hama, Ph.D., U.S. Department of Agriculture, Food Consumption Research Branch; Dr. Kenneth Rudo, Ph.D., State of North Carolina, Department of Environmental Health, Division of Epidemiology; Dr. Yasmin Cypel, Ph.D., U.S. Department of Agriculture, Food Consumption Research Branch; Dr. Rolf Hartung, Ph.D., Department of Environmental and Industrial Health, University of Michigan; and Dr. Dale Hattis, Ph.D., Clark University.
- The CRITFC survey design's credibility is further supported by its use as a template for other Pacific Northwest dietary surveys, with refinements specific for the populations being surveyed. In addition, the CRITFC survey has been referred to in national guidance for policies and procedures for evaluating exposures (EPA's Exposure Factors Handbook 2009 Update and 2011 Edition).

Additional information reviewed

- Harris and Harper (1997) report that a fish consumption rate of 540 g/day represents a reasonable subsistence fish consumption rate for CRITFC's member tribes who pursue a traditional lifestyle. They base this on their review of several nonsubsistence Native American studies, two subsistence studies, and personal interviews of members of the Umatilla and Yakama Tribes.
- A further examination of Columbia River basin tribal populations used information and data collected from the 1994 Columbia River Inter-Tribal Fish Commission's fish consumption survey (Sun Rhodes, 2006). Because of concerns due to chemical contaminants in water and fish for tribal fish-consuming populations along the Columbia River basin, the tribal populations' characteristics were examined for children, women of

child-bearing age, and tribal elders who may be susceptible to adverse health effects from exposure to contaminants due to high fish consumption. A multivariate analysis showed a positive association between fish consumption rates and factors including breastfeeding after the most recent births, percent of fish obtained non-commercially for women who recently gave birth, living off the reservation, and fish consumption for children and the elderly. About 50 percent of women, 80 percent of tribal elders, and at least 40 percent of children consume nonfillet fish parts. Although this reevaluation did not result in any changes or corrections in Columbia River basin tribal consumption rates, it provided additional information regarding susceptible tribal populations that consume fish.

4.3.2 Tulalip and Squaxin Island Tribes of the Puget Sound Region

A survey of finfish and shellfish consumption for the Tulalip and Squaxin Island Tribes living in the Puget Sound region was conducted in 1994 (Toy et al., 1996).

The target populations included adult tribal members (18 years or older), randomly selected from tribal enrollments who lived on or within a 50-mile radius of the reservation, and children aged 5 years or younger who lived in the enrolled member’s household. The survey reported consumption rates of anadromous, pelagic, bottomfish, and shellfish in grams per kilogram body weight per day (g/kg bw/day) over a 1-year period and the portion size of each meal. Adults who did not consume fish (less than 1 percent of those contacted) were not included in the survey. Finfish/shellfish models were used to estimate portion sizes. Finfish/shellfish preparation methods were identified, and sources of finfish and shellfish consumed were reported by tribe and species groups.

Species groups included:

- *Anadromous fish (Group A)*. Salmon (Chinook, pink, sockeye, coho, chum); smelt; steelhead.
- *Pelagic fish (Group B)*. Cod, dogfish, greenling, herring, perch, pollock, rockfish, sablefish, spiny.
- *Bottomfish (Group C)*. Halibut, sole/flounder, sturgeon.
- *Shellfish (Group D)*. Butter clam, clams (manila/littleneck), cockles, Dungeness crab, horse clam, moon snail, mussels, oyster, scallops, sea cucumber, sea urchin, shrimp, squid.
- *Other (Groups E and F)*. Abalone, barnacles, bullhead, chitons, crayfish, eel, geoduck, grunters, limpets, lobster, mackerel, manta ray, octopus, razor clam, shark, skate, trout.

A total of 190 successful interviews were completed from February 25 through mid-May for adult tribal respondents. A tribal parent or guardian answered questions about the fish consumption for children from the same household. Only one child per household, selected randomly, was included in the survey, for a total of 69 children. Results from half of the adult respondents in the Tulalip Tribes were dropped because one of the tribal interviewers did not follow the survey interview protocol. However, repeat interviews were conducted by telephone as a follow-up with 10 percent of the survey respondents. The timing of the survey period may bias the fish consumption estimates. Salmon are present in Puget Sound during different times of the year. The survey was administered during a low season for anadromous (salmon) fish harvest but prior to and during the shellfish harvest season. Because of the timing of the survey, respondents may have underestimated their salmon consumption and overestimated shellfish consumption.

Anadromous finfish and shellfish were most frequently consumed. The main source for the most frequently consumed fish (anadromous finfish and shellfish) was local water bodies of Puget Sound. Fish fillets with skin were consumed by up to 40 percent of the tribal respondents, with mean percent consumption of fish parts (head, bones, eggs, organs, and skin) for up to 11 percent of tribal respondents consuming anadromous fish. Although the survey identified fish parts consumed by respondents, it did not include complex tribal seafood recipes.

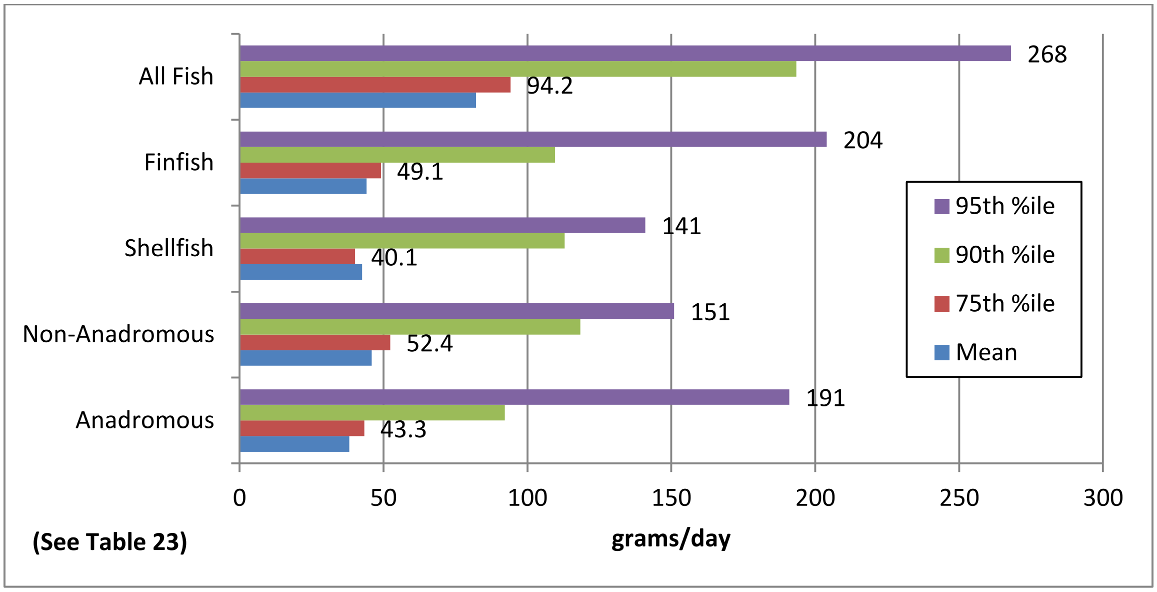
Weight adjusted consumption rates were calculated and reported by tribe, age, gender, income, and species group. The adult mean and median consumption rates for all forms of fish combined were 0.89 and 0.55 g/kg bw/day for the Tulalip Tribes and 0.89 and 0.52 g/kg bw/day for the Squaxin Island Tribe, respectively. Age-adjusted median fish consumption rates for the Tulalip Tribes were 53 g/day for males and 34 g/day for females. Age adjusted median fish consumption rates for the Squaxin Island Tribe were 66 g/day for males and 25 g/day for females. The mean and median consumption rate for children, 5 years and younger for both tribes combined, were 0.53 and 0.17 g/kg bw/day, respectively.

Ecology’s statistical analysis of the Tulalip survey data (individual level respondent data) provides estimates of anadromous, non-anadromous, shellfish, all finfish/shellfish consumption estimates, and source of harvest (Table 23, Figures 5 and 6).

Table 23. Tulalip Tribal Adult Fish Consumption Rates by Species Group and Source

Population Tribal	Species Group	Harvest Source of Fish	Descriptive Statistics (g/day)				
			50th Percentile	Mean	75th Percentile	90th Percentile	95th Percentile
Tulalip	All Fish	All Sources	44.5	82.2	94.2	193	268
	Finfish	All Sources	22.3	44.1	49.1	110	204
	Shellfish	All Sources	15.4	42.6	40.1	113	141
	Non-anadromous	All Sources	20.1	45.9	52.4	118	151
	Anadromous	All Sources	16.8	38.1	43.3	92.1	191
	All	Puget Sound	29.9	59.5	75.0	139	237
	Finfish	Puget Sound	13.0	31.9	33.1	78.4	146
	Shellfish	Puget Sound	14.2	36.9	40.1	111	148
	Non-anadromous	Puget Sound	14.8	35.5	38.8	109	145
	Anadromous	Puget Sound	11.8	30.4	32.4	66.0	148

See Polissar et al., 2012, Table E-1.



(See Table 23)

Figure 5. Tulalip Tribal Adult Fish Consumption Rates, Harvested from All Sources

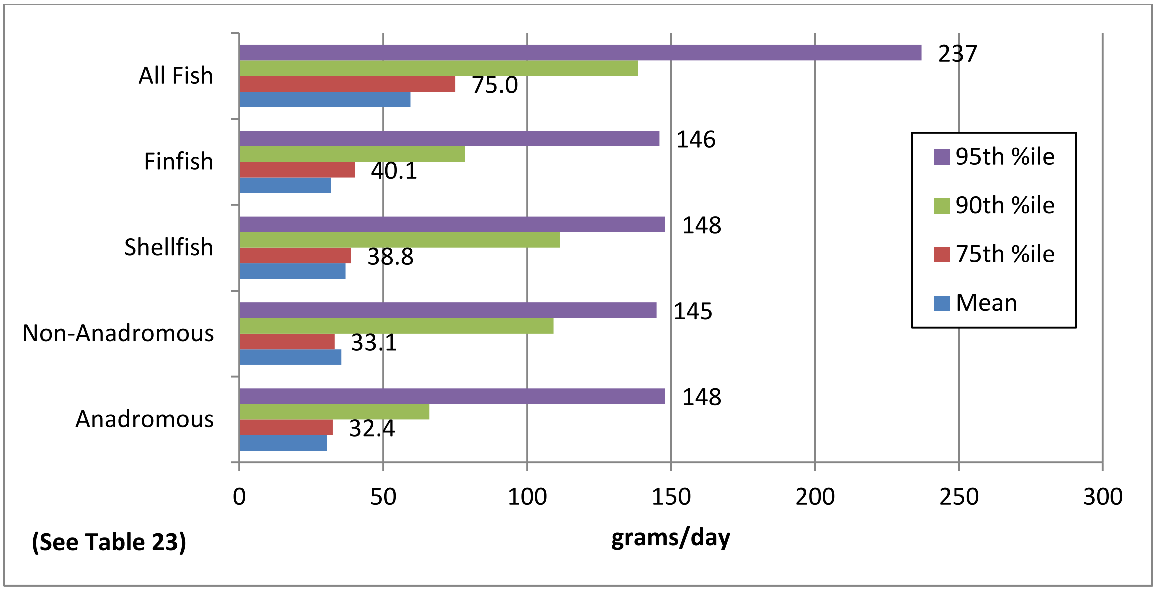


Figure 6. Tulalip Tribal Adult Fish Consumption Rates, Harvested from Puget Sound

Ecology's statistical analysis of the Squaxin Island survey data provides consumption estimates for anadromous, non-anadromous, shellfish, and all finfish/shellfish, and data on source of harvest (Table 24, Figures 7 and 8). Consumption rate estimates for the Squaxin Island adult fish consumers are based on published results of the fish dietary survey.

Table 24. Squaxin Island Tribal Adult Fish Consumption Rates by Species Group and Source

Population Tribal	Species Group	Harvest Source of Fish	Descriptive Statistics (g/day)				
			50th Percentile	Mean	75th Percentile	90th Percentile	95th Percentile
Squaxin Island	All fish	All	44.5	83.7	94.4	206	280
	Finfish	All	31.4	65.5	82.3	150	208
	Shellfish	All	10.3	23.1	23.9	54.0	83.6
	Non-anadromous	All	15.2	28.7	32.3	70.5	95.9
	Anadromous	All	25.3	55.1	65.8	128	171
	All fish	Puget Sound	30.0	56.4	63.5	139	189
	Finfish	Puget Sound	21.6	45.0	56.5	103	143
	Shellfish	Puget Sound	6.4	14.3	14.8	33.5	51.9
	Non-anadromous	Puget Sound	6.5	12.3	13.9	30.3	41.2
	Anadromous	Puget Sound	20.2	44.1	52.6	103	137

See Polissar et al., 2012, Table E-1.

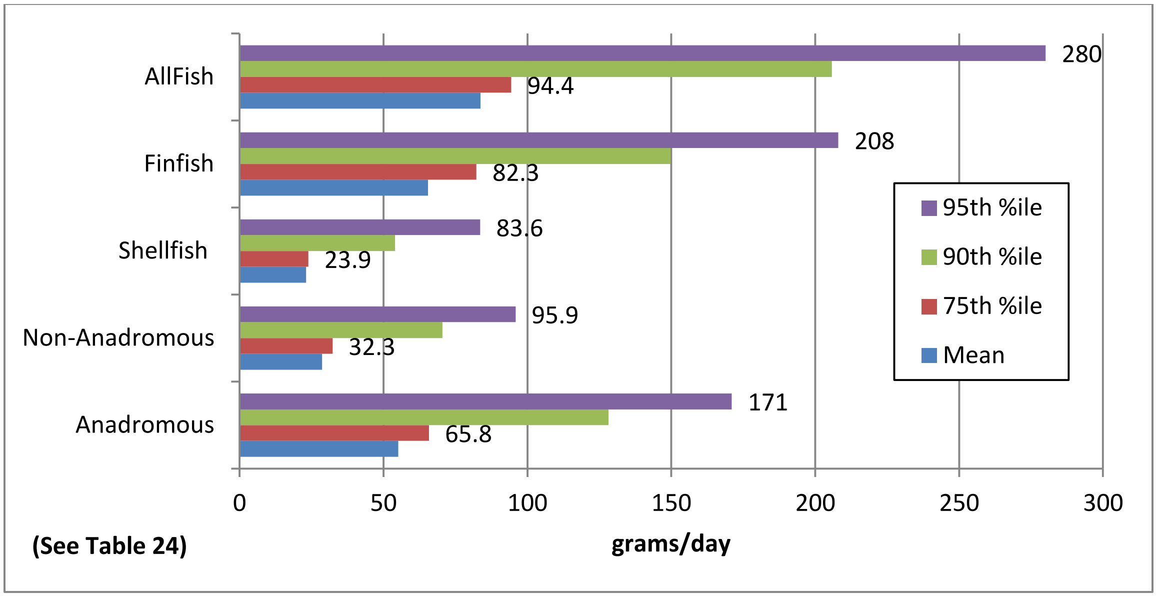


Figure 7. Squaxin Island Tribal Adult Fish Consumption Rates, Harvested from All Sources

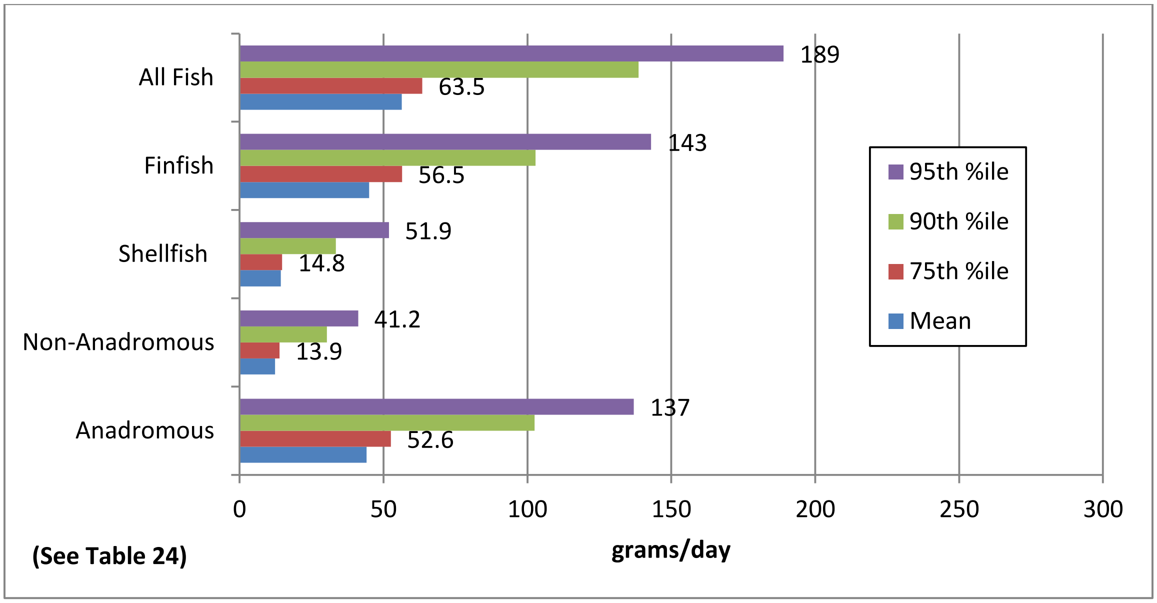


Figure 8. Squaxin Island Tribal Adult Fish Consumption Rates, Harvested from Puget Sound

Technical defensibility

As summarized in Table 25 below, Ecology has determined that the survey of Tulalip and Squaxin Island Tribes of the Puget Sound Region is relevant to Washington and satisfies measures of technically defensibility (Toy et al., 1996).

Table 25. Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region

Metric	Observations and Comments	Evaluation
1. Survey method development		
a. Type and description of survey vehicle	Personal interview survey; 24-hour and seasonal dietary recall; finfish/shellfish identification, portion, frequency, preparation, and harvest locations.	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	Survey was developed in collaboration with Washington DOH, Ecology, EPA Region 10, Tulalip Tribal Department of Environment, Suquamish Tribal Fisheries Department, Board of Directors for Tulalip and Squaxin Island Tribes, Columbia River Inter-Tribal Fish Commission, and Fred Hutchinson Cancer Research Center in Seattle.	
c. Beta testing	Pilot survey and repeat interviews conducted	
2. Survey execution		
a. Establish and document execution standards	Execution of survey questionnaire documented with identifiable QA/QC procedures.	The survey vehicle was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Two members from each tribe trained to conduct interviews.	
c. Finfish/shellfish models used	Finfish and shellfish models used for multiple species.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Finfish/shellfish identification, portion, frequency, preparation, and harvest locations documented and reported.	The data presented in the joint Tulalip and Squaxin Island tribal publication are sufficient to develop consumption distributions with percentiles.
b. Methodology reported	All phases of method development documented and reported.	
c. Results tabulated and stated	Tabulated species-specific consumption with descriptive statistics.	
d. Conclusions clearly reported	Conclusions reported with follow-up interviews for reliability and representation	
f. Variability and uncertainty	Noted and documented with note of “outliers” with reported rates for Tulalip and Squaxin Island Tribes.	
g. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed. Survey results from one interview did not follow protocol and were eliminated.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	Included range of different rates for enrolled Tulalip and Squaxin Island tribal members	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making.
b. Currency of information	Survey conducted in 1996; more recently the consumption estimates were used by Oregon DEQ in developing water quality standards (2011). EPA Region 10 has also utilized the Suquamish survey in its internal policy on assessing tribal seafood consumption risks.	
c. Sufficiency of data	The data are sufficient to provide distribution and percentile estimates of fish consumption for Tulalip and Squaxin Island tribal populations.	

Metric	Observations and Comments	Evaluation
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Technically defensible dietary survey of the Squaxin Island Tribe.	Ecology concludes the survey is technically defensible.
b. Appropriateness for use in risk-based standards	Data were reanalyzed by Nayak L. Polissar, Ph.D., to provide consumer-only consumption rates. It is sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making.	

Source: Toy et al., 1996.

The technical rigor applied to the design and conduct of the Tulalip and Squaxin Island tribal fish dietary survey illustrates a high level of collaboration across state and federal agencies and tribal governments, and closely parallels the CRITFC fish dietary survey. The salient features of this survey are noted below:

- A Technical Advisory Panel was formed to provide assistance and oversight for planning, developing methods, and conducting the dietary survey. Panelists included numerous professionals from the Washington State Departments of Health and Ecology, U.S. Environmental Protection Agency, and the U.S. Public Health Service.
- Tulalip and Squaxin Island tribal staff assisted with organizing and executing the survey. They also provided tribal consultations with other tribal governments and organizations including the Columbia River Inter-Tribal Fish Commission, Portland, Oregon.
- A toxicologist, epidemiologist, tribal biologists, and statistical consultants provided professional guidance and consultations.

4.3.3 Suquamish Tribe

The Suquamish Tribal Council conducted a fish consumption survey during July, August, and September 1998 of Suquamish tribal members living on and near the Port Madison Indian reservation in the Puget Sound area (The Suquamish Tribe, 2000). The survey was conducted to determine the finfish/shellfish consumption rates, habits, and patterns of the Suquamish Tribe. Also, the study was conducted to identify fish consumption-related cultural practices and tribal characteristics that might affect fish consumption rates, patterns, and habits. The survey was administered during months of high availability of fisheries, which may have had a positive bias on the reported fish consumption estimates.

Consumption data were based on a random sample of adults (16 years and older) selected from the tribal enrollment roster. Of 425 tribal members of all ages living on or near the reservation, 284 adults were identified as eligible to participate in the survey. Of these, 142 adults were randomly selected and 92 participated in the survey, for a 64.8 percent participation rate. Consumption data were collected for 31 children under the age of 6 who were living in the same household with adult respondents at the time of the survey. Some households had more than one child who was surveyed. The survey questionnaire was administered by trained tribal members using personal interviews and included two parts: a 24-hour dietary recall, and an assessment of fish consumption over the course of a year.[37] In addition, the survey included information on:

- Fish species identification, portion sizes, frequency of consumption, methods of preparation, harvest locations.
- Shellfish consumption, methods of preparation, harvest location.
- Changes in consumption over time, cultural information, physical information, and socioeconomic information.

Finfish/shellfish models were used to assist tribal respondents regarding amounts and types consumed. Booklets were used to assist in identifying harvest locations of seafood consumed. Finfish/shellfish were grouped into categories based on similarities in life history and practices of tribal members who fish for subsistence, ceremonial, and commercial purposes. The majority of finfish/shellfish consumed by the Suquamish Tribe was harvested from Puget Sound, with Pacific salmon and shellfish consumed more than other fish.

All 92 adult tribal respondents reported consuming some type of fish; hence, no non-consumers of fish were surveyed. Survey results were recorded as grams per kilogram per day (g/kg/day) along with the respondent’s body weight. Adult respondents reported a mean consumption rate of all finfish and shellfish consumption rate of 2.71 g/kg/day. For children under 6 years old, the mean consumption of all finfish and shellfish was 1.48 g/kg/day. Below are weight-adjusted survey results for Suquamish adult fish consumers.

Ecology’s statistical analysis of the Suquamish dietary data for Suquamish tribal adult fish consumers provides finfish, shellfish, and non-anadromous consumption rates by species groups and sources of fish consumed (Table 26, Figures 9 and 10).

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[37] Estimates of maximum amounts of fish consumed, either as a rate or portion size, from a highly positively skewed dataset can be very large with estimates of several pounds of fish consumed. These maximum fish consumption estimates reflect the maximum amount of fish consumed by a subset of fish consumers within a larger indigenous fish-consuming population. Harper, Harris, and Donatuto have indicated that these very high fish consumers are true subsistence populations (fish consumption rate exceeding 454 g/day or 1 pound/day) within the larger indigenous fish-consuming populations (Harris and Harper, 1997; Harper and Harris, 2008; Donatuto and Harper, 2008).

Table 26. Suquamish Tribal Adult Fish Consumption Rates by Species Group and Source

Population Tribal	Species Group	Harvest Source of Fish	Descriptive Statistics (g/day)				
			50th Percentile	Mean	75th Percentile	90th Percentile	95th Percentile
Suquamish Tribe	All	All Sources	132	214	284	489	797
	Shellfish	All Sources	64.7	134	145	363	615
	Non-anadromous*	All Sources	102	169	219	377	615
	Anadromous	All Sources	27.6	48.8	79.1	133	172
	All	Puget Sound	57.5	165	221	397	767
	Shellfish	Puget Sound	52.4	109	118	294	499
	Non-anadromous*	Puget Sound	49.1	126	116	380	674
	Anadromous	Puget Sound	21.8	38.6	62.5	105	136

See Polissar et al., 2012

*Based on an assumed n = 90 consumers.

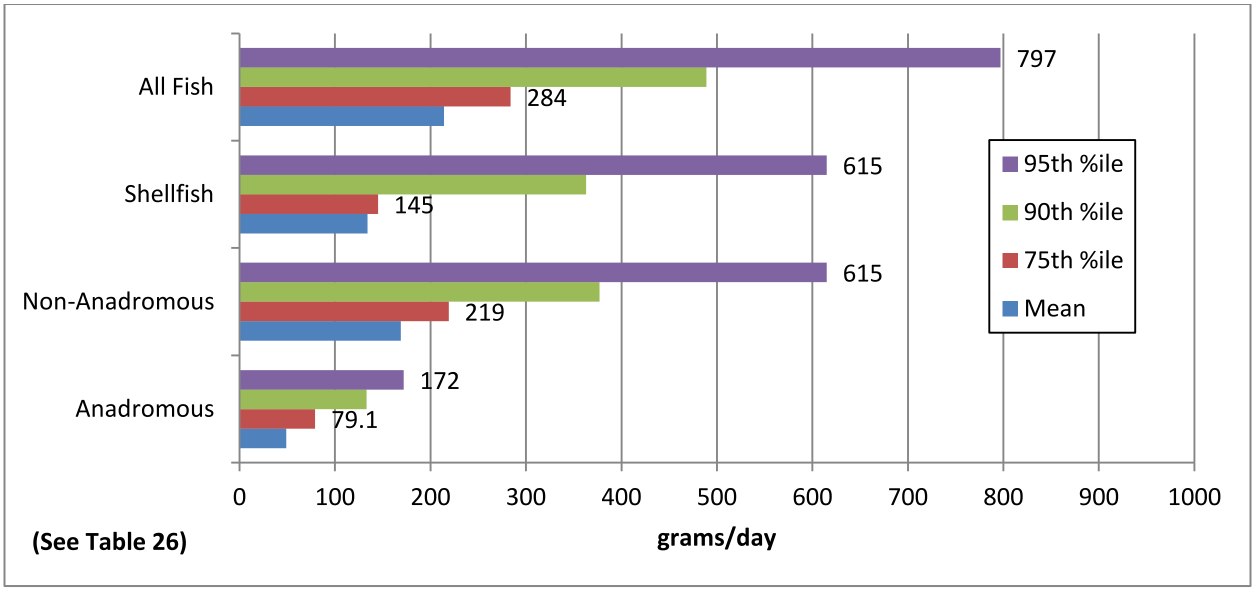

Figure 9. Suquamish Tribal Adult Fish Consumption Rates, Harvested from All Sources

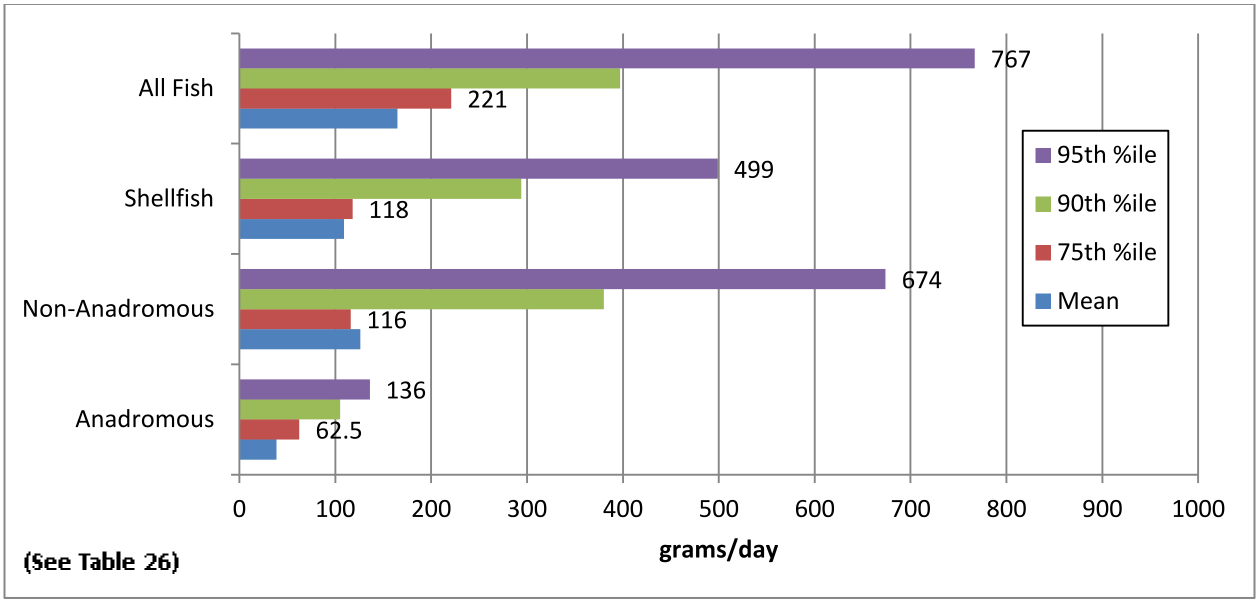

Figure 10. Suquamish Tribal Adult Fish Consumption Rates, Harvested from Puget Sound

Technical defensibility

As summarized in Table 27 below, Ecology has determined that the 2000 survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations of Puget Sound is relevant to Washington and satisfies measures of technical defensibility.

Table 27. Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region

Metric	Observations and Comments	Evaluation
1. Survey method development		
a. Type and description of survey vehicle	Personal interview survey; 24-hour and seasonal dietary recall; finfish/shellfish identification, portion, frequency, preparation, and harvest locations.	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	Survey was developed in collaboration with Washington DOH, Ecology, Agency for Toxic Substances and Disease Registry, University of Washington, EPA Region 10, and Suquamish Tribal Fisheries Department.	
c. Beta testing	Beta testing documented.	
2. Survey execution		
a. Establish and document execution standards	Execution of survey questionnaire documented with identifiable QA/QC procedures.	The survey vehicle was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Training of personnel was conducted by trained Suquamish Tribe members.	
c. Finfish/shellfish models used	Seafood models and a display booklet of seafood illustrations for multiple species were used to aid in identifying the amount of seafood consumed.	

Metric	Observations and Comments	Evaluation
3. Publication of results		
a. Where were results published? Are they clear and complete?	Finfish/shellfish identification, portion, frequency, preparation, and harvest locations were documented and reported.	Suquamish Tribe publication with well-defined method, analysis of species consumed, clear data analysis and interpretation.
b. Methodology reported	The methodology used is clearly described and documented.	
c. Results tabulated and stated	Survey results are reported and summarized in a tabular format suitable for distributional descriptive statistics.	
d. Conclusions clearly reported	Conclusion reported with follow-up interviews for reliability and representation.	
e. Variability and uncertainty	Noted and documented with “outliers” identified and determined impact of outliers on consumption rate statistics of interest.	
f. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	Included range of different rates for enrolled Suquamish Tribe members.	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making.
b. Currency of information	The survey was conducted in 1999; more recently, the consumption estimates were used by Oregon DEQ for developing water quality standards (2011).	
c. Sufficiency of data	The fish-consumption estimates are sufficient to provide descriptive statistics for defined distributions and percentiles for Suquamish Tribal population. EPA Region 10 has also utilized the Suquamish survey information in its internal policy on assessing tribal seafood consumption risks.	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Technically defensible dietary survey of the Suquamish Tribe.	The survey is technically defensible with rates and portion sizes reinforced by independent technical documentation (Harper and Harris, 1997, 2008; Donatuto and Harper, 2008).
b. Appropriateness for use in risk-based standards	The data are sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making. Seafood consumption data provided are for consumption of seafood from all sources. EPA Region 10's tribal seafood consumption framework provides an approach for developing consumption rates of regionally harvested seafood.	

Source: The Suquamish Tribe, 2000.

Many features of the Suquamish tribal member dietary survey are similar to and reflect the experience gained during the development and conduct of the CRITFC dietary survey. These features were identified and described in the survey report, which confers and supports the technical defensibility of the study design, dietary methodology, execution of the survey, and results and conclusions drawn from the dietary survey (The Suquamish Tribe, 2000). The salient features of the technical review procedures for the Suquamish dietary review are noted below:

- The survey was funded through the Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Department of Health and Human Services, and Washington State Department of Health with collaboration regarding the survey questionnaire design to elicit useful dietary information from tribal respondents.
- Technical review and oversight of the planning, design, execution, and evaluation of the data included biologists, epidemiologists, toxicologists, and statisticians from multiple agencies.
- The Suquamish Tribal staff included interviewers, biologists, and a principle investigator.
- Technical collaboration, consultations, and reviews were conducted by the Washington Departments of Ecology and Health, University of Washington, U.S. Department of Health and Human Services, Fred Hutchinson Cancer Research Institute, and the U.S. Environmental Protection Agency.
- Data analysis and review were conducted by two Seattle statistical consulting firms, Mountain-Whisper-Light Statistics and StatPro Consultants.

4.4 Asian and Pacific Islanders

An Asian and Pacific Islander (API) seafood consumption study was conducted during the spring and summer of 1997 in King County, Washington, to obtain information on consumption rates, species and seafood parts consumed, and preparation methods for first- or second-generation members of the API community (Sechena et al., 1999). Survey participants were API seafood consumers 18 years or older. The study was conducted in three phases:

- *Phase I:* Identify target API ethnic groups and develop appropriate questionnaires in the language required to administer the questionnaire to each API ethnic group.
- *Phase II:* Characterize seafood consumption for 10 API ethnic groups within the King County study area.[38]
- *Phase III:* Develop culturally appropriate health messages on risks related to seafood consumption and disseminate to API community.

Of the 202 respondents, 89 percent were first API generation (born outside the United States). API participants were interviewed by trained representatives from each of the 10 API ethnic communities represented and asked to report on the number of annual servings and portion size of the servings. Participants reported their own body weights. Fish consumption rate results were reported as grams per kilogram per day. Because the survey was based on dietary recall, the authors selected 20 API respondents to interview a second time, to assess the reliability of the

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[38] The 10 API ethnic groups are Cambodian, Chinese, Filipino, Hmong, Japanese, Korean, Laotian, Mien, Samoan, and Vietnamese.

responses. The results suggest that the estimated consumption rates are reliable for the API community study area.

Table 28 provides the weight-adjusted survey results for API adult fish consumers.

Table 28. Adult Respondents to the Asian and Pacific Islander Survey

	Number of Adults Surveyed	Descriptive Statistics (g/day)					
		Mean	Median	Percentiles			
				75th	90th	95th	99th
Asian and Pacific Islanders	202	117	78	139	236	306	-

Source: Adapted from Oregon DEQ, 2008, Table 3. See also Polissar et al., 2012; Sechena et al.,1999, 2003.

Survey results indicate that shellfish were consumed more by the API community than any other group of fish. More than 75 percent of the respondents consumed shrimp, crab, and squid. Salmon and tuna were the most frequently consumed finfish. For all fish groups, 79 to 97 percent of the seafood consumed came from either groceries/street vendors or restaurants. Japanese consume a greater percentage of finfish than shellfish (52 percent), while Vietnamese consume more shellfish (50 percent). The mean and median consumption rates for all seafood combined for the 10 API ethnic groups were 1.9 g/kg bw/day and 1.4 g/kg bw/day, respectively. The average shellfish consumption rate for the API community was 0.87 g/kg bw/day. The API community consumed more shellfish than all of the combined categories of finfish consumed (average finfish consumption is 0.82 g/kg bw/day).

Technical defensibility

As summarized in Table 29 below, Ecology has determined that the 1999 survey of King County Asian and Pacific Islanders is relevant to Washington and satisfies measures of technical defensibility. The King County, Washington, API fish consumption survey is considered an outstanding model (gold standard) for culturally sensitive fish dietary surveys.

The fish dietary survey was administered in two phases:

- *Phase 1:* Identification of appropriate API ethnic groups to survey, design culturally sensitive fish dietary survey questionnaire, and then translate and pilot test the questionnaire for each API ethnic group.
- *Phase 2:* Established partnership between the Refugee Federation Service Center and the University of Washington's Environmental Health Department to help support the University of Washington Human Subjects Committee for the design, survey instruments, and execution of the survey.

Table 29. Asian and Pacific Islander Seafood Consumption Study

Metric	Observations and Comments	Evaluation
1. Survey method development		
a. Type and description of survey vehicle	Personal interview survey; 24-hour dietary recall; conducted in three phases.	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	Survey was developed in collaboration with a Community Steering Committee (representatives of the API community, Washington DOH, Ecology, EPA Region 10, University of Washington, and Seattle Refugee Federation Service Center).	
c. Beta testing	The testing of the survey was conducted in phases with follow-up interviews to assess reliability of responses.	
2. Survey execution		
a. Establish & document execution standards	Seafood consumption studies for 10 API groups in King County, Washington. Technical execution guided by Community Steering, Technical, and Advisory Committees.	The survey was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Trained bilingual interviewers from API community.	
c. Finfish/shellfish models used	Seafood models were used to represent approximate portion sizes.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Information on types of seafood consumed, source of seafood, preparation methods, frequency and portion size consumed, demographic information clearly reported.	Robust analysis and evaluation of API community fish consumption habits and patterns
b. Methodology reported	Phase II (fish consumption) followed from identification target API populations with ethnic and language-specific questionnaires.	
c. Results tabulated and stated	Tabulated species-specific consumption across 10 different API ethnic populations; included food preparation methods.	
d. Conclusions clearly reported	Conclusions clearly reported with follow-up interviews.	
e. Variability and uncertainty	Variability and uncertainty were qualitatively recognized and noted.	
f. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	The survey included a range of different API ethnic groups to evaluate consumption representative of API population.	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making.
b. Currency of information	The survey was conducted in 1999; more recently, the consumption estimates were used by Oregon DEQ in developing water quality standards (2011).	
c. Sufficiency of data	The consumption estimates are sufficient to provide descriptive statistics for defined distributions and percentiles for different API populations.	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Technically defensible dietary survey of API populations in King County, Washington.	Ecology concludes the survey is technically defensible.
b. Appropriateness for use in risk-based standards	The data are sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making. The API survey did not correct for cooking weight loss or regionally harvested seafood. See write-up on EPA Region 10's reanalysis of the API survey (Kissinger, 2005).	

Source: Sechena et al., 1999.

Sechena et al., 2003 provides a detailed description of the API fish dietary survey. Detailed descriptions of the survey methodology include:

- A methodology overview.
- Survey instruments.
- Sampling strategy including respondent selection criteria, API ethnic representation and recruitment, questionnaire administration, data analyses.
- Statistical methods used to derive fish consumption rates, treatment of outliers, hypothesis testing, and statistical significance and descriptive statistics.
- Results and discussion with tabulated results in g/kg/day for upper percentile estimates.

4.4.1 Reanalysis by EPA Region 10

EPA Region 10 reanalyzed the API data to correct for cooking weight loss, regional seafood harvest, and extrapolation from the survey to King County API populations (Kissinger, 2005). This reanalysis was used to establish cleanup levels in the Lower Duwamish Waterway (Windward Environmental, 2007). The EPA Region 10 reanalysis of the API 1999 survey included only data for individuals consuming seafood from King County. Weighting factors for King County consumers for various ethnic groups were a function of the percentage of that ethnic group as determined in the census and the number of individuals in that ethnic group that consumed seafood from King County. The 95th percentile ingestion rate (defined as the reasonable maximum exposure [RME] scenario) was developed from the consumer-only dataset of weighted ingestion rates. Adjustments were made to account for some of the shellfish consumption reported on a cooked-weight basis rather than on a wet-weight basis. Revised estimates of average raw shellfish consumption were made by using 25 and 50 percent cooking loss correction factors for those shellfish species for which consumption was reported on a cooked-weight basis. EPA calculated demographically weighted mean ingestion rates for each seafood category for individuals who consumed some seafood caught in King County. Demographically weighted mean ingestion rates were used to derive the percentage of consumption of each seafood category. These percentages were then applied to the total consumption rate (95th percentile of total King County API seafood consumption of 57.1 g/day) to derive consumption rates for each seafood category.

Anadromous fish were not included in the fish consumption scenario because it is problematic to apportion salmon (anadromous fish) contaminant body burden to site-specific chemical contaminants. To estimate the API central tendency consumption rate, the 50th percentile of total King County API consumption was multiplied by the percentage of consumption for the various seafood categories. Total non-anadromous seafood consumption for the API exposure scenarios was 51.1 g/day and 5.3 g/day for the RME and central tendency estimates, respectively.

Reanalysis of the consumption of shellfish (mussels, crabs, and clams) for the API exposures used average demographically weighted consumption of these shellfish species harvested only from King County. These shellfish consumption estimates were used to calculate the percentage of each shellfish type consumed. The demographic weighting factor was used to estimate the consumption of clams, mussels, and crabs. The crab consumption rates were apportioned among crab whole body and edible meat, and the benthic (demersal) fish consumption rates were apportioned among benthic fish fillet and whole body. EPA Region 10 provided demographically weighted average percentages of crab whole-body and crab edible-meat consumption by API populations consuming at least some King County seafood. Also, EPA Region 10 provided average demographically weighted percentages of whole-body and fillet consumption by API members consuming at least some King County seafood.

Technical defensibility

Ecology has determined that the EPA Region 10 reanalysis of the 1999 API survey is a relevant and technically defensible approach for a site-specific evaluation (Lower Duwamish Waterway).

Reanalysis of the API data by EPA Region 10 for King County API adult consumers provided central and upper bound estimates of fish consumption (Table 30). The reported consumption estimates include no adjustment for cooking and may be slightly biased low (i.e., underestimated).

The Kissinger (2005) demographic weighting methodology is not recommended for projecting fish dietary patterns for API populations beyond King County. Because of the small number of respondents for each API ethnic group, there would be a high level of uncertainty in projecting statewide API fish dietary patterns from King County API fish dietary information.

It should be noted that Asian and Pacific Islanders include a broad range of ethnicities[39] and that the Kissinger (2005) analysis presents fish consumption estimates determined from aggregating fish consumption data for small numbers of individuals from these varied ethnic groups. Future fish consumption survey efforts should consider more comprehensive analysis of quantitative fish consumption and cultural factors associated with fish consumption by individual ethnic groups.

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[39] For the ethnicities listed here, the first number is the number of respondents from that ethnic group; the second number is the percentage of the total number of respondents represented by that group (Sechena et al., 2003, Table 1).

Cambodian	20/≈10%	Mien	10/≈5%
Chinese	30/≈14%	Hmong	5/≈2%
Filipino	30/≈14%	Samoan	10/≈5%
Japanese	29/≈14%	Vietnamese	26/≈13%
Korean	22/≈10%	All API Ethnicity	202
Laotian	20/≈10%		

Table 30. API Adult Seafood Consumption Rates by Species Group and Source

Population API	Species Group	Source of Fish	Descriptive Statistics (g/day)		
			50th Percentile	90th Percentile	95th Percentile
Asian-Pacific Islander (API)	Total seafood consumption	All sources	74.0	227	286
	All species	Harvested anywhere	6.5	25.9	58.8
	All species	Harvested from King County	5.7	22.2	48.4
	Non-anadromous species	Harvested anywhere	6.2	37.9	54.1
	Non-anadromous species	Harvested from King County	6.0	20.1	45.5

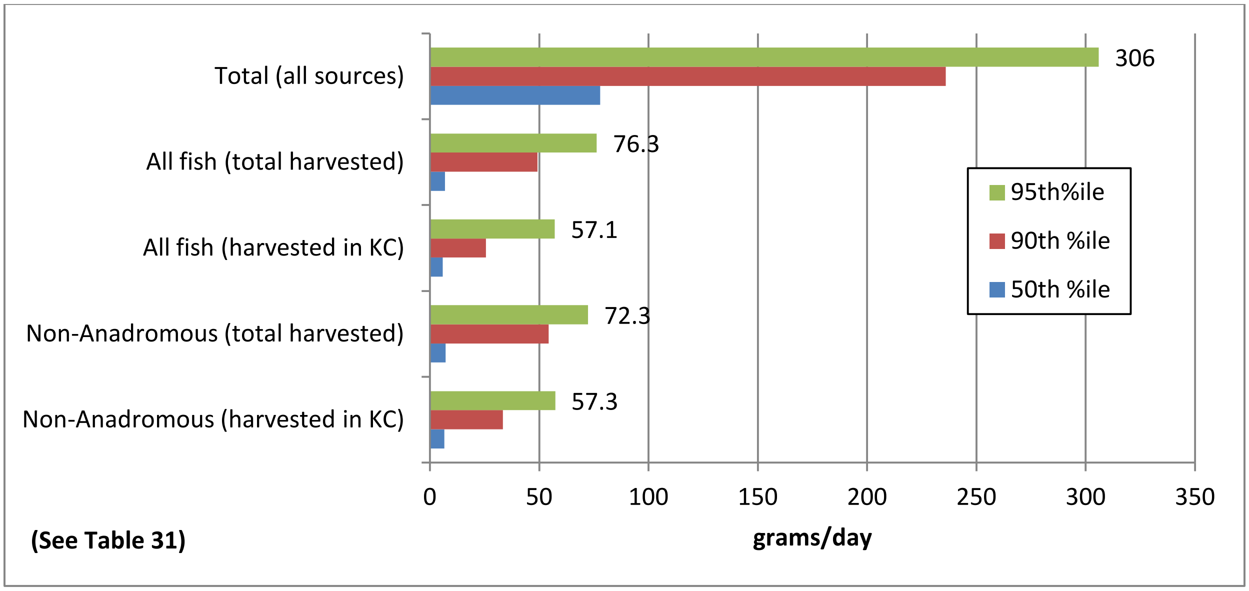
Sources: Adapted from Kissinger, 2005, Table 5. See also Polissar et al., 2012.

In recommending fish consumption estimates for API populations, EPA Region 10 proposed using estimates that accounted for weight lost during cooking. The EPA Region 10 rates included adjustments to account for cooking loss (Table 31).

Table 31. API Seafood Consumption Rates Adjusted for Cooking Loss

Population API	Species Group	Source of Fish	Descriptive Statistics (g/day)		
			50th Percentile	90th Percentile	95th Percentile
Asian-Pacific Islander (API)	Total seafood consumption	All sources	77.8	236	306
	All species	Harvested anywhere	6.9	49.1	76.3
	All species	Harvested from King County	5.8	25.5	57.1
	Non-anadromous species	Harvested anywhere	7.1	54.2	72.3
	Non-anadromous species	Harvested from King County	6.6	33.4	57.3

Source: Adapted from Kissinger, 2005, Table 8. See also Polissar et al., 2012.



Source: Adapted from Kissinger, 2005, Table 8. See also Polissar et al., 2012.

Figure 11. API Adult Fish Consumption Rates, Harvested from King County (KC) and Other Sources, Adjusted for Cooking Loss

4.5 Recreational fishers

Recreational fishing is a popular activity and consideration of recreational fishers provides additional information about fish consumption from Washington waters. Although data for the general population is useful for evaluating fish consumption rates, data on recreational fishing are needed to assess exposure to individuals with potentially higher fish consumption levels. Recreational fishers may consume fish more frequently, and may consume larger portions at each meal, than the general population. In addition, they may frequently fish from a single contaminated source. These factors may put recreational fishers at higher risk of exposure to contaminants in finfish and shellfish.

Several studies have been conducted in Washington State to evaluate the fish consumption of recreational anglers. The Technical Issue Paper *Recreational Fish Consumption Rates* provides detailed information on these surveys and their findings. Many of the available recreational angler surveys were done in the 1980s and are not as current as the other surveys noted above. Additionally, recreational surveys are generally creel, rather than personal interview surveys. These fish consumption surveys can be used to provide an estimate of mean and upper (90th to 95th) percentile marine/estuarine and freshwater fish consumption rates for recreational fishers in Washington State, as follows:

- Mean consumption rates for both freshwater and marine/estuarine finfish and shellfish are in the range of 20 to 60 g/day.
- Upper percentile consumption rates are in the range of 200 to 250 g/day for marine/ estuarine finfish and shellfish, and in the range of 100 to 150 g/day for freshwater fish.

Ecology believes that recreational angler surveys employing a creel methodology are far less appropriate for regulatory use than surveys that utilize a personal interview approach (see Tables 9 and 10).

4.6 Additional fish consumption rate information evaluated by Ecology

In addition to the studies summarized in Section 4.1 to 4.5 above, Ecology considered a range of other sources of information about fish consumption in Washington, as listed in Table 32. These sources provide information on resource use and historical information about fish consumption, which provides a larger and more complete view of finfish and shellfish harvest and consumption in Washington. Appendix B provides a summary of additional tribal fish consumption evaluations reviewed during preparation of this Technical Support Document.

Table 32. Fish Consumption Information Relevant to Washington and Considered by Ecology

Tribal Surveys	Description
A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin [a]	Fish consumption habits & patterns of selected Native American tribes that reside and harvest fish in the Columbia River Basin. Includes Yakama and Umatilla tribes from Washington; Nez Perce and Warm Springs tribes from Oregon State.
A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region [b]	Puget Sound regional survey for two tribes. Provides information on both finfish and shellfish consumption.
Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations, Puget Sound Region [c]	Puget Sound regional survey for two tribes. Provides information on both finfish and shellfish consumption.
Survey of Asian and Pacific Islander	
Asian and Pacific Islander Seafood Consumption Study [d]	King County specific fish consumption estimates for Asian and Pacific Islanders. Survey information has been used by EPA Region 10 to estimate rates for Asian and Pacific Islanders for other Puget Sound areas. Using Sechena et al., 1999, EPA Region 10 reanalyzed data to support Ecology in developing site-specific MTCA cleanup standards and risk assessment for the Lower Duwamish Waterway and Elliott Bay.[e]
U.S. General Population	
Estimated Per Capita Fish Consumption in the United States [f]	Includes fish consumers and non-consumers. (These data were used by Oregon DEQ to estimate the percentage of fish consumers and non-consumers in Oregon.)
State Assessments, Evaluations, and Advisories	
Washington State Department of Health Fish Advisories	Various water body-specific fish consumption rates. DOH advisories provide information on fish meals that should be avoided or can be safely eaten for analytically determined contaminant levels in fish tissue.
Lower Duwamish Waterway Baseline Human Health Risk Assessment [g]	Provides fish consumption information derived from Puget Sound surveys as incorporated in the EPA Region 10 framework describing tribal seafood consumption risk assessment for Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup sites in Puget Sound and modified by tribal consultation. Develops sediment cleanup standards based on tribal RME scenarios.
Lower Elwha Klallam Tribe/Port Angeles [h, i]	In collaboration with Ecology and using the EPA Region 10 framework developed tribal fish consumption rate. Cleanup standards are based on a tribal RME.
Lake Roosevelt, DOH [j]	DOH in cooperation with the Spokane Tribe, water body- and angler-specific creel survey; 42 fish meals/year; assuming 8-ounce meal. This is approximately 26 g/day.
Sinclair Inlet Bremerton Naval Complex [k]	Risk-based screening levels based on Suquamish Tribe adult and children finfish/shellfish ingestion rates and recreational sport fishers (see Appendix A).
Lake Whatcom, DOH [l]	Provided estimated species-specific fish meals sizes for commonly caught and consumed Lake Whatcom fish species (crayfish, cutthroat trout, kokanee, yellow perch, smallmouth bass) with median rates in g/meal; from low (crayfish) of 24 g/meal and high (smallmouth bass) of 220 g/meal.
Rhone-Poulenc [m]	Cleanup standards based on Tulalip tribal and Asian and Pacific Islander seafood consumption data. Range of fish consumption rates referred to and documented in Lower Duwamish Waterway Human Health Risk Assessment.
South Aberdeen-Cosmopolis Area [n]	Chinook, coho, chum; anadromous steelhead and cutthroat trout commonly found and available for harvest. Evaluates fish habitat and recommends habitat restoration and enhancement.
Naval Base Kitsap – Keyport, Washington [o]	Based on Suquamish Tribe shellfish (clams, mussels, crabs, oysters) consumption rate. Based on U.S. general population rate 54 g/day to Suquamish rate 632 g/day for clams.
Oakland Bay, Shelton [p]	Water body-specific evaluation. A range of shellfish consumption rates used, 17.5, 60, 175, 260 g/day; based in part on Squaxin Island tribal consultations.
Umatilla Tribal Water Quality Standard [q]	Consumption rate of 389 g/day approved by EPA Feb. 2010. (Lummi Nation, Shoshone-Bannock Tribe and the Swinomish Tribe are eligible to adopt tribal water quality for their respective reservations.)
Lake Washington [r]	Anglers rate 10.8 g/day; angler 95th percentile 30.2 g/day; children anglers 9.5 g/day with 95th percentile 86.2 g/day. Allowable meal limits determined for northern pikeminnow, yellow perch, cutthroat trout, sockeye salmon.

Table Sources:

a. CRITFC, 1994.
b. Toy et al., 1996.
c. The Suquamish Tribe, 2000.
d. Sechena et al., 1999.
e. Kissinger, 2005.
f. U.S. EPA, 2002a.
g. Windward Environmental, 2007.
h. Lower Elwha Klallam Tribe, 2007.
i. Lower Elwha Klallam Tribe, 2008.
j. Washington DOH, 1997.
k. Naval Facilities Engineering Command Northwest, 2010.
l. Washington DOH, 2001.
m. U.S. EPA, 2006.
n. U.S. Department of the Interior, Fish and Wildlife Service, 1994.
o. ATSDR, 2009.
p. Washington DOH, 2010.
q. U.S. EPA, 2011b.
r. Washington DOH, 2004.

4.7 Key Findings

Ecology reviewed finfish/shellfish dietary surveys and related information relevant to fish-consuming populations in Washington, including general population data from national surveys and regional fish consumption surveys.

1. *National survey data*

   Ecology analyzed general population survey data from national studies. A statistical methodology used by the National Cancer Institute (NCI) was applied to the national survey data to estimate long-term consumption rates from the short-term dietary records collected by these studies. It is noted, however, that national survey data may underestimate fish consumption in coastal states, such as Washington, which have large fish resources available for harvest and consumption.

2. *Regional survey data*

   Ecology identified the following Pacific Northwest tribal surveys as well-designed and well-conducted. They meet measures of technical defensibility and are directly applicable to Washington population groups.

   - *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (CRITFC, 1994).
   - *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region* (Toy et al., 1996).
   - *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations, Puget Sound Region* (The Suquamish Tribe, 2000).

   These surveys provide finfish and shellfish dietary information for Washington fish-consuming populations and identify and quantify consumption habits. Ecology believes that these surveys provide credible information about fish consumption in Washington..

3. *Asian and Pacific Islander survey data*

   The *Asian and Pacific Islander Seafood Consumption Study* (Sechena et al., 1999, including EPA’s 2005 re-evaluation) is well-designed and conducted, but represents only a very small sample of each of the Asian and Pacific Islander populations surveyed. Because of the differences in API populations across the state, it may not be appropriate to apply these results statewide.

4. *Recreational survey data*

   Recreational fish consumption surveys conducted in Washington were generally older and were conducted using less technically defensible methods (creel surveys).

Ecology has reviewed other surveys and fish consumption information used for health assessments for specific populations groups and water bodies throughout Washington State (see Appendix B). Although these surveys are technically sound and help support an evaluation and assessment of potential adverse effects from consuming contaminated fish from specific water bodies, their methodology does not allow for the projection of longer term estimates of fish consumption. Hence, these estimates are tabulated in this chapter to provide multiple lines of evidence, as a weight-of-evidence approach, that people in Washington State harvest and consume large amounts of fish.

Fish consumption rates for the general population and from the three Pacific Northwest tribal surveys identified above are listed in Table 33 below. The dietary survey methodologies employed for these studies are well documented and provide quantifiable dietary information. Ecology applied measures of technical defensibility to these fish dietary surveys to assess their suitability for estimating long-term fish consumption rates for Washington State fish-consuming populations. Ecology believes that these surveys provide credible information about fish consumption in Washington.

Table 33. Summary of Fish Consumption Rates from Studies Meeting the Measures of Technical Defensibility, All Finfish and Shellfish (g/day)

Population	Source of Fish	Number of Adults Surveyed	Mean		Percentiles		
				50th	75th	90th	95th
General population (consumers only)	All sources: EPA method	2,853	56	38	79	128	168
	All sources: NCI method	6,465	19	13	25	43	57
Columbia River Tribes	All sources	464	63	41	65	130	194
	Columbia River	–	56	36	57	114	171
Tulalip Tribes	All sources	73	82	45	94	193	268
	Puget Sound	71	60	30	75	139	237
Squaxin Island Tribe	All sources	117	84	45	94	206	280
	Puget Sound	–	56	30	63	139	189
Suquamish Tribe	All sources	92	214	132	284	489	797
	Puget Sound	91	165	58	221	397	767

See also Polissar et al., 2012

Discussion

Based on the fish dietary surveys for Puget Sound and the Columbia River basin, fish-consuming populations within the Pacific Northwest consume comparable amounts of fish. The average fish consumption rates from all sources for the Columbia River, Tulalip, and Squaxin Island tribes are within a very small range of one another, about 60 to 80 g/day. Central tendency estimates of consumption, either average or median estimates, for Asian-Pacific Islanders, recreational anglers, and national (based on EPA information) estimates are also within this range. Fish consumption estimates from local harvests for tribal fish-consuming populations show a similar but slightly lower trend, around 55 to 60 g/day. The Puget Sound fish-consuming population that consumes the largest amount of fish is the Squamish Tribe, with higher central tendency estimates of consumption of about 130 to 215 g/day. For these fish-consuming populations, the trend for the upper 90th and 95th percentile fish consumption estimates shows a convergence that illustrates a consistently high rate of fish consumption.

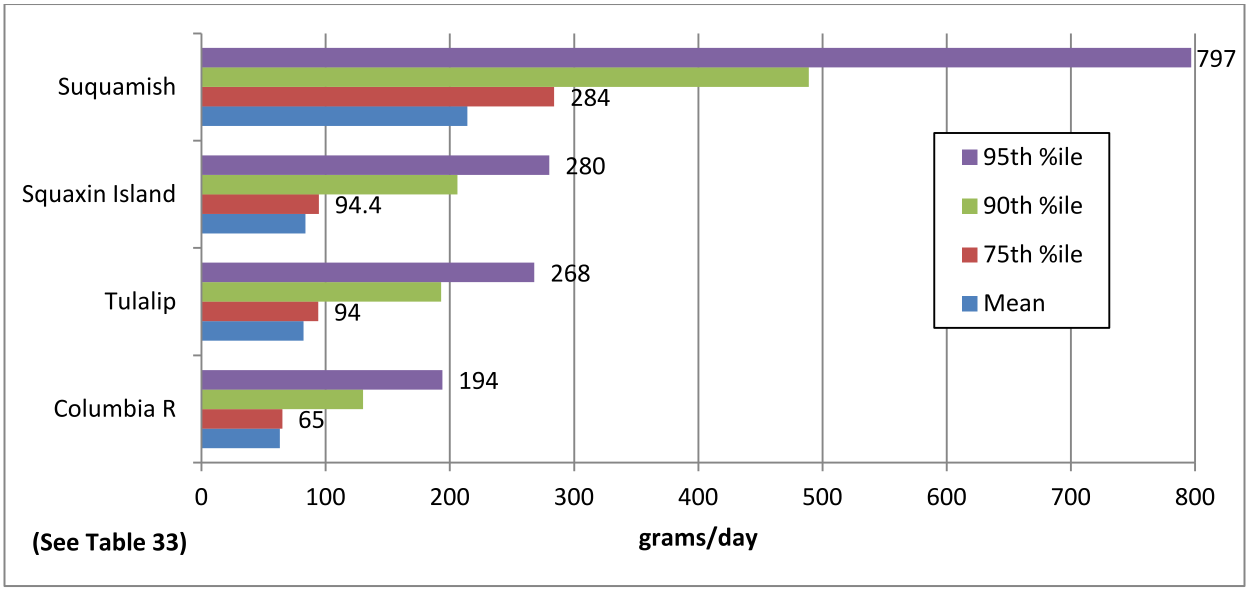


Figure 12. Regional-specific Adult Fish Consumption Rates, Harvested from All Sources

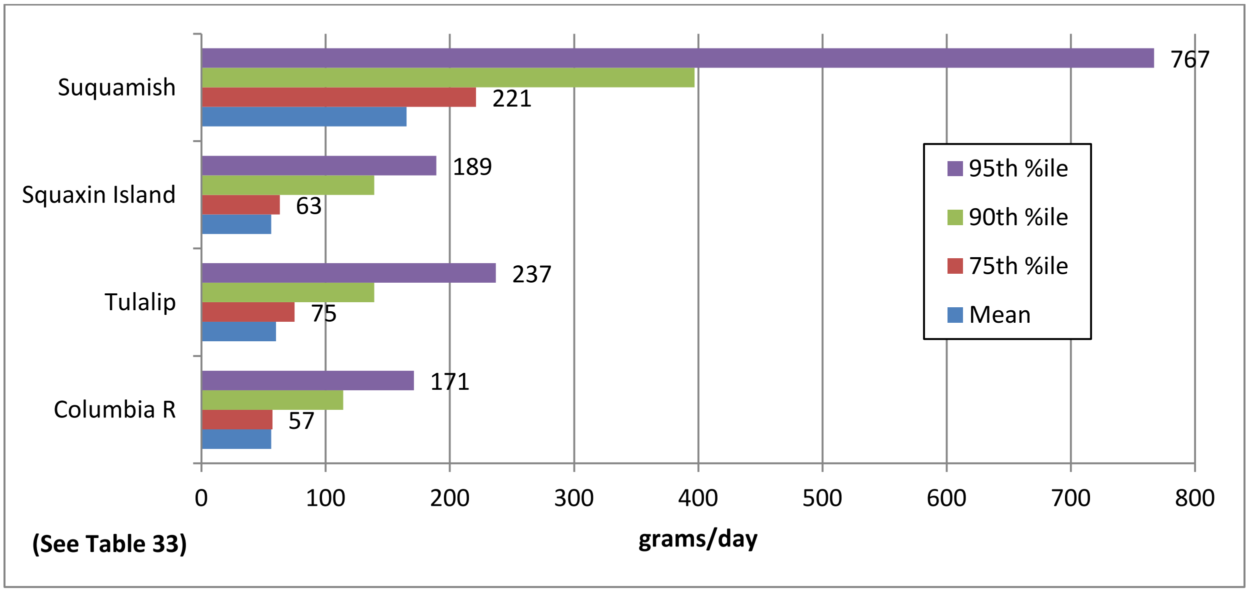


Figure 13. Regional-specific Adult Fish Consumption Rates, Harvested from Local Sources

Computations for all percent estimates of local fish harvests are based on estimates of fish consumption for tribal populations from Table 33. Percent estimates are derived based on upper percentile estimates of fish consumption from all sources compared with sources of fish harvested locally, such as Puget Sound or the Columbia River basin.

For all fish consumed. About 67 to 68 percent of total fish consumed by the Squaxin Island tribal population are locally harvested. The percentage of total fish consumed that is locally harvested is somewhat higher for the other tribal populations surveyed: approximately 88 percent for the Columbia River Tribes, 72 to 88 percent for the Tulalip Tribe, and 81 to 96 percent for the Suquamish Tribe.

Table 34. Percent of Tribal Fish Consumption Rate (All Sources) that is Locally Harvested

Population	At the 90th Percentile	At the 95th Percentile
Columbia River Tribes	88%	88%
Tulalip Tribes	72%	88%
Squaxin Island Tribe	67%	68%
Suquamish Tribe	81%	96%

For anadromous fish consumed. About 72 to 77 percent of anadromous fish consumed by the Tulalip tribal population are locally harvested. The percentage of anadromous fish consumed that is locally harvested is somewhat higher for the other tribal populations surveyed: approximately 88 to 89 percent for the Columbia River Tribes, and 80 percent for the Squaxin Island Tribe. Insufficient data were available on locally harvested anadromous fish consumption for the Suquamish Tribe.

Table 35. Percent of Tribal Anadromous Fish Consumption Rate (All Sources) that is Locally Harvested

Population	At the 90th Percentile	At the 95th Percentile
Columbia River Tribes	88%	89%
Tulalip Tribes	72%	77%
Squaxin Island Tribe	80%	80%
Suquamish Tribe	NA	NA

For shellfish consumed. About 62 to 63 percent of shellfish consumed by Squaxin Island tribal populations are locally harvested. The percentage of shellfish that is locally harvested is somewhat higher for the Suquamish Tribe (81 percent), and highest for the Tulalip Tribes (98 to over 99 percent).

Table 36. Percent of Tribal Shellfish Consumption (All Sources) that is Locally Harvested

Percent of tribal shellfish consumption (all sources) that is locally harvested		
Population	At the 90th Percentile	At the 95th Percentile
Columbia River Tribes	NA	NA
Tulalip Tribes	98%	>99%
Squaxin Island Tribe	63%	62%
Suquamish Tribe	81%	81%

Chapter 5: Sources of Uncertainty and Variability

Ecology and other agencies regularly use available scientific information on finfish and shellfish consumption rates to support regulatory decisions. In these situations, Ecology must generally select a particular value from a range of values. When making these decisions, it is appropriate to identify, recognize, and consider both the uncertainties associated with available data and the variability across individuals, fish species, and geographic areas.

Sometimes these two terms, uncertainty and variability, are lumped together. However, the nature of the errors (and consequences of over- or underestimating results) that arise due to uncertainty in the data is different than those errors that arise as a result of variability across populations, geographic areas, and time. Environmental agencies' responses to uncertainty are inherently different than responses to variability. Specifically:

- *Variability.* With variability, people and organizations know that there is a range of actual values for the parameter in question. In these situations, environmental agencies must simply decide how to characterize the range of values.
- *Uncertainty.* With uncertainty, people and organizations have limited knowledge on the magnitude and range of the parameter in question. In these situations, environmental agencies must decide how to address gaps in information and/or scientific knowledge.

This chapter summarizes important sources of uncertainty and variability in the scientific information used to estimate finfish and shellfish consumption rates.

- Uncertainty associated with dietary intake survey methods.
- Variability in consumption rates for individuals within a specific study population.
- Geographic variations and uncertainties associated with extrapolating survey results to different population groups and different areas.
- Temporal variability and uncertainties associated with estimating long-term exposure.
- Uncertainties associated with estimating future consumption rates and patterns.
- Uncertainties and variability in the relationships between cooked and uncooked tissue weights.
- Uncertainties and variability in sources of finfish and shellfish.
- Temporal variability in the availability of finfish and shellfish.

This chapter is designed to provide a high-level summary. There are several excellent resources that provide information on general sources of uncertainty and variability in risk assessments

(National Research Council, 1994, 2009; U.S. EPA, 2011a). In addition, other agencies and organizations (U.S. EPA, 2007b; Oregon DEQ, 2008; Windward Environmental, 2007) have evaluated sources of uncertainty and variability in fish consumption rates.[40] (Much of the information in this chapter is directly from the sources cited.) See also CalEPA (2001) for a particularly good discussion of sources of variability in fish consumption estimates.

5.1 Survey methodology

Dietary recall surveys are dependent on many factors, and the careful design and execution can minimize or eliminate sources of certain types of errors.

Chapter 3 discusses survey methodology, execution, publication of results, applicability and utility for regulatory decision making, and overall technical suitability to support regulatory decision making. Fish consumption surveys selected as applicable to Washington fish consumers were evaluated in Chapter 4.

Factors contributing to measurement error and bias include:

- Survey design (for example, accurate representation of the target population). Considers attributes of the survey relative to attaining accuracy and precision (e.g., are all species included, are visual aids utilized for portion sizes, will the survey be administered over an entire fishing season, are an appropriate number of individuals interviewed).
- Survey methodology (for example, considers the interaction between the survey methodology chosen and attributes of the target population taking into account literacy, language barriers, and cultural sensitivity).
- Survey execution (for example, coding errors, interviewer bias, recall bias).[41]
- Method of analysis (for example, if and how systematic error is identified and estimated; treatment of outliers and weighting factors).

Various survey types have inherent biases, strengths, and weaknesses that may contribute to variable results demonstrated across these different surveys. It should be noted that regulatory policies (for example, what questions are the surveys designed to answer) can influence the planning and design phases, which can in turn influence the results and conclusions. Furthermore, policy choices may not be consistent across various federal and state agencies and academic institutions.

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[40] See also the National Cancer Institute discussions of measurement error related to dietary surveys. http://riskfactor.cancer.gov/measurementerror/

[41] Recall bias occurs when factors exist that may affect the respondent's memory of an event. For example, an individual that consumed fish in the last 24 hours may provide greater estimates of fish consumption on a seasonal or yearly basis.

EPA examined different fish consumption survey methods, identifying important considerations for survey design, selection of respondents, quality assurance, and statistical analysis (U.S. EPA, 1992). Additional guidance on fish and wildlife consumption surveys thoroughly examines survey instrument design, execution, and analysis (U.S. EPA, 1998).

Limited resources and differing objectives for organizations and groups interested in determining fish consumption rates can influence the design of the survey and how it is conducted. Plausible objectives for fish consumption surveys include: determining average consumption rates, fishing pressure on water bodies, and maximum consumption during the fishing season. Surveys designed to meet one objective may not be suitable for another. Ecology must consider a fish consumption survey's objectives, execution, and evaluation to determine the utility of a survey's use by Ecology for environmental regulation.

5.1.1 Differences due to survey design, terminology, and definitions

Some fish dietary surveys may not include all relevant species in the questionnaire. Terminology across different fish consumption surveys may be highly variable. A lack of a consistent terminology can contribute to variability and uncertainty. For example, *shellfish* usually refers to aquatic invertebrate organisms with a shell. Clams and oysters are easily identified as shellfish. However, selected aquatic animals (squid) have evolved such that the shell has become internal and/or reduced, while in others, the shell has disappeared (octopus). Furthermore, crustaceans (crayfish) have exoskeletons instead of true shells.

Seafood consumption may include finfish and/or shellfish obtained from a variety of sources. Surveys may not differentiate the sources of the finfish and/or shellfish. Indeed, some surveys may consider consumption of fish harvested from a single water body (e.g., Commencement Bay) while other studies determine rates for fish consumption from multiple water bodies. Also, consumption rates reported in different studies may or may not distinguish between consumption of marine, estuarine, and freshwater finfish and shellfish. These differences and their contributions to variability were summarized in a study published in the *Journal of Exposure Analysis and Environmental Epidemiology* (Ebert et al., 1994). This study noted that the consumption rate of an individual comprises the sum of the rates from different sources. It does not differentiate among sources of seafood. Estimates may vary substantially depending on how these different sources are evaluated.

5.1.2 Types of data and methods of collection

The method used to collect dietary information may lead to uncertainty. For example, data collected from creel surveys involve interviewing anglers at fishing locations to provide water body-specific data about fishing frequency, fish species, and sizes caught and/or consumed. Hence, the creel survey method may only provide data about specific species available during specific seasons. Creel surveys, like other surveys methods, are subject to biases. Poor catches, catches below legal size limits, or catches above total allowable limits may not be reported. Persons fishing without a license may avoid participating. See Table 9 for issues associated with creel surveys.

5.1.3 Cooked and uncooked tissue weights

A number of researchers have noted the uncertainty introduced by inconsistency regarding reporting of finfish and shellfish using cooked vs. uncooked weight. Raw fish tissue samples are used to determine chemical contaminant levels for use in human health risk assessments.

The EPA Region 10 Framework recommends that risk assessments be performed using the weight of uncooked fish, with no modification for potential contaminant losses or gains during cooking. This is consistent with the fact that uncooked fish consumption rates were measured in the tribal finfish and shellfish consumption studies cited. EPA notes:

> *Because of the many ways in which fish may be served, quantitative assumptions regarding preparation methods and their effects on contaminant concentrations would be unreliable. Depending upon the preparation and cooking procedures, and upon the nature of the contaminants in the fish, concentrations may decrease or increase [U.S. EPA, 1998]. For fat-soluble compounds such as PCBs, trimming and removing adipose tissue reduces the mass of contaminants in the consumed portion of the fish. Similarly, broiling, frying, or grilling fish is likely to result in reductions of fat-soluble compounds [Sherer and Price, 1993]. Cooking is not likely to change the level of exposure to mercury because it is bound to muscle tissue and is not lost by cooking, which mostly removes moisture and fat [Morgan et al., 1997]. Fish cooked with no prior preparation, as in a stew, might show negligible loss of contaminants, except perhaps for volatile contaminants. Because lead concentrates in bones, preparations where bones are discarded are likely to result in reductions in lead exposure [Ay et al., 1999].*

5.1.4 Variability within a population

A number of factors may contribute to variability in finfish and shellfish consumption survey results (Ebert et al., 1994). Dietary patterns vary within a population and between populations. Different population groups may have different fish consumption rates related to cultural or regional differences. Family preferences, recipes, and individual taste are sources of variability within a population; access to resources, tradition, and custom are sources of variability between populations.

5.1.5 Data analysis and statistical considerations

Without careful definition of the target population, it is possible to bias survey results. For example, to avoid characterizing the consumption for a population that is not at risk from consuming contaminated fish, surveys are designed to evaluate consumers only, with questions allowing identification of persons who never (or rarely) consume fish.

Various statistical techniques have been described to analyze consumption data. For example, different methods of treating missing data or non-response data may contribute to bias. Identification and treatment of potential outliers may contribute to biased datasets (this includes recording outliers as multiples of standard deviations above the mean or eliminating them from the dataset).

Defining subgroups within a larger population (stratification) differently can affect survey results and introduce different levels of bias. An important element of survey design is how well the survey sample population represents the selected target population or population of concern. Weighting schemes designed to make a sample more representative of the population should be carefully defined. Statistical methods should consider sampling rate, differences in sampling days, and other factors that may influence the results.

The fish consumption rates for a fish-consuming population should be sufficiently characterized to provide a population distribution and statistics that contribute to an understanding of the nature of a population exposure distribution such as the mean, median, and upper percentiles (90th or 95th percentile) or bounding estimates (99th or 99.9th percentile). It is essential to understand how these distributions were derived as distributions derived from consumers and non-consumers of fish have different meanings and applications.

It should be noted that 24-hour dietary recall surveys that include food frequency questionnaires enable calculating the upper percentiles with greater confidence (U.S. EPA 1992, 1998). Consistent with federal guidance on fish dietary survey methodologies, all regional Pacific Northwest fish dietary surveys (Tribal and Asian-Pacific Islander populations) employ some permutation of a food frequency questionnaire in their survey methodology to project long-term consumption estimates.

Fish dietary information may be reported as point estimates, usually a mean or median value to represent central tendency estimates of consumption, or as a distribution of values. When the estimates of fish consumption are normally distributed in a population, the mean and median will be close or approximately equal. When the distribution is skewed (e.g., lognormal distribution), the mean and median may be substantially different. The mean fish consumption estimate represents the average value for the sampled population and in a skewed distribution the mean will either be a higher or lower value than the median value. For a highly positively skewed distribution, as found in the Pacific Northwest fish-consuming populations, the mean is higher than the median estimates of consumption. The median value represents the 50th percentile (or midpoint) of the distribution where half of the sampled population consumes more and half consumes less fish, than the median value (Helsel and Hirsch, 2002).

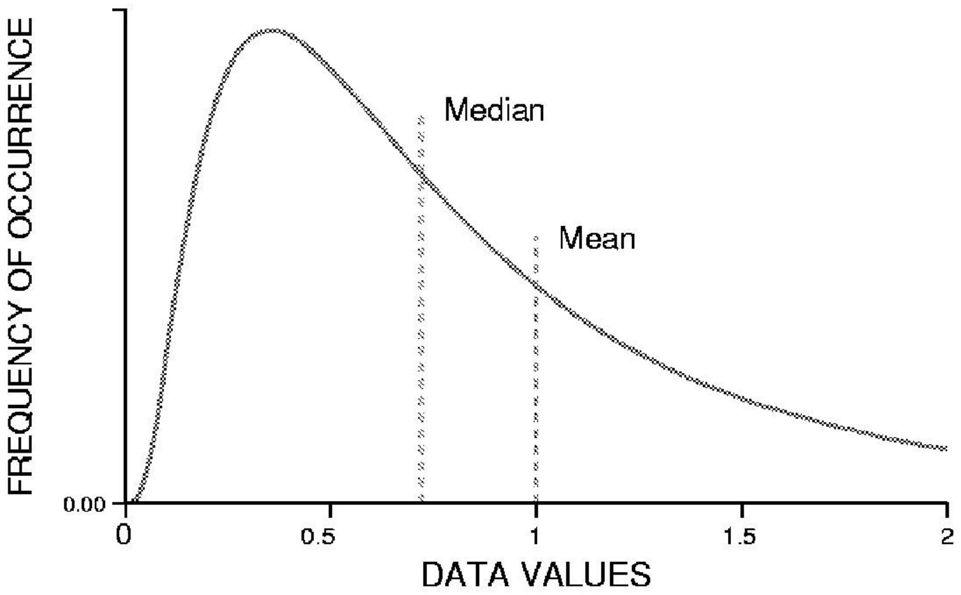

Figure 14. Density function for a positively skewed lognormal distribution

5.1.6 Target populations and characteristics of populations

Different population groups may have different fish consumption rates. Recognizing differences between fish consumption rates for whole populations (including both consumers and non-consumers) and consumption rates in actual consumers of fish is a critical distinction. For example, Oregon's Human Health Focus Group made the clear distinction between per capita fish consumption based on consumers and non-consumers of fish. High fish consumers make up a relatively small portion of the whole population, and may represent extreme upper percentiles in a distribution that includes both consumers and non-consumers of fish.

A distinction is generally made between (a) national per capita consumption estimates inclusive of both consumers and nonconsumers of fish and (b) estimates of fish consumption from local fish consuming populations (EPA Region-10 Framework, 2007; EPA, 2000; CalEPA, 2001; Oregon DEQ HHFG Report, 2008):

- "Per capita rates are primarily useful for trend analyses rather than representing actual consumption. Average per capita rates derived from national surveys for consumption of fish and shellfish by the general population ranged from 10 to 17.9 grams per day. Several analyses of data used to estimate per capita consumption of fish and shellfish found an increase of approximately 25% between 1970 and the early 1990s, indicating that the U.S. population as a whole consumed more fish in more recent years" (CalEPA, 2001, page 3).

- "Consumption rates derived for consumers are preferable to per capita rate for use in describing actual consumption of fish and shellfish in the U.S." (CalEPA, 2001, page 3).

Further distinctions are made between national per capita fish consumption estimates and consumer-only estimates by how consumers of fish and/or shellfish are defined. CalEPA, 2001, provides further insights regarding consumption estimates for populations that consume fish compared to estimates for the general national population as follows:

> *Rates reported for the general national population, usually referred to as per capita rates, differ from those reported for subpopulations such as individuals who catch and consume their own catch of fish and shellfish. It is essential to consider whether rates that apply on a per capita basis are appropriate to the study question or whether rates specific to particular subpopulations are needed. For example, some consumption rates have been derived by averaging over both consumers and nonconsumers, as compared to consumers only. These per capita estimates would not be representative of consumption by actual consumers or other specific subpopulations. Thus, exposure assessments and evaluation of potential risks to consumers must consider consumption rates appropriate for actual consumers.*
>
> *For groups of individuals who consume sport fish and/or shellfish, there is a continuum ranging from intermittent fishers, who may eat fish only occasionally, to those who fish regularly and/or heavily and consume large quantities of the fish that they catch. These "high-end consumers" could include recreational fishers with high rates of success and subsistence fishers who rely on their catch to feed themselves and their families. Therefore, within the subset of the population that fishes (i.e., fishers) there is likely to be a wide range of fishing effort and success, and a single value is unlikely to adequately describe consumption by the entire fishing population (CalEPA, 2001, page 13).*

5.2 Geographic differences

5.2.1 Variation and uncertainty associated with regional differences

Fish consumption surveys conducted across the United States have shown regional variations. There are differences between coastal areas and inland areas and regional preferences for certain types of finfish and/or shellfish. Local variations in climate, fishing regulations, accessibility to fisheries, and seasonal differences in availability of fish contribute to the variability in reported fish consumption rates (Ebert et al., 1994; Moya et al., 2008). Differences in habitat may be relevant (U.S. EPA, 2007b).

Comparing the results of surveys from different geographic locations, each with regional effects plus different methodologies, time frames, or other different survey design elements, makes the interpretation of differences between surveys problematic.

5.2.2 Uncertainty associated with extrapolating survey results to different population groups and different locations

The use of surrogate consumption rates can misrepresent actual finfish and shellfish consumption rates. For example, Puget Sound-harvested finfish and shellfish consumption rates derived using Tulalip and Suquamish tribal data as a surrogate for another tribe could lead to either an overestimate or an underestimate of the actual finfish and shellfish consumption.

For many reasons populations surveyed in a particular study may eat different quantities and ratios of finfish and shellfish than do those who harvest elsewhere. For example, differences in habitat type and quality between fishing grounds can affect the quantity of finfish and shellfish available for harvest.

The EPA Region 10 framework takes this into account. For purposes of the framework, if certain species or types of finfish and shellfish are not present, or will not be present in the future, tribal members are assumed to substitute other species or types of finfish or shellfish that may be equally affected by the site. This assumption of resource switching among local finfish and shellfish is incorporated into the framework by holding constant the total amount of finfish and shellfish consumed.

EPA's policy decision to assume that resource switching occurs is supported by limited data and examples in Puget Sound. For example, individuals in the Suquamish Tribe study (The Suquamish Tribe, 2000) eat "more geoduck now, because they are more available to us, but we used to dry oysters and clams...." Two other respondents reported "reduced consumption of butter clams, cockles, and other clams and shellfish due to pollution," but that this "reduced consumption was offset by the higher availability of geoducks from the Suquamish Tribe." Resource switching has been documented in other areas affected by contamination, such as Alaska (Fall and Utermohle, 1999).

The use of fisheries resources is important to tribes for economic, dietary, and cultural reasons. Tribes will likely use whatever fisheries resources are available to them.

The following observation is made in the National Environmental Justice Advisory Council Meeting report (U.S. EPA, 2002b):

> *For many communities of color, low-income communities, Tribes, and other indigenous peoples, there are no real alternatives to eating and using fish, aquatic plants, and wildlife. For members of these groups it is entirely impractical to "switch" to "substitutes" when the fish and other resources on which they rely have become*

> *contaminated. There are numerous and often insurmountable obstacles to seeking alternatives (e.g., fishing "elsewhere," throwing back "undesirable" species of fish, adopting different preparation methods, or substituting beef, chicken or tofu). For some, not fishing and not eating fish are unimaginable for cultural, traditional, or religious reasons. For the fishing peoples of the Pacific Northwest, for example, fish and fishing are necessary for survival as a people – they are vital as a matter of cultural flourishing and self-determination.*

If certain types of finfish or shellfish preferred by tribal members are not present in their usual and accustomed areas, the framework assumes that tribal members will substitute alternative local types of finfish or shellfish in their diets, generally within the same category of fish or shellfish. Thus, the total consumption rate remains the same, regardless of the availability of a particular type of finfish or shellfish. This is a reasonable and protective assumption for tribal members who, for economic, ceremonial, religious, or personal preference reasons, are likely to substitute one species for another.

The assumption that resources will be switched is likely to result in an overestimate of risks for other tribal members who may decrease their overall finfish and shellfish consumption rate because their preferred types are unavailable. Risks may be underestimated if the actual dietary practices of a tribe would result in consumption of species that have higher contaminant levels than the preferred or assumed types of finfish or shellfish.

5.2.3 Availability of finfish and shellfish

The abundance of finfish and shellfish resources available to a given population may be a source of uncertainty. Different water bodies vary in their capacity to support and sustain different species of finfish and shellfish. Furthermore, the capacity of the water body to support fish resources may change over time, for both natural and human caused reasons.

Regarding the use of surrogate data, the EPA Region 10 framework notes:

> *Although the degree to which site-related risks could be overestimated by the use of any of the fish and shellfish consumption rates presented in this Framework cannot be known precisely, these methods are preferable to alternatives that would be likely to underestimate site-related risks, such as basing a consumption rate (or site-related estimates of risk) on the size of the cleanup site, or reducing the site's estimated contribution to fish and shellfish contamination because nearby sites or sources are associated with similar contaminants. This Framework includes the assumption that the selected Tribal fish and shellfish consumption rates and their associated risk estimates will not be reduced based on consideration of the size of the cleanup site or the presence of additional sources of contamination.*

The use of a consumption rate based on all finfish and shellfish harvested from Puget Sound as a surrogate for a consumption rate based on finfish and shellfish affected by a cleanup site is likely to overestimate the risk of eating finfish and shellfish from the site, since only a portion of the finfish and shellfish diet will have actually come from the site in question. The degree of overestimation depends upon such factors as size and location of the site, type and degree of contamination, and habits of affected finfish and shellfish.

A potential data gap is the lack of information on commercial routes of distribution for locally harvested fish and/or shellfish to local food markets, restaurants, or other food outlets in Washington State. However, seafood supply availability as an indirect measure of consumption has very limited utility. As noted by CalEPA, 2001 (page 15):

> *Approaches to collecting data on fish consumption include both indirect and direct measures. Indirect measures primarily rely on data pertaining to food availability or food disappearance into marketing channels or households, and are best regarded as a measure of food availability into commercial markets and only a rough indicator of consumption. Data from studies on food availability generally have been collected for purposes other than to estimate consumption rates, and data gaps are most serious at the level of the individual consumer; therefore, these types of data are inappropriate for estimating consumption rates for consumers (Anderson, 1986; U.S. EPA, 1992). Additionally, food availability data do not account for waste or spoilage, and interpretation of the results is highly specialized; however, the results from these types of surveys can be useful to assess trends over time (Anderson, 1986).*

On the other hand, some of the finfish and shellfish consumed in restaurants or obtained in grocery stores may have been harvested in Puget Sound, which could lead to an underestimate of exposure.

5.3 Temporal uncertainty and variability

Although estimates of consumption using short-term dietary recall may be reported as g/day, the values may not be the same as long-term consumption rates averaged over time and presented as a daily rate. Study methodologies that consider fish consumption over a longer period of time may be more likely to represent the fish consumption patterns of the population studied.

5.3.1 Using short-term data to estimate long-term exposure

Current health risk models are designed to evaluate health risks associated with exposure over long periods of time. Risk assessors typically use the results from short-term dietary surveys to characterize the amounts of finfish and shellfish eaten on a regular basis over longer periods of time intervals (years).

This approach works well when average values are used in the health risk model. However, regulatory approaches based on concepts like *reasonable maximum exposure* are typically based on the use of upper percentile values (e.g., 90th percentile or above). In this situation, the use of short-term survey results is complicated because the distribution of estimated fish consumption rates over a short period of time will be more spread out than the actual fish consumption over a longer period of time. This means that estimates of the 95th percentile of the fish consumption rates observed over a short period of time (one or two days) will be higher than the 95th percentile of the average daily fish consumption over the longer periods of time considered in health risk assessments (years). This narrowing of the distribution of estimates is called *regression to the mean*.[42]

5.3.2 Temporal factors biasing estimates of fish consumption

The collection of fish consumption information may be subject to temporal biases. Use of 24-hour recall data to estimate fish consumption rates over longer periods are subject to potential biases from the effects of the day of the week or seasonal variations in the availability of fish. Longer term estimates of fish consumption reported by individuals may be subject to recall bias. Rates will be overestimated if fish consumption habits are surveyed when fish are readily available relative to periods when fish are not readily available. Consumption data obtained on consecutive days may be biased due to the consumer correlation with the fish consumed on adjacent days.

Recall bias for estimates of long-term fish consumption is more of an issue for populations where fish may be infrequently consumed and consumption patterns are episodic in nature. In contrast, recall bias in estimating long-term fish consumption rates is minimized for populations in which fish is a primary dietary protein source, is consumed frequently, and where consumption information is hence easily recalled.

The timing of survey administration may or may not account for the biases introduced by seasonal variations in fish availability. Extrapolating estimates of long-term fish consumption from 24-hour recall data or from evaluations of yearly fish consumption may be improved by interviewing fractions of the survey populations during different seasons or by re-interviewing individuals.

Short-term estimates of food intake rates for infrequently consumed items for the general population (e.g., fish) from national short-term surveys are bimodal, varying between zero and the amount typically consumed at a meal. This results in an overestimate of the prevalence of

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[42] Regression to the mean is encountered in many areas of science and everyday life. For example, baseball batting averages have a much larger distribution early in the season compared to the end of the season. The following case study illustrates the implications of this situation. There were 177 major league players with at least 400 plate appearances during the 2011 season. Consider the players' batting averages after their first game and at the end of the 162 game season. The first day estimates for the median and average provide a reasonably good estimate of those values for the whole season. However, the first day estimates for the 90th and 95th percentiles of the distribution of batting averages are much higher than the end-of-the season values. As with many situations, players who did extremely well on the first day of the season also had days where they were hitless. Conversely, players who went hitless on opening day had games later in the season where they had one or more hits.

low and high intake rates relative to those that would be seen over a longer observation period. This variation is particularly relevant for assessments of food chemical exposure where the parameters of interest are at the extremes of the exposure distribution rather than at the center (Lambe, 2002).

Attempts to account for the variability and uncertainty associated with the use of short-term consumption studies have generally included qualitative evaluation of data from a range of sources, coupled with consideration of the intended use of the data. To evaluate long-term (habitual) seafood intake, longer-term survey data are preferable to short-term dietary survey data.

Ecology conducted a statistical reanalysis of short-term national fish consumption data to estimate long-term (usual) national fish consumption rates, using the methodology of Tooze et al., 2006 (as cited in Polissar et al., 2012). National fish consumption rate estimates based on this reanalysis are significantly lower than estimates based on simple extrapolation of the short-term fish consumption data. See also the Technical Issue Paper, *Estimating Annual Fish Consumption Rates Using Data from Short-term Surveys* (Ecology, 2012).

5.3.3 Issues using currently suppressed fish consumption data to predict future fish consumption

The presence (or absence) of finfish and shellfish adversely affected by site-related contamination could suppress consumption rates observed during surveys.

The Oregon DEQ Human Health Focus Group discussed some of the factors that may contribute to depressing fish consumption rates compared to historic rates. They noted (1) significant reductions in fish populations, (2) the belief that fish that reside in polluted waters will bioconcentrate pollutants and are contaminated and unsafe to eat, and (3) the intended impact of local fish advisories or the unintended consequences of national fish advisories of commercial fish species that are not applicable to local waters.

The Human Health Focus Group also noted that some studies excluded or discounted high fish consumers by identifying them as statistical outliers. This would have the effect of underestimating the true range in fish consumption rates. If the rates are already suppressed, the elimination of the highest values may be reporting an artificially low fish consumption rate.

Where tribal members have already reduced their harvest of finfish and shellfish from impaired habitat, the use of current consumption rates could result in underestimations of potential finfish and shellfish consumption rates. As noted in the National Environmental Justice Advisory Council Meeting report (U.S. EPA, 2002b):

> *A suppression effect occurs when a fish consumption rate for a given subpopulation reflects a current level of consumption that is artificially diminished from an appropriate baseline level of consumption for that subpopulation . . . When agencies set environmental standards using a fish consumption rate based upon an artificially diminished*

> *consumption level, they may set in motion a downward spiral whereby the resulting standards permit further contamination and/or depletion of the fish and aquatic resources.*

Cleanup levels in the local aquatic environment, if they are based on current finfish and shellfish consumption rates in the vicinity of the cleanup site, may not reflect the potential for the water body to rebound from its current, relatively contaminated state. This should be considered when deciding whether the use of a surrogate tribal finfish and shellfish consumption rate would better represent potential future consumption rates than would consumption rates that represent only current or near-term contamination and habitat conditions.

Studies indicate that tribal fish consumption rates are suppressed compared with historical rates and presumable rates that would exist given historical fishing stocks. The recommendations in this report, however, were developed using existing data from published studies.

For Native American populations in Washington, evaluating fish consumption rates using common survey methodology may be problematic (Donatuto and Harper, 2008). Surveys and the exposure models they develop provide information only about current consumption patterns. The number of tribal members practicing traditional lifestyles is below known historical levels. Survey data do not provide information on historical fish consumption rates and resource use, which may be more indicative of consumption rates.

Researchers suggest that suppression happens for various reasons (Donatuto and Harper, 2008). Two reasons are contamination and lower abundance. When the fish are contaminated or absent, tribal members may eat less fish and/or substitute other types of fish. While, historically, fish provided the main dietary source of protein, this is true today for only a small subset of the tribal population (Harper et al., 2007; Harper and Harris, 2008; Harris and Harper, 2001). Tribal health experts suggest that current tribal fish consumption rates are suppressed due to diminished access to historical quantities of finfish and shellfish, and some researchers believe that historical rates represent the appropriate baseline level of consumption. Effects of suppression due to chemical contamination should be accounted for in environmental cleanup regulations. However, accounting for suppression in environmental cleanup regulations may be problematic when suppression is due to permanent loss or modification of habitat due to urban infrastructure. Where habitat can be restored, then environmental cleanup regulations need to account for suppression effects in revising fish consumption estimates to help support cleanup decisions.

5.4 Uncertainty in Pacific Northwest fish-consuming populations

Ecology has identified numerous fish dietary surveys in Washington State that reflect high rates of consumption for certain ethnic groups (CRITFC, 1994; Toy et al., 1996; Sechena et al., 1999; The Suquamish Tribe, 2000). Consumption estimates vary among subpopulations by age, sex, mode of harvesting, and by region within Washington State. Washington State fish-consuming populations have been identified (tribal populations, Asian-Pacific Islanders, recreational fishers) and levels of consumption have been estimated from these surveyed populations. These higher fish-consuming ethnic populations and other high-end fish consumers are represented by upper percentile consumption estimates (90th and 95th percentile) derived from distributional analysis of the fish dietary data (CalEPA, 2001; Polissar et al., 2012).

Many of the Pacific Northwest regional-specific surveys note differences in patterns of fish consumption (e.g., eating different fish parts) and fish harvesting techniques, which demonstrates a level of variability across and among these fish-consuming populations (CalEPA, 2001; CRITFC, 1994; Toy et al., 1996; Sechena et al., 1999; The Suquamish Tribe, 2000; EPA EFH, 2011). Central tendency estimates of consumption for these populations are very similar (all fish from local harvests) with upper percentile estimates (90th and 95th percentile) within an order of magnitude.

There is considerable uncertainty inherent in evaluating and estimating fish consumption rates for northwest fish-consuming populations. Much of the uncertainty is because the available information, although substantial, nonetheless provides only a partial picture of fish consumers in Washington. Sources of uncertainties can include the following:

- Whether the available surveys provide a complete picture of the variety of fish consumption practices among various fish consuming populations.
- Evolving and changing lifestyle patterns for various populations across the state.
- Data gaps around dietary habits for other potentially high fish-consuming populations; for example, various ethnic groups, *pescadarians* (people who eat fish but not meat), subsistence fishers, and low income groups.
- Using information about one group as a surrogate for another group’s consumption rate based on evaluation of the similarity or differences in, say, species available or the extent of local shellfish habitat.
- The degree to which lifestyle (ethnic, tribal, subsistence, etc.) is recognized and accounted for in consumption studies.
- Whether or how information from the national fish dietary dataset may be inadequate for understanding fish consumption along coastal states with significant fishery resources.
- Whether and how a particular study addresses consumption of anadromous fish species.

It is expected that as the body of information grows some of these data gaps will be filled and uncertainty about Pacific Northwest fish-consuming populations will decrease.

Chapter 6: Using Scientific Data to Support Regulatory Decisions

The purpose of this Technical Support Document (Version 2.0) is to compile and evaluate available information on fish consumption in Washington State. There are risk management issues related to regulatory decisions based on this information. This is a technical document; it is not designed to resolve policy issues associated with using that information to make regulatory decisions. Ecology will be considering those issues in separate documents and processes.

This chapter is intended to provide context. It offers a brief introduction for people who are interested in the multiple and interrelated questions that arise during regulatory decision making. The Conservation Foundation has stated that it is important that environmental agencies distinguish between scientific and policy choices when making regulatory decisions (Conservation Foundation, 1984, p. 310):

> *A key to understanding the risk assessment process is to distinguish between those aspects of the process that are scientific and those that are matters of policy or personal values, and to appreciate their complex interrelationships …. A risk assessment process that is defensible from both a scientific and a policy standpoint must accurately identify which aspects of the assessment are policy and which are science. The difficulty is that both scientists and policy makers tend to define their realm in the broadest terms.*

The interaction between science and policy in regulatory decision making is complicated. Several equally valid scientific options may resolve a particular issue. In these situations, the regulatory decision essentially represents a policy choice that must take into account statutory directives, implementation issues, and value judgments on how to deal with scientific uncertainty and variability in exposure and susceptibility. As Victor Hugo once wrote, “Science says the first word on everything, and the last word on nothing,” (Hugo and O’Rourke, 1907).

Chapters 4 and 5 of this report provide Ecology’s evaluation and conclusions regarding current scientific information on fish consumption rates in the Pacific Northwest. As the wealth of knowledge continues to grow, additional information will be available in the future. Science-based regulations may have built-in requirements to periodically review and update standards based on new information. This chapter highlights some of the policy choices that will be needed when using this information to support regulatory decisions. The chapter is organized into sections. Each section provides a brief description of a particular regulatory issue and a range of examples to illustrate how agencies have resolved that issue. The issues are:

- Population groups.
- Individual variability in fish consumption rates.
- Geographic variations in fish consumption rates.
- How anadromous species (e.g., salmon) are included in fish consumption rates used for environmental regulation.
- Locally caught vs. store-bought finfish and shellfish.
- Development of regulatory fish consumption rate estimates from consumer-only vs. per capita surveys.
- Other exposure factors (e.g., body weight and exposure duration).
- Acceptable risk.

This is a partial list. Other issues may hold equal or greater importance for particular decisions. In addition, agencies typically do not consider individual policy choices in isolation from other choices. In other words, a decision on one issue may impact the decisions on other issues. For example, decisions on what constitutes an acceptable level of risk may influence decisions on how to address the uncertainties and variability in fish consumption rates.

6.1 Population groups

When developing a regulatory standard based on health protection, agencies must decide what population groups that standard is designed to protect. This is a policy choice that can be made on a programmatic (or statewide) or site-specific basis. This choice can have large implications given the differences in fish consumption rates calculated using information summarized in Chapter 4.

This policy choice is influenced by many factors including statutory requirements, environmental equity, and the nature of the decision (programmatic vs. site-specific). Options typically considered by agencies include:

- *General population.* Environmental and health agencies have established regulatory requirements or fish advisories that are based on the amount of finfish and shellfish consumed by members of the general population. For example, the EPA has adopted guidance for implementing the Clean Water Act that includes a default fish consumption rate of 17.5 g/day. The data used to establish this rate include individuals who do not eat fish. Several states have used this value to develop state water quality standards and cleanup standards for individual sites.
- *Recreational anglers.* Environmental and health agencies have established regulatory requirements or fish advisories using information on the amount of finfish and shellfish consumed by recreational anglers. For example, Ecology in 1991 adopted a default fish

consumption rate (54 g/day) in the MTCA rule that is based on a recreational fish consumption survey.

- *High exposure population groups.* Environmental and health agencies have established regulatory requirements or fish advisories using information on the amount of finfish and shellfish consumed by members of high exposure population groups (such as Native Americans and Asian Pacific Islanders). For example, the Oregon DEQ has adopted a fish consumption rate (175 g/day) that is based on concerns about tribal populations. Ecology has also established sediment cleanup standards for individual sites that are based on assessing exposure for tribal populations.
- *Susceptible populations.* Environmental agencies also establish regulatory requirements or advisories using information on groups that are more susceptible to the effects of toxic chemicals (e.g., children, pregnant women). For example, EPA and DOH have issued fish advisories that are based on limiting mercury exposure for pregnant women.

6.2 Individual variability in fish consumption rates

No two individuals are exactly alike. Exposure to hazardous substances is influenced by multiple factors and may vary widely among individuals within a given population group. Chapter 4 provides information on the variability in fish consumption rates in several study populations. When using that information to support regulatory decisions, Ecology will need to decide which values within this range of variability to use to characterize fish consumption, and consequently the degree of protectiveness Ecology offers when characterizing exposure and making regulatory decisions.

Ecology has compiled information on the distribution of fish consumption rates among the general population, and for participants in the three primary studies identified in the Technical Support Document. The study results were compiled in Table 37 below.

Table 37. Summary of Fish Consumption Rates, All Finfish and Shellfish

Population	Source of Fish	Number of Adults Surveyed	Mean	Percentiles		
				50th	90th	95th
General population (consumers only)	All sources: EPA method	2,853	56	38	128	168
	All sources: NCI method	6,465	19	13	43	57
Columbia River Tribes	All sources	464	63	41	130	194
	Columbia River	–	56	36	114	171
Tulalip Tribes	All sources	73	82	45	193	268
	Puget Sound	71	60	30	139	237
Squaxin Island Tribe	All sources	117	84	45	206	280
	Puget Sound	–	56	30	139	189
Suquamish Tribe	All sources	92	214	132	489	797
	Puget Sound	91	165	58	397	767

See Polissar et al., 2012, Table E-1.

Choosing a summary measure to characterize population exposure reflects an explicit (or implicit) policy choice on the appropriate balance between over- or underestimating exposure levels for particular individuals within the population group. Agencies typically choose one of two approaches for addressing this issue:

- *High end of the distribution.* Many agencies develop standards that are based on protecting more highly exposed individuals within a population group. For example, state and federal cleanup standards are typically based on a reasonable maximum exposure (RME).[43] The RME is defined as reasonable because it is a product of several factors that are an appropriate mix of average and upper-bound estimates. RME estimates typically fall between the 90th and 99.9th percentile of the exposure distribution. This reflects a policy choice that emphasizes the protection of the more highly exposed individuals in a population group. EPA used a similar approach when updating the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (U.S. EPA, 2000b). The EPA methodology provides a broader range of fish consumption rate statistics for tribes and states to choose from than does the Superfund (CERCLA) program. The EPA methodology allows for both upper percentile and central tendency policy choices. The Ambient Water Quality Criteria for the Protection of Human Health does include upper bound and central tendency exposure parameter choices that reflect an RME approach (e.g., 90th percentile drinking water ingestion rate and an average body weight). The EPA methodology provides a default fish consumption rate for the general population (based on protection of recreational fishers). This value (17.5 g/day) reflects the 90th percentile values protective of consuming estuarine and freshwater fish. It is derived for adults only using data from the USDA's CSFII Survey for the years 1994 to 1996.
- *Middle of the distribution.* Agencies also develop standards that are based on protecting the "average" person in a population. Under this approach, individual exposure parameters are selected to represent the middle of the exposure distribution, which may be defined in terms of the mode, median, or mean.[44] Ecology applied this policy option

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[43] The MTCA Cleanup Regulation defines the RME as "the highest exposure that is reasonably expected to occur at a site under current and potential future site use." The RME is designed to represent a high-end (but not worst-case) estimate of individual exposures.

[44] Several scientific advisory committees (National Research Council, 1994, 2009) and scientists have discussed the use of summary statistics to describe variable quantities. For example, Finkel (1989) noted that "…all summary estimators of an uncertain quantity are value laden. Summary measures are little more than ways to interpret facts in light of a subjective calculus of the costs of error…" (pp. 436-437). He described several common statistical measures, which he observed will strike different balances between overestimating and underestimating a particular value.

- Statistical mode (most frequently measured value), which embodies the value judgment that one should minimize the probability of error, without regard to its type (over- or underestimation) and magnitude.
- Statistical median (the 50th percentile value), which embodies the value judgment that the costs of the two types of errors are exactly equivalent.
- Statistical mean (the average of the measure values), which embodies the value judgment that larger errors are more important than smaller errors independent of the direction of the error. He noted that when dealing with highly skewed distributions, the mean of the

when selecting many of the exposure parameters used to calculate Method C cleanup levels in the MTCA rule.

6.3 Geographic variability

Chapter 4 indicates that there is substantial variation in the amount of finfish and shellfish consumed in different parts of Washington. Several factors contribute to these variations:

- Water body characteristics.
- Fish species (shellfish vs. finfish vs. salmon).
- Local communities.

Ecology believes that a certain amount of flexibility is needed to address this type of geographic variability. The question is where to build in the flexibility and where it is most needed. Flexibility is important for considering questions around current and future habitat and resource abundance, as well as the variability of fish species present at a site and their life cycle, including where contaminants are obtained. Ecology also acknowledges that some (but not all) water bodies are large enough to sustain moderate to high fish consumption rates.

Agencies have several options for addressing the geographic variations in fish consumption rates. These options include:

- *Single statewide fish consumption rate.* Regulatory agencies may adopt uniform statewide values that do not fully account for geographic variability in fish consumption rates. (For example, the current Water Quality Standards for Surface Waters are based upon a single fish consumption rate of 6.5 grams/day. Similarly, the MTCA Cleanup Regulation includes a single default fish consumption rate of 54 grams/day.) However, this approach ultimately requires several policy choices regarding the appropriate statewide value.
- *Multiple regional fish consumption rates.* Regulatory agencies may adopt regulatory requirements that use several fish consumption rates that reflect the diversity of fish consumption from various water bodies in Washington. Several people who provided comments on Version 1.0 of this Technical Support Document recommended that Ecology consider this option.
- *Site-specific fish consumption rates.* Regulatory agencies develop site-specific fish consumption rates that are used to establish regulatory requirements that are applicable to specific cleanup sites or dischargers. This approach can be implemented in combination with a default value established on a programmatic basis. As noted above, the MTCA

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distribution will often (but not always) fall at the upper end of the distribution. In some cases, the mean may approach the 95th percentile of the distribution.

Cleanup Regulation includes a default fish consumption rate (54 g/day) that is used to calculate site-specific cleanup standards. However, the rule also provides the flexibility to establish cleanup standards using a site-specific fish consumption rate.

6.4 Salmon

Ecology has evaluated current information on salmon consumption and life cycles in Chapter 4 and Appendix C of this report. Ecology also prepared a separate report that provides additional information and evaluation of this topic. Two main points emerged from those analyses:

- Salmon are a primary fish species consumed by Washington fish consumers.
- In contrast to other species, a significant part of salmon body burden is potentially received in waters and from sources outside of individual MTCA sites or the waters of the state[45] that are regulated under the Clean Water Act (CWA)-based criteria.

Information about salmon is discussed in various places throughout this Technical Support Document, including Chapter 4, Chapter 6, and Appendix C. In addition, a more detailed discussion of salmon is presented in the Technical Issue Paper, *Salmon Life History and Contaminant Body Burdens* (Ecology, 2012). This is an artifact of the ongoing dialogue in response to comments as Ecology continues to consider the various scientific, policy, and regulatory issues.

There are several important issues associated with deciding whether and how consumption of salmon should be taken into account when developing default fish consumption rates used in regulatory decisions. Two key questions are:

- How should the default rates take into account the consumption of fish species like salmon that spend much of their life outside of Washington waters?
- How should the complex life cycle and biology of the different anadromous species like salmon be considered when making regulatory decisions?

Several different approaches are available for resolving these questions. Although others exist, options typically considered by state and federal agencies include:

- *Salmon considered.* Some agencies have established regulatory requirements that are based on fish consumption rates that take into account consumption of all types of finfish and shellfish. In other words, the regulatory requirement is based on a fish consumption rate that includes finfish, shellfish, and anadromous fish. For example, the Oregon DEQ has adopted a fish consumption rate (175 g/day) that includes salmon.
- *Salmon considered when establishing regional rates.* Ecology could establish regional fish consumption rates that reflect the diversity of water bodies, species, and fish consumption patterns. Under this approach, Ecology could include salmon in the rates

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[45] *Waters of the state* include lakes, rivers, ponds, streams, inland waters, underground waters, salt waters, and all other surface waters and watercourses within the jurisdiction of the state of Washington (RCW 90.48.020).

applicable to some water bodies while excluding salmon in the rates for other water bodies. Ecology is not aware of examples where this approach has been used.

- *Salmon considered when establishing site-specific rates.* Ecology could establish site-specific fish consumption rates that include salmon for some (but not all) cleanup sites. Under this approach, Ecology would consider the cleanup site's contribution to salmon body burden when establishing site-specific cleanup standards.
- *Salmon NOT considered.* Some agencies have established regulatory requirements that are based on fish consumption rates that do not include salmon. For example, the EPA used this approach when establishing the default fish consumption rates that are included in the EPA Region 10 framework. Most states have adopted human health-based water quality criteria that do not include anadromous salmon in the fish consumption rate.

6.5 Sources of finfish/shellfish

In some surveys, people are asked to provide information on the source of the finfish and shellfish they have consumed. Sources of finfish and shellfish are generally categorized as self-harvested or purchased from stores or restaurants. Not all locally harvested fish may be affected by site-specific contamination. Chapter 4 summarizes information from the four key regional fish consumption surveys conducted in the Pacific Northwest. Section 4.7 summarizes available information on the source of finfish and shellfish. For these tribal populations, locally or regionally harvested finfish and shellfish represents 67 to 96 percent of total finfish and shellfish consumed.

Several different approaches are used by federal and state regulatory programs to account for patterns of exposure from different sources. Options typically considered by agencies include:

- *Fish consumption rates based on consumption of all finfish and shellfish.* Some agencies establish default and site-specific fish consumption rates using study results that reflect the total amount of finfish and shellfish consumed by study participants (independent of whether the finfish/shellfish were locally harvested or store-bought). For example, the Oregon DEQ used this approach when they revised Oregon's Water Quality Standards for Surface Waters.
- *Fish consumption rates based on consumption of locally harvested finfish and shellfish.* Some agencies establish default and site-specific fish consumption rates using study results that reflect locally harvested finfish and shellfish consumed by study participants. For example, the EPA Region 10 framework explicitly recognizes source contribution issues by adjusting total fish consumption rates to account for fish harvested and consumed from Puget Sound (U.S. EPA, 2007b).
- *Fish diet fraction.* Some agencies make site-specific adjustments to account for the amount of locally harvested finfish and shellfish caught at or near an individual sediment cleanup site. For example, the MTCA rule currently considers the fish diet fraction when

calculating site-specific surface water cleanup standards. The fish diet fraction is defined in the MTCA rule as "….the percentage of the total finfish and/or shellfish in an individual's diet that is obtained or has the potential to be obtained from the site" (WAC 173-340-708(10)(b)). Applying the 0.5 default fish diet fraction under MTCA to the 54 g/day default fish consumption rate (see Figures 15 and 16) results in an effective fish consumption rate of 27 g/day.

6.6 Consumer vs. per capita

Fish consumption surveys typically include people who eat fish and people who don't eat fish. People who don't eat fish are termed *non-consumers*. Those that do eat fish are considered *consumers*. The proportion of non-consumers included in the survey will vary depending on the population being interviewed.

The results from fish consumption surveys can be reported in terms of *consumer-only* rates and *per capita* rates. Consumer-only intake rates refer to the quantity of finfish and shellfish consumed by individuals during the survey period. These data are generated by averaging intake across only the individuals in the survey who consumed finfish and shellfish during the survey period. Per capita intake rates are generated by averaging intake rates over the entire survey population (including those individuals that reported no intake).

There can be large differences in study results reported on a consumer-only and per-capita basis when a large percentage of study participants report that they did not eat any finfish or shellfish during the survey period. For example, EPA evaluated national data from approximately 20,000 individuals (3 years and older). Approximately 28 percent were fish consumers. When expressed on a per-capita basis, the 90th percentile of the reported results was 17.5 g/day. When expressed on a consumer-only basis, the 90th percentile of the reported results was 250 g/day (U.S. EPA, 2002a).

However, there are much smaller differences in studies where a high percentage of study participants reported they ate some amount of fish during the survey period. For example, the per-capita and consumer-only rates from the CRITFC study are virtually identical.

Federal and state environmental agencies have used both types of information to establish regulatory requirements. Options include:

- *Per capita data.* Environmental agencies have used per capita fish consumption rates to establish regulatory requirements. For example, several states have adopted surface water quality standards that are based on the 90th percentile of 17.5 g/day.
- *Consumer-only data.* Environmental agencies have used consumer-only fish consumption rates to establish regulatory requirements. For example, the EPA Region 10 framework includes several default fish consumption rates that are based on consumer-only information.

6.7 Other exposure variables

Ecology uses a risk assessment approach to establish cleanup standards and water quality standards based on human health protection. Risk-based concentrations can be calculated for both cancer and non-cancer health effects using standard risk assessment equations. This document is not designed to provide a detailed discussion on individual exposure parameters and the relationships between those parameters and the fish consumption rate used to calculate risk-based concentrations. However, when selecting fish consumption rates used in regulatory decisions, it is important to consider the following points:

- Regulatory choices on individual parameters need to be based on a common exposure scenario. It is important that agencies select fish consumption rates that are consistent with other exposure parameters. For example, if risk calculations are performed using a child's body weight, the fish consumption rate should be based on the amount of finfish and shellfish eaten by children.
- Regulatory choices on individual exposure parameters need to recognize the value judgments embedded in those parameters and the cumulative impact of those choices. For example, selecting upper percentile values for all exposure parameters will result in a risk estimate that does not represent a "reasonable" maximum exposure scenario (RME).
- Values should be concordant with the populations chosen to represent regulatory exposure scenarios, for example body weight for tribal populations or particular ethnic groups. Similarly, exposure duration should reflect the duration of times populations selected for evaluation use water bodies for fishing. Tribes have Usual and Accustomed fishing areas they may use over long periods of time. Individuals may relocate over limited geographic areas and still utilize water bodies for fishing with the implication that times in a single residence may not be an appropriate exposure duration.
- How bioaccumulation is accounted for is also a source of uncertainty and variability. The use of bioconcentration factors (BCFs) that relate contaminant concentrations in aquatic biota to those in water are being replaced by bioaccumulation factors (BAFs) that relate contaminant concentrations in aquatic biota to those from all sources.
- Figures 15 and 16 illustrate other exposure parameters. Shown are equations used to establish MTCA surface water cleanup standards based on non-cancer hazard and cancer risks (Figures 15 and 16, respectively). In addition to a default fish consumption rate, the equation includes default values for body weight, exposure duration, and fish diet fraction. A similar (but not identical) equation is used to establish water quality standards. Several of the exposure assumptions used to establish water quality standards are different than those used under the MTCA rule.

$$CUL = \frac{(RfD * ABW * UCF1 * UCF2 * HQ * AT)}{(BCF * FCR * FDF * ED)}$$

Where:

CUL = Surface water cleanup standard (µg/L)

RfD = Reference Dose as specified in WAC 173-340-708(7)

ABW = Average body weight During the exposure duration (70 kg)

UCF1 = Unit conversion factor (1000 µg/mg)

UCF2 = Unit conversion factor (1000 g/liter)

BCF = Bioconcentration factor as defined in WAC 173-340-708(9) (liters/kilogram)

FCF = Fish consumption rate (54 g/day)

FDF = Fish diet fraction (0.5, unitless)

HQ = Hazard quotient (1 unitless)

AT = Averaging times (30 years)

ED = Exposure duration (30 years)

Figure 15. MTCA Surface Water Cleanup Standards Equation (Non-Carcinogenic Hazards)

$$CUL = \frac{(RISK * ABW * AT * UCF1 * UCF2)}{(CPF * BCF * FCR * FDF * ED)}$$

Where:

CUL = Surface water cleanup standard (µg/L)

RISK = Acceptable cancer risk level (1 in 1,000,000) (unitless)

ABW = Average body weight during the exposure duration (70 kg)

AT = Averaging time (75 years)

UCF1 = Unit conversion factor (1,000 µg/mg)

UCF2 = Unit conversion factor (1,000 grams/liter)

CPF = Carcinogenic Potency Factor as specified in WAC 173-340-708(8) (kg-day/mg)

BCF = Bioconcentration factor as defined in WAC 173-340-708(9) (liters/kilogram)

FCR = Fish consumption rate (54 grams/day)

FDF = Fish diet fraction (0.5) (unitless)

ED = Exposure duration (30 years)

Figure 16. MTCA Surface Water Cleanup Standards Equation (Carcinogenic Risk)

6.8 Acceptable risk levels

Washington’s current Water Quality Standards and MTCA Cleanup Regulation are both based on an acceptable cancer risk of 1 in 1 million and a hazard quotient of one. These are central policy choices that will continue to be discussed and debated. By necessity, decisions on acceptable risk levels are informed by science but require consideration of a wide range of other factors. For example:

- Statutory requirements.
- Social preferences on risk avoidance and distinctions between voluntary and involuntary risks.
- Uncertainties associated with risk assessment methods.
- Risk tradeoffs, including the health benefits associated with eating finfish and shellfish.
- Risk comparisons, including the risks associated with other common activities.
- Economic impacts of attaining target risk levels.

This technical support document focuses on information about fish consumption. It does not provide a detailed discussion on risk policy. Ecology acknowledges that when selecting fish consumption rates for use in regulatory decisions it will be important to consider the relationships and interactions between the various policy choices.

6.9 Summary

Agencies must address many scientific and policy issues when selecting a fish consumption rate for use in particular regulatory situations. Chapters 3 through 5 compile the currently available information on fish consumption rates in Washington. This chapter describes eight policy choices that should be addressed when using this information in a regulatory context. These policy choices must take into account statutory mandates and values that inevitably reflect explicit or implicit choices on how to deal with scientific uncertainty and variability. There are often multiple answers to these questions surrounding these issues. This chapter provides examples of how Ecology or other agencies have resolved those issues in the past.

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Appendices

Appendix A Information on Bioaccumulation, Fish Consumption by Children, and Species Consumed

This appendix includes information on:

1. Bioaccumulation
2. Children's fish consumption rates
3. Data on species consumed

This information is included in this document to provide additional context for considering fish consumption rates. For additional information readers are referred to references cited.

A.1 Bioaccumulation

Bioaccumulation of contaminants in finfish/shellfish

A detailed discussion regarding the bioaccumulation of chemicals in aquatic biota is beyond the scope of this appendix. The EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) dedicates an entire chapter on the subject of bioaccumulation and changes in methodologies since the 1980s to assess and predict the bioaccumulation of chemicals in aquatic biota. Federal and state guidance documents are available that provide detailed analysis to assess and predict the bioaccumulation of chemicals in aquatic biota (U.S. EPA, 2000b, 2000c, 2007a; State Water Resources Control Board of California, 2004; CalEPA, 2006). An 800-page appendix to EPA's *Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment* provides chemical-specific information relevant to the bioaccumulation of chemicals in aquatic biota (U.S. EPA, 2000c, Appendices).

EPA makes a clear distinction between the terms bioaccumulation and bioconcentration. The term bioaccumulation "refers to the uptake and retention of a chemical by an aquatic organism from all surrounding media (e.g., water, food, sediment)." The term bioconcentration "refers to the uptake and retention of a chemical by an aquatic organism from water only" (U.S. EPA, 2000b). The 2000 EPA guidance reflects the use of bioaccumulation factors (BAFs) to reflect the uptake of a contaminant by fish from all sources rather than just from the water column reflected by the use of bioconcentration factors (BCFs). For chemicals that are persistent and hydrophobic, the magnitude of bioaccumulation by aquatic organisms may be substantially greater than the magnitude of bioconcentration. The 2000 EPA Ambient Water Quality Methodology provides important concepts regarding the bioaccumulation process as follows (U.S. EPA, 2000b, p. 5–2):

> *Another noteworthy aspect of bioaccumulation process is the issue of steady-state conditions. Specifically, both bioaccumulation and bioconcentration can be viewed as the results of competing rates of chemical uptake and depuration (chemical loss) by an aquatic organism. The rates of chemical uptake and depuration can be affected by various factors including the properties of the chemical, the physiology of the organism in question, water quality and conditions, ecological characteristics of the water body (e.g., food web structure), and the concentration and loadings history of the chemicals. When the rates of chemical uptake and depuration are equal, tissue concentrations remain constant over time and the distribution of the chemical between the organism and its sources(s) is said to be at steady-state. For constant chemical exposures and other conditions, the steady-state concentration in the organism represents the highest accumulation potential of the chemical in that organism under those conditions. The time required for a chemical to achieve steady state has been shown to vary according to the properties of the chemical and other factors.*

The EPA further notes that…"criteria for the protection of human health are typically designed to protect humans from harmful lifetime or long-term exposures to waterborne contaminants, the assessment of bioaccumulation that equals or approximates steady-state accumulation is one of the principles underlying the derivation of national BAFs. For some chemicals that require relatively long periods of time to reach steady-state in tissue of aquatic organisms, changes in water column concentrations may occur on a much more rapid time scale compared to the corresponding changes in tissue concentrations. Thus, if the system departs substantially from steady-state conditions and water concentrations are not averaged over a sufficient time period, the ratio of the tissue concentration to a water concentration may have little resemblance to the steady-state ratio and have little predictive value of long-term bioaccumulation potential" (U.S. EPA, 2000b).

There are several important factors that may affect a chemical's bioavailability and influence its bioaccumulation in fish. These factors include a wide range of physical, chemical, and biological characteristics associated with the contaminants, sediments, and aquatic biota (U.S. EPA, 2000c).

Chemical bioavailability. Chemical bioavailability is a complex interplay between the physical-chemical properties of the contaminant as well as the behavior and physiology of the aquatic biota.

Physical factors of sediments affecting bioavailability and bioaccumulation. Sediments are complex and dynamic environments with a wide range of interacting biological and chemical processes that influence a chemical's bioavailability and bioaccumulation into fish tissues.

Variable rates of mixing surficial sediment layers by physical processes of turbulence and bioturbation compete with rates of sedimentation. In addition, resuspension of sediments may also impact the bioavailability of sediment-associated contaminants by exposing filter feeders to contaminated particulates or by increasing the aqueous concentration of a contaminant via desorption from the particulates within the water column.

Chemical factors affecting bioavailability and bioaccumulation. The physical-chemical characteristics of a contaminant (molecular size and polarity) may influence the degree of association with particles and affect the chemical's bioavailability. Many persistent and bioaccumulative toxic chemicals (PBTs) are large, nonpolar compounds, with low water solubilities and a strong tendency to be associated with dissolved and particulate organic matter. Hydrophobic chemicals, those that are strongly lipophilic, are a critical factor in determining the bioaccumulation behavior of organic chemicals in aquatic systems.

Biological factors affecting bioavailability and bioaccumulation. EPA notes that bioaccumulation is a multi-factorial process that combines the chemical with the biological (U.S. EPA, 2000c, p. X):

> *Bioaccumulation is a function of the bioavailability of contaminants in combination with species-specific uptake and elimination processes. Toxicity is determined by the exposure of an animal to bioavailable contaminants in concert with the animal's sensitivity to the contaminant. These processes have been shown to be a function of the organism's lipid content, size, growth rate, gender, diet, and ability to metabolize or transform a given contaminant, as well as the chemical conditions of the surrounding medium. Other biological factors that can affect a contaminant's bioavailability include the burrowing and feeding behavior of the individual organism or species. The depth to which an organism burrows, the type of feeding mechanism it uses (e.g., filter feeding, particle ingestion), the size range of sediment particles it consumes, and its diet all have a large influence on the concentration of contaminant to which the organism will be exposed.*

A.2 Children's fish consumption rates

The *Child-Specific Exposure Factors Handbook* and the *Highlights of the Child-Specific Exposure Factors Handbook* summarize children's fish consumption rates for different age groups. The mean and 95th percentile consumer-only total fish (marine, estuarine, freshwater) consumption rate for 16 to less than18 years of age for the general population is 2.1 grams per kilogram per day (g/kg/day) (136 g/day) and 6.6 g/kg/day (357 g/day), respectively (U.S. EPA, 2008, 2009b). The mean and 95th percentile consumer-only total fish (finfish and shellfish) consumption rate for 3 to under 6 years old for the general population is 4.2 g/kg/day (78 g/day) and 10 g/kg/day (186 g/day), respectively (U.S. EPA, 2009b, Table 1).[46] The *Interim Report Child-Specific Exposure Factors Handbook* summarizes the fish consumption rates among Native American children (consumers only, 5 or 6 years old or younger) using Pacific Northwest fish consumption survey information (U.S. EPA, 2002a).

Table A-1. Fish Consumption Rates of Native American Children 5 or 6 Years of Age or Less

Survey (Native Populations)	Mean (g/day)	90th Percentile [a] (unless otherwise noted, g/day)	95th Percentile (g/day)
CRITFC, 1994 (Umatilla, Yakama, Nez Perce, Warm Springs)	25	63	73
Toy et al., 1996 (Tulalip and Squaxin Island Tribes) [b]	11	21 (86th percentile)	
Suquamish Tribal Survey, 2000 [c]	21	48	103

a. Values are the 90th percentile unless otherwise noted.

b. Consumption rate calculated using the average body weight of 15.2 kilograms reported in Toy et al., 1996.

c. Consumption rate calculated using the average body weight of 14.1 kilograms from the general population.

Although the age groups and body weights may differ across the general and Native American children population groups, the fish consumption rates for the children begin to approximate one another at the upper percentiles (78 to 186 g/day and 63 to 103 g/day). EPA has noted that there is a high degree of variability in fish consumption rates across the Pacific Northwest tribes (U.S. EPA, 2009a). The 2008 Oregon DEQ Human Health Focus Group Report referenced EPA's *Per Capita Fish Consumption in the U.S.* (2002) as supporting documentation for the children's fish consumption rate (consumers only) of 191 g/day (Oregon DEQ, 2008; U.S. EPA, 2002a, Section 5.2.1.1, Table 4). The same documentation and children's fish consumption rate (190 g/day) is used to recognize the variability expressed by different fish consumption rates for different fish-consuming populations.

The following tables summarize analysis of fish consumption rate data for surveys identified by Ecology as meeting measures of technical defensibility. These tables are included here to show age group data.

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[46] This consumption rate uses a body weight of 18.6 kilograms for children 3 to <6 years of age.

Table A-2. Tribal Fish Consumption Rates

Fish Consumption Rate by Age Group From Selected Pacific Northwest Tribes				
Age Group	Mean	50th Percentile	90th Percentile	95th Percentile
Columbia River Basin Tribes (g/day)				
Adults	58.7			
18–39	57.6			
40–59	55.8			
60 and over	74.4			
Tulalip Tribes (g/kg/day)				
0–5	0.2	0.08	0.7	
18–34		0.06	2.0	2.6
35–49		1.0	3.7	4.2
50–64		0.5	1.6	1.6
65 and over		0.2	0.6	0.6
Adults	0.9	0.6	2.9	
Squaxin Island Tribe (g/kg/day)				
0–5	0.8	0.5	2.1	
18–34		0.5	2.3	3.1
35–49		0.5	2.6	3.0
50–64		1.1	3.6	3.6
65 and over		0.8	2.2	2.2
Adults	0.9	0.5	3.0	
Suquamish Tribe (g/kg/day)				
0–6	1.5		3.4	
Adult Males				
16–42	3.3	2.3	8.6	13.0
43–54	5.2	4.6	10.3	
55 and over	1.6	1.4	4.8	
Adult Females				
16–42	1.9	1.0	4.9	10.1
43–54	1.2	0.8		
55 and over	3.7	2.1		

Source: Adapted from Moya, 2004, Table 5, p. 1204.

Table A-3. Fish Consumption Rate Data for Asian and Pacific Islanders

Asian and Pacific Islanders in King County, by Age Group (g/kg/day)	Mean	50th Percentile	90th Percentile	95th Percentile
All respondents	1.9	0.8	2.4	3.9
18–29	1.8		2.1	3.9
30–54	1.6		2.3	3.8
55 and over	2.1		3.2	5.2

Source: Adapted from Moya, 2004, Table 4, p. 1203.

Table A-4. EPA Data on Children's Finfish and Shellfish Consumption Rates for the U.S. General Population

Fish Population Description	Fish Consumption by Age Group (g/kg/day)			
	3 to < 6 years	6 to < 11 years	11 to < 16 years	16 to < 18 years
Total fish				
Mean per capita	0.43	0.28	0.23	0.16
95th percentile per capita	3.0	1.9	1.5	1.3
Mean consumer only	4.2	3.2	2.2	2.1
95th percentile consumer	10	8.7	6.2	6.6
Marine fish				
Mean per capita	0.31	0.20	0.15	0.10
95th percentile per capita	2.3	1.5	1.3	0.46
Mean consumer only	3.7	2.8	2.0	2.0
95th percentile consumer	9.3	8.0	5.2	6.5
Freshwater fish				
Mean per capita	0.12	0.08	0.08	0.07
95th percentile per capita	0.71	0.35	0.48	0.29
Mean consumer only	2.3	1.8	1.3	1.4
95th percentile consumer	7.2	6.2	4.4	3.3

Source: Adapted from U.S. EPA, 2009b, Table 1, p. 20.

A.3 Data on fish species consumed

The EPA Region 10 framework for establishing site-specific fish consumption rates for use at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites provides the following information related to types of seafood consumed.

For adult members of the Tulalip Tribes, a 95th percentile total consumption rate of 194 g/day is obtained after adjusting the total consumption rate of 243 g/day to include only finfish and shellfish harvested from Puget Sound (Table A-5). This is based on information from the EPA Region 10 framework (U.S. EPA, 2007b, as cited in Windward Environmental, 2007, Appendix B).

Table A-5. Seafood Consumed by Adult Members of the Tulalip Tribes

Seafood Category	Examples	Central Tendency Estimate (g/day)	95th Percentile (g/day)	Percent of Fish Diet
Anadromous fish	Salmon/steelhead	14.9	96.4	49.7
Pelagic fish	Smelt, mackerel, cod, perch	1.3	8.1	4.2
Benthic/demersal fish	Halibut, sole, rockfish, snappers	1.2	7.5	3.9
Shellfish	Crabs, clams, mussels, bivalves	12.5	81.9	42.2
	Total ingestion rate	30	194	100

For adult members of the Suquamish Tribe, a 95th percentile total consumption rate of 766.8 g/day is obtained after adjusting the total consumption rate of 796 g/day to include only finfish and shellfish harvested from Puget Sound (Table A-6). This is based on information from the EPA Region 10 framework (U.S. EPA, 2007b, as cited in Windward Environmental, 2007).

Table A-6. Seafood Consumed by Adult Members of the Suquamish Tribe

Seafood Category	Examples	95th Percentile (g/day)	Percent of Fish Diet
Anadromous fish	Salmon/steelhead	183.5	23.9
Pelagic fish	Smelt, mackerel, cod, perch	56.0	7.3
Benthic/demersal fish	Halibut, sole, rockfish, snappers	29.1	3.8
Shellfish	Crabs, clams, mussels, bivalves	498.4	65
	Total ingestion rate	766.8	100

Freshwater fish make up 8.3 percent of the API seafood consumption, based on information from the API fish consumption survey from King County, Washington, as cited in Windward Environmental, 2007 (Table A-7).

Table A-7. Seafood Consumed by Adult Asian-Pacific Islanders (API)

Seafood Category	Central Tendency Estimate (g/day)	95th Percentile (g/day)	Percent of fish diet
Anadromous fish	0.56	5.5	9.6
Pelagic fish	0.5	4.9	8.6
Benthic/demersal fish	0.24	2.4	4.2
Shellfish	4.6	44.2	77.5
Total	5.9	57	99.9

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Appendix B
Additional Fish Consumption Studies

This appendix includes information on additional studies considered by Ecology:

1. Background information
2. Biometric studies of Japanese and Korean populations in Washington State
3. Additional studies evaluated:
    a. Makah Tribe
    b. Port Gamble S'Klallum Tribe
    c. Muckleshoot Indian Tribes
    d. Upper Columbia River Resources Survey – Confederated Tribes of the Colville Reservation
    e. Spokane River Surveys of Selected Ethnic Populations
    f. Swinomish Tribal Study: Bioaccumulative Toxics in Subsistence-Harvested Shellfish – Contaminant Results and Risk Assessment
4. Additional technical publications by Pacific Northwest tribal staff

B.1 Background information

Ecology identified a number of studies that provide information meeting measures of technical defensibility and that are appropriate for consideration of statewide fish consumption rates. Other studies are useful in providing multiple lines of evidence with respect to fish consumption. That is, numerous other studies, designed for various purposes, provide additional information that may be of value for particular evaluations or considerations. Although these studies may not have been conducted to identify specifically fish consumption rates of the population of interest, they assist in providing a robust picture of the importance of finfish and shellfish to the people of Washington.

The studies discussed in this appendix are comprehensive but not exhaustive. For example, from July 2003 through December 2011, The Lands Council as part of the Spokane River Toxics Outreach, completed approximately 5,300 surveys, distributed about 10,000 health advisories, and participated in public education outreach of nearly 16,000 individuals in the Spokane area. This public outreach is to educate and increase public awareness of the health risks of PCBs in the Spokane River fish and heavy metal contamination in the Spokane River sediments. These surveys have targeted Slavic (eastern European, Russian) and Hispanic populations because they frequently harvest and consume fish from the Spokane River. Spokane River fish advisories recommend only one fish meal per month of fish from the river's middle section and avoid eating any fish from the Spokane River's upper stretches.[47] As noted in Chapters 3 and 4 of this Technical Support Document, these water body-specific surveys provide important information to support health protective advisories for people who harvest and consume fish from specific water bodies. All water body-specific fish dietary surveys, usually some form of a creel survey, are not detailed in this Technical Support Document. For a more detailed review of all of the water body-specific surveys and fish advisory information, the reader is referred to the Washington Department of Health's website on fish advisories.[48] The fish consumption related information provided in this appendix is important and credible information used to evaluate and assess the potential health risks from eating contaminated fish (seafood). The additional fish dietary information provided in Table 33 and this appendix provide multiple lines of evidence, as a weight of evidence approach, that people in Washington State harvest and consume large amounts of fish. The estimates of fish consumption detailed in Chapter 4 are based on fish dietary information based on survey methodology that allows for the projection of fish consumption estimates over a long period of time with descriptive statistics for percentile estimates. This type of information is important to help support health protective decisions to clean up contaminated sediments.

B.2 Biometric studies of Japanese and Korean populations in Washington State

Several studies have been conducted in Washington State to evaluate the fish consumption of Japanese and Korean populations (Tsuchiya et al., 2008a, 2008b, 2009; Cleland et al., 2009). These studies were conducted as part of the Arsenic Mercury Intake Biometric Study in collaboration with the University of Washington's Institute for Risk Analysis and Risk Communication and the Washington State Department of Health. The studies were designed to evaluate mercury exposure within the Japanese and Korean communities and arsenic exposures within the Korean community of Washington State. Japanese and Korean populations in Washington State consume fish at higher rates than the national average (Sechena et al., 1999). These high fish-consuming populations may be exposed to mercury and arsenic from the consumption of finfish and shellfish.

The fish consumption survey was based on surveys previously conducted for several other Pacific Northwest fish-consuming populations (tribal surveys and Sechena et al., 1999). The food frequency questionnaire was a validated dietary tool used and developed by the Fred Hutchinson Cancer Research Center and was self administered by the participants of this study. As part of the fish dietary survey, participants were provided a pictorial fish booklet, printed in three languages, containing pictures with names of various fish species commonly consumed by

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[47] Spokane River Toxics Outreach, web location: http://www.landscouncil.org/water/river_toxics.asp?template=false

[48] Washington State Department of Health Fish Advisory Information: http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish.aspx

Japanese and Koreans and seafood commonly found in the Pacific Northwest. Interview questions included frequency of consumption and serving sizes (based on fish models of fish steaks, fillets, sushi pieces, and shellfish samples). Also, participants were asked if they consumed any other fish not listed in the fish booklet. Survey participants were weighed unless they were pregnant. Pregnant women were asked to report their pre-pregnancy body weights.

The survey instrument included a series of questions that allowed for a cross-check of participant response about fish consumption. Mercury fish tissue concentrations were determined from fish commonly consumed by Japanese and Korean communities in the Puget Sound area from local Asian grocery stores. Fish or fish portions were purchased from multiple locations over a 4-week period. Analysis was conducted on skinless edible portions consisting of steaks or fillets.

Results from the Japanese and Korean fish dietary survey are shown in Table B-1 with comparisons made between the mean combined finfish and shellfish consumption rates (in red) with the 95th percentile national consumption rates (in red).

Table B-1. Fish Consumption Rates for Japanese and Korean Washington Populations

Population	Finfish Consumption (g/day)			Shellfish Consumption (g/day)		
	Mean	50th	95th	Mean	50th	95th
Japanese (n = 106)	60	43	159	14	9	59
Korean (n = 108)	59	42	147	23	13	84
Population	**Finfish and Shellfish Combined Consumption (g/day)**					
	Mean	50th	75th	90th	95th	99th
Japanese (n = 106)	73	55	100	164	188	241
Korean (n = 108)	82	64	112	170	230	329
CSFII	14	----	19	47	72	121
NHANES	----	----	0	43	87	----

Source: Adapted from Tsuchiya et al., 2008b, Table 1.

Both Japanese and Korean respondents from this survey consume almost the same amounts of finfish (mean fish consumption of 60 g/day for Japanese and 59 g/day for Koreans). Also, this similarity in fish consumption for Japanese and Koreans is reflected in the finfish consumption distribution with 95th percentiles being 159 g/day for Japanese and 147 g/day for Koreans. Differences in amounts of total fish consumption for these two fish-consuming populations is due to the Koreans consuming nearly 70 percent more shellfish on a daily basis (22.7 g/day/person) compared to the Japanese (13.5 g/day/person). The mean total fish consumption for Japanese (73 g/day) and Koreans (82 g/day) is almost identical to the 95th percentile estimates from CSFII and NHANES national fish dietary data. Based on comparison with national data, the authors noted (Tsuchiya et al., 2008b):

> *The Koreans and Japanese women consume fish in quantities that exceed the national average. Mean values for the average values for the Japanese and Korean cohorts are significantly higher (73 and 82 g/day, respectively). Values of significance within the NHANES and CSFII distributions are the 95th percentile values (87 and 72 g/d, respectively) because the remaining 5% represent many persons. The average consumption values for the Koreans and Japanese approach or exceed these 95th percentile values, indicating that these 2 populations may be contained within the remaining 5th percentile of the NHANES and CSFII distributions. On the basis of the percentile values for the consumption distributions from CSFII and NHANES, the 2 populations investigated by us have central estimate shifts in consumption, leading to distribution patterns displaced to the right and further down the abscissa. Specifically, all the percentile consumption rates representing the national fish consumer were below those determined for the Japanese and Koreans.*

Mean fish consumption estimates for Japanese and Korean women respondents for each of the clinic visits are provided in the table below. Additional details regarding the finfish species consumed and differences in rates from one clinic visit to another are provided in the Technical Issue Paper, *Health Benefits and Risks of Consuming Fish and Shellfish* (Ecology, 2012).

B.3 Additional studies evaluated

Makah Tribe

The Makah Indian reservation is located on the northwestern tip of the Olympia Peninsula in Washington State. The Makah Tribal usual and accustomed areas for harvesting finfish and shellfish extends east to the Elwha River, south to a geographic point between Ozette and the Quileute reservation, and north to the Canadian international border and the Swiftsure Bank. The geographic position of the Makah Indian reservation provides access to diverse terrestrial, freshwater, and marine resources to support subsistence practices.

An examination of the Makah subsistence practices was conducted by the University of Washington, Department of Anthropology, between 1997 and 1999. Jennifer Sepez's 2001 dissertation documents and evaluates the subsistence hunting, fishing, and shellfishing practices of the Makah Indian Tribe. For the purposes of this research, subsistence was defined as "the local harvest of natural resources for local consumption" (Sepez, 2001, p. 9). A random ethnographic survey sample of 15 percent of reservation households provided information on the contemporary subsistence harvests, uses, and consumption of finfish, shellfish, land mammals, marine mammals, and birds. Results indicate that 99 percent of the reservation households participate in some type of subsistence activities. 71 percent of the households engaged in harvesting resources, while 94 percent received resources harvested by another household. This comprehensive examination of Makah Tribal subsistence practices included hunting for deer, elk, and grouse, and fishing for salmon, halibut, rockfish, black cod, and other species (Table B-2). Low tides in Neah Bay or adjacent tide flats provide areas for tribal harvesting of clams, mussels, barnacles, chitons, urchins, and other shellfish. Seal hunting occurs in conjunction with net fishing and canoeing. Regarding the Makah Tribal subsistence practices, the thesis noted (Sepez, 2001, p. 19):

> *There is no homogeneous or even typical subsistence profile of Makahs. However, there are identifiable patterns of resource use in the community, and an accumulated history of legal, political, and ecological circumstances that frame contemporary subsistence activities as a place-and time-specific manifestation of ongoing traditions.*
>
> *Although land-based subsistence harvesting is important, the majority of resources come from the sea. One saying around town that captures this orientation is "when the tide is out, the table is set."*

Table B-2. Percent of Households Using Subsistence Resources during 1997–1998

Percent of Reservation Households	Subsistence Resource
76–100%	Halibut, salmon, clams, crab
51–75%	Mussels, deer, elk, goosenecks [boots], seal (meat and/or oil), salmon eggs, barnacles
26–50%	Steelhead, lingcod, olive shells, chitons [slippers], octopus, rockfish, smelt, black cod, herring eggs, grouse
1–25%	Urchins [sea eggs], lingcod eggs, local cow, petrale, trout, tuna, bear, scallop, oysters, sole/flatfish, sea cucumber, squid, sturgeon, true cod, shrimp, rabbits, abalone, duck, pigeon, skate, sea lion, small gastropods, wolf eel.

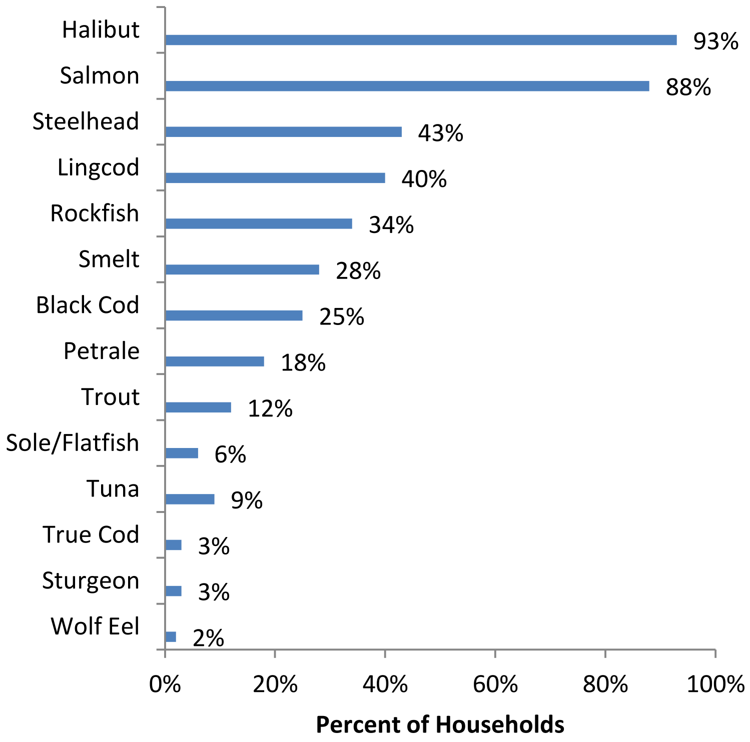
Source: Adapted from Sepez, 2001, Table 4, p. 126.

The Makah tribal subsistence diet is composed mainly of finfish and shellfish. Shellfish contribute 14 percent and finfish contribute 58 percent of the Makah tribal subsistence diet. The percent contribution of fish to the Makah subsistence diet is approximately eight times more than the percent contribution of fish consumed by the average American diet. Halibut is consumed at home by 93 percent of the households. Historical information suggests a strong dietary reliance on halibut, which differentiated the Makah Indian Tribe from other Pacific Northwest tribes whose main fish subsistence resource was salmon. However, 88 percent of the Makah tribal households consume salmon, which surpasses halibut consumption when measured as pounds consumed per household. Table B-3 and Figure B-1 below illustrate the harvest and consumption practices of the Makah Tribe for fish resources in pounds. Salmon and halibut contribute more to the subsistence Makah diet by weight than any other types of fish combined.

Table B-3. Makah Indian Tribe Per Capita Harvest and Consumption of Subsistence Fish (pounds)

Fish Species	Mean per capita harvest (all households)	Mean per capita consumption (all households)	Mean per capita consumption (consumers only)
Halibut	55.6	27.4	28.9
Salmon	49.3	40.1	44.9
Steelhead	3.1	3.8	8.6
Lingcod	2.5	2.9	6.9
Rockfish	2.5	3.3	8.9
Smelt	2.4	2.7	10.0
Black Cod	1.3	1.2	5.9
Trout	0.04	0.1	0.4
Sturgeon	1.0	0.8	28.0
Skates	0.1	NA	NA

Source: Adapted from Sepez, 2001, Table 6, p. 140.



Source: Adapted from Sepez, 2001, Figure 3, p. 139.

Figure B-1.Percent of Makah Tribal Households Consuming Subsistence Fish

The survey vehicle administered to the Makah tribal reservation households obtained subsistence fish harvest and consumption information based on household harvest and consumption practices. Ecology did not use this information because the metrics from the results of the survey of tribal households (percent of tribal household consuming fish) is different than the metrics (grams/day) used for risk-based decision making. Furthermore, since information was not available regarding the number of residents per household, and the residency of the same household may vary depending on the extended family relationship within the Makah Tribe, it is not possible to determine an individual's grams/day fish consumption rate based on this thesis. However, this thesis provides a comprehensive documentation of the composition of subsistence Makah tribal diet and subsistence lifeways and practices.

Port Gamble S'Klallum Tribe

Ecology consulted with the Port Gamble S'Klallam Tribe to determine a tribal fish consumption rate to establish sediment cleanup standards protective of human health. The Port Gamble S'Klallam Tribal fish consumption rates were based on the Suquamish Tribe Fish Consumption Survey using the EPA Tribal Fish Consumption Framework. The daily tribal seafood consumption rate of 499 g/day was determined for selected shellfish only and did not include salmon or other finfish. Tribal consultations are continuing to provide additional information regarding the amounts and types of shellfish consumed. Based on Port Gamble S'Klallam Tribal consultations and the application of the EPA Tribal Fish Consumption Framework, the following shellfish species are consumed:

- Total shellfish consumption (no finfish) is 499 g/day:

Geoduck	96.8 g/day
Littleneck clams	255.9 g/day
Oysters	62.4 g/day
Dungeness crab	83.9 g/day assuming 25% hepatopancreas (20.9 g/day) and 75% meat (62.9 g/day).

Ecology did not use this information to derive a default fish consumption rate because Port Gamble S'Klallam Tribal consultations are continuing to establish an accurate tribal fish consumption rate (Ecology, 2011a).

Muckleshoot Indian Tribes

The Muckleshoot Indian Tribe has not performed a tribal fish consumption survey.[49] However, the Muckleshoot Indian Tribe requested that EPA Region 10 develop a tribal exposure scenario to assist in characterizing the range of seafood consumption risks for the Lower Duwamish Waterway. In consultation with the Muckleshoot and Suquamish Indian Tribes, EPA Region 10

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[49] Public Health Assessments and Health Consultations. ATSDR. http://www.atsdr.cdc.gov/hac/pha/pha.asp?docid=1312&pg=2#path

and Ecology used EPA guidance to develop a tribal exposure scenario and derive fish consumption rates based on the Suquamish and Tulalip seafood consumption data. Using the EPA Region 10 guidance framework tribal exposure scenarios were developed for the Lower Duwamish Waterway for tribal adults consuming anadromous and pelagic finfish, benthic/demersal finfish, and shellfish. The Lower Duwamish Waterway Remedial Investigation Report provides a range of tribal consumption rates specific for the risk management decisions for the Lower Duwamish Waterway (Windward Environmental, 2007). The Lower Duwamish Waterway fish consumption rates are not applicable for Washington State high fish-consuming populations. Hence, the Lower Duwamish Waterway fish consumption rates were not used to derive a default MTCA fish consumption rate to establish surface water cleanup standards.

Upper Columbia River Resources Survey–Confederated Tribes of the Colville Reservation

Background information

The Confederated Tribes of the Colville Reservation and the EPA, Region 10 and Headquarters, collaborated on the Upper Columbia River Resources Survey (Confederated Tribes of the Colville Reservation and U.S. EPA, 2012). The upper Columbia River and Lake Roosevelt areas have been affected by contaminants from Teck Cominco lead-zinc smelter operations for over 100 years. Residents of the Colville Reservation, located 50 miles downstream from Teck Cominco mine, may have been exposed to these contaminants and have collaborated with the EPA to assess and measure exposure pathways from the consumption of natural resources (including fish) that may be contaminated from the Teck Cominco operations. This information will be used by the EPA to conduct a human health risk assessment for the Upper Columbia River and Colville reservation residents. The resource use survey was conducted to support efforts to evaluate and assess the human health risks from exposures to contaminants from the Teck Cominco lead-zinc smelter located just north of the U.S. Canadian border.

Survey methodology

The Upper Columbia River Resources Survey is composed of two survey vehicles designed to investigate the food consumed and non-food uses harvested from local resources by residents of the Colville Reservation located in eastern Washington State. The Food Questionnaire was administered by trained personnel to Colville Reservation residents regarding the consumption over the preceding 12-month period of several types of food groups: fish, birds, wild animals, farm animals, dairy products, fruits, vegetables, and wild plants. The Food Questionnaire survey method was a 24-hour dietary recall and included a previous 12-month food frequency recall and non-food use recall associated with resident uses of the reservation’s natural resources. Out of a pool of 5,893 people, 1,139 people over the age of 2 responded to the Food Questionnaire—approximately 20 percent of the total resident population. A demographic weighting was applied to each respondent to account for the variance in response rate for residence location and age. The percentages and numbers of consumers provided in the Food Questionnaire data report will vary from the percentage of individual respondents because of this demographic weighting of each respondent. The demographic weighting allows the calculation of numbers and percentages of Colville Reservation residents over the age of 2 years that consume selected types of foods.

Results

Selected results of the Food Questionnaire related to fish consumption from Upper Columbia River Tribal Exposure Survey are presented in Table B-4.

Table B-4. Summary of Fish Type Consumed, Percentage of Population that Consumed Fish Type, and Percentage Harvest Source from Local Areas by Colville Reservation Residents

Fish Type	Percentage of Residents Consuming Fish Type	Frequency of Consumption (times/year)	Percentage Consumers Harvest from Local Areas
Salmon	73	15	74
Trout	46	13	92
Walleye	13	9	91
Smallmouth Bass	11	21	93
Crawfish	9	13	85
Mussels	8	9	12
Largemouth Bass	7	22	85
Panfish	6	25	79
Burbot	4	9	30
Sturgeon	3	40	68
Lake Whitefish	2	9	91
Mountain Whitefish	1	8	69
Lamprey	1	12	13
Aquatic Animals	1	18	100
Northern Pikeminnow	1	7	87
Other fish/aquatic animal	<1	6	100
Sucker [a]	<1	head/skin/organ/eggs	0%

Source: Adapted from Confederated Tribes of the Colville Reservation and U.S. EPA, 2012, Table 3.

a. Sucker was the only fish for which the head/skin/organ/eggs were reported to be consumed more frequently than the meat of the fish. However, a very low number of respondents reported eating suckers and all respondents were unsure of the harvest source of suckers consumed.

The 24-hour dietary recall survey provides information on food (fish) portion sizes while the previous year recall provides information on frequency of consumption for specific types of food consumed from local resources. Information about specific consumption rates is not yet available. However, important observations can be made from the above table. About 83 percent of the Colville Reservation residents ate fish in the previous year the survey was administered. The average number of local fish species consumed was 3 species with a maximum number of 13 species consumed by residents. 73 percent of Colville Reservation residents ate salmon on an average of 15 times per year. Also, almost 20 percent ate the head, skin, organs, or eggs of salmon. 61 percent of the respondents noted that all of their salmon was harvested from on or near the Colville Reservation and another 12 percent harvested part of their salmon catch locally.

Freshwater mussels and crawfish are also harvested and consumed by Colville Reservation residents. 8 percent of the Colville Reservation residents ate mussels sometime during the previous year of the administered survey and 9 percent ate crawfish. 13 percent of the mussels were harvested all or partly locally. 81 percent of the crawfish were harvested entirely from local areas.

Many Colville Reservation respondents noted that they do not eat as much local fish as they would prefer because of concerns about smelter contaminants. Suppression of resources and reduced fish consumption remains an important concern by tribal populations. Tribal fish consumption and corresponding rates are artificially reduced due to concerns about contaminants and their associated effects.

Spokane River Surveys of Selected Ethnic Populations

Numerous and different types of surveys have been conducted for the Spokane River by the collaborative efforts of Spokane Regional Health District, Assessment/Epidemiology Center, Washington State's Department of Health, and the Lands Council – Center for Justice. From July 2003 through December 2011, The Lands Council – Center for Justice as part of the Spokane River Toxics Outreach, completed approximately 5,300 surveys, distributed about 10,000 health advisories, and participated in public education outreach of nearly 16, 000 individuals in the Spokane area.[50] Surveys have focused on ethnic populations that may be exposed to legacy contaminants from mining operations (arsenic, lead, cadmium) and PCBs by harvesting and consuming fish from the Spokane River. Two types of surveys are briefly reviewed: (1) 1998 Fish Consumption Survey, Spokane River, Washington (Spokane Regional Health District, 1998), and (2) Lands Council – Center for Justice risk communication and public outreach survey (Robinson Research, 2007), which was directed to specific ethnic communities that harvest and consume fish from the Spokane River.

1998 Fish Consumption Survey, Spokane River

A 1998 Fish Consumption Survey was conducted by the Spokane Regional Health District, Assessment/Epidemiology Center to evaluate how people access the Spokane River for harvesting fish and to assess the fish consumption habits of Russian, Hmong, and Laotian populations. The objectives of the survey were to: (1) identify different types of fish caught from the Spokane River, (2) identify locations where fish are harvested, (3) identify populations who consume fish from the Spokane River, and (4) identify amounts of fish consumed and meal preparation methods. A mail survey questionnaire sampled two fish-consuming populations based on a random sample of Spokane County fishing license holders (2000 sample population)

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[50] Spokane River Toxics Outreach, web location: http://www.landscouncil.org/water/river_toxics.asp?template=false

and individuals from a particular Spokane area fishing club (180 sample population from The Walleye Club). Russian and Laotian community representatives were hired by the Spokane Regional Health District to convene a focus group, serve as interpreters, translate the written survey, and coordinate the survey distribution within Russian and Laotian communities. Key findings for each of the two ethnic communities surveyed are provided below.

Key Russian Community Findings:

- Harvest locations: Upriver Dam, the old Walk in the Wild Zoo, River Front Park, downtown Spokane area, T.J Meenach Bridge, Nine Mile Bridge, and Long Lake.
- Fish harvested: rainbow trout, German (brown) trout, suckers, catfish, crayfish, pike minnow, smallmouth bass, and perch.
- Fish consumption: about 4 pounds per month (about 65 g/day or 2.3 ounces of fish per day).

Key Laotian Community Findings:

- Harvest locations: Nine Mile Bridge where the little Spokane and Spokane River meet.
- Fish harvested: catfish, rainbow trout, perch, bass, walleye, and crawdads.
- Fish consumption: two to three meals of Spokane River fish per month (assuming a fish meal equals an 8-ounce serving, then two to three fish meals per month is about 16 to 24 g/day or less than 1 ounce of fish per day).

2007 Spokane River Toxins Survey

Lands Council – Center for Justice conducted a telephone survey for adults living in Spokane, Lincoln, and Stevens Counties who live close to the Spokane River. The purpose of the survey was to evaluate public attitudes and perceptions regarding pollution in the Spokane River. A total of 600 telephone interviews were completed from December 2006 to January 2007 with 67 percent conducted in Spokane County, 17 percent in Lincoln County, and 17 percent in Stevens County. This telephone survey is part of a broader public outreach and education effort by the Lands Council directed to low-income families, indigenous people, and recent immigrant populations (Hmong, Vietnamese, Slavic, and Hispanic populations). Selection of these populations was based on previous work conducted by the Spokane Regional Health District, and State Departments of Health and Ecology, and suggests these ethnic populations may be at potential health risks from exposure to contaminants in fish harvested from the Spokane River.

There are a significant number of people catching and/or eating fish from the Spokane River. For those eating fish, few are taking precautionary measures in preparation of the fish. Results of the Lands Council – Center for Justice provides insights into public outreach and education challenges:

- 19 percent of respondents fish in the Spokane River.
- 12 percent catch and eat fish. Over half eat two or more fish in months they are regularly fishing.
- Of those who said they eat fish from the Spokane River in a typical year, nearly two-thirds (65%) took no precautions in how they prepared the fish for cooking.
- The majority of fishing that includes eating what is caught takes place below Long Lake Dam (80%), where there are no fish advisories regarding consumption.
- Some fish consumption not in accordance with the Washington Department of Health fish advisory is occurring between Lake Spokane and the Idaho Border.

The harvest locations from the Spokane River are as follows:

- 80 percent below Long Lake Dam.
- 10 percent from Spokane Falls to Long Lake Dam.
- 4 percent from Upriver Dam to Spokane Falls.
- 3 percent from the Idaho State Line to Upriver Dam.
- 3 percent reported as Don’t Know/Refused.

The Laotian anglers were not evaluated for this survey since fewer than five surveys were returned from the 17 mailed surveys to the Laotian community.

Sampling and analysis reports that evaluated for metals and PCBs in the Spokane River, combined with findings from focus groups, established the questionnaire framework for the development of questions concerning fish harvest location and types of fish harvested. A mail survey questionnaire sampled two fish-consuming populations based on a random sample of Spokane County fishing license holders (2000 sample population) and individuals from a particular Spokane are fishing club (180 sample population from The Walleye Club). The mail survey questionnaire included an introductory letter asking participants to complete the survey if they harvest and consume fish from the Spokane River. A $50 gift certificate was included as an incentive to participate when the survey was completed and returned. There was about a 31 percent response rate to this mail survey.

Swinomish Tribal Study: Bioaccumulative Toxics in Subsistence-Harvested Shellfish – Contaminant Results and Risk Assessment

The Swinomish Indian tribal community is a federally recognized Indian tribe; the Swinomish Indian reservation is located on interior Puget Sound, Skagit County, Washington. The Swinomish Tribal Indian Community is a maritime fishing community with strong cultural and dietary dependence on fish and, particularly, shellfish. Shellfish are an abundant resource harvested by the Swinomish Tribal Indian Community throughout their usual and accustomed fishing areas.[51]

The Swinomish Tribal Community Office of Planning and Community Development conducted a study to evaluate the toxicity and assess the risks from the consumption of contaminated clams, crabs, and fish (Swinomish Tribe, 2006). Chemicals of concern evaluated in this study include polychlorinated biphenyls (PCBs), arsenic, dioxins/furans, mercury, polycyclic aromatic hydrocarbons (PAHs), and selected chlorinated pesticides and metals. Focused sampling and analysis was conducted for sediments, clams, and crabs from North and South Skagit Bay, Padilla and Fidalgo Bays, and Crescent Harbor.

An ethnographic-style survey (seafood diet interviews to evaluate current consumption pattern) was conducted for the Swinomish Tribal Community. Based on the ethnographic dietary survey, the Swinomish Tribal Indian Community documents 260 g/day (approximates an 8-ounce fish meal) for all seafood consumed harvested locally. The 260 g/day fish consumption rate was used for both adults and children to assess risks of individual clam and crab samples. Cumulative risks were based on a total of 300 g/day associated with the Swinomish Tribal Community consumption of 100 grams consumed daily each of clams, crab, and salmon. The risks from the consumption of contaminated seafood for the Swinomish Tribal Community are provided in Table B-5 below. The report notes “The ingestion rate of a total of 300 gpd [grams per day] is assumed for children as well as adults, which may overestimate intake for younger children. However, children are more sensitive to health effects, so assuming a higher per capita intake more accurately represents risks for younger children than simply scaling down the intake rate but not correcting for children’s increased sensitivity.” (Swinomish Tribe, 2006, p. 64)

The finfish/shellfish contaminants that contributed the most to human health risks were PCBs, arsenic, and dioxin/furans. Risks attributable from consuming 100 grams (3.5 ounces) of each species daily (total 300 g/day) are in the range of concern with non-cancer risk (HQ) for adults and children above 1 (ranging from 3 to 20), and lifetime cancer risks in the range of 1 in a 1,000.

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[51] United States v. Washington, 459 F Supp. 1020, 1049 (W.D. Wash. 1979) “The usual and accustomed fish places of the Swinomish Tribal Community include the Skagit Rivers and its tributaries, the Samish River and its tributaries, and the marine areas of northern Puget Sound from the Fraser River south to and including Whidbey, Camano, Fidalgo, Guemes, Samish, Cypress, and the San Juan Islands, and including Bellingham Bay and Hale Passage adjacent to Lummi Island.”

Table B-5. Cumulative Risks to Swinomish Tribal Finfish- and Shellfish-Consuming Populations

Sampling Location and Seafood Type	HQ Child (6 Years)	HQ Adult (70 Years)	Cancer Risk (70 years lifetime)
Clams (Skagit Bay)	4	1	7E-04
Clams (Fidalgo and Padilla Bays)	5	1	9E-04
Crab (Skagit Bay)	3	0.7	8E-05
Crab (Fidalgo and Padilla Bays)	3	0.8	1E-04
Puget Sound Salmon	11	2	5E-04
Total Risk Ranges	17 to 21	3-5	1E-03 to 2E-03

Source: Adapted from Swinomish Tribe, 2006, Table 29.

Lummi Nation

The Lummi Indian nation conducted a survey to estimate seafood consumption for Lummi Indians living on the Lummi Indian Reservation and in surrounding areas of northwestern Washington State (Lummi Natural Resources Department 2012). The survey instrument used in the study was developed by the Lummi Natural Resources Department. The survey instrument used 54 species of seafood with questions on amount, seasonality, and frequency of consumption for each species. Separate information was obtained regarding seafood consumption at home and at tribal gatherings, demographic information, and information about fishing activity and patterns of consumption. The study evaluated historical fish dietary practices and rates in 1985 because current rates for the tribe are suppressed (Lummi Natural Resources Department 2012):

> *The environmental baseline chosen for the Lummi Seafood Consumption Study was 1985, as this was the peak fish harvest year for the Lummi Nation in recent history and a goal of the Lummi Natural Resources Department is to restore fish habitat so that at least the 1985 harvest levels can be sustained. As a result, the Tribal Advisory Committee determined that fish consumption rates from 1985 should be used to develop water quality standards and to support risk assessments of clean-up options for contaminated sites along Bellingham Bay. While not at Treaty-time levels, seafood abundance and availability was less of a limiting factor for seafood consumption during 1985 than in 2012. Consequently, the seafood consumption rate would be less suppressed due to environmental degradation or the lack of available fish. A literature review showed that appropriate data could be elicited in recall studies that reach back 25 years.*

The survey results are summarized below:

- Eighty-two (82) participants were interviewed over the May 2011 through March 2012 survey period.

- Outliers were removed before the final calculation, which reduced the overall sample size used to compute the daily seafood consumption rate to 73 respondents. Outliers were defined by the Tribal Advisory Committee as respondents who reported consumption rates above the 90th percentile of the daily seafood consumption rate of all respondents.
- The resultant average Lummi seafood consumption rate was calculated to be 4.73 grams per kilogram per day (g/kg/day) or approximately 383 grams per day (g/day) (0.84 pounds per day [lb/day] or 13.5 ounces per day [oz/day]) for all seafood consumed.
- The median seafood consumption rate was calculated to be 3.82 g/kg/day or approximately 314 g/day (069 lb/day or 11 oz/day).
- The 90th percentile seafood consumption rate was calculated to be 10.03 g/kg/day or approximately 800 g/day (1.76 lb/day or 28.2 oz/day).
- The 95th percentile seafood consumption rate was calculated to be 11.28 g/kg/day or approximately 918 g/day (2.02 lb/day or 32.4 oz/day).
- The final precision of the survey was ± 16.5%.

B.4 Additional technical publications by Pacific Northwest tribal staff

A Native American exposure scenario

This paper (Harris and Harper, 1997) documents a tribal-based subsistence exposure scenario for a variety of different foods and exposure parameters for use at the Hanford nuclear reservation cleanup. A subsistence fish consumption of 540 g/day is based on selected tribal interview from members of the Confederated Tribes of the Umatilla Indian Reservation and other published studies.

Lifestyles, diets, and Native American exposure factors related to possible lead exposures and toxicity

This article (Harris and Harper, 2001) documents that any assessment of the risk from lead exposure to tribal communities requires an understanding of the tribal community, resource base, and culture. Differences in patterns of exposure between different communities or groups of people are noted with documented additional sources of lead exposure for Native Americans.

A possible approach for setting a mercury risk-based action level based on tribal fish ingestion rates

Risks from the consumption of mercury-contaminated fish were evaluated with a recommended action level for mercury protective of Native American tribes in the Columbia River Basin at 0.1 ppm or less (Harper and Harris, 2008). The recommendation is based on the combined risks from mercury exposure plus other fish contaminants and exposures, the higher fish consumption rates associated with tribal populations, the existing cultural deficit due to loss of salmon, the health benefits from fish, and the cultural and economic importance of fish to tribal populations. To assess the risks from the consumption of mercury-contaminated fish, Harper and Harris (2008) defined the following fish consumption rates:

- Less than 100 g/day is the low tribal fish ingestion rate.
- 100 to 454 (1 pound per day) g/day is the moderate tribal fish ingestion rate.
- Above 454 g/day is the true tribal subsistence rate.

Non-cancer and cancer risk to tribal populations from the consumption of mercury-contaminated fish was documented and within a risk range of concern.

Issues in evaluating fish consumption rates for Native American tribes

As a continuation and further refinement of the ethnographic survey conducted for the Swinomish Indian tribal community study, *Bioaccumulative Toxics in Subsistence-Harvested Shellfish – Contaminant Results and Risk Assessment*, Donatuto and Harper (2008) provide a Swinomish seafood dietary interview template as an alternative to conventional fish dietary surveys to estimate contemporary consumption. For traditional subsistence tribal fishers, a multidisciplinary method to reconstruct tribal heritage dietary practices and patterns is recommended. Donatuto and Harper identified several problems associated with conventional fish dietary surveys that are insensitive to cultural tribal practices and may lead to tribal misunderstanding about current fish dietary level and underestimate tribal consumption.

Appendix C
The Question of Salmon

Salmon—showcase of the policy dilemma

The question of whether or how to include salmon in a fish consumption rate highlights the policy choices facing a regulatory agency. Multiple regulations—in this case MTCA and CWA—provide differing approaches to account for anadromous fish, with MTCA providing greater flexibility for site-specific modifications to regulatory standards.

Salmonids employ a complex life strategy. Most – but not all – adult salmon spend a portion of their lives outside of Washington waters. The inclusion of Pacific salmon in fish consumption rates is complicated by the question of where and to what extent salmon assume site-specific contaminants that contribute to their body burdens.

Scientific knowledge related to the biology of the life history for the multiple salmon species has increased considerably with efforts to restore salmon in Puget Sound and throughout Washington. This once abundant resource has been reduced, and wild stocks of some species are endangered. Dams are being removed to restore once great salmon runs, and culvert work by necessity now involves salmon friendly design considerations. Effects of riparian zones, temperature, even predators like seals are studied. Understanding has increased of the differing strategies of fall and spring runs from Chinook, chum, coho, sockeye, and pink salmon, and whether they migrate through estuaries or directly from streams to the ocean. The recycling of contaminants means that when uptake occurs in the open ocean those chemicals are deposited by the dying salmon in their natal streams. In the face of this growing and sophisticated body of knowledge the classification of salmon as a *marine species* lacks subtlety and leads to regulatory dilemma.

For example, Ecology's Toxics Cleanup Program will consider several factors related to risk management when deciding how to address the question of salmon. Some of these factors are discussed in this appendix:

- The abundance of salmon.
- Salmon life cycles.
- Chemical contaminants in ambient waters and sediments.
- The unique quality of Puget Sound and other Washington waters.

Considerations of the complex life cycle and survival strategies of anadromous fish species like salmonids complicate and influence many risk management decisions. For example, risk management cleanup decisions in Port Angeles Harbor and the Lower Duwamish Waterway are influenced by the presence/absences of salmonids in the harbor or waterway, migratory patterns, and contaminant body burdens attributable to site contaminants (Ecology, 2011b; Windward Environmental, 2007). The complication arises because it is difficult to attribute salmon contaminant body burdens to site-specific contaminants.

This appendix describes the life cycle and survival strategies of salmonids. This information is related to policy and technical considerations regarding how to appropriately address the question of salmon when developing fish consumption rates for regulatory purposes.

C.1 Background

Salmon is consumed in abundance. On a global scale, over the last two decades, advances in farmed-salmon production have tripled the world's supply of salmon. In 1985, 6 percent of all salmon consumed around the world was farmed. In 1988, farmed salmon production surpassed wild fisheries. In 2000, 58 percent of all salmon consumed around the world was farmed, almost a tenfold increase from 1985 levels. In the United States, between 1987 and 1999, salmon consumption increased nine times (Institute for Health and the Environment). During that time period, salmon consumption increased annually at a rate of 14 percent in the European Union and 23 percent in the United States (Hites et al., 2004).

Over half the salmon sold globally is farm-raised in Northern Europe, Chile, Canada, and the United States. The annual global production of farmed salmon (Atlantic salmon, *Salmo salar*) has increased from approximately 24,000 to over 1 million metric tons during the past two decades (Institute for Health and the Environment; Charron, 2004, as cited in Hites et al., 2004). Contaminant body burdens in farm-raised salmon have been well documented and compared to wild salmon. European farm-raised salmon have significantly greater organochlorine (dioxin, dioxin-like PCBs, and selected pesticides) contaminant body burdens than those salmon raised in North and South America (Hites et al., 2004).

C.2 Factors influencing the health risk from consuming salmon

There are multiple factors to consider when assessing the risk from consuming salmon. Most Washington salmon spend the largest part of their lives in the open ocean, where exposure to contaminants originating from Washington sources is minimal. Salmon life cycles are complex, and the many species have different survival strategies.

Ecology recognizes that salmon are an available Washington State resource for harvest and consumption. It is appropriate to consider:

- Washington State estimates of recreational and commercial salmon harvests.
- Estimates of Washington State fish-consuming populations.
- Cultural and religious significance of salmon to different Native American fish-consuming populations in Washington State.
- The complexity of the salmon life cycle and survival strategies, local and global salmon contaminant body burdens, and Puget Sound resident and nonresident salmon populations.
- Federal and state regulatory policies and procedures.

Ecology notes that similarities between bioaccumulative and persistent contaminant (organochlorines) salmon body burdens from local and global distributions would preclude the ability to define a chemical fingerprint to attribute salmon body burdens to site-specific bioaccumulative and persistent contaminants

C.3 Information about salmon consumption in Washington

To determine how to appropriately address salmon when developing one or more default fish consumption rates, Ecology examined the regional fish dietary survey information regarding salmon-related consumption. These surveys show that salmon is consumed frequently and in large amounts.

Based on Pacific Northwest regional-specific fish dietary surveys, salmon and selected types of shellfish are the most frequently consumed and consumed in the largest amounts of all seafood. Salmon is the most frequently consumed finfish (more than 90 percent) for all adult respondents from all of the regional-specific fish dietary surveys. (This observation follows the national trend where U.S. salmon consumption grew from 9.5 percent to 15 percent from 1996 to 2005 as a share [percentage] of finfish and shellfish consumption.[52])

For the API populations surveyed, 96 percent of the survey respondents consume anadromous fish comprising greater than 10 percent of all seafood consumed (Sechena et al., 2003, Tables 2 and 5). Also, 99 percent of the survey participants consume shellfish comprising more than 45 percent of all seafood consumed. The API survey participants consume a large variety of finfish and shellfish.

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[52] Fish and Shellfish Consumption data from National Marine Fisheries Service, Salmon Consumption data from National Fisheries Institute. Web location: http://www.fas.usda.gov/ffpd/Newsroom/Salmon.pdf, as cited in USDA, 2006.

For the Tulalip Tribes and the Squaxin Island Tribe, 72 to 80 percent of anadromous fish consumed and 62 to 72 percent of shellfish consumed were harvested in the Puget Sound area (Toy et al., 1996). When fish harvests are accounted for outside of the Puget Sound area, greater than 90 percent of the seafood harvested was anadromous. Of both the Tulalip Tribes and the Squaxin Island Tribe surveyed, greater than 90 percent of the survey respondents consume anadromous fish, which comprises almost 50 percent of all seafood consumed. The Tulalip dataset was adjusted for the harvest and consumption of finfish and shellfish from Puget Sound in the EPA Region 10 framework. With the adjusted rates used in the EPA Region 10 framework, salmon and shellfish comprise about 50 percent each of the Tulalip tribal seafood diet, with salmon consumed in slightly greater amounts than shellfish. Hence, if the total fish ingestion rate did not account for salmon consumption, then the fish consumption rate would be reduced by about 50 percent, from 194 g/day to 97.6 g/day (U.S. EPA, 2007b, Appendix B-1, Table B-1).

The Suquamish fish dietary survey identified the largest variety, most frequently consumed, and consumed in the largest amounts of finfish and shellfish for all of the Pacific Northwest tribal fish-consuming populations surveyed (The Suquamish Tribe, 2000). Fifty percent or more of the respondents consumed various types of anadromous fish and about 10 different types of shellfish. The Suquamish dataset was adjusted for the harvest and consumption of finfish and shellfish from Puget Sound in the EPA Region 10 framework. With the adjusted rates used in the EPA Region 10 framework, salmon and shellfish comprise about 25 percent and 65 percent, respectively, of the Suquamish tribal seafood diet. Hence, if the total fish ingestion rate did not account for salmon consumption, then the fish consumption rate would be reduced by about 25 percent, from 766.8 g/day to about 583 g/day (U.S. EPA, 2007b, Appendix B-2, Table B-2).

The fish dietary survey for the Columbia River tribal populations identified a variety of fish harvested and consumed in large amounts (CRITFC, 1994). However, this survey did not include any questions regarding shellfish consumption. Salmon is consumed by the largest number of adult respondents (92 percent), followed by trout (70 percent), lamprey (54 percent), and smelt (52 percent). Using the weighted mean fish consumption rate for adult fish consuming CRITFC tribal populations, salmon would contribute about 50 percent of the tribal seafood diet (≈25/63 g/day). Hence, if the total fish ingestion rate did not account for salmon consumption, then the fish consumption rate would be reduced by more than about 50 percent, from a weighted mean of 63 to about 40 g/day.

C.4 Pacific salmon life cycle and survival strategies

Salmonids have complex life cycles and survival strategies, with large variations across and among different species (Quinn, 2005). The geographic distribution of Pacific salmonids extends from San Francisco Bay northward along the Canadian and Alaskan coasts to rivers draining into the Arctic Ocean, and southward down the Asian coastal areas of Russia, Japan, and Korea.[53]

Although variation exists, generally, Chinook, coho, and steelhead have migratory patterns along the Pacific continental shelf and remain in freshwater and estuarine environments for longer periods of time than other Pacific salmonid species.

After pink, chum, and sockeye salmon enter the ocean environment, they rapidly migrate northward and westward through coastal waters of North America and are found in the open waters of the North Pacific, Gulf of Alaska, and the Bering Sea by the end of their first year at sea.

Table C-1. Pacific Salmon Life Cycle

Salmonid Life Cycle Environment	← Salmon Species →						
	Chinook	Coho	Sockeye	Chum	Pink	Steelhead	Cutthroat
Riverine rearing	X	X	X			X	X
Estuarine rearing	X	X	X			X	X
Lacustrine rearing			X				X
Nearshore migration	X	X	X	X	X	X	X
Continental shelf migration	X	X				X	
Mid-oceanic migration			X	X	X		

Salmonid contaminant body burden

All seven Pacific salmon species are biotranporters of pollutants to and from the Pacific Ocean and their spawning sites in freshwater (Ewald et al., 1998). During river ascent, salmonids use their muscle lipid and triacyglycerol deposits for energy and gonadal development. Particularly in female salmonids, the organic pollutant body burden redistributes and accumulates in the lipid-rich gonads and salmon roe. Furthermore, the lipid depletions and redistribution during the river ascent are not coupled with a simultaneous elimination of the organic pollutant body burden in the salmonids.

The pollutants in the salmonids are readily available for bioaccumulation, because the migrating salmonids, salmon roe, and salmon carcasses are a direct food source for predators (birds, mammals, and other fish). Hence, salmonids redistribute their pollutant body burdens back to their spawning grounds, to the open-ocean predators, or to the food web as bioaccumulation.

The redistribution, biotransportation, and bioaccumulation of the salmonid pollutant body burden helps contribute to food web contamination.

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[53] The definition and usage of terms *freshwater*, *estuarine*, and *marine* may vary according to context, with different writers using the terms differently. Readers should always verify how any terms are being defined.

Persistent bioaccumulative toxics

Persistent bioaccumulative toxics (PBTs) are a group of chemicals that, because of their chemical and physical properties, exist within the environment for long periods of time, are lipophilic and bioaccumulate in fish tissue and animal fat, and are highly toxic to animals and humans (Puget Sound Action Team, 2007). The unique geologic and hydrogeologic nature of Puget Sound, in combination with the bioaccumulative, persistent, and toxic nature of the PBT-type contaminants, creates additional risks to the Puget Sound ecosystem. Some of the PBTs that continue to contaminate, threaten, or harm the Puget Sound ecosystem include PCBs, PAHs, dioxins and furans; polybrominated diphenyl ethers (PBDEs), and hormone-disrupting chemicals (e.g., bisphenol A). PBTs are contaminants throughout the entire pelagic food web in Puget Sound (Puget Sound Action Team, 2007).

Of the different PBTs that permeate the Puget Sound food web, PCBs are well-documented contaminants in coho and Chinook Pacific salmon (O'Neill et al., 1998). Pacific salmon exposure to PBTs, and PCBs in particular, is in part contingent on migratory patterns, residency time in Puget Sound, proximity of the salmon to contaminated sediments and waste sites, and different behavior and dietary patterns as the fish mature (Puget Sound Action Team, 2007; O'Neill et al., 1998). PCBs were detected in composite samples of adult Chinook and coho salmon collected from various in-river and marine locations in Puget Sound. Chinook salmon PCB tissue concentrations were greater than coho salmon PCB concentrations collected from in-river and marine locations.

Table C-2. Average PCB Concentrations for Coho and Chinook Salmon from In-River and Marine Locations, Puget Sound (µg/kg)

Salmon Species	Location		Mean Concentration
	Marine	In-River	
Chinook	74.2	49.1	53.9
Coho	35.1	26.5	28.3
Mean	55.3	38.6	41.85

Source: Adapted from O'Neill et al., 1998. p. 316, Table 1.

The authors of a 1998 study investigating different factors and correlates associated with PCBs in muscle tissue of Chinook and coho salmon from marine and in-river locations in Puget Sound observed "…that Chinook salmon had significantly higher PCB concentrations than coho salmon and within each species, PCB concentrations were higher in fish caught in marine areas than in-river areas" (O'Neill et al., 1998, p. 323). Taking into account differences in their anadromous life cycles, age, and information from other studies evaluating contaminant exposures of salmon in the Puget Sound estuaries, this study suggested "…that Chinook and coho salmon accumulate most of their PCB body-burden in the marine waters of Puget Sound and the ocean, and because

Chinook salmon live longer and stay at sea longer than coho salmon they accumulate higher PCB concentrations in their muscle tissues" (O'Neill et al., 1998).[54] The authors further noted that the salmon contaminant body burden attributable to freshwater and estuarine environments was negligible compared with residency time, growth patterns, and feeding habits of the salmon at sea. A 2005 study on the behavior and ecology of Pacific salmon and trout noted that salmon have high metabolic rates, feed heavily, and grow fast in the ocean (Quinn, 2005).

Salmon can double their body length and increase their body weight tenfold during their first summer at sea. More than 98 percent of the final body weight of most salmon is attained at sea. For example, pink salmon entering the ocean may have a body weight of 0.2 gram but return from the sea weighing 2 kilograms, a ten thousand-fold increase. Further study also associates the percent contaminant body burden with fish biology (O'Neill et al., 2006). Coho and Chinook salmon populations that have more coastal migratory distributions have higher tissue concentrations of PCBs compared with those salmonids with more oceanic migratory distributions (chum, pink, and sockeye). Variations in the contaminant body burdens were noted and attributed to the marine distribution of the species (O'Neill et al., 2006, pp. 3–4):

> *…Chinook salmon returning to Puget Sound had significantly higher concentrations of PCBs and PBDEs compared to other Pacific coast salmon populations we sampled. Furthermore, Chinook salmon that resided in Puget Sound in the winter rather than migrate to the Pacific Ocean ("residents") had the highest concentrations of POPs [persistent organic pollutants], followed by Puget Sound fish populations believed to be more ocean-reared. Fall Chinook from Puget Sound have a more localized marine distribution in Puget Sound and the Georgia Basin than other populations of Chinook from the west coast of North American and are more contaminated with PCBs (2 to 6 times) and PBDEs (5 to 17 times).*

Residence time in Puget Sound

Ecology evaluated a variety of information related to the residence time of salmon in Puget Sound and different river systems of Puget Sound. Several factors have a bearing on the salmon residence time:

- Biological variability exists across and within salmon species regarding migratory habits and behavior patterns.
- The location of rivers or streams within Puget Sound. Locations deep within the sound lengthen the time the salmon reside in the sound.

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[54] Chinook and coho salmon occupy three distinct habitat types during their life cycle: (a) Freshwater habitats (eggs hatch and fry develop); (b) Puget Sound (smolts enter marine waters to feed and reside during migration); and (c) Ocean habitat.

- Selected salmonid species do not die after spawning, and may spawn more than once, migrating to and from the same river/stream in Puget Sound.
- With considerable species variability, selected salmonid populations do not migrate to the open ocean and, instead, remain in Puget Sound.

Different residency times of salmon within Puget Sound will result in more or less exposure to chemicals that contaminate the sound and, therefore, contribute to the contaminant body burden of salmon. Some salmon (resident “blackmouth” or Chinook salmon populations) may spend significant portions of their lives in Puget Sound.

Salmon abundance

Interpreting salmon abundance records and historical records on salmon counts is complicated. Salmon are difficult to count because salmon populations are variable due to continual changes in freshwater and marine environments or to the cyclic nature of salmonid behaviors. Very long time-series records (a decade or longer) of catch or escapement are required for detecting large changes (50 percent or greater) in population abundance. Also, long-term changes in abundance may not occur as a continuous linear series of events and, therefore, are not accounted for with standard statistical evaluations. Therefore, records of abundance for short periods of time may suggest an increase or decrease in salmonid populations when, in fact, long-term trends are the reverse. The inherent biological variability of salmonids confers a level of uncertainty about the abundance counts and records associated with the different salmonid species (National Research Council, 1996, pp. 77–79).

Puget Sound salmon

The Puget Sound Basin includes the river systems in Puget Sound, Hood Canal, and the Strait of Juan de Fuca. As shown in the tables below (which provide the status of Washington and Puget Sound Salmon Stocks), there is a wide range of salmon population conditions in Puget Sound ranging from critical to healthy.[55] Generally, for Puget Sound, the Washington Department of Fisheries (now referred to as the Washington Department of Fish and Wildlife) in 1993 classified about 44 percent of the salmon stocks as healthy, about 21 percent as depressed, about 5 percent as critical, and about 30 percent unknown. Puget Sound is considered to have more depressed salmon stocks compared to the Washington coastal regions but fewer depressed stocks than the Columbia River Basin (National Research Council, 1996, pp. 86–90). Many wild salmon, steelhead, and bull trout stocks have been listed under the Endangered Species Act by the National Marine Fisheries Services or the U.S. Fish and Wildlife Service. As of 1998, less than 50 percent of Washington’s salmon stocks were considered to be healthy (Governor’s Salmon

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[55] Stock is defined by Governor’s Salmon Recovery Office (http://www.governor.wa.gov/gsr0/glossary/default.asp) as “fish spawning in a particular lake or stream(s) at a particular season which to a substantial degree do not interbreed with any group spawning in a different place at the same time, or in the same place at a different time.” The National Research Council (1996, pp. 12–13) notes that salmon stocks refers to a geographic aggregate of salmon populations that includes many local breeding populations of varied size and productivity.

Recovery Office, 1999, pp. II.9 – II.10). The tables below summarize the status of salmon stocks for Puget Sound and Pacific Coastal areas and percentages associated with the different regional salmon stocks.

Table C-3. Status of Washington Salmon Stocks as of 1992

Status	Puget Sound		Washington Coasts		Columbia River		All Of Washington	
	Number of Stocks	%	Number of Stocks	%	Number of Stocks	%	Number of Stocks	%
Healthy	93	44.7	65	56.5	29	26.1	187	43.1
Depressed	44	21.2	8	7.0	70	63.1	122	28.1
Critical	11	5.3	0	0	1	0.9	12	2.8
Unknown	60	28.8	42	36.5	11	9.9	113	26.0
Total	**208**	**100**	**115**	**100**	**111**	**100**	**434**	**100**

Source: Adapted from National Research Council, 1996, Table 4-4. Original data source is WDF et al., 1993.

Note: Status descriptors defined by the Washington Department of Fisheries (status criteria descriptors may change depending on regulatory agency or publication); as used by National Research Council, 1996:

Healthy: Stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Depressed: Stock of fish whose production is below expected levels based on available habitat and natural variations in survival rates but above the level where permanent damage to the stock is likely.

Critical: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Unknown: There is insufficient information to rate stock status.

Table C-4. Status of Puget Sound Salmon Stock as of 1992

Status	Chinook	Chum	Coho	Pink	Sockeye	Steelhead	Total
Healthy	10	38	20	9	0	16	93
Depressed	8	1	16	2	3	14	44
Critical	4	2	1	2	1	1	11
Unknown	7	13	9	2	0	29	60

Source: Adapted from National Research Council, 1996, Table 4-3. Original data source is WDF et al., 1993.

The 1992 Salmonid Stock Inventory (SaSI) recognized 435 stocks of salmon and steelhead, one of which was extinct (WDF et al., 1993). When the 2002 data were published, WDFW made this information available online. Queries were available by Water Resource Inventory Area (WRIA), species, and stock. The 2002 update recognized an additional 54 stocks for a revised total of 489 salmon and steelhead stocks. However, the summary table for these stocks provided by WDFW on the SaSI 2002 update website only included 486 stocks. The 2002 status of these 486 Washington State stocks is provided in Table C-5.

Table C-5. 2002 By-Species Summary Update of WDFW's Salmonid Stock Inventory (SaSI) Status for Washington State Salmon and Steelhead Stock Classifications.

Status	Chinook (2002)	Chum (2002)	Coho (2002)	Pink (2002)	Sockeye (2002)	Steelhead (2002)	Total
Healthy	35	41	47	6	4	33	166
Depressed	39	9	9	4	4	58	123
Critical	14	2	2	2	0	2	22
Extinct	1	8	0	0	0	0	9
Unknown	10	23	34	1	1	97	166
Total	99	83	92	13	9	190	486

Source: http://wdfw.wa.gov/conservation/fisheries/sasi/sasi_2002_introduction.html

When the geographic scale changes from Puget Sound to broader geographic areas of Pacific salmon habitat for the Northwest, the picture of abundance changes but still reflects declining populations. There is a drop in Pacific adult salmon returning to rivers to spawn. Historically, 56 to 65 percent of the Pacific salmon returned to Alaska's streams, 19 to 26 percent returned to streams in British Columbia, and 15 to 16 percent returned to streams in Oregon, Washington, Idaho, and California. Currently in the Pacific Northwest only 1 percent of Pacific salmon are returning (Lichatowich, 1999, pp. 206–207).

WDFW hatchery release estimates to Puget Sound:

WDFW provided Ecology with hatchery releases of yearling Chinook salmon into Puget Sound from 1993 to 2005. Chinook salmon released as yearlings tend to remain in the Sound for their entire life cycle. Although the Chinook salmon release estimates may be subject to revision, the queried data by WDFW provide the most current estimates for Chinook salmon releases in the Puget Sound area and from the Dungeness and Elwha River hatcheries. Total hatchery releases of yearling Chinook salmon into Puget Sound (the Straits and North and South Puget Sound) ranged from a low of 1,835,320 in 2005 to a high of 3,367,106 in 1994 (WDFW, 2008b).

C.5 Chemical contaminants in Puget Sound

Chemical contamination of Puget Sound has occurred over a long period of time (150 years by some estimates) with various chemicals posing risks to the environment, aquatic life, and humans.

Ecology noted at the March 2008 Science Advisory Board meeting, that PBTs pose a significant threat to the Puget Sound ecosystem. This section provides information about the presence, transport, and fate of chemical contaminants in and throughout Puget Sound. These chemicals may be factors to consider when evaluating the chemical contaminant body burdens of salmon acquired on a site-specific basis.

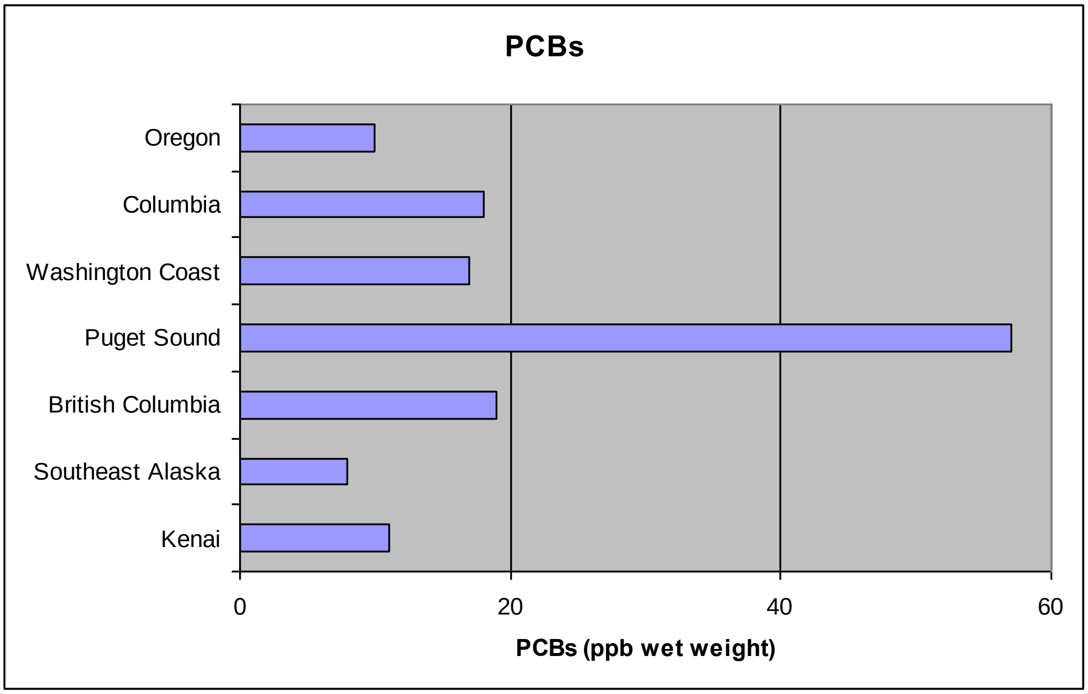
Some of the chemical contaminants of concern for Puget Sound are:

Metals (Inorganic Contaminants)	Organic Contaminants
∗ Lead	∗ Polychlorinated biphenyls (PCBs)
∗ Cadmium	∗ Polycyclic aromatic hydrocarbons (PAHs)
∗ Tributyl tins	∗ Dioxins and furans
∗ Copper	∗ Selected pesticides
∗ Mercury	∗ Phthalate esters
∗ Arsenic	∗ Polybrominated diphenyl ethers (PBDEs)
∗ Others	∗ Hormone disrupting chemicals (Bisphenol A)
	∗ Petroleum and petroleum by-products
	∗ Pharmaceuticals

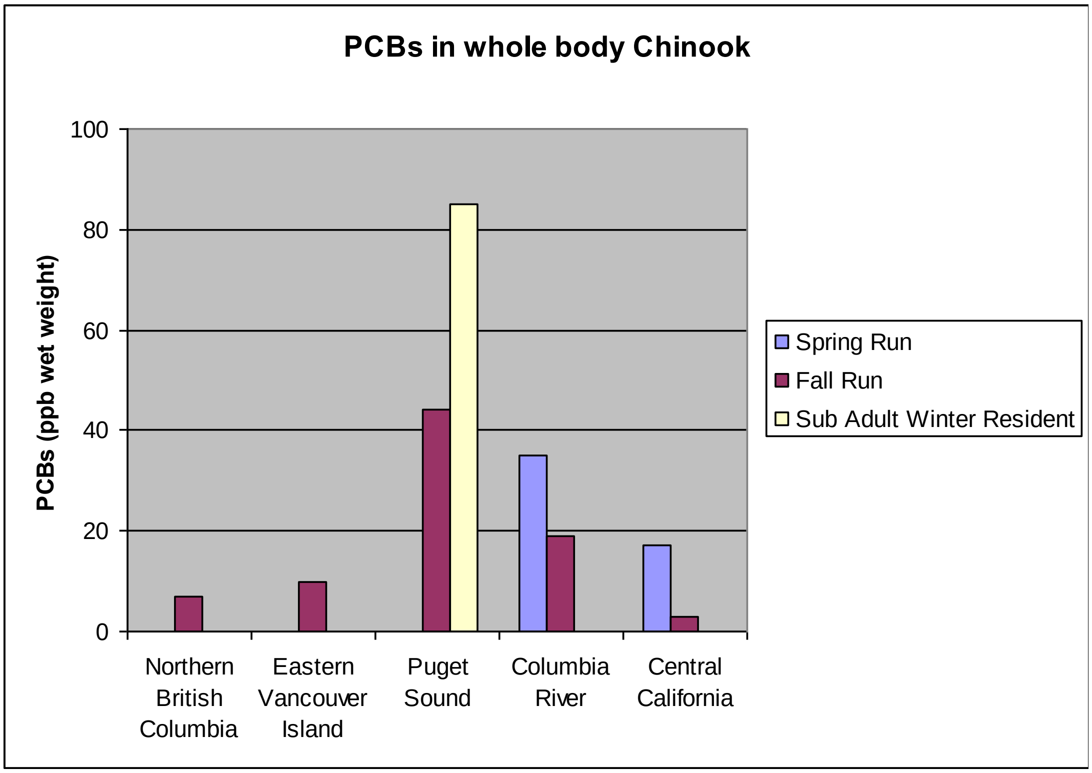
Sources: Puget Sound Action Team, 2007, Table 4-1; West et al., 2011a, 2011b.

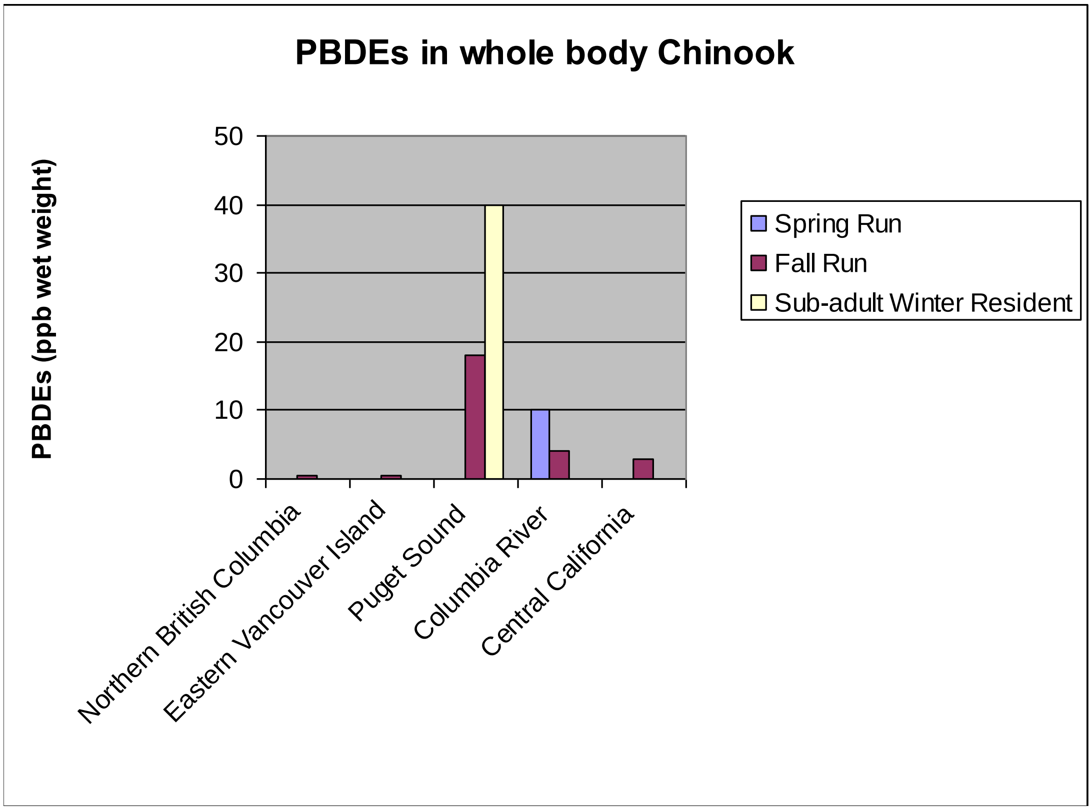
Polychlorinated biphenyls

PCBs are persistent, bioaccumulative, and toxic chemicals found throughout Puget Sound. The bar chart below compares PCBs sampled in Chinook salmon fillets from Puget Sound and Chinook salmon fillets sampled for PCBs from other Pacific west coast areas. Puget Sound Chinook salmon fillets are almost three times more contaminated than fillets of Chinook salmon from other Pacific west coast areas (Puget Sound Action Team, 2007, adapted from Figure 4-18, p. 156).



The bar charts below illustrate differences in contaminant body burdens for salmon from Pacific West Coastal areas. The bar charts illustrate that Puget Sound resident Chinook salmon had the highest contaminant body burden of PCBs and PBDEs compared to other Pacific west coast areas. PCBs and PBDEs in whole body samples of individual summer/fall Chinook salmon from Puget Sound were 2 to 6 times more contaminated with PCBs and 5 to 17 times more contaminated with PBDEs than other populations of Chinook salmon from the Pacific west coast areas (Puget Sound Action Team, 2007, p. 157, Figure 4-19; O’Neill et al., 2006).





C.6 Chemical contaminant transport in and around Puget Sound

Puget Sound has unique geologic qualities among North American estuaries. These unique features confer a greater residence time for contaminants and trap them within the Sound, thereby increasing the potential for exposure.

The transport and fate of site-specific contaminants

Site-specific chemical contaminants in sediments may be relocated throughout Puget Sound by mechanical or biological transport mechanisms. Based on their life cycle, salmon play a unique role in the biological transport of contaminants in and through Puget Sound and contribute to the chemical contamination of the food web.

Hydrodynamic conditions of Puget Sound

Puget Sound is unique among North American estuaries. Shallow sills at the northern and southern ends of central Puget Sound, where water is rapidly transported across the sills by tidal currents, influence circulation patterns. “The sills alter the normal pattern of estuarine circulation by causing mixing and by restricting the exchange of water with adjacent basins” (Ecology, 2007b).

Contaminant residence times

The residence times for contaminants in Puget Sound are extended because the circulation conditions of the Sound, including the shallow sills associated with different inlets, freshwater/marine water gradients, and highly variable flow velocities in different areas of the Sound, all facilitate the trapping and mixing of toxic chemical contaminants. Chemical contaminants spend longer in the Sound increasing exposures to aquatic organisms, humans, and the environment.

Mechanical transport

Plastic debris may be transporting hydrophobic contaminants to sediments and sediment-dwelling (benthic infaunal communities) organisms (Teuten et al., 2007). Representative plastics (polyethylene, polypropylene, and polyvinyl chloride) were used to evaluate the preferential sorption of PAHs in plastics compared to sediments in marine environments. The addition of small amounts of PAH-contaminated plastics to sediments significantly increased the bioaccumulation of PAHs (phenanthrene) in sediment dwelling organisms. In addition, sorption of hydrophobic chemicals to plastics facilitates the transport of the contaminants to other areas in marine environments and to marine aquatic life.

Contaminant dispersal, re-suspension, and transport

Chemical contaminants can be transported and dispersed throughout Puget Sound by a variety of processes. Chemical contaminants within different estuaries and marine water bodies can be transported and dispersed through different watersheds, bay and harbor areas, and inlets. The implications for the transport and dispersion of chemical contaminants throughout these water bodies is an increased potential for exposure to these contaminants by aquatic life and humans, regardless of where the contaminants originated from.

Dispersal

Sediment reservoirs of historically discharged contaminants (metals, PAHs, PCBs, selected pesticides) may be disturbed and distributed by bioadvection, biodiffusion, and physical processes. The sediment-bound contaminants may be moved from the subsurface to upper sediments where the contaminants may undergo further resuspension and redistribution. Benthic infaunal communities (annelids, mollusks, crustaceans), storm events, and tidal influences contribute to the redistribution and dispersion of contaminated sediments (Niedoroda et al., 1996; Stull et al., 1996; Swift et al., 1996).

Resuspension and transport

Historically deposited chemical contaminants buried in sediments may be resuspended in the water column and then transported and redeposited into coastal areas distant from the bay areas where the contaminants originated. Hydrodynamic processes include diffusion, tidal dispersion and transport of chemicals, sediment-water interactions, and adsorption-desorption of chemicals to and from suspended particulate matter. Models evaluate the transport and fate of chemical contaminants from tidal estuaries and bay areas to other proximate marine environments. Empirical data support modeled outputs related to the remobilization of sediment contaminants, resuspension of the contaminants into the water column, and the subsequent redeposition of the contaminants to distant areas (Zeng and Venkatesan, 1999; Zeng et al., 2005).

Biological transport

All seven Pacific salmon species are biotranporters of pollutants to and from the Pacific Ocean and their spawning sites in freshwater (Ewald, 1998). During river ascent, salmonids use their muscle lipid and triacyglycerol deposits for energy and gonadal development. Particularly in female salmonids, the organic pollutant body burden redistributes and accumulates in the lipid rich gonads and salmon roe. Furthermore, the lipid depletions and redistribution during the river ascent are not coupled with a simultaneous elimination of the organic pollutant body burden in the salmonids. The pollutants in the salmonids are readily available for bioaccumulation because the migrating salmonids, the salmon roe, and salmon carcasses are a direct food source for predators (birds, mammals, and other fish). Hence, salmonids redistribute their pollutant body burdens back to their spawning grounds, to the open-ocean predators, or bioaccumulate in the food web. The redistribution, biotransportation, and bioaccumulation of the salmonid pollutant body burden contribute to food web contamination.

Chemical contaminants are exhibited through the salmon life cycle, which contributes to the transport and distribution of contaminants in Puget Sound:

- Depletion of lipid reserves during upstream migration can cause significant biomagnifications of contaminant body burdens in eggs and gonadal tissues (Kelly et al., 2007).
- Post spawning decay of Chinook salmon carcasses are sources of persistent organic pollutants (POPs), such as PCBs, and dichlorodiphenyltrichloroethanes (DDTs), where body burden contaminants are released into river sediments and, furthermore, are released into the water column of tributary streams (O’Toole et al., 2006).
- Areas in the Pacific Northwest where Chinook salmon are harvested may account for the variations in their PCB body burden concentrations. Although some contamination of the Chinook salmon occurs in the Pacific Ocean, a larger source of the salmon body burden occurs within Puget Sound or along the migratory route within Puget Sound for Chinook salmon (Missildine et al., 2005).
- Chemical contaminants (selected pesticides and POPs) have been documented in outmigrant juvenile Chinook salmon (Johnson et al., 2007).

Life histories and biological variability in life histories of Pacific coast salmonids

The following tables present detailed information on the life histories and biological variability of Pacific coast salmonids.

Additional information on biological transport of contaminants is provided in the following publications:

- Data Report for Lower Columbia Juvenile Salmon Persistent Organic Pollutant Exposure Assessment. NOAA Damage Assessment Center, Portland Harbor Natural Resource Trustees,
- O'Toole, Shaun, Chris Metcalfe, Ian Craine, and Mart Gross. Release of persistent organic contaminants from carcasses of Lake Ontario Chinook salmon (*Oncorhynchus tshawytscha*). *Environmental Pollution* 140 (2006), 102-113.
- Missildine, Brian. Polychlorinated Biphenyl Concentrations in Adult Chinook Salmon (*Oncorhynchus tshawytscha*) Returning to Coastal and Puget Sound Hatcheries. Master of Environmental Studies Thesis. The Evergreen State College. February 2005.
- Missildine, Brian, R., Roger J. Peters, Gerardo Chin-Leo, and Douglas Houck. Polychlorinated Biphenyl Concentrations in Adult Chinook Salmon (*Oncorhynchus tshawytscha*) Returning to Coastal and Puget Sound Hatcheries of Washington State. *Environmental Science & Technology*. 2005, 39, 6944-6951.
- Merna, James W., Contamination of Stream Fishes with Chlorinated Hydrocarbons from Eggs of Great Lakes Salmon. *Transactions of the American Fisheries Society* 115:60-74, 1986.
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- Fletcher, Demetrius. Concentrations of PCBs and PBDEs in water in the Cedar River and fish from the Lake Washington/Cedar/Sammamish Watershed. Master of Science, University of Washington. 2009.
- Report for 2001AK3481B: Final Report: Mercury Levels in Alaskan Rivers: Relationship between Hg levels and young salmon.
- Ewald, GÖran, Per Larrsson, Henric Linge, Lennart Okla, Nicole Szarzi. Biotransport of Organic Pollutants to an Inland Alaska Lake by Migrating Sockeye Salmon (*Oocorhynchus nerka*). *Arctic,* Vol 51, No. 1 (March 1998) pp. 40-47.
- Blais, Jules M., Robie W. Macdonald, Donald Mackay, Eva Webseter, Colin Harvey, and John P. Smol. Biologically Mediated Transport of Contaminants to Aquatic Systems. Critical Review. *Environmental Science & Technology*. 2007, Vol 41, No 4, 1075-1084.
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Table C-6. Life Histories of Pacific Coast Salmonids

Species	Spawning Migration	Spawning Period	Spawning Area	Life History	Most Common Age at Maturity (Years)
Anadromous Salmon					
Chum salmon	Summer to Winter	Summer to Winter	Usually near tidewater	Fry go directly to sea; 2–5 years ocean	4
Pink salmon	Late summer to early Fall	Late summer to early Fall	Usually near tidewater	Fry go directly to sea; 2 years ocean	2
Sockeye salmon	Spring to fall	Late summer to fall	Tributaries of lakes	1–3 years lake 2–3 years ocean	4–5
Coho salmon	Summer to fall	Fall to early winter	Small headwater streams	1–3 years freshwater 6 months Jack ocean 18 month adult ocean	3
Chinook salmon	Spring to fall	Summer to early winter	Large rivers	3 months to 2 years freshwater 2–5 years ocean	4–5
Anadromous Trout and Char					
Steelhead trout	Summer to winter	Late winter to spring	Small headwater streams	2–3 years freshwater 1–3 years ocean *Repeat spawners*	4–5
Searun cutthroat trout	Fall to winter	Late winter to early spring	Small headwater streams	2–4 years freshwater 2–5 months ocean *Repeat spawners*	3–4
Dolly Varden [a]	Late summer to fall	Fall	Main channels on rivers	2–4 years freshwater 2–4 years ocean *Repeat spawners*	Mature 5–6 Die 6–7
Resident Species					
Kokanee salmon	Late summer to fall	Late summer to fall	Tributaries of lakes, lakeshores	Juveniles migrate to lakes to reside	3–4
Rainbow trout	Spring	Spring	Small headwater streams	Variable residence in natal, streams, rivers, & lakes	2–3
Cutthroat trout	Spring	Spring to early summer	Small headwater streams	Variable residence in natal, streams, rivers, & lakes	3–4
Bull trout [a]	Fall	Fall	Large streams with groundwater infiltration	Juveniles migrate from tributaries to lakes or large streams at about 2 years, highly variable	4–9
Mountain white fish	Fall	Fall	Mid-sized streams, lakes	Reside in streams and lakes	3–4

Source: Spence et al., 1996.

a. On occasion WDFW lumps bull trout and Dolly Varden together because both are listed under the Endangered Species Act and it is hard to differentiate the two species in the field; genetic studies have found bull trout throughout Puget Sound and the Strait (Duncan, 2008, personal communication).

Table C-7. Biological Variability in Life Histories of Pacific Salmonids

Species of Salmon	Life History	Spawns In			Rears In			
		Lakes	Streams	Intertidal	Lakes	Streams	Estuaries	Ocean
Pink salmon	Anadromous		X			X	X	X
	Anadromous		X					X
	Anadromous			X			X	X
Chum salmon	Anadromous		X			X	X	X
	Anadromous		X			X		X
	Anadromous		X					X
	Anadromous			X			X	X
Coho salmon	Anadromous		X			X	X	X
	Anadromous		X			X		X
Sockeye salmon	Anadromous		X		X			X
	Anadromous	X			X			X
Chinook salmon (spring)	Anadromous		X			X	X	X
	Anadromous		X			X		X
Chinook salmon (fall)	Anadromous		X				X	
	Anadromous		X			X		X
Steelhead Trout	Anadromous		X			X		X
Dolly Varden [a]	Anadromous		X			X	X	X
Kokanee salmon	Resident		X		X			
	Resident	X			X			
Cutthroat trout	Resident		X			X		
	Resident		X		X			
Cutthroat trout (searun)	Anadromous		X			X	X	X
	Anadromous		X			X		X
Rainbow trout	Resident		X		X			
	Resident		X		X			
	Resident	X						
Bull trout [a]	Resident		X			X		
	Resident		X		X			
Mountain whitefish	Resident		X			X		
	Resident	X			X			

Source: Spence et al., 1996.

a. On occasion WDFW lumps bull trout and Dolly Varden together because both are listed under the Endangered Species Act and it is hard to differentiate the two species in the field; genetic studies have found bull trout throughout Puget Sound and the Strait (Duncan, 2008, personal communication).

Table C-8. 2001–2002 Freshwater Salmon Sport Catch for Puget Sound River Systems

Catch Area	Species	2001									2002			Total
		April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	
Dungeness River	Coho							5,949	597		12			6,558
	Steelhead					9		43	22	107	58	9	4	252
Elwha River	Coho							816	127					943
	Steelhead			5	46	5	5	36						97
Morse Creek	Steelhead							4						4
													Total Salmon Sport Catch	7,854

Source: Adapted from Manning and Smith, 2005, Table 26, p. 42; Table 35, p. 92; and Table 35, p. 90.

Table C-9. 2001–2002 Sport Salmon Catch for East Juan de Fuca (Port Angeles Areas)

Species	2001								2002		Total
	April	May	June	July	August	Sept	Oct	Nov	Feb	Mar	
Chinook	136				18	17	132	171	172	115	761
Coho			10	239	1,492	1,806	199	8			3,754
Pink			21	840	5,742	951					7,554
Sockeye					2						2
Chum						3	3	4			10
Steelhead			6			6					12
										Total Salmon Sport Catch For Area	12,093

Source: Adapted from Manning and Smith, 2005, Table16, p. 25 and Table 35, p. 101.

Table C-10. 2002–2003 Freshwater Salmon Sport Catch for Puget Sound River Systems

Catch Area	Species	2002									2003			Total
		April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	
Dungeness River	Coho							398	711	25				1134
	Steelhead							4	3	5	15	15	3	45
Elwha River	Coho							948	175					1123
	Steelhead				2	1	1	9	59	92	17	9	2	192
Morse Creek	Steelhead								3	15	5	10		33
													Total Salmon Sport Catch	2527

Source: Adapted from Kraig and Smith, 2008, Table 25, p. 41; Table 34, p. 87; and Table 34, p. 88.

Table C-11. 2002–2003 Sport Salmon Catch for East Juan de Fuca (Port Angeles Areas)

Species	2002								2003		Total
	April	May	June	July	August	Sept	Oct	Nov	Feb	Mar	
Chinook	55					3	12	59	103	81	313
Coho				43	281	713	35				1072
Pink				21							21
Sockeye											0
Chum							12				12
Steelhead				3			3	3(Dec)	3(Jan)		12
										Total Salmon Sport Catch For Area	1430

Source: Adapted from Kraig and Smith, 2008, Table 16, p. 25 and Table 34, p. 97.

Table C-12. Salmonid Stock Inventory for the Port Angeles Harbor and Adjacent Areas

Anadromous Fish		Total Escapement Estimates		WDFW Designated Status		Comments
Species	Stock	From Year: Est. #	To Year: Est. #	1992	2002	
Chinook	Dungeness Chinook	1986: 238	2003: 640	Critical	Critical	Critical due to chronically low escapements below goal of 925 adults; increased escapement #'s due to continuing hatchery supplementation; spawning mainstream Dungeness River.
	Elwha Chinook	1986: 3,127	2003: 1,045	Healthy	Depressed	Depressed due to long-term negative trend and chronically low escapements since 1992; Spawning lower 4.9 mile of river below Elwha Dam.
Chum	Dungeness Summer Chum	1992: Unknown	2002: Unknown	Not Rated	Unknown	No abundance trend data available; Numbers so low that may not represent a self-sustaining stock; Summer timed limited #'s observed in Dungeness River.
	Dungeness Fall Chum	1992: Unknown	2002: Unknown	Unknown	Unknown	Live + dead counts in one day, one mile section of (Lower Dungeness tributary) Beebe Creek 1997: 303, 1998: 1,025; 2001: 1,062.
	Elwha Fall Chum	1992: Unknown	2002: Unknown	Unknown	Unknown	No abundance trend data available.

Source: WDFW, 2002. Salmon Stock Inventory. Water Resource Inventory Area (WRIA) 18 – Elwha-Dungeness.

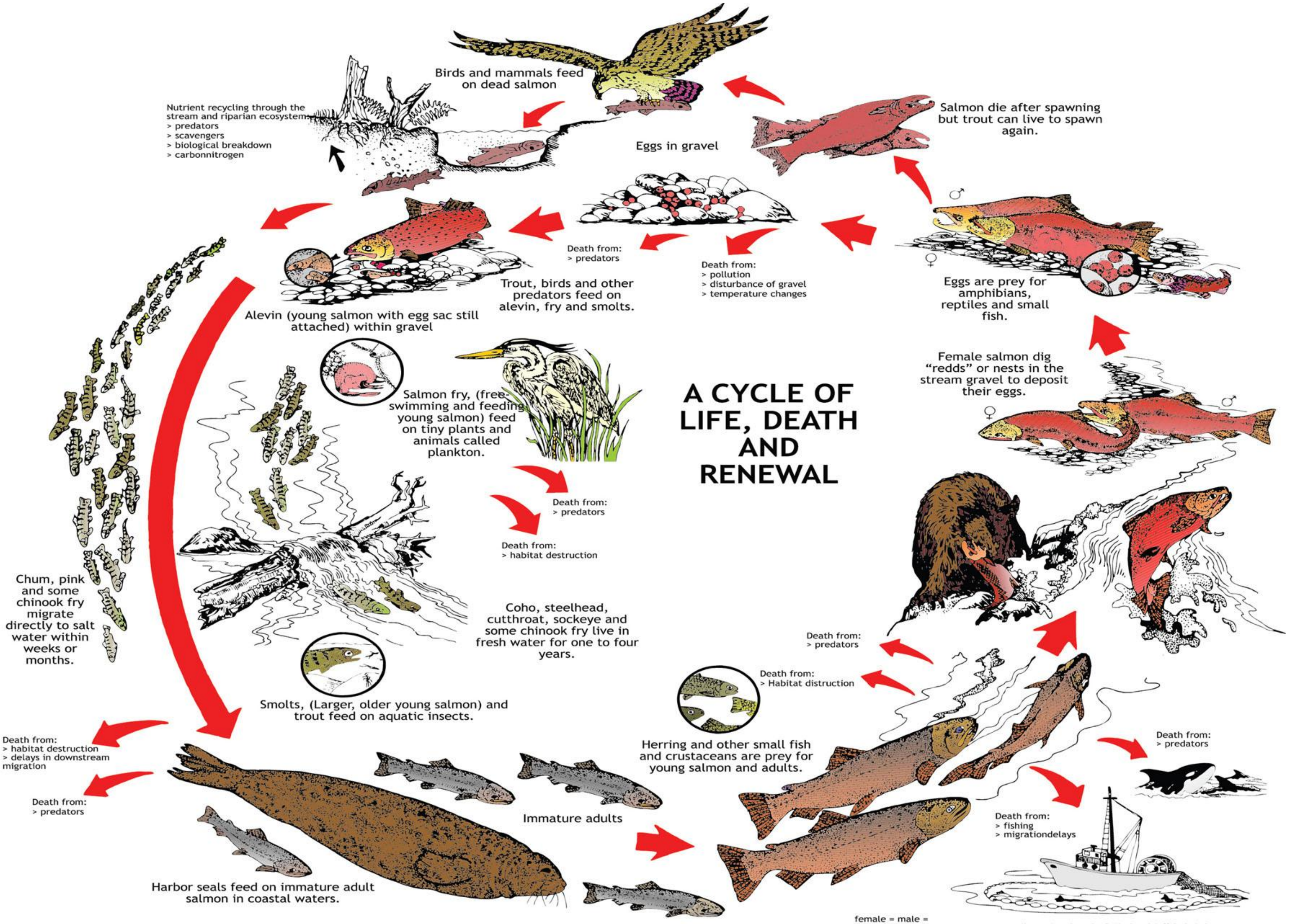
Table C-13. Salmonid Stock Inventory for The Port Angeles Harbor and Adjacent Areas

Anadromous Fish		Total Escapement Estimates		WDFW Designated Status		Comments
Species	Stock	From Year: Est. #	To Year: Est. #	1992	2002	
Coho	Dungeness Coho	1992: Depressed	2002: Unknown	Unknown	Unknown	No abundance trend data available; Limited recent-year estimates of smolt production suggest significant natural production Dungeness R. watershed.
	Morse Creek Coho	1998: 488 adults and 511 smolts	2002: 676 adults and 2, 966 smolts	Depressed	Depressed	Spawning distribution: McDonald, Siebert, Morse, Ennis, Valley and Tumwater Creeks; Depressed because of chronically low “redd” counts; mixture of wild and farm-raised stock.
	Elwha Coho	Unknown	Unknown	Healthy	Unknown	No abundance trend data available; Healthy rating based on escapement estimates from Strait of Juan de Fuca tributaries.
Pink	Lower Dungeness Pink	1985: 966	2001: 11,072; 2003: 3,540	Critical	Critical	Estimates based on counts from mainstem of Dungeness R., Gold Creek, and Gray Wolf River; Critical designation due to chronically low escapements.
	Upper Dungeness Pink	1985: 3,764 1989: 10,579	2001: 69,272 2003: 11,576	Depressed	Depressed	Prior to 1981 escapements usually in excess of 20,000; stock status depressed because of chronically low escapements.
	Elwha Pink	1985: 30 1991: 0	2001: 605 2003: 32	Critical	Critical	In early 1970s instantaneous counts over a thousand pinks were made; since 1981 not more than 30 pinks have been seen on any one day; stock status depressed because of chronically low escapements.

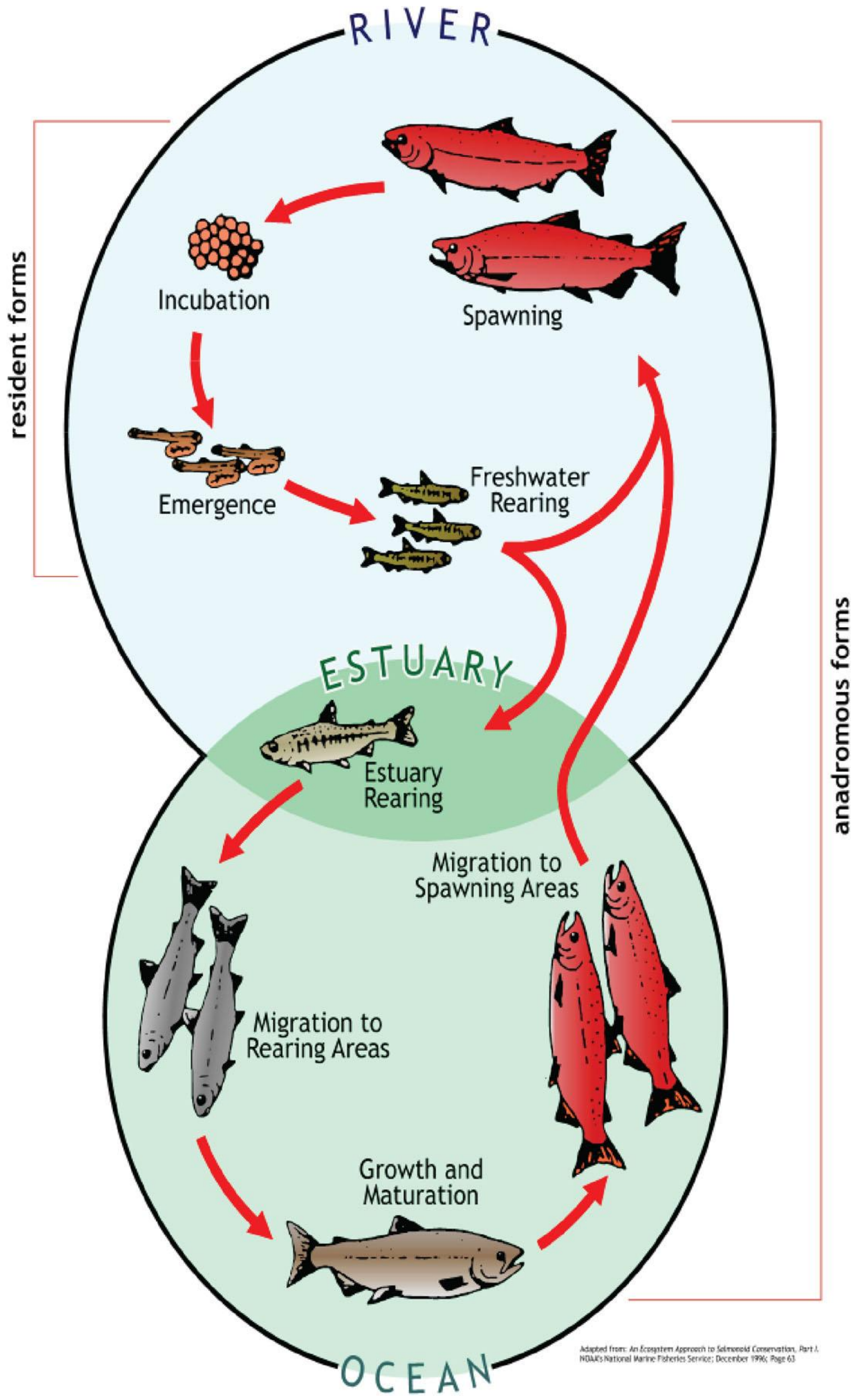
Table C-14. Salmonid Stock Inventory for the Port Angeles Harbor and Adjacent Areas

Anadromous Fish		Total Escapement Estimates		WDFW Designated Status		Comments
Species	Stock	From Year: Est. #	To Year: Est. #	1992	2002	
Steelhead	Dungeness Summer Steelhead	Unknown	Unknown	Depressed	Unknown	No abundance trend data available. Due to fisheries closures and low harvest numbers sport harvest is no longer adequate to assess stock status.
	Dungeness Winter Steelhead	1988: 438 1993: 338	2000: 165 2001 183	Depressed	Depressed	Depressed status because of long term negative trends.
	Morse Creek Winter Steelhead	1986: 105 1988: 138	1997: 183 2003: 84	Depressed	Depressed	Escapement estimates based on redd counts; depressed due to chronically low escapements.
	Elwha Summer Steelhead	Depressed	Unknown	Depressed	Unknown	No abundance trend data available.
	Elwha Winter Steelhead	1986: 834 1989: 416	1992: 560 1997: 153	Depressed	Unknown	Access to historic spawning areas blocked by Elwha Dam; Average of 50 redds/year; Lack of systematic abundance trend data.

Source: WDFW, 2002. Salmon Stock Inventory. Water Resource Inventory Area (WRIA) 18 – Elwha-Dungeness.



Ilustration above by S. Noel and Jeff Cedarholm



Adapted from: *An Ecosystem Approach to Salmonoid Conservation, Part I.* NOAA's National Marine Fisheries Service; December 1996; Page 63

Source: Adapted from Spence et al., 1996.

Appendix D
Glossary

Anadromous fish: fish that hatch in freshwater, spend a portion of their life maturing in saltwater, then return to freshwater habitats to spawn.

Angler: one who fishes with hook and line, sometimes used to denote “fishers.”

Aquatic: from or living in a water body, including both marine and freshwater.

Bottomfish: fish that include Pacific cod, Pacific tomcod, Pacific hake, walleye Pollock, all species of dabs, sole and founders (except Pacific halibut), lingcod and all other species of greenling, ratfish, sablefish, cabezon, buffalo sculpin, great sculpin, red Irish lord, brown Irish lord, Pacific staghorn sculpin, wolf-eel, giant wry mouth, plainfin midshipman, spiny dogfish, six gill shark, soupfin shark and all other species of shark, and all species of skate, rockfish, rattails and surfperches except shiner perch.

Coastal waters: a term that refers to waters having a coastline that forms the boundary between land and freshwaters and marine and/or estuarine waters. This term encompasses all freshwaters of statewide significance (lakes, rivers, streams, etc.) and those marine and/or estuarine waters extending from the landward edge of a barrier beach or shoreline of coastal bay to the outer extent of the Continental Shelf.

Commercial fishers: those individuals who harvest finfish and/or shellfish by any method from Washington State waters (marine, estuarine, and freshwaters) for economic gain as a livelihood.

Creel survey: on-site interview with fishers to obtain information such as species caught; number, length, and weight of catch; location; etc.; typically for use by fisheries managers; may or may not include information on consumption.

Demersal fish: fish that dwell at or near the bottom of a body of water.

Estuarine: from an estuary, i.e., a partly enclosed water body, such as an inlet of the ocean or the mouth of a river where it meets the ocean that contains brackish water (a mixture of salty and freshwater) such as Elliott Bay in Seattle, Washington.

Finfish: fish; a term that is usually applied to the consumption of true fish as opposed to shellfish.

Fish: any of various aquatic animals (belonging to the subphylum Vertebrata) having gills, commonly fins, and bodies usually but not always covered by scales, including those having bony skeletons (bony fishes) and more primitive forms with cartilaginous skeletons (lampreys; hagfishes; and sharks, skates, and rays).

Fish consumers: those individuals who consume finfish and/or shellfish; synonymous with Washington State fish-consuming populations.

Fisher: one who fishes for any type of seafood by any method, inclusive of hook and line and other methods of catching seafood.

Freshwater: water bodies including lakes, ponds, rivers, and streams that contain water with relatively low salinity, i.e., less that 0.5 parts per trillion; species inhabiting freshwater bodies.

Game fish: sport fish that are caught for food.

Indian (Native American) Reservation: land set aside by the federal government for the use, possession, and benefit of a Native American tribe or group of Indians; created by some formal legal directive such as a treaty, statute passed by Congress or an executive Presidential order.

Marine: from, or living in, the ocean; saltwater, with a salinity of approximately 35 parts per trillion.

Native American: a member of the indigenous peoples of the Western Hemisphere. In this technical support document the term “Indian” is used only with reference to the name of a specific Native American tribe.

Noncommercial fisher: one who fishes for recreation and/or home consumption; synonymous with recreational fisher, sport fisher.

Pelagic fish: fish that live near the surface or in the water column of coastal, oceanic, and lake waters.

Reasonable maximum exposure (RME):

The **MTCA definition** of RME (WAC 173-340-200) is as follows:

> *Reasonable maximum exposure means the highest exposure that can be reasonably expected to occur for a human or other living organisms at a site under current and potential future site use.*

The **EPA definition** of RME is as follows:

> *Actions at Superfund sites should be based on an estimate of the* ***reasonable maximum exposure (RME)*** *expected to occur under both* ***current*** *and* ***future*** *land-use conditions. The reasonable maximum exposure is defined here as the highest exposure that is reasonably expected to occur at a site. RMEs are estimated for individual pathways* (U.S. EPA, 1989b, page 6-4 to 6-5).

The worst-case exposure represents an extreme set of exposure conditions, usually not observed in an actual population, which is the maximum possible exposure where everything that can plausibly happen to maximize exposure happens (U.S. EPA Guidelines for Exposure Assessment, Federal Register Notice, Vol. 57, No. 104, May 1992, pages 22888-22938).

The preamble to the **National Contingency Plan** further indicates that the RME will:

> *…result in an overall exposure estimate that is conservative but within a realistic range of exposure. Under this policy, EPA defines "reasonable maximum" such that only potential exposures that are likely to occur will be included in the assessment of exposures. The Superfund program has always designed its remedies to be protective of all individuals and environmental receptors that may be exposed at a site; consequently, EPA believes it is important to include all reasonably expected exposures in its risk assessments…*

Recall bias: Dietary recall surveys may cover specific periods of time or seasons; short term recall surveys may cover a 24-hour food recall to obtain information on the diet of an individual in the prior 24 hours. Dietary surveys that rely on an individual's recall of their diet may undergo some recall errors that introduce an element of bias in the dietary estimates. These recall errors may result in either overestimation or underestimation of fish consumption. Factors that contribute to recall error and bias include how commonly or frequently the food (fish) is consumed, time frames covered by the survey that contribute to seasonal variation in food consumption, survey methods used including provisions to enhance dietary memory or recall (food models), and the desirability or cultural influences on the food consumed. Generally, recall error increases as the length of the recall period increases, with recall periods of 1 year likely to result in the least reliable estimates of consumption. The optimal recall period will be long enough to accurately portray typical dietary (fish consumption) habits and patterns without impairing the ability of respondents to recall their dietary (fish) consumption (Chu et al., 1992).

Recreational fisher: one who fishes primarily for recreational purposes; recreational catch is used primarily for home consumption; synonymous with noncommercial fisher, sport fisher.

Seafood: aquatic organisms that are consumed, including mainly finfish and shellfish, and less frequently, other invertebrate animals or plants or marine mammals.

Shellfish: aquatic invertebrate animals having a shell or exoskeleton, the term usually used in the context of food, including species belonging to the following taxa (some of which have evolved such that the shell has become internal and/or reduced, or has disappeared entirely): (1) mollusks, including bivalves (e.g., clams, oysters, mussels, scallops), gastropods (e.g., snails, limpets, abalone), and cephalopods (e.g., squid, octopods); (2) crustaceans (e.g., crabs, shrimps, lobsters); and (3) echinoderms (e.g., sea urchins, sea cucumbers).

Sport fish: fish that are caught by a sport fisher as opposed to purchased or caught commercially, synonymous with sport-caught, recreationally caught, and noncommercial fish.

Sport fishers: those individuals who harvest finfish and/or shellfish by any method from Washington State waters (marine, estuarine, and freshwaters) for recreation; synonymous with recreational fisher or noncommercial fisher.

Subsistence: Although no single universally accepted definition is available to define what is meant by subsistence or subsistence-based populations, several definitions of subsistence fishers may apply to Washington State ethnic groups and/or fish-consuming populations. It is difficult to define and to quantify subsistence fishers. Definitions and perceptions of what constitute subsistence fishers and fishing may vary among regions and cultures. The 1994 Presidential Executive Order 12898, Section 4-4. Subsistence Consumption of Fish and Wildlife noted differential patterns of subsistence consumption of fish and wildlife for populations who principally rely on fish and/or wildlife for subsistence.[56] Differential patterns of subsistence consumption of fish and wildlife relates to subsistence and differential patterns of subsistence, and means differences in rates and/or patterns of fish, water, vegetation and/or wildlife consumption among minority populations, low-income populations, or Native American tribes, as compared to the general populations. As a response to Executive Order 12898, the 1999 National Academy of Sciences publication noted the following (Institute of Medicine, 1999, p. 17):

> *… differences in behavior, employment, and lifestyles among subgroups in the population may result in differences in exposure. For example, among the Alutiiq, Yup'ik, and Inupiat Alaskan Native peoples, the yearly intake of wild foods per person is between 171 and 272 kilograms (375 and 600 pounds). Increasing evidence of certain contaminants such as mercury in the wild food supply of these Alaskan Natives has been exhibited by methyl mercury levels that exceed those provisionally established as safe by the World Health Organization.*

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[56] Presidential Executive Order 12898: Federal Actions To Address Environmental Justice In Minority Populations and Low-Income Populations. Signed by President William J. Clinton, February 11, 1994 web location: http://www.epa.gov/region2/ej/exec_order_12898.pdf

Tribal subsistence exposure scenario and fishers: “Subsistence” refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples (Confederated Tribes of the Umatilla Indian Reservation, 2004, p. 4). Subsistence utilizes traditional, small-scale technologies for harvesting and preserving foods as well as for distributing the produce through communal networks of sharing and bartering. Because it often misinterpreted, an explanation of “subsistence” is taken from the National Park Service (Confederated Tribes of the Umatilla Indian Reservation, 2004):

> *While non-natives tend to define subsistence in terms of poverty or the minimum amount of food necessary to support life, native people equate subsistence with their culture. Among many tribes, maintaining a subsistence lifestyle has become the symbol of their survival in the face of mounting political and economic pressures. It defines who they are as a people. To Native Americans who continue to depend on natural resources, subsistence is more than eking out a living. While it is important to the economic well-being of their communities, the subsistence lifestyle is also the basis of cultural existence and survival. It is a communal activity. It unifies communities as cohesive functional units through collective production and distribution of the harvest. Some groups have formalized patterns of sharing, while others do so in more informal ways. Entire families participate, including elders, who assist with less physically demanding tasks. Parents teach the young to hunt, fish, and farm. Food and goods are also distributed through native cultural institutions. Most require young hunters to distribute their first catch throughout the community. Subsistence embodies cultural values that recognize both the social obligation to share as well as the special spiritual relationship to the land and resources. This relationship is portrayed in native art and in many ceremonies held throughout the year.*[57]

The average subsistence adult fish consumption rate is 620 g/day (500 pounds/year) for the Confederated Tribes of the Umatilla Indian Reservation.[58]

Usual and Accustomed Fishing Areas: also referred to as U & A areas or U & A fishing areas. The term refers to the 1854 and 1855 negotiated treaties with the Pacific Northwest Native Americans in Washington state: “The right of taking fish at usual and accustomed grounds and stations is further secured to said Indian in common with all citizens of the Territory…”

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[57] National Park Service. Archeology Program. Preservation On the Reservation [And Beyond] Web location: http://www.nps.gov/archeology/cg/fa_1999/Subsist.htm

[58] Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual. August 2007. Appendix 3: Fish Consumption Rate. Web location: http://www.hhs.oregonstate.edu/ph/tribal-grant-main-page2

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Western Washington
NPDES Phase I Stormwater Permit

Final S8.D Data Characterization 2009-2013

by

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- 17080003, 17110010, 17110011, 17110012, 17110013, 17110014, 17110019

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Abstract

Stormwater and storm sediment discharge data were collected by NPDES Phase I Municipal Stormwater permittees, under Special Condition S8.D, between 2007 and 2013. This report is a summary of the data results. The Phase 1 permittees, all located in western Washington, collected highly representative storm-event data under a prescribed monitoring program that represented multiple land uses, storm characteristics, and seasons. The main goals of this study were to (1) compile and summarize the permittees' data using appropriate statistical techniques and (2) provide a western Washington regional baseline characterization of stormwater quality.

These findings are based on the analysis of 44,800 data records representing 597 storm events. Up to 85 parameters were analyzed in stormwater samples, and 67 parameters were analyzed in stormwater sediments. Metals, hydrocarbons, phthalates, total nitrogen and phosphorus, pentachlorophenol, and PCBs were detected more frequently and at higher concentrations from commercial and industrial areas than from residential areas. Residential areas exported stormwater with the highest dissolved nutrient concentrations.

For context, data were compared to previous stormwater studies and the Washington State water quality criteria. Stormwater pollutant concentrations were lower than those reported by EPA in the mid-1980s, but higher than stream and river concentrations draining to Puget Sound during storms. Across all land uses, copper, zinc, and lead were found more often than not to exceed (not meet) water quality criteria. Mercury and total PCBs exceeded criteria in 17% and 41% of the samples, respectively. For most parameters measured in both stormwater and stormwater sediments, concentrations in stormwater sediments paralleled the trends found in water samples across all four land uses.

The statistical analyses used in this study have produced reliable statistical summaries and allowed for robust comparisons of the impacts of land use and seasons on contaminant concentrations and mass loads. The statistical summaries form a baseline for contaminant concentrations in stormwater that will allow for future comparisons.

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- City of Seattle
- City of Tacoma
- Port of Seattle
- Port of Tacoma

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Executive Summary

Introduction

In 1995, when the Washington State Department of Ecology (Ecology) issued its first National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permit, limited national stormwater data were available. The permit relied on data from the mid-1980s and a few local Superfund sites to provide a reasonable picture of pollutant types and ranges of concentrations in stormwater runoff. In developing the Phase I Municipal Stormwater Permit conditions, Ecology intended to help fill this data gap.

The 2007-2012 Phase I Municipal Stormwater Permit (permit) included stormwater discharge monitoring requirements in Section D of Special Condition 8 (S8.D) to gain local stormwater quality data. These monitoring requirements enabled uniform data collection and similar laboratory methods to represent runoff from local land uses. The Phase I permittees were four counties (Clark, King, Pierce, and Snohomish), two cities (Seattle and Tacoma), and two ports (Seattle and Tacoma). The monitored sample locations and land uses are detailed in Figure ES-1. Phase I permittees spent a tremendous amount of time and effort to collect the data compiled for this report. Some permittees continue to conduct outfall monitoring at some of the same sites under the current 2013-2018 permit, but this report only evaluates data collected under the 2007 permit.

The extensive multi-year effort to characterize sources and reduce toxics from riverine inputs to Puget Sound (*Control of Toxic Chemicals in Puget Sound: Phase 3 Data and Load Estimates*; herein called *PS Toxics Study*) took place concurrently with the permittees monitoring of outfalls. Results of the *PS Toxic Study* identified stormwater discharge data as a data gap (Herrera, 2011), while S8.D monitoring by permittees was underway. The *PS Toxics Study* reported that concentrations and loadings of toxic pollutants in monitored rivers and streams were higher during storm events than during baseflow, for all land uses.

Purpose

The primary purpose of this report is to summarize the S8.D stormwater discharge characterization monitoring data collected by the Phase I permittees under the 2007 permit.

What were the goals?

The primary goal for monitoring under the permit was to gather data directly from stormwater discharges and establish a regional (western Washington) baseline of data representing municipal stormwater quality. Such data were to be representative of stormwater discharge quality over the course of individual storm events.

The secondary goal in data analysis was to explore variability in stormwater concentrations across different land uses and seasons and to identify chemicals of interest in stormwater.

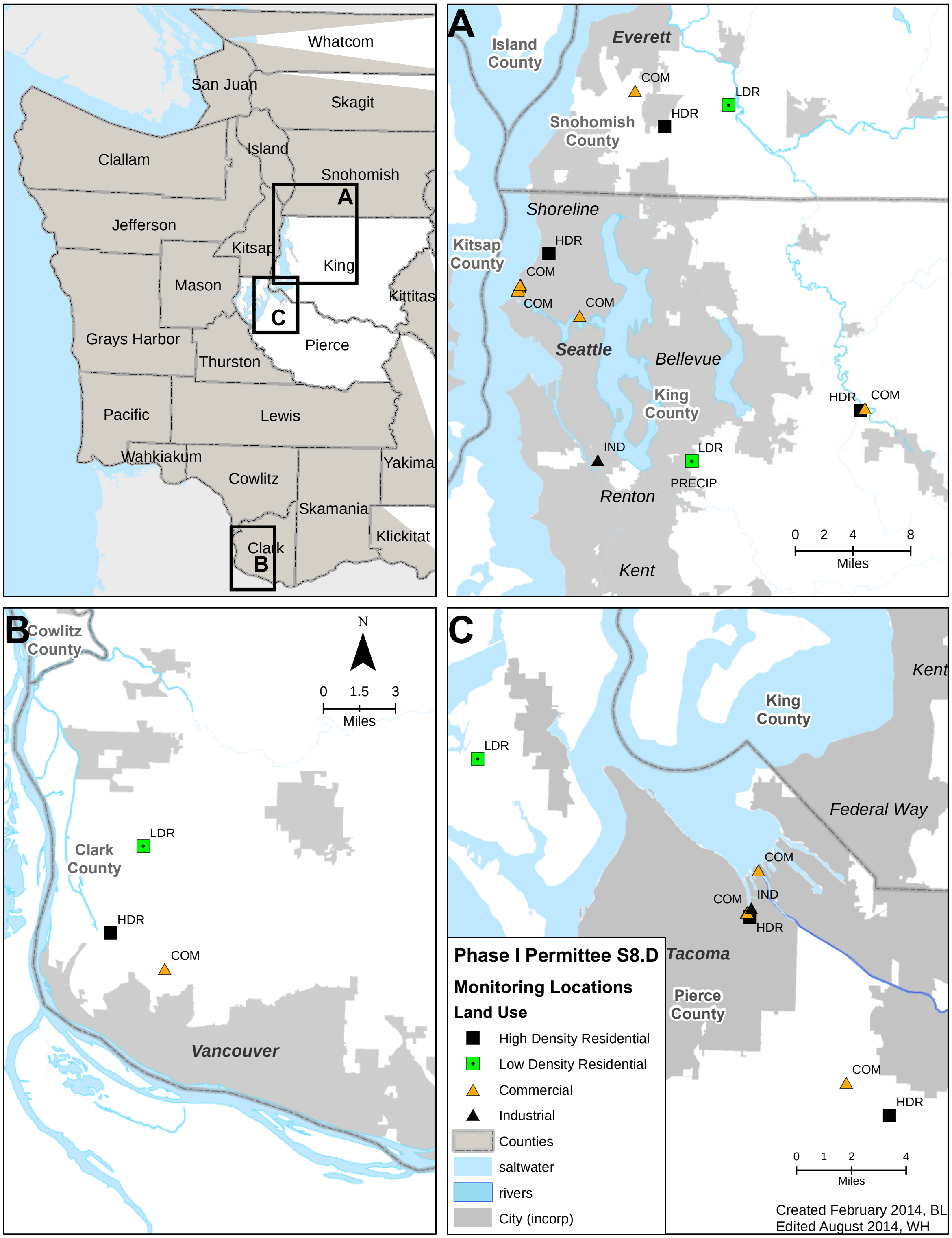

Figure ES-1. Site locations of monitored stormwater catchments and corresponding land use.

Land use types: LDR = low-density residential; HDR = high-density residential; COM = commercial; IND = industrial

What was achieved?

This report provides statistical summaries for municipal storm-event concentrations for 172 parameters across four land uses and wet and dry seasons in western Washington. Ecology recognizes the substantial contribution made by the permittees to our collective understanding of stormwater chemistry in western Washington.

Methods

For this final report, Ecology downloaded, compiled, and analyzed the complete permit monitoring data from Ecology's Environmental Information Management (EIM) database. Stormwater was monitored from 2009 through 2013, and samples were collected using flow-weighted automatic composite samplers for most parameters. Each location has at least three years of data.

Composite sample volumes were in compliance with the required collection approach of a storm's hydrograph under the permit. Samples generally spanned 75% or more of the first 24 hours of each storm. Permittees submitted rainfall amount, runoff volume, and concentration data for stormwater samples to Ecology's EIM database. Concentration data for stormwater-related sediments are also available in EIM; however, these data were collected less uniformly, using either grab samples or traps in the storm pipe system.

Results

The final data set encompassed 44,800 records submitted to Ecology by Phase 1 permittees, representing an estimated 597 storm events. Up to 85 chemicals were analyzed for any given stormwater sample, and 67 chemicals were analyzed in stormwater sediment samples. The composite stormwater samples were found to be representative of storm length, storm volumes, and frequency of storm events in western Washington. The database is suitable for characterizing stormwater quality in western Washington.

Detection Frequency

The rate of detection varied across land use and by parameter. Overall, metals, nutrients, and conventional parameters were detected in nearly all stormwater and stormwater sediment samples. The following parameters were frequently detected in stormwater:

- Conventional parameters (biochemical oxygen demand, pH, conductivity, chloride, turbidity, total suspended solids) had a 98% detection rate. Surfactants were detected in 60% of the samples.
- Metals except mercury were commonly detected; arsenic, copper, lead, magnesium, and zinc were found in 90% of the samples. Cadmium was detected in just over 60% of the samples.
- Nutrients (nitrogen and phosphorus) were detected in 90% of the samples.
- Polycyclic aromatic hydrocarbon (PAHs) were detected in 73% of the samples.
- Total petroleum hydrocarbons (diesel range fractions) were detected in 73% of the samples.
- bis(2-ethylhexyl)phthalate was found in 62% of the samples.

The detection rate of organic compounds (such as total petroleum hydrocarbons – diesel fractions, PAHs, and phthalates) and certain metals (copper, lead, and zinc) in stormwater sediments was more than 90%. Diesel, motor oil, copper, and zinc were found in all stormwater sediment samples collected.

Chemicals are considered *non-detect* if the concentration was not measured above the method detection limit. The following parameters were either infrequently detected or not detected at all:

- Benzene, toluene, ethylbenzene, and xylenes (BTEX) in stormwater were found in less than 3% of the samples.
- Malathion, prometon, chlorpyrifos, and diazinon in stormwater and stormwater sediments were found in less than 4% of the samples.
- Triclopyr and mecoprop was detected at a rate of 8% in stormwater sediments and approximately 11% in stormwater samples.
- Most phenolics in stormwater sediments were not detected at all, except for pentachlorophenol, o-cresol, and p-cresol (detection rates of 25, 19, and 77% respectively).

Land Use

Metals, hydrocarbons, phthalates, total nitrogen and phosphorus, pentachlorophenol, and PCBs were detected more frequently and at higher concentrations from commercial and industrial lands than from residential lands. Residential lands exported stormwater with the highest dissolved nutrient concentrations.

All parameters with high rates of detection exhibited statistically different concentrations across land uses. Individual parameters showed strong differences among land uses. However, when parameters were grouped or summed (e.g., sum of PAHs), greater overlap in stormwater chemistry among land uses was found.

Chemicals of Interest and Importance

To put the results of this compilation effort into context, Ecology compared these results using two primary sources of information. The first source was a suite of literature including the Nationwide Urban Runoff Program (NURP; EPA, 1983) and analysis of the National Stormwater Quality Database (Maestre et al., 2005). These are discussed in the next section. The second primary source was the Washington State Water Quality Criteria. The national studies and Washington's water quality criteria form the "bookends" for comparing the stormwater discharge results of this compilation. The intent of this report is to characterize data, not to evaluate compliance. The comparison to criteria presents an understanding of parameters and land uses where stormwater improvements and resources can be focused to improve water and sediment quality.

Across all four land uses, copper, zinc, and lead were−more often than not−found to exceed (not meet) water quality criteria (Table ES-1). Dissolved zinc and copper in stormwater samples exceeded acute aquatic life criteria in 36% and 50% of the samples, respectively, over the three years of data. Mercury and total PCBs exceeded chronic aquatic life criteria in 17% and 41% of the samples, respectively. Commercial and industrial lands contributed higher concentrations of these compounds.

Table ES-1. Parameters ranked in order of percent of samples exceeding the aquatic life water quality criteria.

Acute aquatic life criteria			Chronic aquatic life criteria		
Parameter	Exceeds (%)	Samples (total)	Parameter	Exceeds (%)	Samples (total)
Dissolved Copper	50.30	600	Dissolved Copper	57.80	600
Dissolved Zinc	36.00	606	Total PCBs	40.70	27
Dissolved Lead	0.30	627	Dissolved Zinc	39.90	606
Dissolved Cadmium	0.30	635	Dissolved Lead	27.60	627
Diazinon	0.30	644	Total Mercury	17.40	455
Chloride	0.20	551	Chloride	0.70	551
Total PCBs	0.00	27	Dissolved Cadmium	0.50	635
Pentachlorophenol	0.00	473	Diazinon	0.30	644
Chlorpyrifos	0.00	644	Pentachlorophenol	0.00	473
Dissolved Arsenic	0.00	16	Chlorpyrifos	0.00	644
Dissolved Mercury	0.00	444	Dissolved Arsenic	0.00	16

PAHs, a significant component of the stormwater pollutants, do not have promulgated numeric criteria in water for the protection of aquatic life.

For most parameters measured in both stormwater and stormwater sediments, concentrations in the stormwater sediments reliably paralleled the trends found in water samples across land uses. Insoluble parameters had much higher frequencies of detection in stormwater sediments than in water. When concentrations in stormwater sediments were compared to the Washington State Sediment Cleanup Objectives (SCOs) for freshwater sediments under the Sediment Management Standards, the number of samples exceeding the SCOs was found highest for phthalates[1] (82% and 29% of samples) and PAHs (34% of samples). To a lesser extent, concentrations of phenolics (20%) and metals (1-18%) exceeded the SCOs.

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[1] Bis(2-ethylhexyl) phthalate – 82% of samples; di-n-octyl phthalate – 29% of samples

Seasonality and Loads

Higher contaminant concentrations and mass loads were measured for nutrients and metals during the dry season (May through September). This provides strong evidence for an influence of seasonality (or antecedent dry periods) on stormwater concentrations, particularly in late summer through early fall; it also supports the idea that there is a degree of "buildup" in the dry periods between storms. Metals, diesel hydrocarbons, and total nutrient loads were higher in the dry season and highest from commercial and industrial areas.

PAHs, phthalates, and detected pesticides (dichlobenil and pentachlorophenol) did not exhibit this significant seasonal difference, suggesting a consistent source throughout the year and no buildup in the dry months.

Discussion

This study improves Ecology's understanding of the quality of stormwater discharges to receiving waters. The study provides:

- Local and land use-based stormwater quality data.
- Flow-weighted composite sample data which are superior in quality to grab samples and best represent storm-event concentrations.
- Direct baseline to measure the performance of stormwater management actions at a regional scale.
- Summary statistics from a very large data set that are not biased by substituting for *non-detect* results.

Generally in this stormwater discharge data set, individual storm-event concentrations were within the ranges reported in the National Stormwater Quality Database (NSQD) (Maestre et al., 2004 and 2005), but median values were consistently lower (Figure ES-2). These concentrations are also much lower in some cases (e.g., lead is 23 times lower) than those from the earliest national study on stormwater, NURP (EPA, 1983). This may be due to the age of the early studies, subsequent improvements in stormwater quality and management since the NURP sampling, or possibly our wetter climate that allows for more wash off between monitored storms. Nevertheless, the current study offers many of the same conclusions about land-use patterns as the *PS Toxics Study* (Herrera, 2011) and NURP/NSQD studies of the 1980s and 1990s. For example, concentrations of metals from commercial and industrial land uses have remained high.

For many of the parameters, concentrations were higher in stormwater discharges in the current study than levels found in the recent *PS Toxics Study* (Figure ES-2). This finding is not surprising given the *PS Toxics Study* sampled ambient receiving waters, while these current stormwater data are representative of discharges to receiving waters.

In the current study, metals (total and dissolved) were much lower (2 to 15 times) than in the NURP and NSQD data sets (Figure ES-2). Compared with the *PS Toxics Study*, metals were generally higher in stormwater, with the exception of dissolved arsenic. High background arsenic from the regional geologic setting yields higher dissolved concentrations in receiving waters of rivers and streams. The largest difference in metals concentrations between this study and the *PS Toxics Study* was found in lead and zinc (12 and 8 times, respectively; Figure ES-2).

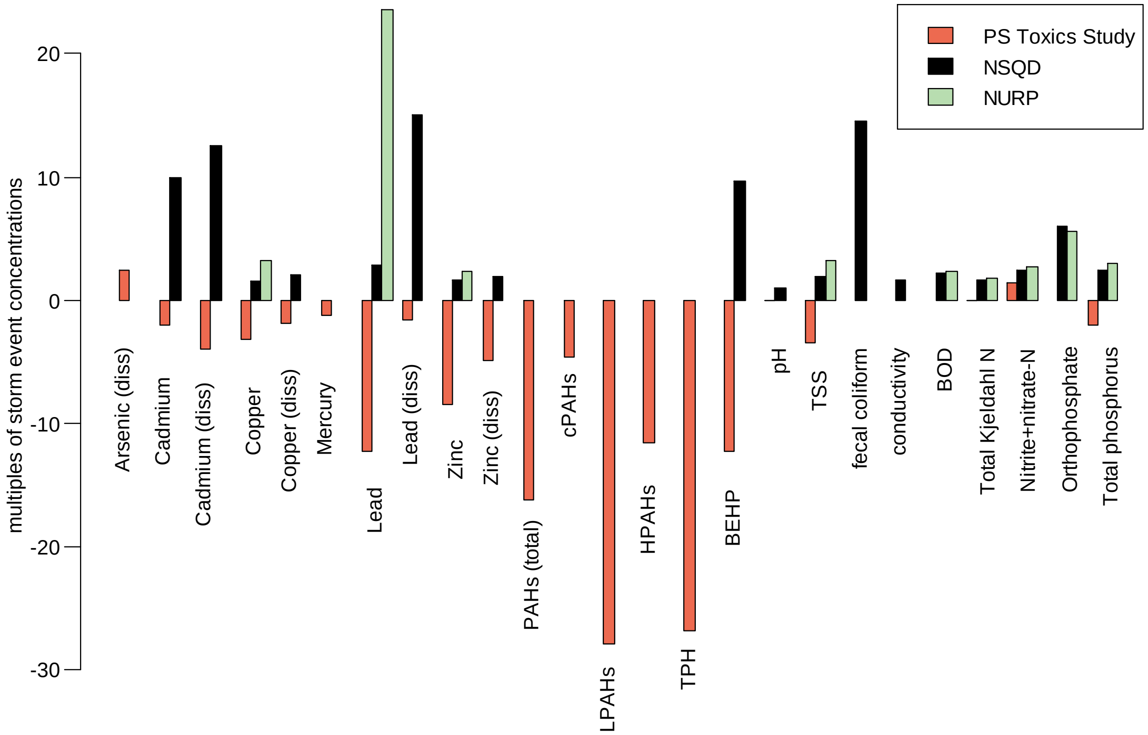

Figure ES-2: Summary of S8.D median stormwater concentrations relative to other studies.

The Y-axis units are the differences (multiples) of the S8.D stormwater median concentrations reported in the other two studies. Bars show the magnitude of difference as less than (negative) or more than (positive) the S8.D results. Many parameters were not measured in the previous studies.

Total nutrients and dissolved nutrients were found to have different land-use patterns. Like many of the metals and organic contaminants, total nutrients were found in higher concentrations and loads from areas of commercial and industrial land use. Total phosphorus concentrations in stormwater discharges were found to be double the receiving water concentrations under storm flows as reported in the *PS Toxics Study* for combined land uses.

Dissolved nutrient concentrations (nitrite+nitrate and orthophosphorus) were higher in stormwater from residential areas. Dissolved nutrients were lower in stormwater discharges than in receiving waters under storm events sampled in the *PS Toxics Study* (Figure ES-2). This suggests the major sources of dissolved nutrients are probably not in piped stormwater systems represented in this data set. This suggests that nonpoint sources for dissolved nutrients may be important delivery mechanisms for dissolved nutrients. Possible sources are shoreline sheet flow drainage, non-urbanized land runoff (such as agriculture and open space), other surface water bodies (such as wetlands), and groundwater.

The permittees analyzed far more parameters than the two older national studies did, particularly organic parameters such as PAHs that were frequently detected in western Washington stormwater. Hydrocarbon median concentrations (PAHs and TPH) were measured at 5 to 26 times higher in this study than those in the *PS Toxics Study* (Figure ES-2). This compilation of stormwater discharge data corroborates the *PS Toxics Study* findings about the dominant source of PAHs. High concentrations of PAHs are observed during storm events, with the greatest contribution of PAHs from areas with commercial and industrial land uses. No seasonal differences in PAH concentrations were found in this study.

Overall, the highest concentrations and the most frequent exceedances of water quality criteria for toxic compounds were found in stormwater and stormwater sediments discharged from basins with a higher percentage of commercial and industrial land uses. Residential lands contributed the highest concentrations of dissolved nutrients and the pesticides dichlobenil and triclopyr. Triclopyr, which had a high frequency of detection in the *PS Toxics Study,* was found in only 10% of the 575 stormwater samples analyzed under the permit in this current study.

Recommendations

Future Monitoring and Stormwater Management

- Continue collecting high quality data representing storm-event concentrations. This is realistic, since all eight permittees met sample frequency and representativeness of the qualifying storm event described in the permit.
- Reduce or eliminate from future stormwater monitoring those parameters which were rarely detected:
  - Benzene, toluene, ethylbenzene, and xylenes (BTEX) in water.
  - Malathion, prometon, chlorpyrifos, and diazinon in water and sediments.
  - Triclopyr and mecoprop in sediments.
- Limit testing of phenolics in sediments to pentachlorophenol, o- cresol, and p-cresol.
- Expand the spatial scale and number of sites for collection of annual stormwater sediment samples to enhance the survey of possible contaminant sources. Stormwater sediment samples effectively reflect the relative contaminant concentrations by land use.
- Apply the findings of this analysis to future stormwater management activities.
  - Stormwater management programs can sweep and conduct other housekeeping best management practices (BMPs) in industrial and commercial areas during the dry season to reduce high stormwater loads of metals, diesel hydrocarbons, and total nutrients during the first-season storms.

Future Puget Sound Monitoring and Modeling

- Use this study's measurements of storm-event concentrations to fill data gaps in Puget Sound models (identified by the *PS Toxics Study)* for areas draining directly to marine or fresh receiving waters. These areas were missed when monitoring the larger drainages in that study (Herrera, 2011).
- Use this stormwater data set in modeling studies for more accurate estimates of toxics loading from stormwater in the Puget Sound basin.
- Conduct future studies of BMP effectiveness in the sampled basins, using a similar suite of stormwater chemistry for comparison to these baseline data. For example, evaluate the best timing for sweeping high traffic areas, ports, and parking lots.

Further Study

- Consider providing the data online in a simple, user-friendly interface that stormwater managers could use to directly compare to future stormwater chemistry results.
- Link this data set with the NSQD to increase the temporal range of the data set.
- Further investigate statistical approaches to define "typical" stormwater chemistry for each land use or other basin characteristics (e.g., total impervious area, effective impervious area, vehicular uses, pollution-generating activities).
- Continue analysis of unusually high runoff coefficients (percent of a storm's rainfall that is directed through the stormwater system) that were calculated for some high-density residential sites. This could show whether the runoff coefficient influences the contaminant contributions from these sites.
- Explicitly test the influence of antecedent dry periods and seasonal first-flush events in stormwater discharges.
- Evaluate the data set for patterns that could help identify and reduce sources of pollution to stormwater. For example, analyze the relationship between the timing of the highest metals concentrations from commercial and industrial areas and whether BMPs can reduce the discharge of copper, zinc, and lead.
- Further investigate the data set for relationships between seasonality and land use (or other basin characteristics) for each parameter (e.g., total phosphorus exhibits strong statistical differences among land uses during the wet season, but no significant differences during the dry season).
- Evaluate more descriptive landscape variables (e.g., vehicle traffic or road density) with the concentration data.

Data Access

This data set is available from Ecology's Environmental Information Management (EIM) database. Inquiries can be made by contacting report authors B. Lubliner or N. Kale.

Introduction

Stormwater transport of pollutants to receiving waters is a local and national concern. The U.S. Environmental Protection Agency (EPA) states, "*Polluted stormwater is the leading cause of impairment to the nearly 40% of surveyed U.S. waterbodies which do not meet water quality standards.*" (EPA Stormwater website). The Washington State Department of Ecology (Ecology) is authorized to administer the Clean Water Act's National Pollutant Discharge Elimination System (NPDES) permits to implement controls designed to prevent stormwater pollutants from impairing local water bodies.

To understand the extent of pollutant loading by stormwater to streams, lakes, rivers, and Puget Sound, Ecology included monitoring requirements in the 2007-2012 Phase I Municipal Stormwater permit (permit)[2] (Ecology, 2006 and 2007). Ecology issued the permit to four counties, two cities, and two ports[3]. Special Condition 8 (S8) of the permit consisted of three main monitoring elements:

- Stormwater discharge characterization monitoring and assessment of seasonal first flush toxicity (S8.D).
- Stormwater treatment and hydrologic best management practices (BMP) evaluation monitoring (S8.E).
- Targeted stormwater management program effectiveness monitoring (S8.F).

This report summarizes the results of stormwater discharge characterization monitoring (S8.D) only. Appendix A provides a summary of the screening level toxicity of the first storms in the dry season. This report of the Phase I Permit's S8.D stormwater monitoring data represents the largest local data set characterizing municipal stormwater discharge quality. Compilation and analysis of stormwater discharges helps fill a data gap identified by a receiving water study: *Control of Toxic Chemicals in Puget Sound: Phase 3 Data and Load Estimates* by Herrera Environmental Consultants, Inc. (Herrera, 2011), herein called the *PS Toxics Study*. The *PS Toxics Study* stated the major data gap was in regional stormwater quality information from conveyance systems, and that discharge data were needed to improve loading estimates to Puget Sound.

Purpose

Characterization of stormwater pollutant discharges by land use on a regional scale is an Ecology priority. Stormwater management solutions and decisions are based on knowledge gathered from monitoring the types of pollutants in populated industrial, residential, and commercial land-use areas. The National Estuary Program (NEP) also identified stormwater discharge characterization as a priority. In 2012, NEP provided grant funding to Ecology to compile and

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[2] The 2012-2013 Phase I Municipal Stormwater Permit continued the 2007 permit's monitoring requirements, clarifying endpoints for these monitoring programs and requirements for data submission.

[3] The Phase I Municipal Stormwater Permit also covers Secondary Permittees which were not required to conduct the monitoring discussed in this report.

review the S8.D monitoring data collected from 2007 through 2012. An interim report was published based on results available at the time (Lubliner and Newell, 2013). After the interim report was published, the remaining stormwater monitoring data were submitted to Ecology. This final compilation builds on the interim report and establishes a regional baseline of stormwater discharge quality based on monitoring results from the Phase I Permit.

The information presented herein provides natural resource managers and stormwater managers with actual stormwater discharge data in western Washington, which can decrease reliance on national studies that may not represent western Washington's climate or land uses. Improved confidence in local stormwater event concentrations is useful for stormwater managers, regulators, treatment technology development, and future contaminant studies (e.g., source identification and loading studies). This report provides recommendations for future analysis of this data set and recommendations for separate studies. This report also identifies parameters that provide little information about stormwater quality.

Permit-Defined Stormwater Monitoring

Stormwater Monitoring Design

Monitoring Permittees

The 2007 monitoring requirements applied to eight Phase I permittees:

- Cities of Tacoma and Seattle
- King, Snohomish, Pierce and Clark counties
- Ports of Tacoma and Seattle

To ensure consistency across jurisdictions, monitoring was conducted under Quality Assurance (QA) Project Plans written by the permittees and approved by Ecology. The monitoring program for each permittee is described in detail in each permittees' QA Project Plan (referenced in Appendix B and available from the permittees). A few aspects of the monitoring programs are important for understanding the monitoring results presented here.

Site Selection for Stormwater Characterization

The permit instructed permittees to monitor land uses where, ideally, the drainage area would constitute ≥80% of a particular land use. However, Ecology and the permittees found that stormwater sub-basins tended to contain more variety of land uses and meeting this 80% goal was not possible in all circumstances (Table 1). Permittees monitored one location for each different land-use type. The land-use types monitored by permittees were:

- Counties: commercial, high-density residential, and low-density residential.
- Cities: commercial, high-density residential, and industrial.
- Ports: commercial.

The permit required stormwater monitoring for a total of three years of data collection for each site and each permittee. Table 1 shows the land-use characterization of the drainage areas monitored by each permittee and lists the total impervious area (TIA) estimated in each of the stormwater subbasins monitored. Because estimates of effective impervious area (e.g., impervious surfaces that are connected via sheet flow or discrete conveyance) were not available, the TIA information was intended to provide context for the amount of land area available for dispersion to the ground surface. Not all selected monitoring locations were outfalls to receiving waters; in many cases, the monitoring location was a catch basin or other node in the system that met the project needs. Both ports monitored locations primarily representative of parking lot runoff. The locations of the monitoring sites are shown in Figure 1.

Table 1. Phase I S8.D sites and land-use summary.

Permittee	Land Use			
	Low-Density Residential	High-Density Residential	Commercial	Industrial
Clark County	43 acres 100% residential 7% TIA	239 acres 99% residential 1% open space 52% TIA	27 acres 83% commercial 17% residential 76% TIA	NA
King County	43 acres 100% residential 17% TIA	5 acres 100% residential 50% TIA	5 acres 80% commercial 20% residential 80% TIA	NA
Pierce County	219 acres 43% residential 55% open space 2% other 5% TIA	125 acres 62% residential 16% commercial 14% roadway 8% open space 28% TIA	11 acres 96% commercial 4% open space 96% TIA	NA
Snohomish County	68 acres 85% residential 15% school 26% TIA	20 acres 100 residential 40% TIA	34 acres 100% commercial 77% TIA	NA
City of Seattle	NA	85 acres 95% residential 5% commercial 50% TIA	152 acres 61% commercial 37% residential 2% open space 61% TIA	137 acres 37% industrial 32% residential 18% open space 13% commercial 51% TIA
City of Tacoma	NA	1821 acres 80% residential 19% commercial 5% open space 0.8% industrial 42% TIA	181 acres 97% commercial 3% residential 65% TIA	36 acres 15% commercial 85% residential 90% TIA
Port of Seattle	NA	NA	1.3 acres 100% commercial 95% TIA	NA
Port of Tacoma	NA	NA	1.3 acres 100% commercial 82% TIA	NA

NA: Not applicable
TIA: Total impervious area

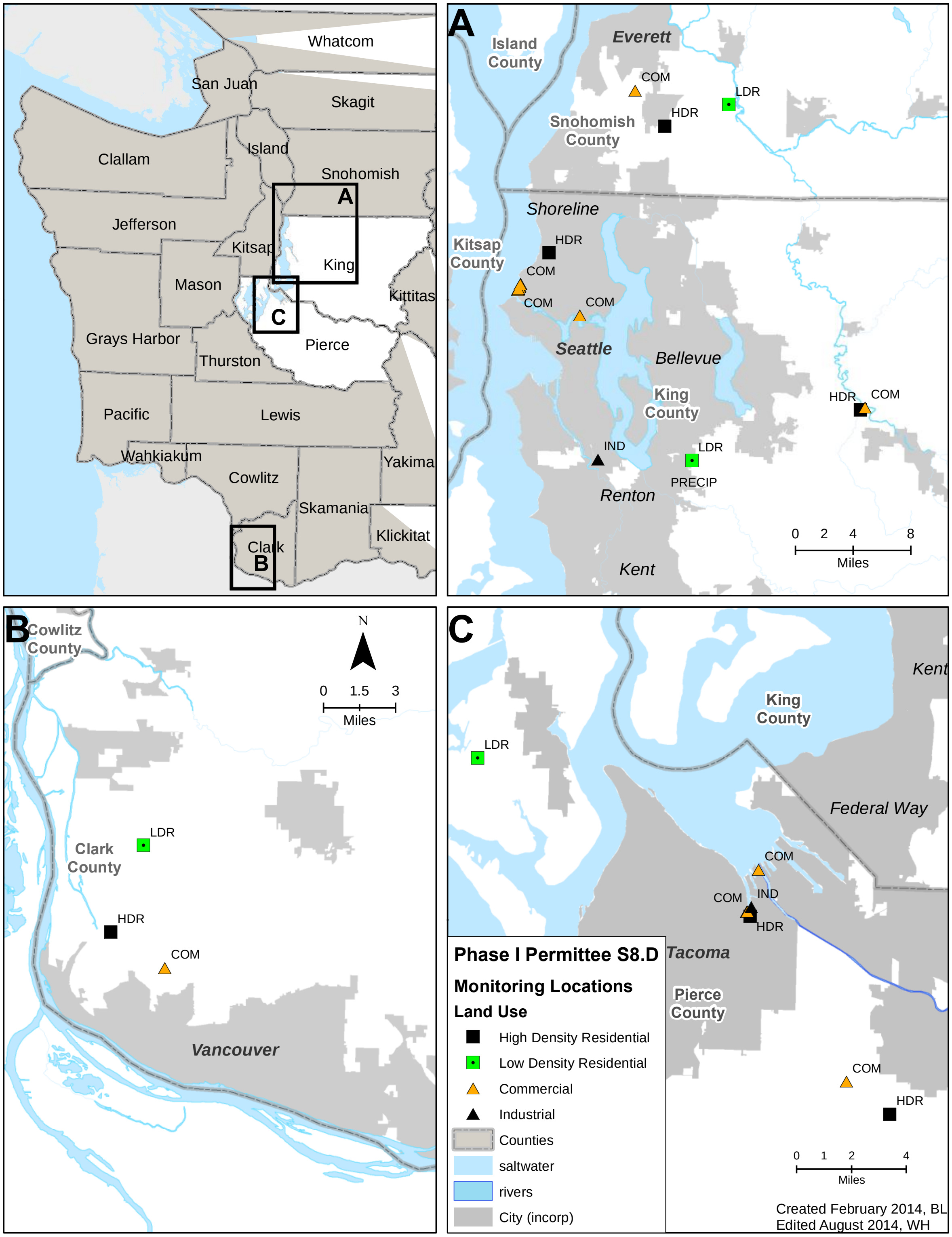

Figure 1. Site location map.

Land-use types: LDR = low-density residential; HDR = high-density residential; COM = commercial; IND = industrial

Storm-Event Criteria and Frequency

The permit specified the qualifying rainfall, antecedent dry period, and inter-event dry periods to define a storm event. The permit's criteria were highly specific and necessary to ensure consistent sampling for a regional program, particularly when considering the Pacific Northwest's winter climate with constant and sometimes overlapping wet weather patterns. Qualifying storm events were defined for the wet and dry season as follows:

All Storms

- Rainfall depth: 0.2 inch minimum, no maximum
- Rainfall duration: no fixed minimum or maximum
- Inter-event dry period: 6 hours

Wet Season (October 1 through April 30)

- Antecedent dry period: ≤ 0.02 inch rain in the previous 24 hours

Dry Season (May 1 through September 30)

- Antecedent dry period: ≤0.02 inch rain in the previous 72 hours

Permittees were required to monitor 67% of the forecasted qualifying storm events, up to a maximum of 11 storms per water year. The goal was to distribute sampling across the year with 60-80% of the storms representative of the wet season and 20-40% representative of the dry season. If, for a variety of reasons and despite good faith efforts, 11 "qualifying" storms were not sampled in a given year, a permittee could submit data from three storms that were "non-qualifying" for the 0.2 inch rainfall depth criterion.

Permittee information on timing of sampling or logistics in relation to storms is not evaluated in this report. Non-qualifying storm-event data were included in this project summary and were not differentially treated.

Parameters

Parameters were specified in both S8.D and Appendix 9 of the permit and were prioritized for each land use when the sample volume was limited. Table 2 lists the water quality parameters monitored in stormwater.

Stormwater Sample Collection

Stormwater samples were required to be collected using flow-weighted composite sampling techniques for all but two parameters. Flow-weighted composite samples best represent storm-event concentration. Flow-weighted stormwater samples were collected by automatic samplers (such as ISCO samplers), which were triggered to begin sampling once either the rainfall criteria of 0.02" of rainfall or a presence of flow in the conduit was detected. Permittees used telecommunications and automated equipment to ensure proper sample collection. A qualifying flow-weighted composite sample was required to be collected over 75% of the storm-event hydrograph. The permit defined a composite sample as at least ten aliquots, but as few as seven aliquots were accepted if all other criteria were met. Analytical results from this monitoring program are thus representative of storm-event concentrations, which provide the best indicator of the quality of the discharge over the length of a storm.

Two parameters, fecal coliform bacteria and total petroleum hydrocarbons, were required to be collected as grab samples.

Precipitation and flow volume data for each storm event were also monitored in real-time via electronic sensors.

Stormwater Sediment Monitoring Design

Entrained stormwater solids and sediments (stormwater sediments) were collected once annually. The list of parameters monitored in the stormwater sediment matrix included conventional parameters, PCBs (Aroclors), and phenols (Table 2).

The permit recommended that the sampling protocol use inline traps or other similar collection system, although a single specific sampling technique was not required. As a result, permittees used a variety of stormwater sediment sampling approaches from in-line traps to grab samples. Monitoring in-line stormwater solids using traps can be unpredictable and requires long periods of submersion and/or deployment to adequately trap sediments sufficient for analysis. Other permittees collected grab samples of stormwater sediments that had settled in catch basins. Permittees may also have treated samples differently following collection. Some may have decanted overlying water prior to laboratory analysis, whereas others may not have.

Uncertainty is higher for this stormwater sediment data in general due to the lack of defined protocols for collection and post-collection processing. This variety in collection and processing methods has an unknown impact on the variability of the stormwater sediment concentrations in the data set. For simplicity, Ecology overlooked the method of collection and combined all the stormwater sediment data for analysis, because there are far fewer numbers of samples in the data set due to the monitoring design. For the purposes of this data summary, the annual stormwater sediment samples were presumed to be comparable, and all results were compiled and evaluated. All stormwater sediment results are reported on the basis of dry weight.

Table 2. Permittee-monitored parameters.

Hydrology		
Storm-Event Precipitation Storm-Event Flow Volume Sampling-Event Flow Volume		
Water Quality		
Conventional Parameters	*Bacteria*	*Organics*
Total suspended solids	Fecal coliform	PAHs[a]
Turbidity		Phthalates[b]
Conductivity	*Metals (dissolved and total)*	Pesticides: Nitrogen (Prometon)
Chloride	Zinc	Pesticides: Organophosphates (Diazinon)
BOD$_5$	Lead	Herbicides: (2,4-D, MCPP, Triclopyr, Dichlobenil, Pentachlorophenol)
Particle Size Distribution	Copper	
Grain Size	Cadmium	
pH	Mercury	*Petroleum Hydrocarbons*
Hardness as $CaCO_3$		NWTPH-Dx
thylene Blue Activated Substances (MBAS)		NWTPH-Gx
Nutrients		
Total phosphorus		
Ortho-phosphate as phosphorus		
Total Kjeldahl nitrogen		
Nitrite+Nitrate as N		
Sediment Quality		
Conventional Parameters	*Metals*	*Organics*
Total Solids[c]	Zinc	PAHs[a]
Total Organic Carbon	Lead	Phthalates[b]
Grain Size	Copper	Phenolics[d]
Total Phosphorus	Cadmium	PCB Aroclors
Total Volatile Solids	Mercury	Pentachlorophenol
		Diazinon
		Chlorpyrifos and Malathion
		Petroleum Hydrocarbons
		NWTPH-Dx

(a) PAH compounds include at a minimum but are not limited to: 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo[b]fluoranthene, benzo(k)fluoranthene, benzo[ghi]perylene, benzo(a)pyrene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene, and pyrene.

(b) Phthalates include at a minimum but are not limited to: bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, di-N-butyl phthalate, diethyl phthalate, dimethyl phthalate, and di-n-octyl phthalate.

(c) Appendix 9 of the permit mistakenly called for "Total Solids" when it should have said "Percent Solids" in the sediment parameter list. Despite the error in the text, this parameter was correctly analyzed by laboratories as the percent of the sediment sample that is the solid material (as opposed to water).

(d) Phenolics include but are not limited to: 2-methylphenol, 4-methylphenol, 2,4-dimethylphenol, and pentachlorophenol.

Laboratory Analytical Methods

The permit specified analytical methods and reporting limit targets for each parameter to ensure the stormwater data under this monitoring program were analyzed consistently and with comparable rigor among the various laboratories. In some cases, it allowed multiple methods (thought to be comparable) to be used for analysis of a parameter, provided the reporting limit target could be met. For example, conductivity could be analyzed using SM 2510 or EPA Method 120.1. Permittees used 15 laboratories for analysis; no permittee used only a single laboratory for all parameters. All data for a given parameter were pooled for analysis regardless of laboratory and regardless of analytical method.

Laboratory Quality Assurance

Each permittee's QA Project Plan was approved by Ecology and contains sections outlining the QA process and quality control (QC) procedures for its stormwater monitoring program. QA is a decision-making process, based on all available information that determines whether the data are usable for all intended purposes (Lombard and Kirchmer, 2004). QC refers to a set of standard operating procedures for the field and laboratory that are used to evaluate and control the accuracy of measurement data. Determination of laboratory QC and the overall stormwater monitoring program QA was performed by each permittee, per their QA Project Plans.

For this data analysis project, data entered into the EIM database are believed to be usable for the purpose of creating a baseline summary report as stated in the permittees' QA Project Plans.

Methods

Data Qualification

Quantitation and Reporting Limits

Reporting limits lower than those specified in the permit were allowed, provided that permittees' QC procedures were met and their instrumentation allowed resolution at a lower limit. Reporting limit and method detection limit terminology are illustrated in Figure 2. Appendix 9 of the permit listed reporting limit targets for each parameter and stated in the footnote:

> *"All results below reporting limits should be reported and identified as such. These results may be used in the statistical evaluations."*

It is Ecology's expectation that the detected concentrations below the target reporting limit were quantified and flagged as an estimate (e.g., typically a "J" flag).

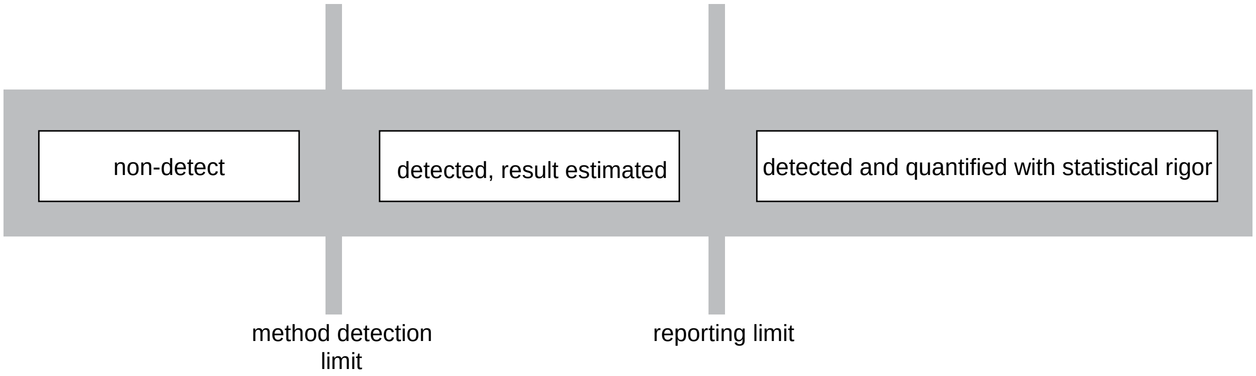

Figure 2. Simplified diagram of laboratory thresholds and data results.

Qualified Data

Data verification is the process of evaluating the completeness, correctness and conformance/ compliance of a specific data set against the laboratory method and study QA objectives. Data verification applies to activities in the field, at the laboratory, and the data user's (permittee's) review. Both the laboratory and the permittee's reviews determine whether the data record is usable as is or requires a corrective action, re-analysis, or flag to indicate qualification as estimate (J flag) or is rejected and is unusable (R or REJ flag). J flags may be given at the laboratory due to a slightly out of range QC sample or by the data QA managers (within the permittees' monitoring programs).

- *Method Detection Limit (MDL)* – The MDL is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. The MDL is determined using the procedure at 40 CFR 136, Appendix C. The permit did not specify MDLs.

- *Reporting Limit (RL)* – The reporting limit has multiple definitions and values, because it is a user-defined value imposed upon the reporting laboratory. RL is the lowest concentration at which an analyte can be detected in a sample and its concentration can be reported with a reasonable degree of accuracy and precision. The reporting limit may vary based on the purpose and use of the data. Reporting limits should always be based on statistical rigor at each laboratory. Analyte detections between the MDL and the reporting limit are reported as having estimated concentrations. Reporting limits are typically three to five times the MDL.

Ultimately, a lack of a signal below the MDL or RL was flagged as "U" meaning the parameter was not detected. In this report Ecology refers to the non-detected data as "non-detect".

Variation in Reporting Limits

Permittees' results had highly variable reporting limits, both between samples and between laboratories. Some variability is common and expected. Generally, the laboratories met the reporting limits listed in Appendix 9 of the permit. In some cases, analyses and/or labs were changed during the three-year data collection period to ensure compliance with permit requirements.

Figure 3 shows an example of the variability in the reporting limits for one of the non-detected compounds. This type of plot was constructed for every parameter with non-detect data. The colored bars represent the non-detect value as extending from "zero" up to the threshold reported for each laboratory. This threshold may have been the MDL or the reporting limit (RL), and this was not determined for this project. Based on the data gathered for this report, there may be differences where laboratories reported the detection threshold. Below Figure 3 is a color key associated with each of the laboratories that contributed data. In this example, dichlobenil (an herbicide) had 611 storm-event concentration records, but 392 of those records were non-detects (64.2% of the records). The non-detects were reported at approximately 20 different reporting limits spanning two orders of magnitude. The Permit gave a target reporting limit of 0.01 – 1.0 ug/L for dichlobenil and other pesticides.

Non-detect data are shown in these plots as line segments extending from zero to the laboratory reporting level. The color of the line segment indicates which laboratory performed the analysis. Laboratory names were removed and represented by a number. The focus of this plot is not to identify permittees or their laboratories, but rather to illustrate the number of laboratories and RLs reported. The information about the non-detect RLs could be used to define a single, realistic RL for each parameter. However, this is outside the scope of this report.

Reporting limits vary for several reasons. Natural variability of concentrations in stormwater samples typically is greater than in surface water or wastewater samples. Natural variability is due to numerous factors such as rainfall intensity, season, air deposition, land use, and potential sampling bias towards seasonal or event-based first flush.

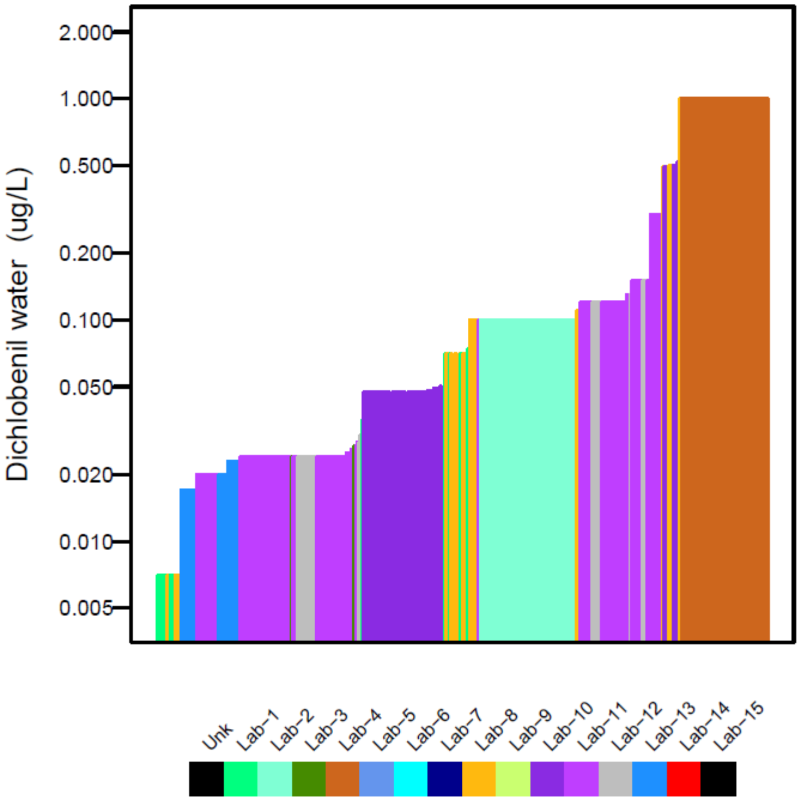

Figure 3. Non-detect reporting limits for dichlobenil by laboratory.

Other reasons for variability come from sampling design or sampling bias (e.g., sample volume collected). The sample volume typically required for an analysis has a predictable error rate associated with the analysis. When a smaller than normal volume is analyzed, the standard error increases, which increases the reporting limit. The anticipated stormwater volume was difficult to predict; it depended on the climatic event and was constrained by the capacity of the compositors. As a result, some samples were likely sent to the laboratory with less than ideal volumes.

Another major stormwater sampling source for variability is interference by compounds present in the stormwater sample (called *interfering matrix).* Stormwater samples can contain debris, sediment, oil, and other compounds that can interfere with sensitive analytical equipment. Laboratories must clean up dirty samples prior to analyzing for the contaminant of interest. This often results in loss of resolution at low levels and, in turn, elevates the reporting limit.

Permittees were required to conduct QC and QA reviews on reported data. Because data verification was performed by the permittees, the data received by Ecology were thought to be usable. For this report, Ecology used the data as reported with few exceptions. Several obvious outliers were verified with permittees and errors resolved. Rejected records were not requested and, if supplied, were not used for summary statistics.

Data Compilation and Management

Data Collection and Accessibility

Permittees were responsible for submitting data collected under the S8.D stormwater monitoring permits, with the exception of the toxicity results, to Ecology for entry into the agency's Environmental Information Management (EIM) system (http://www.ecy.wa.gov/eim/). Toxicity results were submitted to Ecology for review. Ecology prepared a summary of stormwater seasonal first-flush toxicity on trout embryos. This summary is presented in Appendix A.

The S8.D data summarized and presented here are available in EIM. Data may be searched by various characteristics (e.g., parameter, study, geographic area). The study identification codes (IDs) for the S8.D data are detailed in Table 3.

Table 3. Summary of permittee data compiled for this report.

Permittee	EIM Study ID	Period of Record
Clark County	WAR044001_S8D	2009-2012
King County	WAR044501_S8D	2009-2013
Pierce County	WAR044002_S8D	2010-2013
Snohomish County	WAR044502_S8.D	2009-2012
City of Seattle	WAR044503_S8.D	2009-2012
City of Tacoma	WAR044003_S8D	2009-2012
Port of Seattle	WAR044701_S8.D	2009-2012
Port of Tacoma	WAR044200_S8.D	2009-2012

Data Compilation

Ecology downloaded all data associated with the project into a Microsoft Access Database File (.accdb) to query, reorganize, and manage the data into a uniform output file for analysis (Table 4). Reorganization of the data set included such items as renaming a parameter due to variability in nomenclature among the 15 labs. In addition, a number of macros for Microsoft Excel were written in Visual Basic to sum selected parameters. Once the data set was in the final form, it was exported into a comma-separated value (.csv) format, where it could be easily used in a variety of statistical packages.

Table 4. Summary of organizational considerations for stormwater data submitted to the EIM database.

Organizational Steps	Example Issues	Initial Form	Final Form
Removed extra parameters	Laboratory control samples, surrogates, or calculated sums.	Examples of removed parameters include: 1. Maximum conductivity 2. Total PAHs	NA
Parameter names	Different laboratories use slightly different naming conventions; these had to be resolved in the database.	Approximately 25 names were resolved. Example: Triclopyr Trichlopyr Triclopyr (Garlon)	Triclopyr was the chosen parameter name for the database. See Table 2 for list of parameters in the database.
Specific parameter issues (two examples)	NWTPH-Dx Multiple products can be reported.	No guidance was given for reporting.	Sums for several categories created. See description below.
	Percent Solids was erroneously named as Total Solids in permit. Total Solids refers to a water measurement, not solids.	Most of the data were labeled Total Solids	Left as Total Solids, but is thought to be Percent Solids because the sample matrix is sediment for all data points.
Units for parameters	Laboratories and permittees reported using equivalent but different units due to the methods.	Example: 1. Fecal coliform MPN/100 mL or cfu/100 mL 2. ug/L or ng/L or mg/L	Units were preserved as sent in one column, and a lookup table was used to create new columns with data in one unit per parameter for graphing and statistics analysis. Fecal coliform units were assumed to be equivalent.
Sample fraction	Dissolved, total, or total recoverable. Labs used total and total recoverable interchangeably.	There were many blanks in these fields that needed to be populated for the database.	Sample fraction for metals was understood to be totals if blank. The terms *Total* and *Total Recoverable* are interchangeable for NPDES program (EPA, 1998).

Petroleum Hydrocarbon Summations

Petroleum hydrocarbons in stormwater were monitored using an Ecology laboratory method called NWTPH (Northwest Total Petroleum Hydrocarbon; herein called *TPH*) developed in the late 1990s (Ecology, 1997).

TPH-Gx, also called gasoline range hydrocarbon method, is both a qualitative and quantitative method (extended) for assessing volatile ("gasoline") petroleum products in soil and water. Six chromatograms identified by this method include:

- Gasoline
- Weathered gasoline
- Naphtha
- Mineral spirits #1, #2, and #3

TPH-Dx, also called diesel range hydrocarbon method, is also a qualitative and quantitative method (extended) for determining semi-volatile (diesel) petroleum products in soil and water. 24 different chromatograms can be identified by this method, including:

- Jet fuels
- Kerosene
- Diesel fuel
- Diesel oils
- Hydraulic fluids
- Mineral oils
- Lubricating oils
- Fuel oils

According to the method guidance, these NWTPH chromatograms should be summed into a single TPH value. Many of the permittees' results were reported in partial-sum categories typically used at the laboratories. For example, TPH-Dx was reported not as a summed total but as sub-categories, such as "residual range organics" or "heavy fuel oil".

Ecology determined the best path forward for these results was to rename obvious and similar results, preserve the partial-sum designations, and develop a summation plan. The summed TPH-Gx fractions (gasoline, naphtha, and mineral spirits) are called Gasoline Range Hydrocarbons. For TPH-Dx, results are presented in five sub-categories: Diesel Range Hydrocarbons, Heavy Oil Range Hydrocarbons, Heavy Fuel Oil, Lube Oil, and Motor Oil.

PAH and PCB Summation

Polycyclic aromatic hydrocarbons (PAHs) were summed based on functional categories and as a total PAH concentration. Low molecular weight PAHs (LPAH) summed included:

- Acenaphthene
- Acenaphthylene
- Anthracene
- Fluorene
- Naphthalene
- Phenanthrene

High molecular weight PAHs (HPAH) summed included:

- Benzo(g,h,i)perylene
- Total benzofluoranthenes
- Fluoranthene
- Pyrene

Carcinogenic PAHs (cPAH) summed included:

- Benz(a)anthracene
- Benzo(a)pyrene
- Chrysene
- Dibenzo(a,h)anthracene
- Indeno(1,2,3-cd)pyrene

Polychlorinated biphenyls (PCBs) were summed based only on those Aroclors that were detected. All non-detect data were omitted from the sum.

Numerical Analysis

Non-Detect Data

Data sets with non-detect results, particularly with multiple reporting limits, presented complications for data analysis. A considerable amount of complexity accompanied data handling when non-detects made up a large fraction of the data set. However, data were not cast aside or uniformly substituted as a simple approach. Ecology used the approach detailed by Helsel (2012), who describes the nature, analysis, and interpretation of non-detect data.

For the analysis, no substitutions were made for non-detect data, and the data (ranks) were considered. In combining multiple data sets from the permittees, sample sizes increased and statistical power increased with more observations, which improved our confidence in using non-substitution techniques. The statistical approaches used to include the non-detect data are described in the following sections. All statistical analyses were carried out using R (R Core Development Team, 2012) and the NADA package (Helsel, 2012; Lee, 2013).

Data Distributions

Parameters with greater than a 90% detection rate were tested using the distribution hypothesis Shapiro-Wilk Test. The test excludes non-detect data and therefore is not reliable for parameters with a lot of censored data. The Shapiro-Wilk test statistic "W" tests the null hypothesis that the data represent a normally (or log-normally) distributed population. When the p-value is less than the alpha level of 0.05 (in this study), the null hypothesis is rejected.

Probability plots were prepared to assess the log-normal distribution of most parameters, including those with less than 90% detection rates. The plots provide a visual means to estimate the data distribution for any given parameter. Probability plots are described in Appendix C and shown in Appendix F.

In reality the distribution of the data was used largely for descriptive purposes only. Statistical analysis of the data was carried out using Kaplan-Meier (KM) methods which do not rely on transformed data. For those parameters summarized using tools that require data transformation (e.g., regression on statistics [ROS]), the empirical distribution function (EDF) distribution was consulted to define the necessary transformation.

Descriptive Statistics

Categorical Evaluations and Summary Statistics

For statistical analyses, Ecology defined categories within each parameter based on the rate of detection and number of observations. Categories of data are referred to as Case A, B, or C. These categories are based on Helsel's (2012) work and are delineated largely by the reliability of summarizing data using appropriate tools (Table 5). KM and ROS were employed to calculate summary statistics for the reported storm-event concentrations; (mean, median, standard error, and lower and upper confidence levels).

Table 5. Methods for estimating summary statistics.

Adapted from Table 6.11 in Helsel, 2012.

Case	Amount of Data by Parameter		
	Percent non-detect	<50 Observations	> 50 Observations
A	< 50% non-detects	Kaplan-Meier	Kaplan-Meier
B	50-80% non-detects	Kaplan-Meier Robust MLE, robust ROS	Kaplan-Meier MLE
C	> 80% non-detects	Report ranges or % above a meaningful threshold	Report ranges and high percentile concentrations

Case A

Parameters where non-detects make up less than 50% of the data set were summarized using KM statistics. Non-parametric statistics make no assumption about the data's distribution and can also be used on log-normal data to develop summary statistics. The data are ranked, including the non-detect data points, and the statistical analysis (KM) is carried out on the entire ranked data set. The method was not used if more than 50% of the data set was non-detect. For Case A data, the KM method yields robust measures of median, mean, and standard deviation.

Case B

Parameters with 50-80% of the data reported as non-detects were handled according to results from the distribution tests. For the parameters that follow parametric distributions, Helsel (2012) recommends that either substitution methods, robust Maximum Likelihood Estimations (MLE) or robust Regression on Order Statistics (ROS), be followed. However, the majority of the parameters that fell into the Case B situation were not normally distributed.

For these, Ecology calculated summary statistics on the portion of Case B parameters that had more than 50 observations. ROS was used to estimate the summary statistics for this portion of the Case B data.

However, for data sets with fewer than 50 observations, both ROS and MLE provide poor estimates of summary statistics. Thus these data were summarized as a Case C category because Ecology determined that the statistics would be unreliable.

Case C

Case C data were simply summarized as ranges. Calculating other summary statistics would have been unreliable (Helsel, 2012).

Land-Use Significance

To determine if there were significant differences between land uses for a given parameter, Ecology relied on the Peto-Prentice test. The Peto-Prentice score test has been shown to perform well with data sets that have unequal sample sizes and unequal censoring (i.e., detection limits) (Helsel, 2012). The Peto-Prentice is a modified generalized Wilcoxon test, where scores are weighted by the EDF. The Peto-Prentice test identifies when at least one land use among the four has significantly different concentrations. To visualize any significant differences among land uses for each parameter, a plot of the EDF can be produced.

Summary Plots

Ecology relied on six types of plots as visual tools to describe the concentration data (Appendix C). Each set of plots for each parameter consists of:

- Jitter Plot
- Probability Plot
- Non-Detects
- Empirical Distribution Function (EDF)
- Box Plot by Land Use
- Box Plot by Season

Appendix C contains a description of how to read each of these six plots (reproduced from Lubliner and Newell, 2013). Appendix F contains a page for each parameter with all six plots and matrix combination. Ecology also used box plots, cumulative density functions, and jitter plots to describe the contaminant loads (Appendix H).

Multivariate Statistics

In order to summarize multiple parameters for each stormwater catchment together with land use and observe any relevant similarities or associations among them, Ecology relied on principal components analysis (PCA). PCA is a statistical tool that describes the relative similarities among environmental variables (stormwater parameters) and study sites. Multiple axes or components are computed in decreasing order of strength or importance. Each axis represents a synthetic gradient across the sample sites, some more important than others. Visually, a plot of the two most dominant axes (an ordination diagram) can provide an effective means to describe large complex data sets. Points or sites on the plot that cluster together are more similar than those that are more distant. Ecology selected those variables that appeared to be statistically relevant from the prior Peto-Prentice test. The PCA was run on the median concentration values as described above using the statistical techniques for non-detect data. Only parameters which were complete across all study sites were included in the analysis. Data were log transformed, centered, and standardized prior to the analysis. PCAs were run using the R framework and the Vegan package (Oksanen et al., 2013).

Additional tools used to detect similarities among the parameters across the land uses included a hierarchical cluster analysis and an analysis of similarities. The same data set used for the PCA analysis was used for the cluster analysis. Ecology calculated the Euclidean distance (measure of dissimilarity) between sample sites and computed the cluster analysis using Ward's minimum variance method (Hartigan, 1975). This technique is a way of identifying groups of data (sites) that are similar. Visually, a cluster diagram or dendrogram shows the groups of sites starting with the most dissimilar and then continues to separate the sites into groups until each site is on its own branch of the tree (dendrogram). We used the first two major separations of sites in the cluster dendrogram to describe similar 'groups' of sites based on their stormwater chemistry.

Analysis of similarities is a tool to statistically test whether there are significant differences between two or more groups of sampling units based on a dissimilarity matrix. We used the same dissimilarity matrix as the cluster analysis. Ecology employed this test to help determine whether there is a significant difference among land uses based on all sites and all relevant parameters. This differs from the previously described Peto-Prentice test for land-use significance, which tests a single parameter for significant differences.

Comparison to Stormwater Studies and Water Quality Criteria

To put the results of this compilation effort into context, Ecology used three primary sources of information for comparison of these results:

- A suite of literature including the Nationwide Urban Runoff Program (NURP) (EPA, 1983) and analysis of the National Stormwater Quality Database (Maestre et al., 2005).
- Washington State Water Quality Criteria. The national studies and the WA state water quality criteria form the "bookends" for comparison of the stormwater discharge results of this compilation effort.
- A local study to characterize stormwater concentrations and load to Puget Sound from the receiving water during storm events, *Control of Toxic Chemicals in Puget Sound: Phase 3 Data and Load Estimates* (Herrera, 2011) (called *PS Toxics Study* in this document).

Relevant Stormwater Studies Explored

The median concentrations from this study are compared to the median concentrations of a few other stormwater studies where data exist. Comparisons made to these other studies are informative for this database and are included to give context to the results of this study.

- The Nationwide Urban Runoff Program (NURP) (EPA, 1983).

- Nonparametric Statistical Tests Comparing First Flush and Composite Samples from the National Stormwater Quality Database (NSQD) (Maestre et al., 2004).
- The National Stormwater Quality Database, Version 1.1; A Compilation and Analysis of NPDES Stormwater Monitoring Information (Maestre et al., 2005) http://rpitt.eng.ua.edu/Publications/Stormwater%20Characteristics/NSQD%20EPA.pdf
- Control of Toxic Chemicals in Puget Sound: Phase 3 Data and Load Estimates (Herrera, 2011) (called *PS Toxics Study* in this document).

NURP and NSQD

The NURP study was a research project conducted by the U.S. Environmental Protection Agency (EPA) between 1979 and 1983. NURP was the first comprehensive study of urban stormwater pollution across the United States and established the national stormwater quality benchmark. NURP samples were also collected to represent the storm-event concentration, which allows us to compare results from the permittees directly. The study evaluated the stormwater data distributions and concluded that 90% of their study parameters followed a log-normal distribution.

The NSQD was created in the mid-1980s to store stormwater data collected by the NURP study and other Phase I MS4 data. Over time, the database gained some specialized U.S. Geological Survey stormwater studies and more recently selected outfall data from the International BMP Database. Several reports have been published by Alex Maestre and Robert Pitt, summarizing the stormwater monitoring data contained in versions of the database over the last 20 years (Version 1.0, 1.1 and 2). Version 3 of the NSQD is available online at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml.

PS Toxics Study

The *PS Toxics Study*, the largest local study of receiving waters to date, was initiated to assess the relative loading and identify sources of toxic contaminants to Puget Sound. River and streams were sampled in 2009-2010 in multiple watersheds during baseflow and storm-event flows. Stormwater discharges were not directly sampled. Contaminant concentrations were measured and annual mass loads and annual loading rates were calculated.

In this report Ecology compares the stormwater discharge concentrations to the *PS Toxics Study* ambient data, and acknowledges this as an "apples to oranges" comparison. The permittees collected flow-weighted composites from stormwater discharges across 75% of the storm event's hydrograph. The *PS Toxics Study* samples were collected as grab samples from the receiving waters during storm events. The instream concentrations as captured by the *PS Toxics Study* were anticipated to be lower than stormwater discharge concentrations, particularly in urban areas. Nevertheless, it does give us a sense of the scale of differences and an understanding of where patterns in the results are similar.

Loads calculated for this stormwater discharge data compilation are event loads and not annual loads like those calculated in the *PS Toxics Study*. Thus, loading results are too dissimilar and are not comparable. Ecology can compare the trends across land uses for both concentrations and loads.

Water Quality Criteria

Promulgated water quality standards as well as non-promulgated criteria exist for a number of parameters measured in these stormwater discharges. The authors of this report used the Washington State acute and chronic freshwater standards (WAC[4] 173-201A), for comparison to provide context for the stormwater discharge results. For stormwater sediments, the authors made a comparison to freshwater sediment chemical criteria (Chapter 173-204 WAC). The comparisons do not include any consideration of the receiving water. These comparisons are not intended to, and are not appropriate for, determining compliance with regulatory requirements, such as water quality standards and permit conditions.

Water

The criteria for the protection of aquatic life in surface waters of the State of Washington are promulgated under Chapter 173-201A WAC. As defined by EPA (1994), the exposure periods assigned to the acute criteria are expressed as: (1) an instantaneous concentration not to be exceeded at any time or (2) a 1-hour average concentration not to be exceeded more than once every three years on the average. The exposure periods for the chronic criteria are either: (1) a 24-hour average not to be exceeded at any time or (2) a 4-day average concentration not to be exceeded more than once every three years on the average.

Each individual stormwater sample (recall that each sample is a composite across a storm event) was compared to the criteria value. For pH and hardness dependent criteria, Ecology wrote scripts in R to use each stormwater sample's pH and hardness result. If the concentration for a sample was non-detect, then it was excluded from the comparison. See Table ES-1 for results of the criteria comparisons.

Sediment

Sediment criteria are found in Washington State's Sediment Management Standards (SMS) (Chapter 173-204 WAC). The marine Sediment Quality Standards (SQS) found in Part III of the SMS are approved by EPA as water quality standards for the protection of the benthic community. Because these promulgated water quality standards values are for marine sediments only, the authors compared the stormwater sediment data to the freshwater sediment chemical criteria established as Sediment Cleanup Objectives (SCOs) in WAC 173-204-563. These SCO criteria are based on a "no adverse effects level" to the freshwater benthic community. At the time of this publication, EPA has neither approved nor disapproved the numeric freshwater sediment criteria as water quality standards.

Stormwater sediment concentrations are expressed as dry weight and not normalized to organic carbon content, which is suitable for the purposes of this contextual comparison (Michelson, 1992).

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[4] Washington Administrative Code

Approaches to Non-Detected Data in the Stormwater Literature

In the NSQD Version 1.1 review, Maestre et al. (2005; Chapter 3) provide a review of how non-detects have been handled in stormwater studies. More recent environmental, and particularly stormwater, studies have used substitution techniques to substitute either one-half or full value of the method detection limit (MDL) for the value of the non-detect. This has been a common practice for data sets with relatively few non-detect data points. Antweiler and Taylor (2008) indicate that using substitutions for non-detects produces comparable summary statistics.

In the NURP study, non-detected data were summarized using substitution of the value of the reported detection limit. In the NSQD version 1.1 data summary, non-detected values were estimated using the Cohen's maximum likelihood method. This is a method that randomly generates the missing data based on the known probability distributions of the data (Maestre et al., 2005). The *PS Toxics Study* estimated the non-detect values by substituting one-half the value of the detection limit (Herrera, 2011). Comparisons of the permittee's data results to NURP, NSQD, and the *PS Toxics Study* are considered approximate because the methods for sample collection and data analysis differed among the studies.

Despite different methods for handling non-detects, comparisons of median values were retained in this report because the NURP and NSQD represent the earliest and largest national stormwater quality characterization efforts in the United States. Most of the parameters monitored in the NURP and NSQD were limited to the conventional parameters, nutrients, and metals where non-detections are infrequent and typically have less influence on summary statistics. The *PS Toxics Study* is the most recent regional publication with wet weather surface water concentrations for toxic pollutants.

Results and Discussion

Database Description

The final stormwater discharge characterization data set comprises 44,800 records across 172 parameters, where each record is a single value for a particular parameter. Table 6 summarizes this database by permittee, period of record, land use, and data type. Permittees achieved three years of data collection in different ways. In some cases, partial years were summed to achieve the permit requirements. In other cases, more than three years of data were collected in part to accommodate individual permittee objectives for evaluating loading on a water year basis.

Table 6. Number of records by permittee, land use, and year.

Permittee	Land-Use Type	Number of Records					
		2009	2010	2011	2012	2013	Totals
Clark County							
	Commercial	--	624	1034	324	--	1,982
	High-Density Residential	--	417	945	436	--	1,798
	Low-Density Residential	--	489	533	549	--	1,571
King County							
	Commercial	189	603	647	391	355	2,185
	High-Density Residential	191	498	433	298	73	1,493
	Low-Density Residential	145	815	664	130	212	1,966
Pierce County							
	Commercial	--	321	652	500	217	1,690
	High-Density Residential	--	76	393	171	97	737
	Low-Density Residential	--	139	548	346	183	1,216
Snohomish County							
	Commercial	407	1,012	816	544	--	2,779
	High-Density Residential	582	855	734	520	--	2,691
	Low-Density Residential	543	972	1,305	424	--	3,244
City of Seattle							
	Commercial	202	986	861	372	--	2,421
	High-Density Residential	372	913	654	509	--	2,448
	Industrial	203	941	879	376	--	2,399
City of Tacoma							
	Commercial	332	987	753	461	--	2,533
	High-Density Residential	352	723	1,223	870	--	3,168
	Industrial	289	655	624	456	--	2,024
Port of Seattle							
	Commercial	1,465	1,435	1,106	171	--	4,177
Port of Tacoma							
	Commercial	362	699	731	486	--	2,278
	Totals	5,634	14,160	15,535	8,334	1,137	44,800

Data Quality

Suitability for All of Western Washington

Concentrations monitored under the Permit reflect a range of results by land uses that can be applied to urban and suburban stormwater discharges in western Washington. The permittees monitored both large and small drainages. Ecology determined that both the range of concentrations and median values were useable and represented stormwater quality in western Washington. By summarizing multiple years of data, Ecology also accounted for inter-annual variability.

Pollutant concentrations overlapped between the land uses, and this variability increased confidence in the representativeness of the monitored basins. Table 1 illustrates the mix of land uses for each monitored basin.

Laboratory and Field Quality Control

The data entered into EIM has already undergone external quality control methods (e.g., field replicates, laboratory and field blanks) as defined by the permit. Laboratory assigned data qualifiers were relied upon to define detection rates and the degree to which a parameter is censored. No further quality assessment of the data quality was carried out during this analysis. The number of samples with data qualifiers (flags) for each parameter is presented by matrix in Appendix D, Table D-2, and by land use in Table D-3.

Data Distribution and Case Summary

The distribution defined by the Shapiro-Wilk test for each parameter is described in Table D-1. Parameters are divided into three categories: normal, log-normal, and distribution-free.

Water samples were found to have the following distributions:

- log-normal (18 parameters)
- distribution-free (59 parameters)

Sediment samples were distributed as follows:

- normally (3 parameters)
- log-normally (15 parameters)
- distribution-free (32 parameters).

Ecology restricted distribution testing to the parameters with the highest rates of detection and found that many of the parameter's probability plots (Appendix F) appeared nearly linear, indicating log-normal distribution.

Data Case Summary

The reliability of the data summaries depends on the level of detection for each parameter and is defined by the "case" category for each parameter as indicated in Table 5. Table D-4 describes, by land use, the case category for each parameter. Overall, 88 parameters were classified as Case A, 31 parameters as Case B and 53 parameters as Case C.

These results largely agree with the National Urban Runoff Program (NURP) results. NURP, a large national stormwater study, found that stormwater event mean concentrations (EMCs) for most parameters followed either log-normal distributions or were distribution-free (non-parametric) (EPA, 1983).

High Frequency Non-Detected Parameters

This monitoring program provided a suitable sample number and range of conditions to determine whether certain parameters could be reduced in sampling frequency or excluded from future stormwater monitoring studies. Note however that site-specific or study-specific circumstances may still necessitate the collection of these parameters.

With the exception of dissolved mercury (91.2% non-detect), the inorganic parameters were largely detected. Mercury was analyzed using a different method from other metals (SW7470). Reduction in frequency of dissolved mercury analysis using this method is justified; another method with a lower reporting limit may be more suitable in future studies.

The parameters detailed in Table 7 for stormwater and stormwater sediments were almost completely (>90%) undetected.

Insoluble Organics

The parameters in Table 7 were largely insoluble organic pollutants such as volatile and semi-volatiles; PCBs, phthalates, pesticides, or PAHs. Many organic compounds tend to adsorb to solids, making them easier to detect in the sediments. More volatile or more easily degraded (low molecular weight) chemicals may not have been found in stormwater samples, because they may have been older and weathered.

However, monitoring costs would not likely be reduced by removing a limited number of organics from the monitoring list, since the non-detected parameters from the EPA Method 8270D analytical list are often measured at no additional fee. However, for parameters that require a separate sample or a different extraction method, elimination of those parameters would reduce costs. For example, several pesticides were not found in stormwater or stormwater sediments. In particular, malathion, diazinon, prometon and chlorpyrifos were infrequently detected in both water and sediment. Furthermore, many of the phenols analyzed in sediment samples were detected in only 1 or 2 samples, although the sediment data set has fewer sample number. Pentachlorophenol and phenol degradation products (e.g., p-cresol) may be the most worthwhile parameters to monitor on a consistent basis.

Soluble Organics

The BTEX compounds were all listed in Table 7. This indicates that these four parameters are not found in stormwater, either because they are infrequent contaminants or because they volatilize prior to sampling.

Table 7. Stormwater and stormwater sediment parameters with >90% non-detect data.

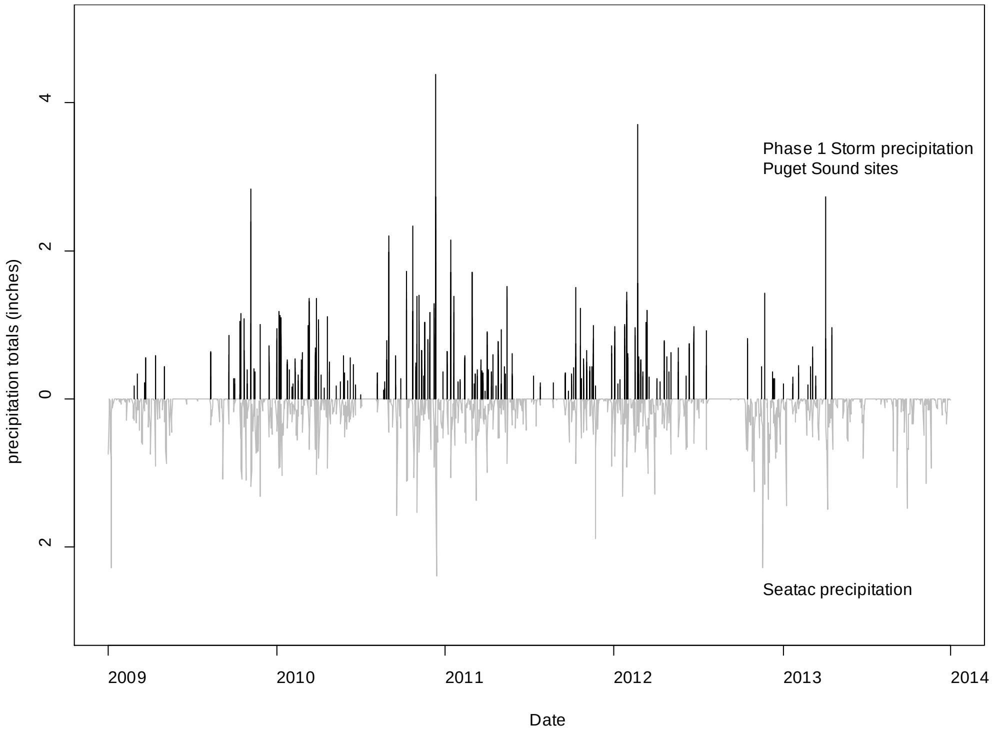
Parameter in stormwater	% non-detect	Number of samples	Parameter in stormwater sediment	% non-detect	Number of samples
Insoluble organics			***Organics***		
Chlorpyrifos	99.8	644	2-Nitrophenol	100.0	23
Diazinon	99.1	644	2,4-Dichlorophenol	100.0	24
Malathion	98.9	643	2,4,5-Trichlorophenol	100.0	24
Prometon	96.4	607	2,4,6-Trichlorophenol	100.0	23
1-Methylnaphthalene	96.2	290	Prometon	100.0	15
Acenaphthylene	93.5	634	Chlorpyrifos	98.1	53
p-Cresol	92.3	26	Diazinon	98.1	52
Mercury	91.2	444	Malathion	98.1	53
Acenaphthene	90.2	634	4-Chloro-3-Methylphenol	95.2	21
			4-Nitrophenol	95.2	21
			Diethyl phthalate	94.6	56
			PCB-Aroclor 1248	93.9	33
			2,4-Dimethylphenol	92.9	42
			2,4-D	91.7	12
			Mecoprop	91.7	12
			Triclopyr	91.7	12
Soluble Organics					
Ethylbenzene	100.0	120			
Benzene	99.2	120			
BTEX	97.5	120			
Toluene	97.5	120			
Total Xylenes	99.2	120			

Hydrology

Storm Events

Storm events were described by the permittees as *sample volume* and *storm volume*. Sample volume represents the volume that flowed between the first and last automated sample. Storm volume represents the total volume that flowed during the storm. Permittees also measured the total precipitation amount during the storm.

Ecology assessed how the precipitation amounts of the sampled storms compared to the complete record of precipitation from SeaTac International Airport and Vancouver, Washington as a way of showing how representative the storms were (Figure 4). Ecology recognizes that comparing only to SeaTac precipitation records for the Puget Sound region does not acknowledge the regional variability. Data were accessed from the National Climatic Data Center (administered by NOAA) and are daily precipitation totals, while permittee data are median storm-event precipitation totals. From Figure 4 it is clear that the sampling by permittees did an excellent job of capturing the general timing of major storm events for the regions.



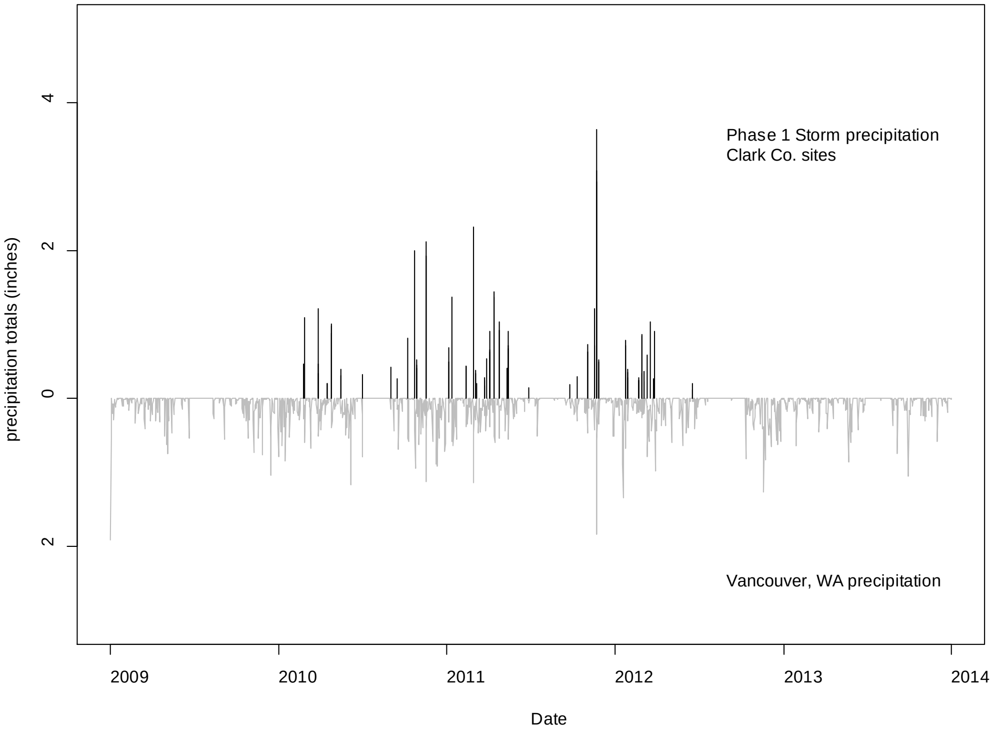


Figure 4. Median measured event precipitation totals for sample locations in the Puget Sound region and Clark County (upper sections of the graphs), combined with daily precipitation totals from SeaTac International Airport and Vancouver, Washington (lower sections of the graphs).

The total number of successfully sampled storm events is estimated in Table 8 by counting the unique start date at each location sampled. Some parameters were collected as discrete grab samples and could possibly be double-counted if two grab samples were collected over two storm-event days. However, given the small number of grab samples (< 1% of samples), it is unlikely this impacts the summary in Table 8. Each permittee was required to sample 67% of the forecasted qualifying storms, up to a maximum of 11 actual events per year. The Port of Seattle and Tacoma had low total numbers of samples, but this reflected a single sample point. In general, these two ports sampled storm events that were well distributed throughout the year. Pierce County collected the fewest number of samples distributed over each year, particularly for the high- and low-density residential land use. The lack of samples in Pierce County residential sites did not appear to bias the overall sample totals for these land-use types.

Table 8. Number of unique sampling dates for each permittee and land use.

Permittee	Count of Unique Sample Events	Land Use	Count of Unique Sample Events
City of Seattle	102	Commercial	262
City of Tacoma	110	High-density Residential	164
Clark County	79	Industrial	66
King County	80	Low-density Residential	105
Pierce County	44		
Port of Seattle	40		
Port of Tacoma	29		
Snohomish County	113		
Total	597	Total	597

Sample Representativeness

As detailed in the *Introduction* section, water samples were collected using flow-weighted automated samplers that allow for a sample that is representative of storm-event concentrations. The permit required the collection of at least 75% of the hydrograph for storms lasting less than 24 hours. For those storms greater than 24 hours, samples were collected for at least 75% of the storm during the first 24 hours. The remaining 25% of the event was typically sampled no more than 48 hours. Permittees reported both the volume of the sampled event and the whole storm event to Ecology. The representativeness of each storm by the respective sample was calculated from the data set by comparing these two reported volumes (Table E-1).

The vast majority of the sites showed that the collected and analyzed composite sample represented approximately 80-90% of the whole storm (Figure 5). The permit required the collection of at least 75% of the hydrograph, which appears to have been achieved. Visually comparing the percent of the storm sampled to the size of the storm, site location, wet or dry season, or the sample year, there appears to be no bias by these parameters on the percent of the storm sampled (Appendix E).

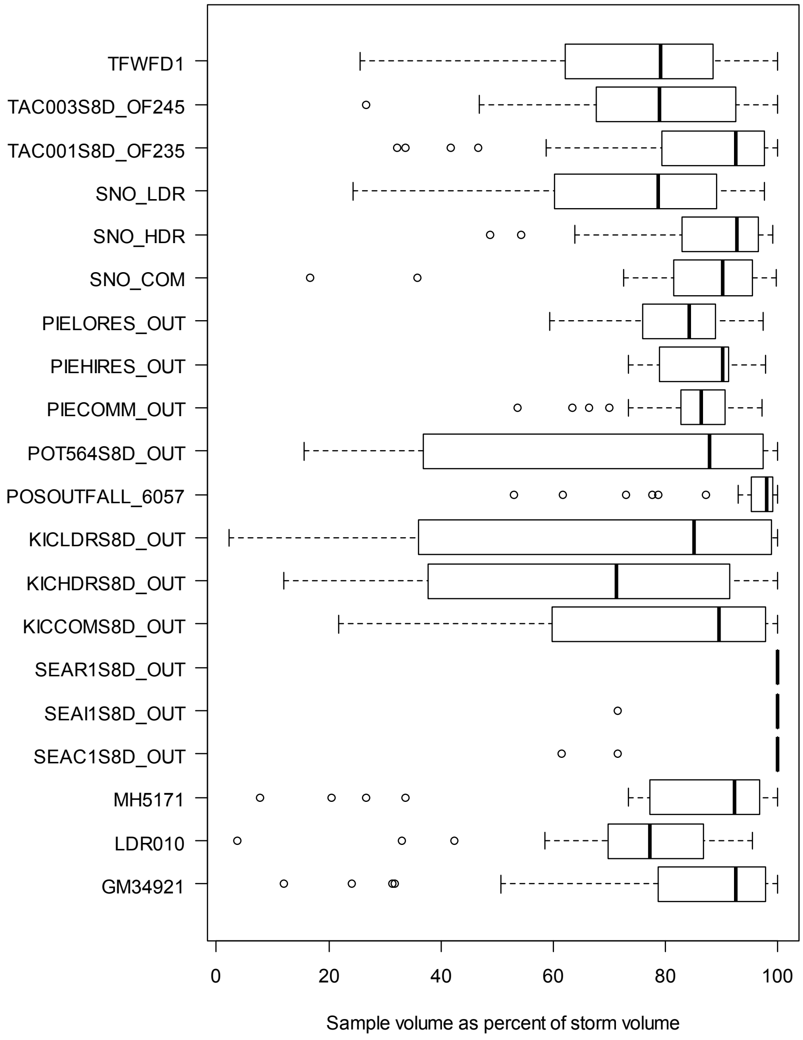


Figure 5. Percent of each storm captured by sampling for each sample site.

The permit required that the permittee collect grab samples for total petroleum hydrocarbons (TPH) and bacteria at the beginning of the storm. Permittees also sometimes collected grab samples for other parameters when the stormwater flow was insufficient for a composite or when attempting to sample the first flush. Overall, 535 records of samples collected using grab methods for parameters other than TPH and bacteria were found in the final data set. This represented only ~ 1% of the records, and these samples were not removed from the data set.

Runoff Coefficients

Ecology calculated the runoff coefficient for each stormwater catchment. The runoff coefficient is the ratio of total stormwater volume that flowed between the first and last automated sample (sample volume) to total rainfall volume across the catchment area. It therefore represents the amount of total rainfall that is captured by the stormwater drainage. Runoff coefficients ranged from 0.05 to 1.00. Typically, Ecology would expect that as the amount of paved surface (percent total impervious surface) increased, more rainfall would have been directed into the storm catchment (yielding a higher ratio). This was true for sample sites with greater than 40% impervious surface (Figure 6). For sample sites with less than 40% impervious surface, the relationship was more variable. Two of the high-density residential catchments with low-percent impervious surface had very high runoff coefficients, suggesting that in these drainage basins the conveyance of precipitation to the stormwater system was greater than in drainage basins with more paved surface. It is unclear why this was the case, and it deserves further inquiry. Ecology can say that it did not appear to be related to catchment size or storm volume. We can speculate that the unusual runoff coefficients may be a result of: (1) incorrect basin delineation or (2) inaccurate flow data.

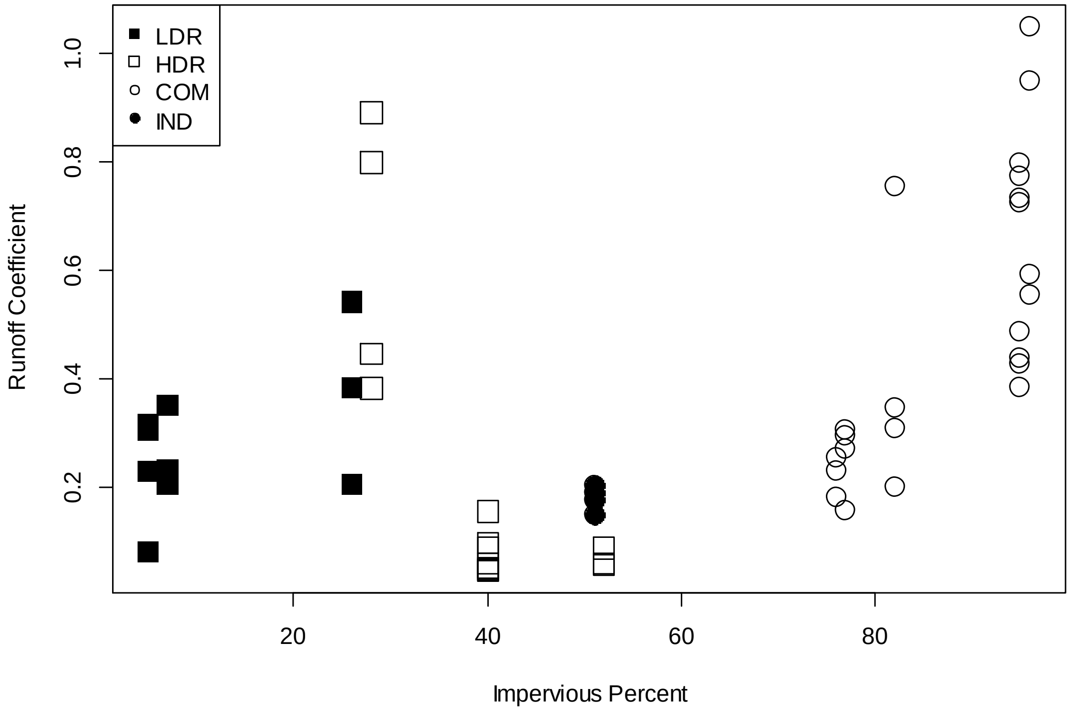


Figure 6. Runoff coefficient for each catchment basin, categorized by land use, relative to the percent impervious surface within each catchment.

Land-use types: LDR = low-density residential; HDR = high-density residential; COM = commercial; IND = industrial

Contaminant Concentrations

In this section, contaminant concentrations are discussed as *median values* (50th percentile) unless otherwise noted; therefore, Ecology is purposely not using the acronym EMC (event *mean* concentration). A summary table of each parameter appears below the parameter headings in each of the subsequent sections. Further detail on parameter summary statistics are calculated and shown as combined land uses in Appendix G, Table G-1, separated by land uses in Table G-2, and by wet and dry seasons in Table G-3.

Where applicable, the contaminant concentrations were compared with water quality criteria as defined in the earlier section, *Water Quality Criteria*. The graphical description of each parameter's concentrations (in alphabetical order) is provided in Appendix F. Summary Figures G-1 through G-3 show graphics of stormwater concentrations ranges in comparison to various water quality criteria.

Conventional Parameters

The conventional parameters (except surfactants) were detected with high frequency (except surfactants) (Table G-1) and were considered as Case A for statistical summaries. All of the conventional water parameters, except pH, were found to have at least one land use for which concentrations were significantly different. Stormwater sediment conventional parameters (TOC and grain size) did not differ between land uses. Figure 7 summarizes the range, median, and 90th percentile for each conventional parameter in stormwater.

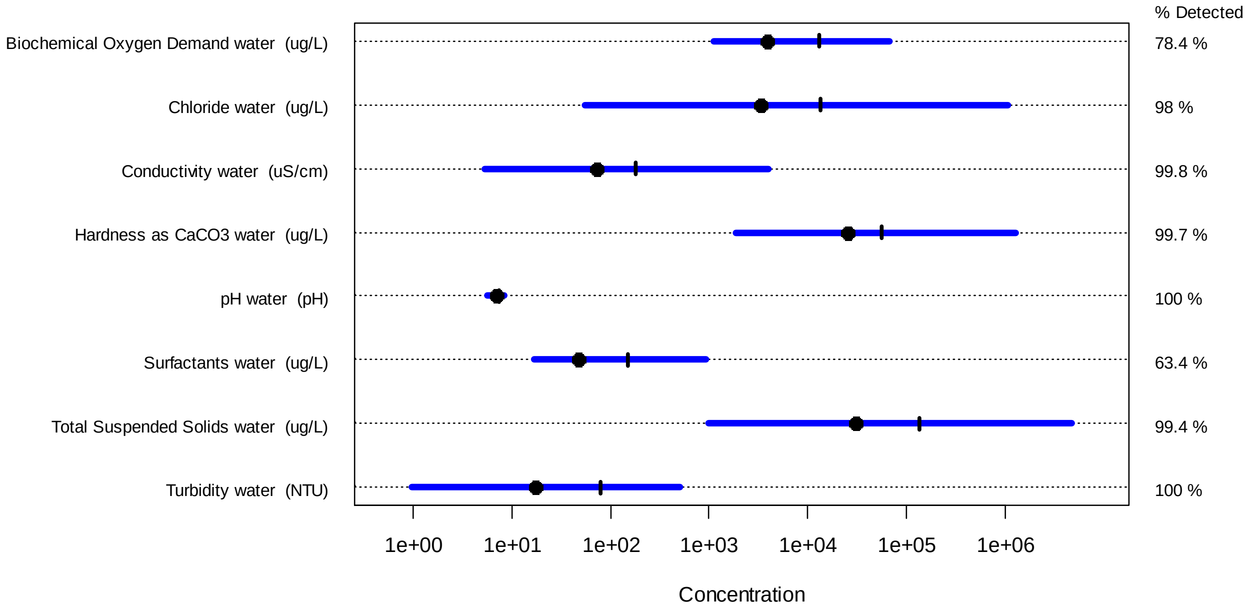


Figure 7. Summary of conventional parameters in water.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis.

Fecal Coliform

Only 6.6% of the fecal coliform samples were below the detection limits, and the majority of these were in areas of low-density residential land use. Significantly lower fecal coliform counts were found in low-density residential land use (47 cfu 100 ml^{-1}), while none of the other land uses showed significant differences (Table 9). Fecal counts were also significantly higher during the dry season (1,220 cfu 100 ml^{-1}) compared with the wet season (300 cfu 100 ml^{-1}).

Table 9. Summary of fecal coliform bacteria data (cfu/100mL).

Land Use	Detected (%)	Count	Min	Max	Geometric mean	Arithmetic mean	SE	Median	90th percentile
Industrial	100	49	2	9.2×10^4	1,062	4,683	1,969	991	12,000
Commercial	96.8	251	1	1.1×10^6	442	7,198	4,392	515	6,900
High-density residential	94.3	157	2	1.6×10^5	260	3,631	1274	350	5,000
Low-density residential	80.6	103	1	1.6×10^4	40	675	209	47	1,600
Overall	93.4	560	1	1.1×10^6	264	4,778	2,009	350	5,400

SE = standard error of the arithmetic mean

The median values for fecal coliform were well below those observed from the NSQD; however, the ranges found in both studies overlapped. Seasonal data from NSQD (Pitt et al., 2004) also suggested that higher concentrations prevail during the summer and fall months. This is similar to the findings of the compiled permittee data set.

Surface water standards for fecal coliform apply to waters with a recreational intended use. For those waters in the secondary contact recreation category, fecal coliform counts cannot exceed a geometric mean of 200 cfu 100 ml^{-1}, with no more than 10% of the samples exceeding 400 cfu 100 ml^{-1}. Each land-use class, except low-density residential, exceeded the criteria (Table 9).

Conductance, Hardness, pH, and Chloride

Table 10. Summary of conductivity, hardness, pH, and chloride concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Conductance (uS cm^{-1})	99.8	5.3	72.3	4,020	yes	yes
Hardness (as ug L^{-1} $CaCO_3$)	99.7	1,900	25,200	1,300,000	yes	yes
pH	100	5.6	7.0	8.26	yes	no
Chloride (ug L^{-1})	98	55	3,300	1,080,000	yes	no

Conductance was significantly higher in discharges from industrial land-use areas (158 uS cm^{-1}; Appendix F). Interestingly, low-density residential land-use areas discharged runoff significantly higher in conductance (99 uS cm^{-1}) than commercial and high-density residential land-use areas. No real differences were found between dry and wet season samples.

Similar trends were found for both hardness (as CaCO3) and chloride concentrations. Chloride is regulated under the water quality standards. For chloride concentrations, 4 out of 551 samples exceeded (did not meet) the chronic water quality criteria for the protection of aquatic life. No samples exceeded the acute criteria.

The pH of the samples varied very little. The range of pH was 5.6 to 8.3 with a mean ± 95% confidence interval (CI) of 6.9 ± 0.03. Areas of high-density residential land use had slightly lower pH values. No significant differences between wet and dry seasons were found (Appendix F).

Surfactants and Biochemical Oxygen Demand (BOD)

Table 11. Summary surfactants and biochemical oxygen demand concentrations.

Parameter (ug L^{-1})	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Surfactants	63.4	17	47	920	yes	yes
BOD	78.4	1,100	3,900	68,000	yes	yes

Stormwater surfactant concentrations were strongly influenced by land use, where industrial and commercial land uses discharged comparable concentrations (63 ug L^{-1} and 64 ug L^{-1}, respectively) compared with significantly lower concentrations from high-density residential (36 ug L^{-1}) and low-density residential (14 ug L^{-1}) land-use areas. In low-density land-use areas, 70% of the samples were below the detection limit. Greater concentrations of surfactants were found during the dry season than the wet season (mean ± 95%CI; 114.5 ± 23.4 ug L^{-1} and 64.7 ± 7.0 ug L^{-1}, respectively).

BOD was detected in 78.4% of all samples. The vast majority of the non-detects occurred in discharges from the low-density residential land use (62.4% of the non-detects). Commercial land-use areas discharged the highest concentrations (5,600 ug L^{-1}). Higher BOD concentrations were found during the dry season (7,200 ug L^{-1}) compared with the wet season (3,600 ug L^{-1}).

BOD measurements in the NSQD were very similar in range to the data in this study, with commercial land uses discharging the highest concentrations. The median values for land-use categories were not as high as those in the NSQD. Surfactants were not quantified in other studies.

Turbidity and Total Suspended Solids (TSS)

Table 12. Summary of turbidity and total suspended solid concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Turbidity (NTU)	100	0.98	17.3	500	yes	no
TSS ($mg L^{-1}$)	99.4	1	31	4,700	yes	no

Significantly higher turbidity was found in industrial areas compared with the other land uses (34.5 NTU). Significantly higher TSS concentrations were also found in industrial land-use discharges (48 $mg L^{-1}$) when compared with low-density residential land-use areas (14 $mg L^{-1}$). No significant differences in turbidity or TSS were found between wet (17.9 NTU and 29.8 $mg L^{-1}$, respectively) and dry (15 NTU and 34.6 $mg L^{-1}$, respectively) seasons (Appendix F).

In comparison to the *PS Toxics Study*, TSS concentrations in this data set were similar for residential land uses but significantly higher for industrial land uses. Overall, across all land uses, the median TSS values were much higher than that reported for the receiving waters sampled in the *PS Toxics Study*. However, median TSS concentrations reported here were much lower than results reported in the NSQD and NURP but within the ranges reported in these databases.

Total Organic Carbon (TOC) and Grain Size in Sediment

Table 13. Summary of total organic carbon concentration in sediments.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
TOC (%)	100	0.002	11	68	yes	no

The TOC of sediment samples ranged from <1% to 68%, and generally varied very little among samples (median was 11; mean of 12.7 ± 1.2% standard error). Slightly higher concentrations of TOC were noted in samples from commercial land-use areas. Overall, stormwater sediment composition was 29.4% fines and 77.3% sand, median values for combined land uses (Table G-1). The sediment composition did not vary among the land uses.

Nutrients

Figure 8 summarizes the range, median, and 90th percentile for each nutrient parameter in stormwater.

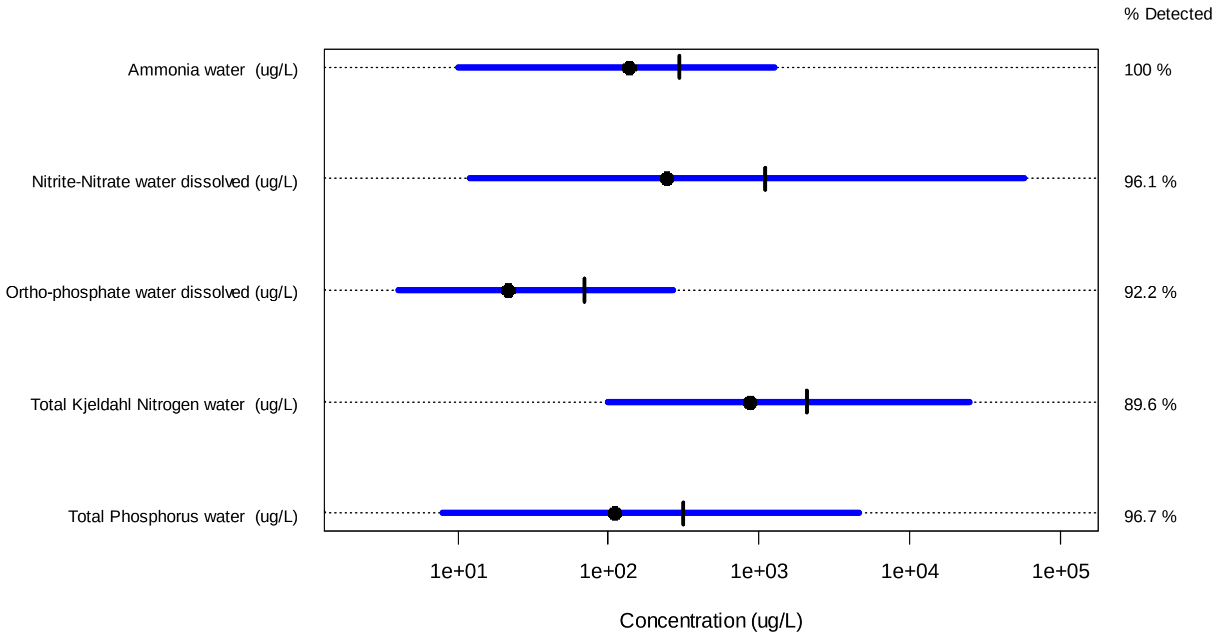


Figure 8. Summary of nutrient concentrations in water.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis.

Phosphorus

Table 14. Summary of phosphorus concentrations.

Parameter (ug L^{-1})	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Orthophosphate	92.0	4	21.6	270	yes	yes
Total phosphorus	96.7	8	110.0	4,600	yes	yes

Phosphorus in water was measured as total phosphorus and orthophosphate, the dissolved, bioavailable fraction. Orthophosphate concentrations were significantly higher in stormwater from the low-density residential land-use areas (Appendix F). Significantly higher concentrations of orthophosphate were present during the dry season (26 ug L^{-1}) compared with the wet (20.7 ug L^{-1}).

Total phosphorus concentrations in the stormwater showed a different trend with the highest concentrations from industrial land-use areas (171 ug L^{-1}) and significantly lower concentrations from low-density residential land-use areas (90 ug L^{-1}). This trend could be related to a particulate form in the industrial discharge, as it follows the same trend as the concentrations for surfactants, turbidity, and TSS results. Total phosphorus had a median value of 110 ug L^{-1} for the combined land use (mean was 155 ug L^{-1}).

Ecology found total phosphorus concentrations in stormwater discharges were greater than the documented median for the *PS Toxics Study* but less than the concentrations in the NSQD and NURP databases. The land-use trends observed were also different from the *PS Toxics Study* where commercial and industrial areas had lower concentrations than residential and agricultural areas.

Nitrogen

Table 15. Summary of nitrogen concentrations.

Parameter (ug L^{-1})	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total Kjeldahl N	89.6	100	863	25,000	yes	yes
Nitrite+nitrate N	96.1	12	245	58,000	yes	yes
Ammonia	100	10	136	1260	yes	yes

Nitrogen inputs were measured as total Kjeldahl nitrogen (TKN), nitrite+nitrate as nitrogen (NO_2+NO_3), and ammonia (NH_3). TKN is the sum of organic nitrogen, ammonia, and ammonium (NH_4). TKN was found at significantly lower concentrations in the low-density residential areas (600 ug L^{-1}) compared with other land-use areas (Appendix F). The dry season had higher TKN concentrations (1,300 ug L^{-1}) than the wet (800 ug L^{-1}).

Nitrite+nitrate concentrations were significantly greater in discharges from low-density residential land use, which was similar to the orthophosphate trends (Appendix F). Indeed, the nitrite+nitrate concentrations from both the high- (320 ug L^{-1}) and low-density residential land uses (510 ug L^{-1}) were higher than concentrations from the commercial (200 ug L^{-1}) and industrial (232 ug L^{-1}) land uses. Concentrations during the dry season were significantly higher (462 ug L^{-1}) than the wet season (213 ug L^{-1}) for nitrite+nitrate; however, a great deal of variability was found during the dry season (mean ± 95%CI was 493 ± 262 ug L^{-1}).

Ammonia was not a required parameter under the 2007 permit, but ammonia concentrations were reported by one permittee with 71 observations across three land uses. Significant lower concentrations were observed from industrial (190 ug L^{-1}) compared with commercial (123 ug L^{-1}) and high-density residential (85 ug L^{-1}) land uses. Samples displayed a strong difference between the dry season (163 ug L^{-1}) and the wet season (130 ug L^{-1}) (Appendix F).

Acute and chronic standards for the protection of aquatic life exist for ammonia, and these standards were not exceeded by any samples (Appendix G, Figures G1-G2).

TKN concentrations and ranges were very similar for all land uses to those reported in the NSQD (Pitt et al., 2004). Nitrite+nitrate concentration ranges were also similar to the NSQD, with the exception that residential land uses tended to have higher concentrations in this current study. In the NSQD, discharges from industrial land uses had higher nitrite+nitrate concentrations. Ecology found similar concentration ranges and trends across land uses to the NURP study (EPA, 1983). In comparison with the nitrite+nitrate concentrations observed in the *PS Toxics Study*, Ecology found much lower concentrations in waters discharged from residential land uses (~ 1000 ug L^{-1} in the *PS Toxics Study*). This finding suggests that dissolved nitrogen species were contributed from residential land uses via pathways other than stormwater drainage (e.g., groundwater). In commercial and industrial land-use areas, stormwater discharge and stormflow receiving water median concentrations in the *PS Toxics Study* were roughly similar.

Metals

Metals results in water are given in ug L^{-1}, also referred to as parts per billion (ppb). For stormwater sediments, the units are ug Kg^{-1}, which are also parts per billion (ppb). Figures 9 and 10 summarize the ranges and summary statistics (median and 90th percentile) for each metal parameter in stormwater and stormwater sediments, respectively. Metals concentrations in water and sediments across land uses showed similar trends, suggesting that the sediment serves as a representative sample of metals in the stormwater conveyance systems.

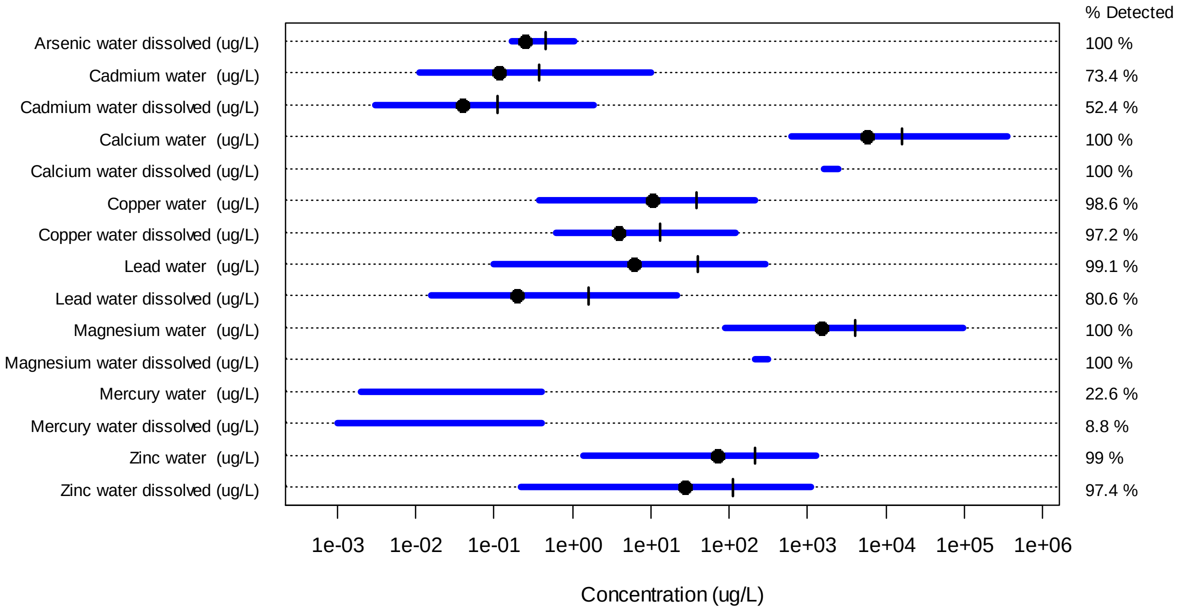


Figure 9. Summary of metals concentrations in water.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis.

Arsenic

Table 16. Summary of dissolved arsenic concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Dissolved As (ug L^{-1})	100	0.17	0.25	1.04	NA	no

Dissolved arsenic was not a parameter required by the permit, but was reported by one permittee. Total arsenic was not measured in water or sediments. Dissolved arsenic (As) was detected in all of the 16 samples analyzed. All but one of these samples was collected from stormwater discharged from low-density residential land-use areas (Appendix F). Dissolved arsenic showed no differences between the wet and dry seasons. None of the measured concentrations exceeded the arsenic water quality criteria for the protection of aquatic life.

Dissolved arsenic concentrations in water from residential land uses sampled during the *PS Toxics Study* (0.60 ug L^{-1}) were twice the median concentrations found by the permittee. Concentrations of dissolved arsenic in the NSQD were considerably higher than observations in this current study (NSQD median = 1.5 ug L^{-1})

Cadmium

Table 17. Summary of cadmium concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total Cd (ug L^{-1})	73.4	0.011	0.1	10.1	yes	yes
Dissolved Cd (ug L^{-1})	52.4	0.003	0.04	1.85	yes	yes
Cd in sediment (ug Kg^{-1})	90	0.78	819	4,900	yes	NA

Total cadmium showed clear differences among land uses (Appendix F). Areas of industrial land use discharged the highest median concentrations (0.22 ug L^{-1}) followed by commercial (0.17 ug L^{-1}), high-density residential (0.09 ug L^{-1}), and low-density residential (0.03 ug L^{-1}) land uses. Discharges from low-density residential land use had a 50% non-detect rate and fell into the Case B data classification for statistical analyses. No seasonal differences were found for total cadmium.

Dissolved cadmium showed a similar trend to total cadmium across land uses; however, a high rate of non-detect data made these interpretations more uncertain (Appendix F). Higher rates of non-detect also led to all but the commercial land use data being classified as Case B for statistical analyses. Sufficient sample numbers were attained for reliable summary statistics. No difference was noted between samples from the wet and dry seasons. Of the 635 samples analyzed for dissolved cadmium concentrations, two exceeded (did not meet) the acute water quality criteria and three exceeded the chronic criteria.

The median NSQD concentrations for both total and dissolved cadmium were much greater than concentrations observed in this study. Industrial land uses were also found to discharge the highest concentrations of cadmium in the NSQD. Concentrations found in the *PS Toxics Study* were much lower than those in this study. In fact, total cadmium measured during most storm events in the river systems had low rates of detection.

Cadmium concentrations in the sediment had a high rate of detection. Trends across the different land uses reflected those of the total cadmium in water, with significantly higher concentrations in the industrial and commercial catchments (Appendix F). Cadmium in stormwater sediments exceeded the SCO for 6% of the samples.

Copper

Table 18. Summary of copper concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total Cu (ug L^{-1})	98.6	0.38	10.4	218	yes	yes
Dissolved Cu (ug L^{-1})	97.2	0.62	3.9	122	yes	yes
Cu in sediment (ug Kg^{-1})	100	156	81,000	1.26×10^6	yes	NA

Total copper median concentrations were statistically higher in discharges from industrial and commercial land uses (16.0 ug L^{-1} and 19.6 ug L^{-1}, respectively) compared with both high-density (7.7 ug L^{-1}) and low-density (2.8 ug L^{-1}) residential land uses (Table G-2 and Appendix F). Significantly higher concentrations were noted during the dry season (mean ± 95%CI; 25.7 ± 5.6 ug L^{-1}) compared to the wet season (14.7 ± 1.2 ug L^{-1}) (Table G-3).

Dissolved copper median concentrations were significantly different among all land uses; stormwater from commercial land use (6.25 ug L^{-1}) was statistically higher than the other land uses. Industrial (4.4 ug L^{-1}) and high-density residential (3.05 ug L^{-1}) land uses were quite similar, but stormwater discharged from low-density land use was significantly lower (1.84 ug L^{-1}) (Appendix F). Again, the dry season had statistically higher concentrations than the wet season across all land uses. 50% of the dissolved copper results exceeded the acute water quality target. 58% exceeded the chronic target.

Total and dissolved copper concentrations were similar to those reported in the NSQD. The *PS Toxics Study* found lower copper concentrations in waters from industrial and commercial land uses, but roughly similar concentrations in waters from residential land uses. Road systems are often implicated in contributions of copper to stormwater from brake pads and tires (McKenzie et al., 2009). This trend was evident in data from the NSQD. This stormwater data set may provide sufficient resolution to separate parking lots from the combined land uses; however, this was beyond the scope of this study and was not investigated.

Copper concentrations were detectable in all stormwater sediment samples. Similar to copper concentrations in water, significant differences were found in sediment samples between commercial and industrial land uses (157,000 ug Kg^{-1} and 114,000 ug Kg^{-1}, respectively) and between high-density (39,600 ug Kg^{-1}) and low-density residential land uses (15,000 ug Kg^{-1}). Copper in stormwater sediment exceeded the SCO for 9% of the samples (Figure G-3).

Lead

Table 19. Summary of lead concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total Pb (ug L^{-1})	99.1	0.1	6.1	294	Yes	no
Dissolved Pb (ug L^{-1})	80.6	0.016	0.2	21.8	Yes	yes
Pb in sediment (ug Kg^{-1})	97.5	360	114,000	1.79×10^6	Yes	NA

Total lead concentrations were statistically different among the land uses: commercial (14.4 ug L^{-1}), industrial (7.94 ug L^{-1}), high-density residential (4.05 ug L^{-1}), and low-density residential 0.72 (ug L^{-1}). Commercial land use had statistically higher concentrations of total lead. Interestingly, the distribution of concentrations from high-density residential was similar to that of industrial land-use areas, above the 70th percentile (approximately 7 ug L^{-1}), but overall the distributions were statistically different ($p=0.003$) (Appendix F). No significant difference in total lead concentrations was found between wet and dry seasons.

Dissolved lead in stormwater had a high non-detect rate, although this varied across land uses. Commercial land use had statistically higher dissolved lead concentrations. High-density residential and industrial land use did not have significantly different dissolved lead concentrations. Industrial, high-density residential, and low-density residential land use had between 25 to 33% non-detects (Appendix F).

Dissolved lead trends across land uses were similar to those observed for total lead. Commercial (0.32 ug L^{-1}) and industrial (0.25 ug L^{-1}) land uses discharged higher concentrations than high-residential (0.17 ug L^{-1}) and low-residential (0.065 ug L^{-1}) land uses. The higher frequency of non-detect data added uncertainty to the trends across land uses. Dissolved lead concentrations appeared to be higher during the dry season. Two samples for dissolved lead exceeded the acute water quality criteria (< 0.5%), but 173 exceeded the chronic criteria (28%).

Lead concentrations in this data set were generally lower than in the NSQD, but much higher than the in-stream concentrations found in the *PS Toxics Study*. Activities in commercial and industrial land uses have been highlighted as the major contributors of lead in all studies.

Lead concentrations in sediment samples followed similar trends as the water samples across land uses (Appendix F). Only two samples had non-detect lead concentrations. Detected concentrations ranged from 360 to 1.79×10^6 ug Kg^{-1} with a median of 114,000 ug Kg^{-1}

(Figure 10). Lead in stormwater samples exceeded the SCO for 18% of the samples (Figure G-3).

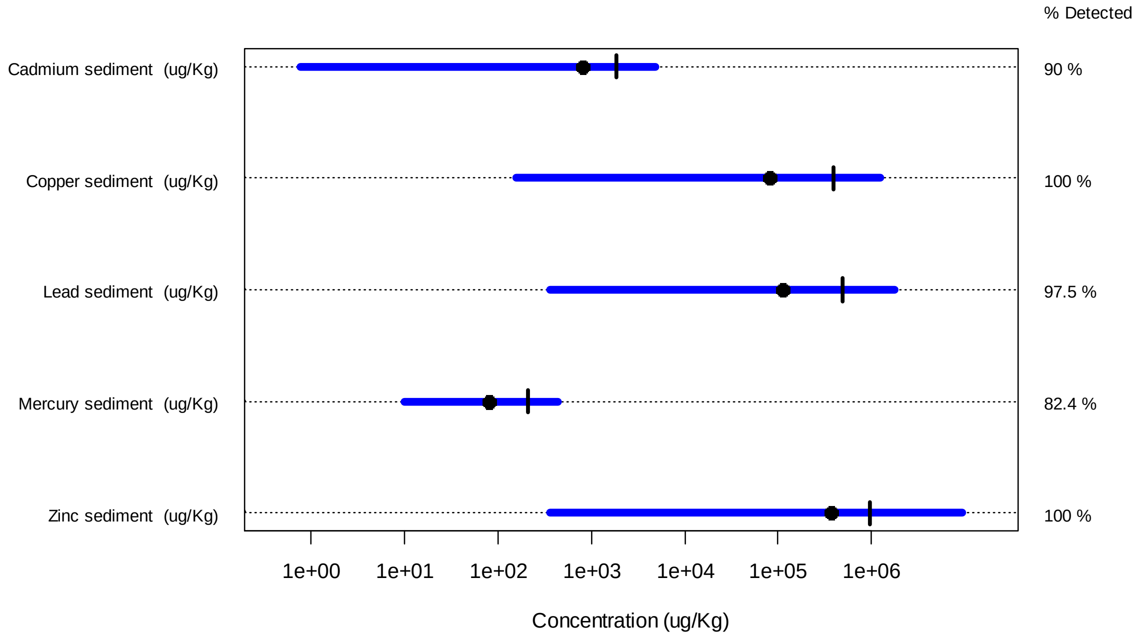


Figure 10. Summary of metals concentrations in stormwater sediment.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis.

Mercury

Table 20. Summary of mercury concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total Hg (ug L^{-1})	22.6	0.002	0.01	0.4	NA	no
Dissolved Hg (ug L^{-1})	8.8	0.001	NA	0.4	NA	NA
Hg in sediment (ug Kg^{-1})	82.4	10	80	442	yes	NA

Total and dissolved mercury concentrations in stormwater were not frequently detected. Overall, total mercury was classified as Case B for statistical analyses. When detected in stormwater, total mercury was primarily measured in samples from commercial land-use areas (median 0.01 ug L^{-1}) and, to a lesser extent, in samples from high-density residential land-use areas (0.028 to 0.30 ug L^{-1}). The chronic water criteria, 0.012 ug L^{-1}, was frequently less than the detection limit for total recoverable mercury achieved for these samples (ranging from

0.02 to 0.2 ug L^{-1} depending on the lab). As such, the total mercury results cannot be effectively evaluated against known criteria.

Dissolved mercury results were classified as Case C. No samples exceeded the acute water quality target.

Total mercury concentrations in water from the *PS Toxics Study* were an order of magnitude lower than in this study (median combined land use was 0.008 ug L^{-1}). Total mercury in the NSQD had a median concentration set near the detection limit, which is not an accurate description of environmental concentrations. Therefore, concentrations appeared similar across land uses.

Mercury was detected in sediments at a much higher frequency compared to water. Concentrations of mercury in sediments from commercial (130 ug Kg^{-1}) and industrial (71 ug Kg^{-1}) land uses were significantly higher than concentrations from high-density (31.1 ug Kg^{-1}) and low-density (27 ug Kg^{-1}) residential land uses. The comparisons are less certain due to the greater proportion of non-detects from residential land uses. None of the samples analyzed for mercury in sediments exceeded the SMS levels.

Mercury appears to be found in localized areas and does not appear to be a widespread contaminant in western Washington stormwater.

Zinc

Table 21. Summary of zinc concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total Zn (ug L^{-1})	99.0	1.4	70.6	1,290	yes	yes
Dissolved Zn (ug L^{-1})	97.4	0.22	26.9	1,090	yes	yes
Zn in sediment (ug Kg^{-1})	100.0	366	373,000	9.25×10^6	yes	NA

Total zinc concentrations (median values) in stormwater collected from commercial (102 ug L^{-1}) and industrial (123 ug L^{-1}) land uses were not significantly different (p=0.08). Total zinc concentrations from high-density residential land-use areas (41.2 ug L^{-1}) were significantly lower, as were those from low-density residential land-use areas (13.7 ug L^{-1}) (Appendix F). This was similar to the trend found for copper concentrations. Significantly higher concentrations were detected during the dry season (mean ± 95%CI; 171.4 ± 41.6 ug L^{-1}) than the wet season (86.9 ± 8.0 ug L^{-1}).

Trends for dissolved zinc concentrations were similar across land uses to those found for total zinc (Table 21; Appendix F). Dissolved zinc concentrations were also significantly higher during the dry season than during the wet season. 36% of the samples exceeded the acute water quality criteria and 40% exceeded the chronic criteria.

Zinc concentrations from this study had considerably higher median concentration (5-10 times) than reported by the *PS Toxics Study*. Zinc concentrations were within similar ranges compared with the NSQD. In this study and both the *PS Toxics Study* and the NSQD, the highest concentrations were found in areas of industrial land use.

Zinc concentrations in sediment followed a trend similar to those in water. Zinc in stormwater sediments exceeded the SCO for 1% of the samples.

Hydrocarbons

TPH

Table 22. Summary of total petroleum hydrocarbon concentrations.

Parameter ($\mathrm{ug\ L^{-1}}$)	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
TPH-Dx	72.7	14	433	12,100	yes	yes
TPH-Gx	10.4	11	NA	395	NA	NA
Diesel range organics	57.5	13	130	4,900	yes	yes
Lube oil	41.6	194	207	1,550	NA	no
Motor oil	81.9	200	930	5,800	yes	no

Gasoline range total petroleum hydrocarbons (TPH-Gx) were detected at a low frequency. These data were classified as a Case C for statistical analyses. TPH-Gx is composed of volatile compounds. Insufficient numbers of detections were available to describe any differences among land uses or across seasons.

The diesel range hydrocarbon (TPH-Dx) analysis sums multiple hydrocarbon fractions (lube oil, motor oil, diesel fuel, and diesel range organics). Hydrocarbon fractions have variable rates of detection (Table 22). Significantly higher TPH-Dx concentrations were observed in stormwater from industrial and commercial land uses (890 ug $\mathrm{L^{-1}}$ and 870 ug $\mathrm{L^{-1}}$, respectively) compared with high-density (320 ug $\mathrm{L^{-1}}$) and low-density (113 ug $\mathrm{L^{-1}}$) residential land uses. A greater proportion of non-detects were found in samples collected from residential land uses. TPH-Dx concentrations were significantly greater during the dry season (840 ug $\mathrm{L^{-1}}$) than the wet season (390 ug $\mathrm{L^{-1}}$).

Looking more closely at the components of TPH-Dx, the trends in land use were driven largely by the diesel range organics. Lube oil was not reported separately in industrial samples and was only detected in commercial samples (Appendix F). Motor oil was not reported in low-density residential samples but had a high rate of detection in other land uses. Discharges from industrial land uses were the major contributor of motor oil (1400 ug $\mathrm{L^{-1}}$), followed by those from high-density residential land use (950 ug $\mathrm{L^{-1}}$) and then commercial land uses (620 ug $\mathrm{L^{-1}}$). Each of these differences was significant. Interestingly, the concentrations for each land use at the higher end of the ranges (> 80th percentile) were very similar. No statistical difference was found between contributions of motor oil during the dry season (980 ug L^{-1}) compared with the wet season (910 ug L^{-1}).

TPH-Dx was measured in the *PS Toxics Study,* and concentrations were considerably lower. With the exception of those from commercial and industrial land uses, median concentrations from other land uses were only estimates. Concentrations in commercial and industrial land uses in this study were an order of magnitude greater than those in the *PS Toxics Study*.

It is difficult to comment on any trends for TPH in sediments, as sample numbers were low. Appendix F and Table 22 provide the available data for the parameters. Concentrations of heavy fuel oil and diesel range organics suggested that greater concentrations were prevalent in sediments from commercial and industrial land uses.

BTEX

Table 23. Summary of BTEX concentrations.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
BTEX (ug L^{-1})	2.5	1.1	NA	6.4	NA	NA

Benzene, toluene, ethylbenzene, and xylenes (BTEX) were measured in 120 water samples and detected in only three samples. Benzene was detected once, ethylbenzene was not detected, toluene was detected three times, and total xylenes were sufficiently detected in one sample. The volatile nature of these compounds is the reason for the low detection rates. Continued monitoring for BTEX in stormwater samples does not appear to be cost-effective.

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) are cyclic compounds with various numbers of six-carbon rings. PAHs vary in volatility and rates of detection in stormwater samples. Half the individual PAHs were classified as Case B for statistical analysis, due to low detection rates but adequate numbers of samples to reliably summarize the data (Table 24). Only three PAH compounds had a high enough detection frequency to be classified as Case A: fluoranthene, phenanthrene, and pyrene. Fluoranthene concentrations were significantly higher in stormwater discharged from commercial land-use areas. No other significant differences were found among the remaining land-use types (Appendix F). Higher concentrations were discharged during the dry season (mean; 0.8 ug L^{-1}) than the wet season (0.4 ug L^{-1}). Phenanthrene and pyrene had very similar trends across the land uses; seasonal differences were weak to non-existent.

Low molecular weight PAH concentrations were summed and reported as LPAH. High molecular weight PAHs were summed and reported as HPAH. Likewise, the carcinogenic PAHs (cPAH) and total PAHs were summed and reported (Table 24; Figure 11). All PAH sums had similar trends across land uses, where commercial land-use discharges had statistically higher concentrations than the other land uses ($p<0.001$). In the case of cPAHs, there was no significant difference between high-density residential and industrial land use ($p=0.17$). No seasonal differences existed for the summed concentrations.

Table 24. Summary of individual PAHs in stormwater (ug L^{-1}).

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
1-Methylnaphthalene	3.8	0.100	-	1.6	NA	NA
2-Methylnaphthalene	17.2	0.003	-	2.5	NA	NA
Acenaphthene	9.8	0.003	-	1.5	NA	NA
Acenaphthylene	6.5	0.003	-	1.5	NA	NA
Anthracene	11.2	0.004	-	5.4	NA	NA
Benz(a)anthracene	34.4	0.004	0.006	11.0	NA	no
Benzo(a)pyrene	28.4	0.004	0.005	15.0	NA	no
Benzo(b)fluoranthene	30.4	0.020	0.014	13.0	NA	no
Benzo(b,k)fluoranthene	49.2	0.005	0.010	0.3	NA	no
Benzo(g,h,i)perylene	40.0	0.004	0.013	12.0	NA	no
Benzo(k)fluoranthene	24.0	0.014	0.007	13.0	NA	no
Benzofluoranthenes	45.6	0.067	0.091	5.7	NA	no
Chrysene	45.9	0.003	0.020	16.0	NA	no
Dibenzo(a,h)anthracene	13.9	0.005	-	5.3	NA	NA
Fluoranthene	59.1	0.007	0.039	33.0	yes	no
Fluorene	12.6	0.003	-	1.6	NA	NA
Indeno(1,2,3-cd)pyrene	28.7	0.004	0.005	10.0	NA	no
Naphthalene	31.1	0.004	0.017	2.2	NA	no
Phenanthrene	51.8	0.006	0.026	16.0	yes	no
Pyrene	63.3	0.007	0.048	26.0	yes	no
PAH Sums						
LPAH	61.4	0.021	0.162	172.5	yes	no
HPAH	67.3	0.012	0.110	154.3	yes	no
cPAH	51.6	0.004	0.044	83.3	yes	no
Total PAH	98.8	0.021	0.162	172.5	yes	no

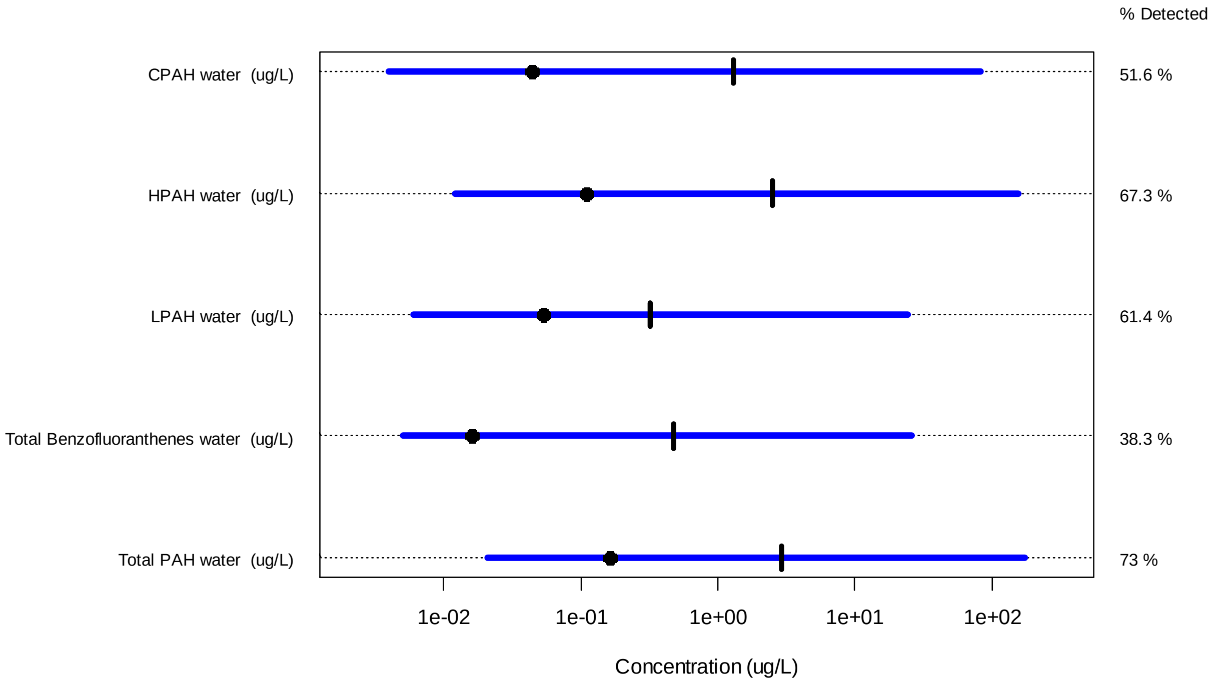


Figure 11. Summary of total PAH concentration sums in water.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis.

Total PAHs all had sufficient levels of detection to be classified Case A data for statistical analyses. Median total PAH concentrations in stormwater discharges from commercial and industrial land uses were found to be 0.53 and 0.11 ug L^{-1}, respectively.

Median concentrations from areas of commercial land use were substantially higher (22 times) than concentrations reported in the *PS Toxics Study* (0.18 ug L^{-1}). Concentrations of individual PAH compounds had low rates of detection in NSQD, similar to this study. However, median concentrations of detected fluoranthene, phenanthrene, and pyrene were two orders of magnitude higher in the NSQD compared with this study.

PAHs were detected much more frequently in stormwater sediments than in stormwater discharges (Table 25; Figure 12). Most individual PAH compounds were classified as Case A data for statistical analyses. Overall, the trends across land-use types followed those observed in the water samples. Runoff from areas of commercial land use had significantly higher concentrations than runoff from the other land uses. Concentrations in discharges from industrial and high-density residential land uses did not differ greatly, while discharges from low-density residential land-use areas were significantly lower (Appendix F). 34% of the stormwater sediment samples exceeded the SCO criteria.

Table 25. Summary of individual PAHs in stormwater sediments (ug Kg^{-1}).

Parameter	% detected	Minimum	Median	Maximum	Land-use differences
1-Methylnaphthalene	40.4	1.07	6	870	yes
2-Methylnaphthalene	47.4	1.12	13	1,500	yes
Acenaphthene	54.4	8.70	34	8,900	yes
Acenaphthylene	32.9	15.80	28	3,600	yes
Anthracene	73.4	17.00	131	33,000	yes
Benz(a)anthracene	88.4	9.40	800	210,000	yes
Benzo(a)pyrene	82.3	16.20	720	260,000	yes
Benzo(b)fluoranthene	80.0	1.07	240	240,000	yes
Benzo(b,k)fluoranthene	100.0	110.00	1400	2,900	yes
Benzo(g,h,i)perylene	88.7	4.00	800	160,000	yes
Benzo(k)fluoranthene	71.1	10.20	131	230,000	yes
Benzofluoranthenes	100.0	177.00	57000	340,000	yes
Chrysene	92.4	1.07	1100	280,000	yes
Dibenzo(a,h)anthracene	73.4	6.54	190	73,000	yes
Fluoranthene	93.7	1.02	1900	590,000	yes
Fluorene	59.0	19.30	60	14,000	yes
Indeno(1,2,3-cd)pyrene	86.1	19.40	540	160,000	yes
Naphthalene	59.5	1.02	24	6,900	yes
Phenanthrene	93.6	2.16	950	250,000	yes
Pyrene	94.9	1.37	1800	490,000	yes
PAH Sums					
LPAH	94.2	1.94	1200	307,500	yes
HPAH	96.7	3.46	7840	2,683,000	yes
cPAH	93.9	1.07	3130	1,453,000	yes
Total PAH	98.8	4.10	6728	2,990,960	yes

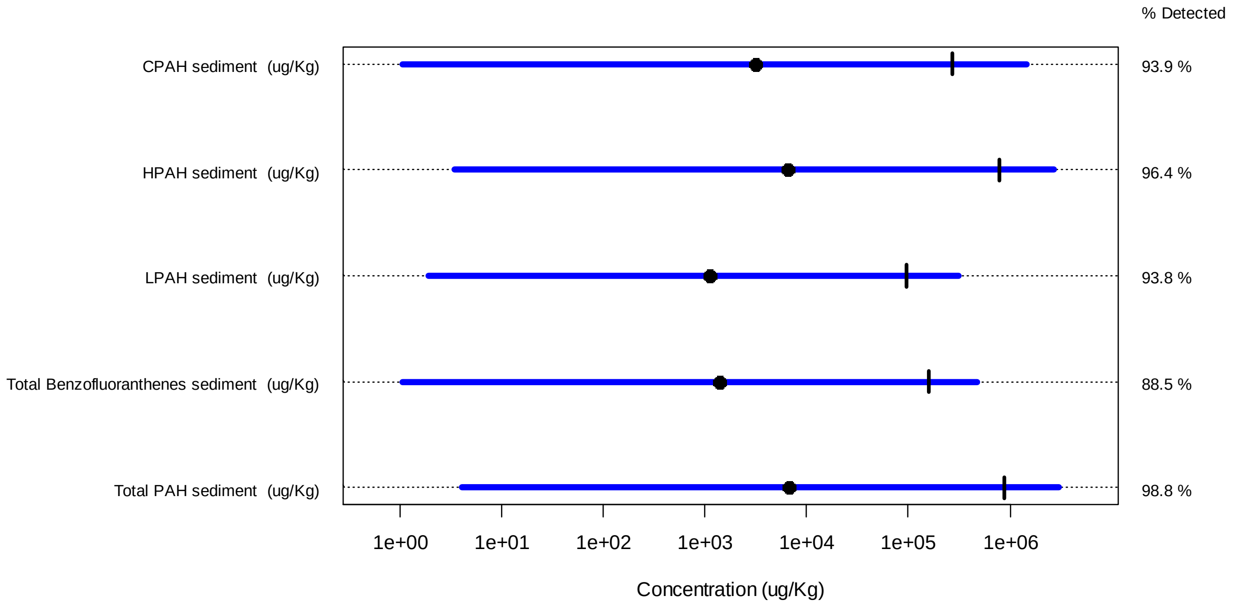


Figure 12. Summary of total PAH concentration sums in stormwater sediment.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis.

Phthalates

Many of the analyzed phthalates had low rates of detection (Table 26), with one exception. Bis(2-ethylhexyl) phthalate had a detection frequency of 61.9%. Bis(2-ethylhexyl) phthalate showed a significant difference across land uses; commercial land-use areas discharged greater concentrations than other areas. Industrial and high-density residential land-use areas discharged similar concentrations, and low-density residential areas discharged significantly lower concentrations. Both residential areas had much lower rates of bis(2-ethylhexyl) phthalate compound detection.

A similar trend across land uses was observed for butyl benzyl phthalate and dibutyl phthalate. Diethyl phthalate did not show differences across land uses, but this was not assessed, given the high rates of non-detection (Appendix F). Diethyl phthalate was more frequently detected in residential samples and had higher concentrations during the wet season, though not significantly higher. No seasonal differences were observed for any of the other phthalates.

Table 26. Summary of phthalates in stormwater (ug L^{-1}).

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Bis(2-ethylhexyl) phthalate	61.9	0.150	0.977	41.4	yes	no
Butyl benzyl phthalate	22.6	0.022	0.0995	2.82	NA	no
Di-N-Octyl Phthalate	11.2	0.018	-	3.19	NA	NA
Dibutyl phthalate	31.8	0.024	0.1128	5.08	NA	no
Diethyl phthalate	30.6	0.026	0.1325	8.9	NA	no
Dimethyl phthalate	14.8	0.025	-	2.8	NA	NA
Sum						
Total phthalates	76.5	0.032	1.1600	41.4	yes	no

This study found much higher rates of detection but lower concentrations for bis(2-ethylhexyl) phthalate than did the NSQD. The *PS Toxics Study* reported rates of detection similar to those found in this study for commercial and industrial land uses. Bis(2-ethylhexyl) phthalate concentrations found in river systems (*PS Toxics Study)* were much lower than concentrations found in stormwater in this study.

The median sediment concentrations were calculated for four of the phthalates (Table 27). Bis(2-ethylhexyl) phthalate and benzyl butyl phthalate (Table 27) were found highest in discharges from industrial land-use areas, followed by commercial, high-density residential, and low-density residential land-use areas. The differences among land uses were significant (Appendix F). This finding is similar to results for water samples. Bis(2-ethylhexyl) phthalate and di-n-octyl phthalate exceeded the SCO in 82% and 29% of samples, respectively.

Table 27. Summary of individual phthalates in stormwater sediments (ug Kg^{-1}).

Parameter	% detected	Minimum	Median	Maximum	Land-use differences
Bis(2-ethylhexyl) phthalate	92.7	22	4,800	34,000	yes
Butyl benzyl phthalate	56.1	22	96	60,000	yes
Di-N-Octyl Phthalate	28.6	116	31	10,000	NA
Dibutyl phthalate	28.1	16	16	2,070	NA
Diethyl phthalate	5.4	81	-	123	NA
Dimethyl phthalate	19.6	28	-	628	NA
Sum					
Total phthalates	88.1	22	3,970	94,000	yes

Pesticides

The pesticides 2,4-D, chlorpyrifos, diazinon, malathion, mecoprop, phenol and p-cresol, prometon, and triclopyr were sampled but infrequently detected in stormwater. Summary statistics were not calculated for these. Only two of the 11 pesticides had rates of detection high enough to justify statistical analysis (Table 28; dichlobenil and pentachlorophenol).

Table 28. Summary of pesticides in stormwater.

Parameter ($ug\ L^{-1}$)	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Dichlobenil	35.8	0.012	0.024	1.3	yes	no
Pentachlorophenol	25.4	0.02	0.06	5.1	yes	no
Diazinon	1.0	0.026	NA	0.53	NA	NA
2,4-D	16.9	0.02	NA	28.4	NA	NA
Triclopyr	11.0	0.02	NA	18.3	NA	NA

For an herbicide, dichlobenil, concentrations were highest in discharges from high-density residential land-use areas followed by concentrations in discharges from commercial and industrial land uses. Samples from low-density residential land uses had very low rates of detection (two of 113 samples). No differences in dichlobenil concentrations were found between wet and dry seasons, suggesting either a year-round application of the herbicide or a year-round runoff from soil residuals.

Pentachlorophenol is used as both an herbicide and insecticide. Most of the pentachlorophenol detections and highest concentrations were in discharges from areas of commercial land use. Similar concentrations of pentachlorophenol were measured throughout the year. None of the analyzed samples exceeded the acute and chronic criteria for the protection of aquatic life (Appendix G, Figures G-1 and G-2).

Concentration ranges are provided in Table G-1. Two sample results for diazinon exceeded the acute and chronic criteria for the protection of aquatic life.

Higher frequencies of detection were found for diazinon and 2,4-D in the NSQD study. Despite poor detection overall, triclopyr detection rate and concentrations were much higher in this study than in storm-event samples collected in the *PS Toxics Study*, which evaluated agricultural land uses.

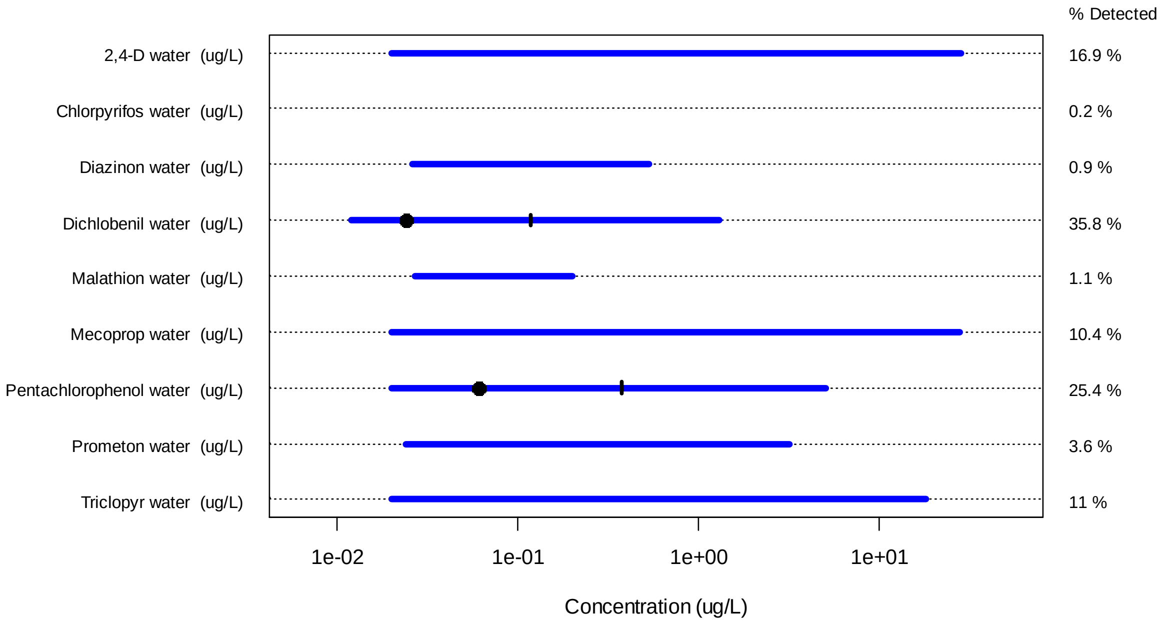


Figure 13. Summary of pesticide concentrations in stormwater.

Blue horizontal segment is the contaminant range, black dot is the median concentration, vertical black segment is the 90th percentile concentration. The x-axis is logarithmic. The rate of detection for each parameter is listed on the secondary y-axis. If no statistical summaries are presented the data are largely non-detect.

Pesticides in sediments also had very low rates of detection. Diazinon, chlorpyrifos, and malathion were detected in only 1 sample out of 53. Phenolics were the only chemical group with a sufficient amount of detected results to provide a summary. Pentachlorophenol and its degradation product, p-cresol, appeared to have higher concentrations in sediments sampled from commercial land-use areas. Concentrations of p-cresol were also high in discharges from high-density residential land-use areas. Other phenolics (2,4-dichlorophenol, 2,4-dimethylphenol, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, 4-chloro-3-methylphenol, 4-nitrophenol, phenol) and the remaining pesticides (2,4-D, dichlobenil, mecoprop, prometon, and triclopyr) were detected infrequently in most cases (5 - 10% of the samples). Pentachlorophenol in stormwater sediments exceeded the SCO for 1% of the samples. Phenol (Figure G-3) in stormwater sediments exceeded the SCO for 20% of the samples.

Table 29. Summary of pesticides concentrations in stormwater sediments.

Parameter (ug Kg^{-1})	% detected	Minimum	Median	Maximum	Land-use differences
Pentachlorophenol	24.7	7.8	11.2	17,800	NA
p-cresol	76.7	2.46	180	24,100	yes

PCBs

The permit only required monitoring polychlorinated biphenyls (PCBs) once annually in stormwater sediment samples; however, at least one permittee reported PCB monitoring results for stormwater samples across land uses as well. PCBs were measured as Aroclors in water and sediments. Only 27 stormwater samples were analyzed, and no samples were obtained from low-density residential land-use areas. Only 1 of 9 samples from high-density residential sites had a detected concentration, while all 8 samples from areas of commercial land use had detected Aroclor 1254 concentrations. Insufficient samples were collected for total PCBs to assess seasonal differences.

Table 30. Summary of total PCB concentrations in stormwater and stormwater sediments.

Parameter	% detected	Minimum	Median	Maximum	Land-use differences	Seasonal differences
Total PCBs[1] (ug L^{-1})	55.6	0.01	0.011	0.096	NA	NA
Total PCBs[1] (ug Kg^{-1})	51.5	8.5	9.6	770	NA	NA

[1] Sum of detected Aroclors (only 1248, 1254 and 1260)

PCBs in sediments were measured in 33 samples; however, detected concentrations were found only in samples from commercial and industrial land-use sites. One sample from a high-density residential site had detected concentrations. None of the measurements on individual Aroclors had a sufficient number of detected concentrations to summarize.

Contaminant Concentrations - Summary of Findings

Based on contaminant concentrations measured in stormwater discharges across multiple land uses, several major findings are worth highlighting as we move on to discuss land uses and seasonal differences more directly.

- The following parameters had high frequencies of detection and therefore were classified as Case A for statistical analyses:
  - Conventional parameters
  - Metals except mercury
  - Nutrients
  - PAH sums and TPH-Dx
  - PCB Aroclor 1254
  - Bis(2-ethylhexyl) phthalate

- All parameters with high frequencies of detection exhibited statistically different concentrations across land uses. Land use is discussed in detail in the next section of the report.

- Strong evidence exists for discharge of higher contaminant concentrations in stormwater during the dry season (May to September). This suggests the influence of a buildup/wash off relationship, particular to the first dry-season storm events for the following parameters:
    - Conventional parameters: conductivity, hardness, surfactants, BOD
    - Nutrients: all monitored
    - Total and dissolved cadmium, copper, and zinc
    - Dissolved lead
    - TPH-Dx
    - Organics: bis(2-ethylhexyl) phthalate and p-cresol

- For most parameters, stormwater sediment concentrations showed the same trends across land uses as those measured in water samples. Insoluble parameters in sediments had much better detection rates than those in water.

- Nutrients: Ortho-phosphate and nitrite+nitrate were found at higher concentrations in discharges from low-density residential land-use areas. Total nitrogen and phosphorus were highest in discharges from industrial and commercial land-use areas. Significantly higher nutrient concentrations were found during the dry season than the wet season.

- Metals: Commercial and industrial land uses discharged stormwater with comparable concentrations for zinc and copper. These frequently exceeded (did not meet) the water quality criteria. Areas of commercial land use discharged lead and mercury at statistically higher concentrations than other land uses. Areas of industrial land use discharged statistically higher cadmium concentrations. Statistically higher concentrations of zinc and copper were found during the dry season across all land uses.

- PAHs: No seasonal difference in PAH concentrations were found. Stormwater from commercial land-use areas routinely contained the highest concentration of PAHs.

- Total Petroleum Hydrocarbons: Diesel range (TPH-Dx) was discharged at significantly higher concentrations in stormwater from commercial and industrial land uses during the dry season. The motor oil component of TPH-Dx was generally observed at significantly higher concentrations in discharges from industrial land uses (median concentration). However, the higher concentrations (> 80th percentile) did not differ among industrial, commercial, and high-density land use. No seasonal differences were observed. TPH-Gx had very low rates of detection, and BTEX compounds were almost always below detection limits.

- Pesticides: Few samples had detected concentrations of pesticides. Dichlobenil was found at the highest concentrations in stormwater from areas of high-density residential land use throughout the year. Areas of commercial land use contributed stormwater with the highest pentachlorophenol concentrations throughout the year.

Land Use Significance

Peto-Prentice Test

Significant differences among land uses for each of the parameters were tested using the Peto-Prentice test, described in the *Methods* section under *Descriptive Statistics*. We found statistically significant differences among land uses for all parameters detailed in Table 31. The Peto-Prentice test indicates that at least one of the land uses was significantly different from the others, but it does not list exactly which ones differ.

Land uses were separated into two categories for the Peto-Prentice test results: dominant and minor (Table 31). Dominant land use refers to the land use that has the highest concentrations and is the major contributor of the parameter. Minor land use has the lowest concentrations and contributes the least. The determination of major and minor land uses was based subjectively on the Peto-Prentice density functions, as detailed in Appendix F. The reason for defining the major and minor land use for each parameter is to aid in prioritizing the contributions by land use. Reference Table G-3 provides "typical" concentrations for a specific contaminant across land uses.

Table 31. Case A parameters with evidence of differences in water contaminant concentrations by land use.

Parameter	Dominant Land Use	Minor Land Use
Conventionals		
Turbidity	industrial	low-density residential
TSS	industrial	low-density residential
BOD	commercial	low-density residential
Surfactants	industrial and commercial	low-density residential
Fecal Coliform	industrial, commercial, and high-density residential	low-density residential
Conductivity	industrial	commercial/high-density residential
Hardness	industrial	commercial/high-density residential
Chloride	industrial	commercial/high-density residential
Nutrients		
Orthophosphate	low-density residential	commercial/high-density residential
Total Phosphorus	industrial	low-density residential
TKN	industrial, commercial, and high-density residential	low-density residential
Nitrite+nitrate	low-density residential	commercial and industrial
Ammonia	industrial	high-density residential

Table 31 (continued)

Parameter	Dominant Land Use	Minor Land Use
Metals		
Cadmium (total and dissolved)	industrial	low-density residential
Copper (total and dissolved)	industrial and commercial	low-density residential
Lead (total and dissolved)	commercial	low-density residential
Mercury	commercial	low-density residential
Zinc (total and dissolved)	commercial and industrial	low-density residential
Hydrocarbons		
TPH-Dx	commercial and industrial	low-density residential
Diesel range organics	commercial and industrial	low-density residential
Motor oil	industrial	commercial
Fluoranthene	commercial	low-density/ high-density residential
Phenanthrene	commercial	low-density/ high-density residential
Pyrene	commercial	low-density/ high-density residential
CPAH	commercial	low-density/ high-density residential
LPAH	commercial	low-density/ high-density residential
HPAH	commercial	low-density/ high-density residential
Total PAHs	commercial	low-density/ high-density residential
Additional Organics		
Bis(2-ethylhexyl) phthalate	commercial	low-density residential
Dichlobenil	high-density residential	low-density residential
Pentachlorophenol	commercial	low-density residential

The differences among land uses for each parameter have been detailed previously in the discussion of contaminant concentrations. For some parameters, e.g., zinc, the major land-use type is different at low concentrations compared with high concentrations. In other words, at a median zinc concentration, commercial land uses contributed higher concentrations. In contrast, at the 90th percentile of the distribution of concentrations, high-density residential land uses contributed higher concentrations. This finding shows that the relationship of a particular contaminant to land use is not linear. There may be a steady discharge of a contaminant from one land-use type across sites and large variability in discharge across sites for another land-use type.

Principal Components Analysis

The Peto-Prentice test showed significant differences among land uses for individual parameters. We used multivariate statistics to decipher trends among the sample sites and parameters, combined. Using the variables from Table 31 in a principal components analysis (PCA), the distribution of sample sites relative to contaminant parameters can be plotted (Figure 14).
In Figure 14, the arrows represent concentration gradients of the parameters, and the points (circles and squares) represent sample sites. The arrow points to increasing concentration of that parameter, and parameters that had similar concentration trends across the sample sites are close together. Sample sites (points on Figure 14) that had similar stormwater chemistry are grouped together. Sample sites the arrows point to are sites that have high concentrations of these parameters.

The key observation from the PCA (Figure 14) is the general grouping of the sites (points) by land use, suggesting similar stormwater quality. For instance, all the low-density residential sites are grouped in the lower right quadrant of Figure 14. There is also considerable overlap for some sites. In particular, there is overlap between many commercial and high-density residential sites. This observation implies that stormwater chemistry from these land uses can be very similar. In addition, industrial sites do not group together and show more similarities to commercial and high-density residential sites.

The overlap of land uses is likely due to characteristics of the drainage area as described by the permittees (Table 1). For example, Pierce County high-residential site (PIEHIRES_OUT) appeared more similar to a low-density residential site (Figure 14). As shown in Table 1, PIEHIRES_OUT had a very low total impervious surface area, which could explain why the stormwater chemistry resembled the low-density residential sites.

By using multivariate statistics, we gained a greater understanding of how stormwater chemistry can be defined by land use; however, significant overlap or variability exists from site to site within the same land-use category.

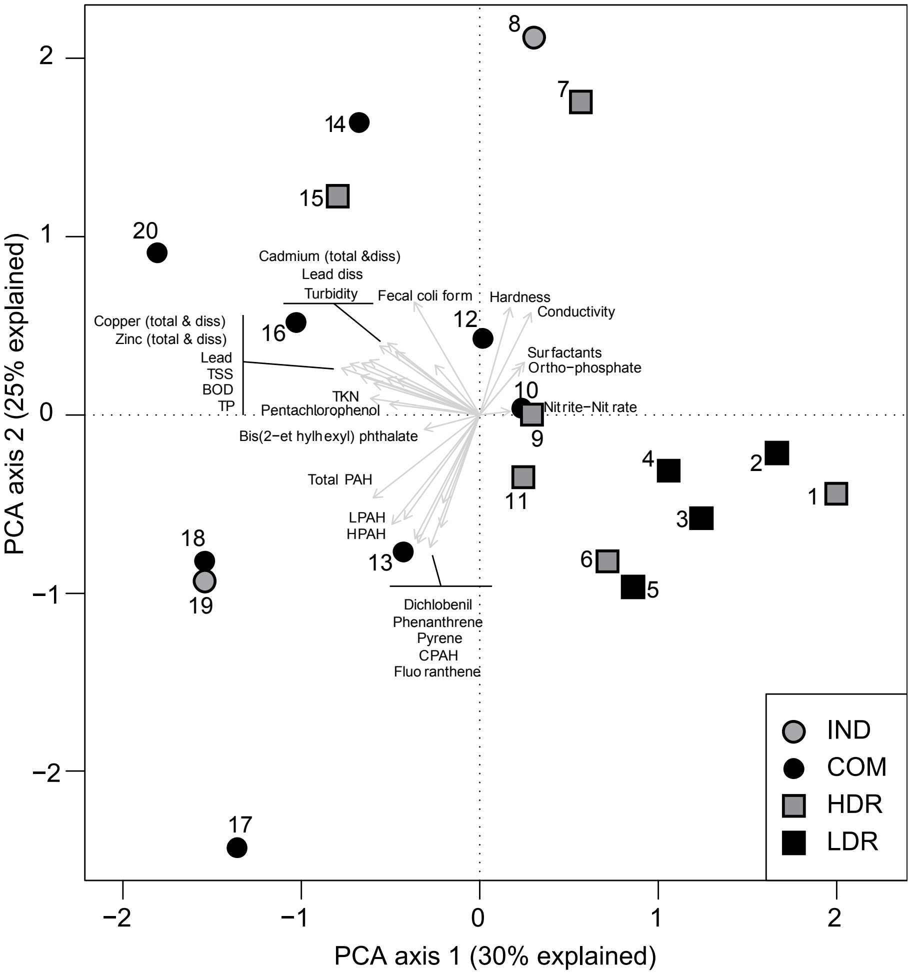


Figure 14. Principal components analysis of stormwater samples.

Biplot shows study sites (points) by land use and contaminant parameters (gray lines) that are statistically relevant across land uses. The amount of variation in the data explained by each axis is detailed in the axis titles.

Sediment concentrations observed in annual sediment samples from the basins strongly paralleled trends in water concentrations across the land uses. For example, those sites with high concentrations of metals in stormwater had high concentrations of metals in catch basin sediments. Similar to water samples, there is an overlap among land uses and variability from site to site within a land use (Figure 15). A significant amount of variation among sites can be explained by the first axis of the PCA (84%; axis 2 explains a further 8% of the variation). Overall, there was a significant difference among the land uses when analyzing all sites and all sediment contaminants (analysis of similarities p=0.004). Note that overall there were fewer parameters available for the sediment PCA compared with the water samples, but similar contaminant groups were represented (metals, phenols, and PAHs).

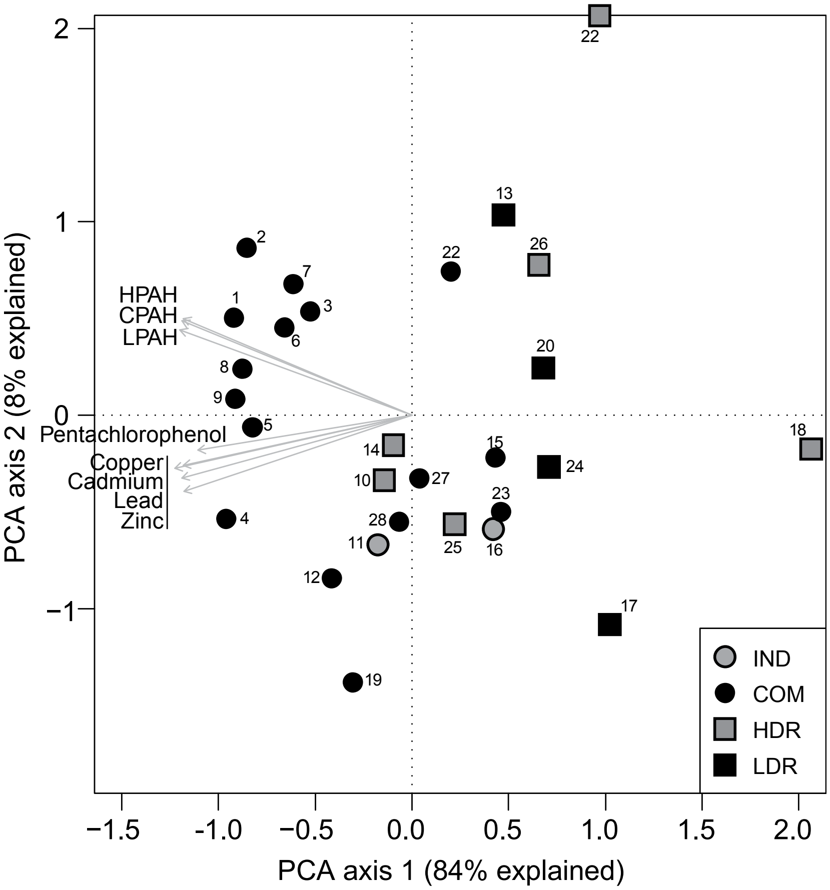


Figure 15. Principal components analysis of stormwater sediment samples

Biplot shows study sites (points) by land use and contaminant parameters (gray lines) that are statistically relevant across land uses. The amount of variation in the data explained by each axis is detailed in the axis titles.

The major difference among the sediment samples was that sediments from the Port of Seattle commercial sites (samples 1 through 9 on Figure 15) were very distinct from the others. Using a cluster analysis (described in the *Methods* section on *Multivariate Statistics*), we were able to define three main groupings of the sites, a "group" of sites having statistically similar sediment chemistry (Figure G-5). Each of these groups was a mixture of land uses, which is the same observation made from the PCA, where many land uses overlap. An example of this overlap is Group 2A in Figure G-5, which had a mixture of industrial (City of Seattle), commercial (City of Seattle, Pierce Co., Clark Co. and the City of Tacoma), and high-density residential sites (King Co. and City of Seattle). Therefore, similar conclusions to those made for the water concentration data can be drawn for sediments: there was considerable overlap in contaminant concentrations among land uses and high variability among sites within a land use.

Overall, the multivariate analysis for water and sediment samples suggests that defining a 'typical' sediment or water contaminant composition for a particular land use is unrealistic. However, this analysis was successful in showing that statistically significant differences exist among land uses over multiple sample sites and parameters.

Parameter Similarities

The grouping of parameters used in the PCA of water concentrations indicated that some parameters were closely related across the sites (Figure 14). This was determined visually by noting which arrows on the PCA plot (Figure 14) were closer together. Parameters that appeared to be positively correlated include:

- PAHs and dichlobenil
- copper, zinc, total lead, TSS, BOD, and total phosphorus
- cadmium, dissolved lead, and turbidity
- TKN and pentachlorophenol
- hardness, conductivity, surfactants, and ortho-phosphate

Nitrite+nitrate and bis(2-ethylhexyl) phthalate are inversely related. Fecal coliform is not strongly related to other parameters.

The apparent similarities among some parameters were related to land-use practices and reflected a common source. For instance, the main group of metals (defined as the second group listed above) was most strongly associated with two commercial sites (KICCOMS8D_OUT and SEAC1S8D_OUT). Also, this group was most weakly associated with residential sites.

The apparent similarities among some parameters could inform stormwater managers whether additional parameters need to be included in a monitoring program. For example, a program that monitors for PAHs may want to consider analyzing for dichlobenil. An additional example is the significant positive relationship between surfactants and ortho-phosphate ($p=0.01$). Further analysis of this relationship suggests that samples from commercial ($p<0.001$) and high-density residential land use ($p<0.001$) are the land uses with strong statistical significance. Surfactants also appear to have a strong relationship with dissolved copper and dissolved zinc in samples from commercial areas ($p<0.001$ in both cases), but not in residential areas. Surfactants do not appear to have any relationship with total suspended solids ($p=0.21$) or turbidity ($p=0.74$). This analysis highlights some of the potential this data set has for exploring relationships between key parameters.

Seasonality

The seasonality and "first flush" storm events are important characteristics for stormwater management. To truly capture first flush events, an instantaneous sample must be taken early in the storm (within approximately 30 minutes). It can then be compared with a composite sample from the same storm event. Few first flush samples from particular storm events were collected by the permittees. Thus, no conclusions can be drawn about the relative load of contaminants discharged during the initial hour of storm events. The dry season in the Pacific Northwest has long antecedent dry periods prior to storms; therefore, Ecology expected the dry-season storm events to exhibit higher contaminant concentrations.

To compare the seasonality of contaminant discharge during storm events, Ecology compared a wet and dry season. In reality, there was considerable overlap between the wet and dry seasons in western Washington (Figure 16). However a statistically significant difference existed between the volume of runoff generated in the two seasons (p = 0.009).

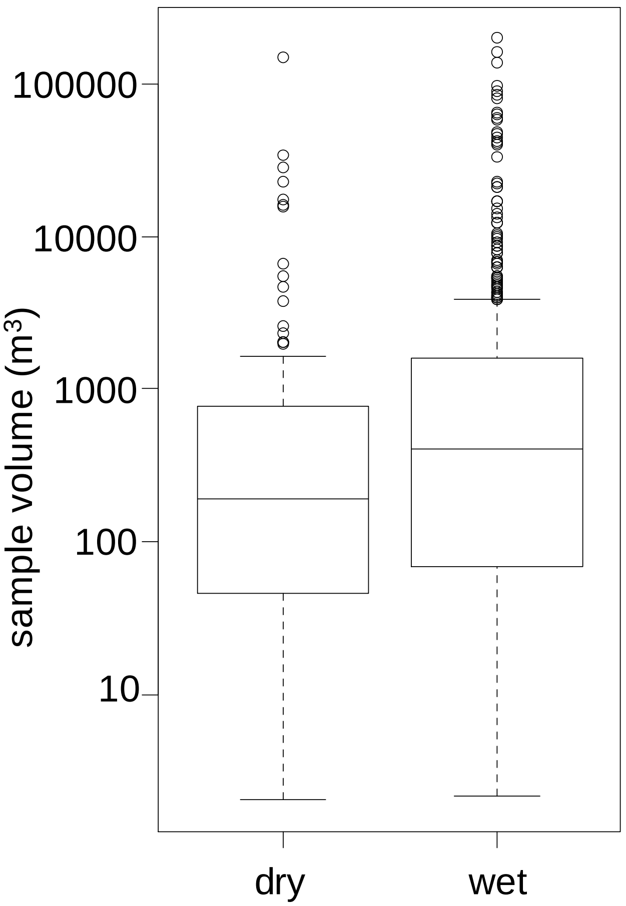


Figure 16. Box plot of measured storm volume (m^3) during the wet and dry season.

Median values is the solid black line within each box. Box extremities from bottom to top are the 10th, 25th, 75th, and 90th percentile.

For some parameters, significantly higher concentrations were measured in the dry season (Table 32). Metals concentration data show particularly strong differences between the seasons, with the exception of total lead (Appendix F). The possible mechanisms for seasonal differences are: (1) a reduction in water volume with a similar contaminant mass throughout the year or (2) greater contaminant contributions during the dry season. Figure 16 suggests that the difference in concentrations between seasons was due to a smaller dry-season storm volume. Yet, when Ecology assessed mass loads of the contaminants per storm event (kg per storm event), which normalized the data, the same group of parameters exhibited seasonal differences. In reality, both of these mechanisms likely contributed to greater contaminant concentrations during the dry season.

A further analysis of concentrations and loads compared to the antecedent dry-period length is a natural next step. Unfortunately, Ecology did not require antecedent dry period data to be submitted to EIM; therefore, the analysis could not be conducted.

Table 32. Seasonality of stormwater concentrations.

Conventional Parameters	Nutrients	Metals	Hydrocarbons	Pesticides	Phthalates	PCBs
Significant seasonal difference						
BOD Surfactants Fecal coliform Conductivity Hardness as CaCO3 Turbidity	Total phosphorus Ortho-phosphate TKN Nitrite+nitrate Ammonia	Cadmium (total and dissolved) Copper (total and dissolved) Lead (dissolved) Zinc (total and dissolved) Mercury	TPH-Dx Diesel Range Organics Fluoranthene Heavy Fuel Oil Pyrene	none	none	none
No seasonal difference						
pH Total suspended solids	none	Lead (total)	Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Benzo(b,k)fluoranthene Benzo(g,h,i)perylene Indeno(1,2,3-cd)pyrene CPAH HPAH LPAH Lube Oil Motor Oil Phenanthrene Total PAH Total TPH-Dx	Dichlobenil Pentachlorophenol Phenol	Bis(2-ethylhexyl) phthalate Dibutyl phthalate Diethyl phthalate Total Phthalate	PCB-Aroclor 1254 PCB-Aroclor 1260 Total PCB

Findings in this study that the dry-season contaminant concentrations were significantly higher for *some* of the parameters was consistent with findings from the NSQD which show that first flush events were detectable for some parameters predominantly in areas of commercial and residential land uses (Maestre et al., 2004). The *PS Toxics Study* also observed greater concentrations during fall storm events when longer antecedent dry periods prevailed.

Contaminant Loads

Data summaries for storm-event contaminant loads were calculated for the Case A parameters. For those contaminants that were classified as Case B and had more than 50 observations (summarized used Robust ROS techniques), contaminant loads should be considered estimates. For all other parameters, a range of contaminant loads was given. Often the ranges were limited by the analytical detection limit, thus ranges were not an accurate assessment of environmental contaminant loads. Event loads were summarized using the same statistical approach as used for the concentration data (i.e., data qualifiers associated with the each concentration were used for the corresponding load). Loads were not calculated for parameters collected by grab samples, as these do not represent the load throughout a storm event.

Ecology calculated both weight-based (mass) loads (kg per storm event) and loads per unit area (kg ha^{-1}) based on the catchment area given in Table 1 for each stormwater basin.

Loads calculated here are reliable, as no bias towards large volume storms was evident across the sample sites, and sample representation of the storms was excellent. Loads are summarized by land use in Table I-2 (mass) and I-5 (per unit area). All data summaries are detailed in Table I-1 through I-6. Graphical summaries for each parameter load are detailed in Appendix H. Peto-Prentice and Kaplan-Meier cumulative density functions were also run on the load by area to describe any significant differences among land uses.

Unfortunately, Ecology could not directly compare to load estimates presented in the *PS Toxics Study*, which were true annual loads; those presented in this study were event loads. However, trends across land uses were compared. In general, mass loads exhibited the same seasonal trends as contaminant concentrations. Contaminant loads per unit area in general followed seasonal trends, but with more exceptions. Contaminant loads per unit area for each parameter are discussed in greater detail below.

Summary of Loads per Unit Area

In this section, contaminant loads (kg per hectare) are discussed as *median values* (50th percentile) unless otherwise noted. Tables I-3 through I-6 detail the data summaries for contaminant loads per unit area (hectares).

Conventional Parameters

Surfactants

Contributions of surfactants were 0.0002 kg per hectare per storm event. Significant differences existed among land uses, but not between wet and dry seasons. Loading data followed trends similar to concentration data across land uses. Commercial and industrial land uses contributed greater loads.

Total Suspended Solids (TSS)

TSS load varied significantly across land uses and showed a significant difference between wet and dry seasons (Table I-3). Loads from industrial and commercial land uses were significantly greater (0.71 kg ha^{-1} and 0.28 kg ha^{-1}, respectively) than loads from high-density residential land use (0.06 kg ha^{-1}) and low-density residential land use (0.04 kg ha^{-1}). TSS load exhibited a clearer difference among land uses than concentration, consistent with findings from the *PS Toxics Study*.

Nutrients

Phosphorus

Total phosphorus loads per unit area had a median value of 0.00045 kg ha^{-1} with 8.46 x 10-5 kg ha^{-1} contributed as ortho-phosphate. Land uses contributed significantly different loads on a per unit area basis. Seasonal loads were not different, in contrast to concentration data where concentrations were significantly higher during the dry season.

As with concentration, total phosphorus loads were significantly greater in stormwater from the commercial and industrial land uses. The residential land uses were significantly lower and quite similar to each other (in kg ha^{-1}; Table I-5).

Dissolved phosphorus load (as ortho-phosphate) from low-density residential land use (1.1 x 10^{-4} kg ha^{-1}) was similar to the load from industrial (1.5 x 10^{-4} kg ha^{-1}) and commercial (1.1 x 10^{-4} kg ha^{-1}) land use. These results are an order magnitude higher than high-density residential land use (3.5 x10^{-5} kg ha^{-1}).

Findings from this study agreed with the *PS Toxics Study* which found that commercial and industrial land uses contributed a higher load of total phosphorus than residential land uses. Dissolved phosphorus was not measured in the *PS Toxics Study*.

Nitrogen

The observed nitrogen loads suggested that 0.0043 kg ha^{-1} of nitrogen was discharged per storm event (sum of total Kjeldahl N and nitrite+nitrate, as nitrogen), with a 90th percentile of 0.026 kg ha^{-1} N. The TKN loads (as kg ha^{-1}) across land uses differed from that observed for concentrations. TKN loads were dominated by contributions from commercial and industrial land-use areas, with residential land-use contributions significantly lower. Nitrite+nitrate loads were also highest in discharges from commercial and industrial land uses. Above the 75th percentile of the distribution, the highest loads observed in the data set were discharged from residential land-use areas. This finding highlights the complexity and variability among land uses and among sites.

There was no difference in nitrogen loads between wet and dry seasons.

The *PS Toxics Study* found that residential land uses contributed the majority of nitrite+nitrate, which was similar to observations of this study. Commercial and industrial land uses were found to contribute the lowest nitrite+nitrate load in the *PS Toxics Study*, which was contrary to the findings of this study in which commercial and industrial land uses contributed the greatest median loads.

Metals

Metals loading (as kg ha^{-1}) generally followed trends similar to concentration data. Commercial and industrial land-use areas discharged the greatest load, followed by discharges from residential land uses. Some deviations from this trend were noted for lead. Similar loading trends during storm events among land uses were noted in the *PS Toxics Study*. All metals showed greater loading during the dry season.

Cadmium

The 90th percentile of the total cadmium load from all land uses was 3.37×10^{-6} kg ha^{-1} per storm event with a median of 4.83×10^{-7} kg ha^{-1}. Approximately 20% of the total cadmium was in dissolved form. The differences among land uses were similar to the cadmium concentration data, where commercial and industrial land uses discharged significantly higher loads than residential land uses. No significant differences were found between the wet and dry seasons for loads per unit area.

Copper

The 90th percentile of copper load discharged during each storm was 3.6×10^{-4} kg ha^{-1} and the median was 5.1×10^{-5} kg ha^{-1}. Approximately 25% of the copper was in dissolved form. Trends across land uses and between seasons were similar to those found for cadmium.

Lead

The 90th percentile of the distribution of total lead load was 3.0×10^{-4} kg ha^{-1} per storm event, and the median was 2.7×10^{-5} kg ha^{-1} per storm event. Land-use trends for loads were similar to those found for concentrations. Commercial land-use areas discharged significantly higher loads; industrial and high-density residential land uses discharged roughly similar loads. Low-density residential land-use areas discharged significantly lower lead loads. No significant differences were found between the wet and dry seasons for loads per unit area.

Mercury

Mercury loads were heavily influenced by the number of non-detect concentrations. Only for areas of commercial land use could the loads be quantified (Appendix I). No seasonal differences were apparent in the loads of mercury from commercial land-use areas.

Zinc

The median zinc load was 3.1×10^{-4} kg ha^{-1} per storm event, while the 90th percentile of the load distribution was 1.5×10^{-3} kg ha^{-1} of zinc per storm event. Land-use trends for loads were very similar to those measured for concentrations, where commercial and industrial land uses showed nearly identical loads. Commercial and industrial lands had significantly higher loads of zinc, than did residential lands. No significant differences were found between the wet and dry seasons for loads per unit area.

Hydrocarbons

TPH

TPH-Dx had significantly higher loads in stormwater (as kg ha^{-1}) from commercial and industrial land uses compared with residential land uses, similar to the concentration trends. The 90th percentile of the distribution of TPH-Dx load was 0.02 kg ha^{-1} per storm event, and the median across all land uses was 2.0×10^{-3} kg ha^{-1}. The motor oil component of TPH-Dx was discharged at a load of 0.02 kg ha^{-1}(90th percentile), with a median of 3.0×10^{-3} kg ha^{-1} per storm event. The TPH-Dx load from high-density residential land use was significantly lower than the load from commercial and industrial land use. No significant differences were found between the wet and dry seasons for loads per unit area.

Polycyclic Aromatic Hydrocarbons (PAHs)

Individual PAH compound concentrations were well-quantified for fluoranthene, phenanthrene, and pyrene. These three compounds displayed trends similar to concentration trends for land uses, where significant differences were present between loads from commercial, industrial, high-density residential, and low-density residential. The 90th percentile of the total PAH mass loads was 2.0 x 10-5 kg $ha^{-1,}$ and the median was 6.7×10^{-7} kg ha^{-1} contributed per storm event. Trends across land uses for loading of total PAHs, CPAHs, LPAHs, and HPAHs were the same as described for the individual PAH compounds.

Significant differences in PAH loads were found between wet and dry seasons, contrary to concentration data. Greater PAH loads were found during the wet season.

Phthalates

Bis(2-ethylhexyl)phthalate was the only well-quantified phthalate in stormwater from all land uses. Ecology estimated the 90th percentile of the load was 3.5 x 10 -5 kg ha^{-1}, and the median was 3.9×10^{-6} kg ha^{-1} discharged per storm. Significant differences in load trended downward from commercial to industrial to high-density residential to low-density residential land uses. A similar pattern was observed for total phthalates across land uses. A significant difference was found between wet and dry seasons.

Pesticides

The load of dichlobenil did not vary across the three land uses (commercial, industrial, and high-density residential) where concentrations were detected. The estimated load per unit area was a median of 4.82×10^{-8} kg ha^{-1} of dichlobenil per storm event. No difference in dichlobenil load was found between wet and dry seasons.

Pentachlorophenol load in stormwater was calculated only for commercial land-use areas, where the estimated median was 6.31×10^{-8} kg ha^{-1} per storm event. No difference in pentachlorophenol load was found between wet and dry seasons.

Contaminant Load Summary

Storm-event mass (kg) and load per unit area (kg ha^{-1}) were calculated for contaminants that were quantified above detection limits in stormwater. Contaminant loads showed trends similar to the contaminant concentrations, with the exception of nutrients. While contaminant mass loads (kg) were not discussed in detail in this report, we observed similar seasonal trends to the contaminant concentration data. On the other hand, loads per unit area were generally constant throughout the year. Contaminant loads per unit area are summarized below:

- *Nutrients*: Total nitrogen and phosphorus loads were highest from commercial and industrial land uses. Low-density residential land uses contributed as much ortho-phosphate load as the commercial and industrial land uses, while ortho-phosphate load from high-density residential land use was significantly lower. Dissolved nitrogen (as nitrite+nitrate) load from high-density residential land use was greater than the 75th percentile of the load from commercial and industrial land uses. Nutrient loads calculated per area were constant throughout the year, although nutrient concentrations were higher in the dry season.

- *Metals*: Commercial and industrial land uses discharged the greatest metal loads, and lower loads were discharged from residential land uses. All metals showed no significant difference in loading between the wet and dry season, contrary to the concentration data and mass loads (kg). A high mass loading observed during the dry season seemed more highly influenced by elevated concentrations rather than by volume.

- *Hydrocarbons:* Commercial and industrial land uses contributed the greatest loads of diesel range total petroleum hydrocarbons (TPH-Dx) and PAHs. Overall, loads per unit area (kg ha^{-1}) showed significant differences between seasons, with greater loads during the wet season.

- *Pesticides*: Commercial, industrial, and high-density residential land uses had comparable dichlobenil loads. No seasonal differences in contaminant loads were noted.

Summary

Stormwater and storm sediment discharge data were collected by NPDES Phase I Municipal Stormwater permittees, under Special Condition S8.D, between 2007 and 2012. This report is a summary of data results contained in Ecology's Environmental Information Management (EIM) System. The eight Phase 1 permittees, all located in western Washington, collected highly representative storm-event data under a prescribed monitoring program that represented multiple land uses, storm characteristics, and seasons. The main goals of this study were to (1) compile and summarize the permittees' data using appropriate statistical techniques and (2) provide a western Washington regional baseline characterization of stormwater quality.

Ecology's analysis provides a comprehensive review of the pollutants in western Washington stormwater from 2007 - 2012. These findings are based on the analysis of 44,800 data records representing 597 different storm events. Up to 85 chemicals were analyzed in stormwater samples, and 67 chemicals were analyzed in stormwater sediment samples. Compiling data from multiple sources was challenging due to differences in parameter names, sample fractions, units, reporting limits, and basin characteristics.

The representativeness of the collected samples across storm events appeared to be of high quality, generally representing above 90% of storm hydrographs. Samples showed no bias of storm volume. The distribution of sampling events over the year was also of high quality with few exceptions.

The statistical analyses used in this study have produced reliable statistical summaries and allowed for robust comparisons of the impacts of land use and seasons on contaminant concentrations and mass loads. The statistical summaries form a baseline for contaminant concentrations in stormwater that will allow for future comparisons. Results can be used to track improvement in stormwater quality as local programs continue to be implemented.

Key Findings

The following key findings are highlighted from this report.

Stormwater Monitoring Program

- Ecology finds the permittees' stormwater monitoring data to be representative of storm events in western Washington. The stormwater discharge data set is large, captured a wide variety of storm events, and does not appear to have biases toward storm size, limb of hydrograph, land use, or season. Results are suitable for creating a baseline understanding of stormwater discharges in western Washington.
- Stormwater monitoring as required in the 2007 permit was met (qualifying storm, sample frequency, and representativeness). The continued collection of high quality data representing storm-event pollutant concentrations seems realistic.
- "Typical" stormwater chemistry for a particular land use was difficult to define.
- This database is a suitable baseline to compare stormwater contaminant concentrations against management actions in future studies.
- Permittees' initial efforts to assess toxicity of stormwater on trout embryos per permit requirements in S8.F were met with considerable logistical and bioassay complexity. Twelve of the 17 samples analyzed using bioassays had no adverse effects. Only samples from larger commercial areas showed toxicity to trout embryos, with the likely toxicants being zinc and copper. Appendix A provides a summary of the bioassay effort and lessons learned.

Stormwater Discharge Quality

- Commercial and industrial areas discharged stormwater with the highest concentrations of metals, hydrocarbons, phthalates, total nutrients, and a few pesticides.
- Residential areas discharged stormwater with the highest dissolved nutrient concentrations.
- Copper, zinc, and lead most frequently exceeded (did not meet) the water quality criteria for protection of aquatic life. Cadmium and mercury also exceeded criteria for protection of aquatic life. Mercury was not a widespread contaminant in western Washington stormwater, although localized areas of concern existed. Comparisons to water quality criteria were made for context in this report.
- Metals concentrations monitored during the dry season (May through September) were statistically higher than concentrations monitored during the wet season. Dissolved zinc, copper, and lead exceeded acute and chronic water quality criteria regularly. Comparisons to water quality criteria were made for context in this report.
- Higher contaminant concentrations and mass loads (kg per storm event) were measured for nutrients and metals during the dry season. This supports the idea that there is a "buildup" during the dry season, when the antecedent dry periods are longer.

- PAHs, phthalates, PCBs, and the few detected pesticides did not exhibit a significant seasonal difference, suggesting these parameters were being discharged from a consistent source throughout the year.
- Bis(2-ethylhexyl) phthalate was frequently found in stormwater and stormwater sediment.
- NWTPH-Dx compounds were persistent stormwater contaminants. Commercial and industrial areas discharged much higher concentrations and loads than did residential areas. When the motor oil fraction was considered separately, the highest load was from residential areas.
- NWTPH-Gx was poorly detected and, if present, was likely volatized before monitoring.
- Individual parameter concentrations showed strong differences between land uses.
- The most volatile organics (some pesticides, lighter weight PCBs, and PAHs) were poorly detected (less than 10% of the samples).
- The most volatile parameters (BTEX) provided less useful information when gathered from composite samples.

Stormwater Sediment Quality

- While the data set for stormwater sediment samples is smaller the data set for stormwater samples, contaminants in stormwater sediments showed trends similar to contaminants in stormwater across land uses.
- The stormwater sediment monitoring design precluded an understanding of sediment pollutants across seasons. A more refined sediment design for both spatial and temporal monitoring would improve our understanding of stormwater sediments.
- Bis(2-ethylhexyl) phthalates in stormwater sediments exceeded the freshwater aquatic life criteria (Sediment Cleanup Objectives) 82% of the time. Di-n-octyl phthalate exceeded the criteria 29% of the time.
- Total PAHs in stormwater sediments exceeded the freshwater aquatic life criteria (SCO) 34% of the time.
- Copper (9%) and lead (18%) were the main metals in stormwater sediments exceeding the SCO. Zinc and mercury were not of concern in stormwater sediments.
- Phenol in stormwater sediment exceeded the SCO 20% of the time.

Comparisons with Relevant National and Local Stormwater Studies

Generally, contaminant concentrations reported in this study were within the ranges reported in the National Stormwater Quality Database (NSQD), but median values were often lower. This is primarily due to the age of the NSQD (early 1980s) and improvements in stormwater quality and management since the National Urban Runoff Program (NURP) sampling. Many of the contaminant concentrations in this study were higher than those found in the *PS Toxics Study*.

This finding is not surprising given that the *PS Toxics Study* sampled receiving waters, not stormwater discharges, during storm events.

- The *PS Toxics Study* found high concentrations of PAHs in receiving waters during storm events. The majority of PAHs were contributed from commercial and industrial areas, which was corroborated by this current study. PAHs in stormwater discharges showed no seasonal differences in concentrations.
- The pesticides, dichlobenil and pentachlorophenol, were reliably detected in this study. Triclopyr, which was detected in the *PS Toxics Study,* was found in only 10% of the 575 samples analyzed in this study.
- The few samples with detected concentrations of PCBs in water showed much lower concentrations in this study than in the *PS Toxics Study*.
- Dissolved nutrients (orthophosphate and nitrite+nitrate-nitrogen) were much lower in stormwater discharges as compared to receiving waters sampled in the PS Toxic Study. This suggests that dissolved nutrient contributions are larger to receiving waters from pathways other than stormwater drainages (e.g., tributary streams and groundwater).
- Higher concentrations and storm-event loads of metals were contributed to receiving waters from commercial and industrial areas than from other land-use areas. The *PS Toxics Study* also found the highest metals concentrations in waters from commercial and industrial areas.

Recommendations

Based on the findings of this study, further actions and data analysis are recommended.

- Implement best management practices (BMPs) and adjust stormwater management programs based on these findings. Use findings to help prioritize activities within stormwater programs.

- Present the data online in a simple, user-friendly interface that stormwater managers could use to directly compare with future stormwater chemistry results.

- Link this database with the National Stormwater Quality Database (NSQD) to increase the temporal range of the data set.

- Further investigate the relationships between seasonality and land use for each parameter. For example, total phosphorus exhibits strong statistical differences between land uses during the wet season but no significant differences during the dry season.

- Conduct further analysis to identify the land use associated with each sample that exceeded (did not meet) water quality criteria.

- Expand the number of sites for annual sediment sample collection to enhance the spatial survey of possible contaminant sources.

- Use results from this study to fill gaps found in the *Control of Toxic Chemicals in Puget Sound: Phase 3 Data and Load Estimates* (Herrera, 2011; *PS Toxics study*): for example, areas draining directly to marine waters or fresh receiving waters that were missed when monitoring the larger drainages in that study.

- Reduce the sampling frequency of, or eliminate, the following parameters from further stormwater discharge sampling:
    - BTEX in water and sediments.
    - Malathion, prometon, chlorpyrifos, and diazinon in water and sediments.
    - Triclopyr and mecoprop in sediments.
    - Limit phenolics in sediments to pentachlorophenol, o- cresol, and p-cresol.

- Evaluate the data set for patterns among parameters that could help identify sources of pollution to stormwater.
    - Explicitly test the influence of seasonal first flush, or antecedent dry period lengths, on stormwater discharge concentrations.
    - Explore whether the correlations between some parameters and land uses are causative or coincident. For example, surfactants and copper; does the application of surfactants increase the mobilization of copper from the catchment?
    - Investigate dissolved nutrient concentrations in stormwater from low-density residential areas and investigate pollution reduction approaches.

- Track and evaluate any BMPs within each basin using a similar suite of stormwater chemistry (e.g., timing of sweeping or cleaning of Ports or parking lots).
- Explore the high-runoff coefficient calculated for specific high-density residential sites to determine whether the high-runoff coefficients influence the contaminant contributions from these sites.

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Appendices

Appendix A. Municipal Stormwater Trout Embryo Toxicity Testing: Results from First Flush, 2010-2011

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Monitoring Strategy

The permittees under the Phase I Municipal Stormwater Permit made attempts to sample seasonal first flush stormwater for toxicity testing in August through October of 2010 and 2011. Each permittee sampled only in one of those years but targeted three of the following four landuse types:

- Commercial.
- Industrial.
- Low density residential.
- High density residential.

Half of the permittees could only sample the discharge from two landuse types because of inadequate discharge volumes during the seasonal first flush timeframe defined in the permit. This monitoring did not provide for results from multiple years or multiple seasons and must be considered no more than a snapshot of any of the discharge locations. In addition, only nine of the seventeen samples were collected in August and represented well a seasonal first flush. Five of the seventeen samples were collected in October.

Metals in water with higher hardness are less toxic and water quality criteria for metals are calculated based upon hardness. The hardness of receiving water is often significantly higher than stormwater. The permit allowed the hardness of stormwater samples to be adjusted to match receiving water hardness to provide some environmental realism.

However, other relevant features of the receiving water environment were not incorporated into test conditions. Features left out include:

- Upstream sources of metals and other pollutants.
- Pulsed pollutant exposures.
- Dilution
- Dissolved organic carbon.
- Suspended solids.
- Variability of stream chemistry during storms.

The monitoring results have limited environmental relevance.

The trout embryo viability test is good for assessing conditions for the first 7 days of a trout or salmon's life. The test measures survival and development during this time. It misses other sensitive lifestage transitions such as hatch or swim-up. Since the toxicity testing did not include other organisms, lifestages, and biological endpoints, the results need to be considered solely within the context of the 7-day trout embryo test.

Test Method and Results

Labs conducted the Environment Canada 7-day trout embryo viability test[5] on the stormwater samples. Tests began with freshly fertilized rainbow trout eggs and continued for a week. At the end of 7 days the labs counted the number of live embryos and the number of normally developed embryos. All tests provided valid results based upon control response. Twelve of the seventeen tests showed no adverse effects to either survival or development.

Only the Port of Tacoma and Port of Seattle samples had EC50s equal to or less than 100% sample[6] and triggered the follow-up actions in the permit. Follow-up actions compare chemical analysis results on split samples to published toxic thresholds. The comparison revealed zinc to be the likely toxicant for the Port of Tacoma sample and copper to be the likely toxicant for the Port of Seattle sample. Ports are especially large and intensive commercial operations.

The dissolved copper and zinc concentrations in the samples from the commercial landuse types were 2 to 10 times higher than the concentrations of the same metals in samples from residential landuse. The Pierce County and Snohomish County commercial samples had higher concentrations of zinc than the one industrial landuse area sampled. The Snohomish County commercial sample also had higher copper than the industrial sample. Parking lots are significant sources of copper and zinc. Galvanized metal roofs can produce runoff with toxic concentrations of zinc. Commercial areas have abundant parking lots and galvanized steel. Table A-1 shows the average concentration of copper and zinc in the same samples from the various landuse types that were tested for toxicity.

Table A-1 – Average Copper and Zinc Concentrations in Samples from Different Land Uses.

	Copper	Zinc
Commercial (n = 6)	17.9	100.8
Residential (n = 8)	5.4	18.4
Industrial (n = 1)	19.2	125.0
Port of Seattle	101.0	171.0
Port of Tacoma	13.7	767.0

Copper and zinc concentrations along with toxicity test results for all samples are listed in Table A-2.

The samples from the commercial landuse types for the City of Seattle, Pierce County, and Snohomish County were moderately toxic. The toxicity test result for the Snohomish County

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[5] EPS 1/RM/28

[6] This toxicity test used a series of dilutions of the sample (starting at 100% concentration). Therefore if the half maximal effective concentration (EC50) was equivalent to or less than the raw sample, the sample had regulatory significant toxicity.

commercial sample nearly triggered the follow-up actions in the permit, but the results from the other commercial samples were not as close. None of the residential landuse samples showed any toxicity. The one industrial sample did not either. Toxicity test results are given in Table A-2.

Lessons Learned

- Rainbow trout do not naturally spawn in late summer through early fall. The hatchery had to make a special effort at that time to bring fish into spawning condition. Permittees and labs had to predict a qualifying seasonal first flush storm event enough in advance to arrange for the hatchery to have trout gametes available for setting up tests. Scheduling was not always successful and most tests needed variances from sample holding times. Ten out of seventeen samples were past the recommended sample holding time of 36 hours at test startup. Two samples were slightly older at test setup than the EPA maximum allowed holding time of 72 hours.
- Uneven quality of trout gametes due to the time of year may have produced variability in response that led to poor statistical sensitivity. Five out of the seventeen trout embryo tests did not meet the chronic statistical power standard[7] of being able to determine that a reduction in survival or development of 40% or more is statistically significant. The percent minimum significant differences (PMSDs) highlighted in Table A-2 show which tests failed to meet the power standard. These municipal stormwater tests had 50% of the PMSDs ≥ 40% from all ninety-seven trout embryo tests in the toxicity test database even though they are only 18% of the total.
- The seasonal first flush was over by early fall in 2010 and probably most years. It was also more pronounced for commercial (metals 3.5 to 4 times higher than average) rather than residential (metals 1.5 to 2.5 times higher) sites. See Table A-3 for an example.
- The most experienced lab closed at the beginning of the 2011 monitoring season. The replacement labs failed to take advantage of the opportunity to adjust sample hardness to match the receiving water.
  - The Port of Seattle's sample may not have been toxic if its hardness had been adjusted.
  - The Port of Tacoma's sample would likely have still been toxic even if hardness was adjusted.
  - The King County samples were also not adjusted.
- Available information is more than adequate to guide stormwater management for many years. These toxicity test results confirm what Ecology already knows about urban sources of copper and zinc. Commerce depends upon transportation and supporting infrastructure. Transportation and infrastructure are major sources of copper and zinc.
- Toxicity testing of stormwater or urban streams should be reintroduced when stormwater controls are well-implemented in order to see if they are missing pollutants or sources.

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[7] See WAC 173-205-020

Table A-2 – Trout Embryo Toxicity Test Results with Sample Handling and Copper (Cu) and Zinc (Zn) Concentrations.

Phase I Permittee	Land Use	Collected	Start Date	Sample Holding Time	Hardness Adjusted?	Test Hardness (ppm)	diss. Cu (µg/L)	diss. Zn (µg/L)	Endpoint	NOEC	LOEC	PMSD	EC50	EC25	% Response
City of Tacoma	Commercial	10/10/2010	10/11/2010	38.7	Yes	100	18.2	51.7	Survival	100	> 100	11.4%	> 100	> 100	87%
									Development	100	> 100	15.2%	> 100	> 100	89%
	Residential	10/10/2010	10/11/2010	38.1	Yes	100	3	19.4	Survival	100	> 100	17.1%	> 100	> 100	83%
									Development	100	> 100	18.6%	> 100	> 100	93%
Clark County	Commercial	8/31/2010	9/2/2010	41.3	Yes	84	22.2	106	Survival	100	> 100	17.4%	> 100	> 100	87%
									Development	100	> 100	52.0%	> 100	> 100	78%
	Low Density Residential	10/24/2010	10/25/2010	36.7	No	44	5.5	9.6	Survival	100	> 100	42.8%	> 100	> 100	89%
									Development	100	> 100	29.0%	> 100	> 100	94%
King County	Commercial	10/11/2011	10/13/2011	59.5	No	29	6.6	14.9	Survival	100	> 100	21.8%	> 100	> 100	76%
									Development	100	> 100	2.1%	> 100	> 100	100%
	High Density Residential	10/11/2011	10/13/2011	59.1	No	12	1.9	2.4	Survival	100	> 100	24.9%	> 100	> 100	92%
									Development	100	> 100	2.8%	> 100	> 100	100%
	Low Density Residential	10/11/2011	10/13/2011	55.5	No	9.4	3.1	4.0	Survival	100	> 100	49.1%	> 100	> 100	75%
									Development	100	> 100	1.8%	> 100	> 100	100%
Pierce County	Low Density Residential	8/23/2011	8/24/2011	26.7	No	56	0.7	< 0.5	Survival	100	> 100	2.7%	> 100	> 100	98%
									Development	100	> 100	13.0%	> 100	> 100	94%
	Commercial	8/23/2011	8/24/2011	25.1	No	44	15.4	134	Survival	100	> 100	2.7%	> 100	> 100	99%
									Development	50	100	9.1%	> 100	> 100	84%
Port of Seattle	Parking Lots & Buildings	9/18/2011	9/21/2011	81.0	No	27	101	171	Survival	25	50	23.0%	47.1	37.8	44%
									Development	100	> 100	11.5%	> 100	> 100	87%
Port of Tacoma	Parking Lots & Buildings	9/18/2011	9/21/2011	80.3	No	15	13.7	767	Survival	12.5	25	32.2%	12.5	9.5	0%
									Development	25	> 25	28.0%	58.0	30.2	NC
City of Seattle	Commercial	8/22/2010	8/23/2010	27.9	No	68	22.6	54	Survival	100	> 100	28.2%	> 100	104.5	75%
									Development	100	> 100	62.6%	> 100	87.1	58%
	Industrial	8/31/2010	9/1/2010	29.4	Yes	96	19.2	125	Survival	100	> 100	6.0%	> 100	> 100	98%
									Development	100	> 100	23.9%	> 100	> 100	89%
	Residential	8/31/2010	9/1/2010	23.6	Yes	76	16	26	Survival	100	> 100	2.4%	> 100	> 100	98%
									Development	100	> 100	13.6%	> 100	> 100	89%
Snohomish County	Commercial	8/8/2010	8/9/2010	40.3	Yes	128	22.4	244	Survival	50	100	12.4%	101.3	84.5	52%
									Development	100	> 100	71.3%	> 100	> 100	57%
	Low Density Residential	8/8/2010	8/9/2010	36.4	Yes	76	6.2	63.5	Survival	100	> 100	2.6%	> 100	> 100	99%
									Development	100	> 100	25.8%	> 100	> 100	84%
	High Density Residential	8/8/2010	8/9/2010	29.3	Yes	92	6.8	22	Survival	100	> 100	5.7%	> 100	> 100	98%
									Development	100	> 100	25.6%	> 100	> 100	84%

Sample had some toxicity based upon EC50 ≤ 100%, EC25 ≤ 100%, LOEC ≤ 100%, or % response ≤ 65%.

PMSD did not meet the power standard of < 40%.

Recommended sample holding time of 36 hours exceeded.

Maximum sample holding time of 72 hours exceeded.

Table A-3 – Dissolved Copper, Zinc, and Lead Stormwater Concentrations over a Year from Tacoma Commercial and Residential Areas.

Tacoma Phase I monitoring as example for seasonal and storm event variability

commercial outfall 235	10/9/2010	10/31/2010	11/9/2010	11/30/2010	12/12/2010	1/21/2011	1/29/2011	2/13/2011	3/5/2011	4/4/2011	4/13/2011	5/2/2011	5/25/2011	8/22/2011	mean	SD	CV
dissolved copper (µg/L)	18.2	8.24	9.84	2.7	5.23	7.64	9.56	5.59	6.35	9.02	18	28.5	20.9	63.3	15.22	15.62	1.03
dissolved zinc (µg/L)	51.7	28.8	37.8	40.4	22.6	28.1	30.8	24.3	27.2	23.6	41	60.3	42.7	153	43.74	33.36	0.76
dissolved lead (µg/L)	16.8	5.32	6.9	0.178	2.66	2.99	2.32	1.03	2.12	3.44	3.72	9.55	6.32	21.3	6.05	6.10	1.01
	normalized to mean (value/mean) to produce a multiplier indicating the degree to which value is less than or exceeds the mean for all samples														min	max	
dissolved copper (µg/L)	1.2	0.5	0.6	0.2	0.3	0.5	0.6	0.4	0.4	0.6	1.2	1.9	1.4	4.2	0.18	4.16	
dissolved zinc (µg/L)	1.2	0.7	0.9	0.9	0.5	0.6	0.7	0.6	0.6	0.5	0.9	1.4	1.0	3.5	0.52	3.50	
dissolved lead (µg/L)	2.8	0.9	1.1	0.03	0.4	0.5	0.4	0.2	0.4	0.6	0.6	1.6	1.0	3.5	0.03	3.52	
mean	1.7	0.7	0.9	0.4	0.4	0.5	0.6	0.4	0.5	0.6	0.9	1.6	1.1	3.7			

residential outfall 237B	10/10/2010	10/31/2010	11/18/2010	12/12/2010	1/21/2011	2/12/2011	3/4/2011	4/4/2011	4/13/2011	4/26/2011	5/15/2011	5/25/2011	8/22/2011	mean	SD	CV
dissolved copper (µg/L)	3	1.76	2.26	3.41	1.81	2.12	2.07	2.1	2.83	3.66	2.39	4.35	8.06	3.06	1.69	0.55
dissolved zinc (µg/L)	19.4	15.1	66.6	12.7	21.2	21.4	13.9	11.3	21.8	12.8	11.9	16.6	36.4	21.62	15.09	0.70
dissolved lead (µg/L)	0.185	0.315	0.287	0.167	0.219	0.297	0.241	0.235	0.324	0.229	0.194	0.308	0.358	0.26	0.06	0.23
	normalized to mean (value/mean) to produce a multiplier indicating the degree to which value is less than or exceeds the mean for all samples													min	max	
dissolved copper (µg/L)	1.0	0.6	0.7	1.1	0.6	0.7	0.7	0.7	0.9	1.2	0.8	1.4	2.6	0.57	2.63	
dissolved zinc (µg/L)	0.9	0.7	3.1	0.6	1.0	1.0	0.6	0.5	1.0	0.6	0.6	0.8	1.7	0.52	3.08	
dissolved lead (µg/L)	0.7	1.2	1.1	0.6	0.8	1.1	0.9	0.9	1.3	0.9	0.8	1.2	1.4	0.65	1.39	
mean	0.9	0.8	1.6	0.8	0.8	0.9	0.8	0.7	1.1	0.9	0.7	1.1	1.9			

Appendix B. Permittees' Quality Assurance Project Plans

Website link to QA Project Plans on file with Ecology
www.ecy.wa.gov/programs/wq/stormwater/municipal/s8dswmonitoring.html

Clark County
Quality Assurance Project Plan for Stormwater Characterization Monitoring. Conducted Under Section S8.D of the Phase I Municipal Stormwater Permit by Clark County. Prepared by U.S. Geological Survey, Oregon Water Science Center. Revised March 2011 by Clark County Department of Environmental Services, Clean Water Program, Vancouver, WA.

King County
Quality Assurance Project Plan for King County Stormwater Monitoring Under the NPDES Phase 1 Municipal Permit WAR04-4501 (Issued February 2007). Updated November 2010. King County Department of Natural Resources and Parks, Water and Land Resources Division, Science Section. King Street Center, KSC-NR-0600, 201 South Jackson Street, Suite 600, Seattle, WA 98104.

Pierce County
Quality Assurance Project Plan for Pierce County Phase I Municipal Stormwater NPDES Permit Section S8.D – Stormwater Characterization. November 5, 2009. Prepared for Pierce County Surface Water Management, 2702 South 42nd Street, Suite 201, Tacoma, WA 98409-7322. Prepared by Herrera Environmental Consultants.

Snohomish County
Quality Assurance Project Plan (QAPP) Stormwater Characterization Monitoring S8.D Final. December 2008. Prepared by Snohomish County Public Works, Surface Water Management Division, 3000 Rockefeller Ave, Everett, WA 98201.

City of Seattle
Section S8.D - Stormwater Characterization Quality Management System Planning Document, Quality Assurance Project Plan. NPDES Phase I Municipal Stormwater Permit, Permit No.: WAR04-4503. Revision: R2D0 (Final). Draft revised: 03/31/2011.

City of Tacoma
Section S8.D - Stormwater Characterization Quality Assurance Project Plan, Phase I Municipal Stormwater NPDES Permit, Permit No.: WAR04-4003. Revision: S8.D-003 (Final). Revision Date: 08/16/2009. City of Tacoma, Tacoma, WA.

Port of Seattle
Quality Assurance Project Plan for Stormwater Monitoring Conducted Under Section S8.D of the Phase I Municipal Stormwater Permit. Addendum #1. November 2011. Port of Seattle Marine Division. Prepared by TEC Inc. and Otak, Inc. for Port of Seattle.

Quality Assurance Project Plan for Stormwater Monitoring Conducted Under Section S8.D of the Phase I Municipal Stormwater Permit. February 20, 2009. Port of Seattle Marine Division. Prepared by TEC Inc. and Otak, Inc. for Port of Seattle.

Port of Tacoma
Quality Assurance Project Plan for Stormwater Monitoring Conducted Under the Phase I Municipal Stormwater Permit by Port of Tacoma. Final August 2009.

Appendix C. Description of the Statistical Plots

This appendix describes each of the six plots created for data analysis. Four parameters are displayed and described for each of the six plot types. The four parameters are fecal coliform bacteria, total phosphorus, total copper, and Dichlobenil (an herbicide). These parameters were selected because they display a variety of discussion elements, considerations for data summaries, and peculiarities encountered in this report. For both the jitter and box plots, the x-axis is categorical and uses the abbreviations defined below:

Land Uses
Ind = Industrial
Com = Commercial
HRes = High-Density Residential
LRes = Low-Density Residential

Sample Result
Det = Count of detected records
ND = Count of non-detected records and the percent non-detected records of the total

Season Type
Winter = Winter Quarter (January, February, March)
Spring = Spring Quarter (April, May, June)
Summer = Summer Quarter (July, August, September)
Fall = Fall Quarter (October, November, December)
DrySeas = Dry Season (May 1 through September 30)
WetSeas = Wet Season (October 1 through April 30)

1. Jitter Plot

Jitter plots offer an excellent visual of the data. The jitter plot (Figure C-1) shows both the detected data as points and the non-detected data as bars extending from zero to provided reporting limit. The bar is useful in conveying the idea that the true value of the non-detect is unknown; only the range for which its true value may occur. The two-toned purple dots are the detected data points, divided into dry and wet seasons.

The jitter plots are divided into four vertical panels. Each panel represents a different land-use type. Within each panel, the x-values are randomized (jittered) to spread the data out and make them easier to view. Land-use types are indicated by abbreviations below the x-axis, along with the number of detects, the number of non-detects, and the percentage of non-detect data.

As seen in the jitter plots, most of the data for fecal coliform, total phosphorus, and dissolved copper were detected values, whereas the majority of the data for Dichlobenil were non-detects as indicated by the gray lines.

The fecal coliform jitter plot shows that the data spans 5 orders of magnitude and includes non-detects.

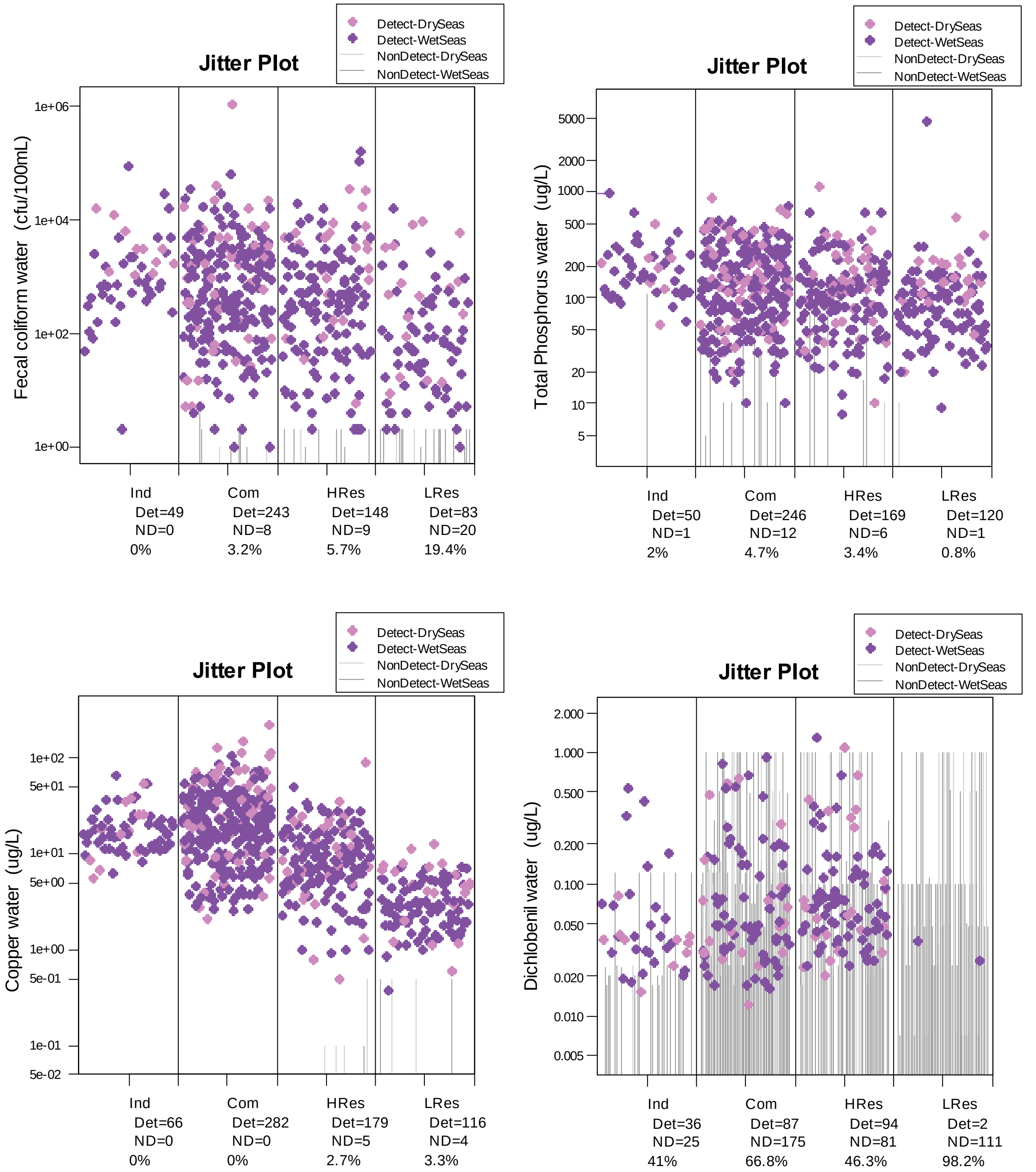


Figure C-1. Jitter plots for four example parameters.

The total phosphorus data range from 0.008 to 4.6 mg/L. There are a number of non-detects at elevated reporting limits. The reason for these elevated non-detects is unknown. This could be due to matrix interference, or this could illustrate a gap in the data QA process (QA) at the laboratory or the data review level. Ecology did not investigate peculiarities such as these for two reasons: (1) The data had already been QA reviewed by the laboratory and the permittees and therefore were useable for summarization into the regional data set, and (2) time was limited under the grant process to investigate a small number of oddities.

The jitter plot for Dichlobenil shows that the bulk of the data were non-detect. Organic contaminants in stormwater were more likely to contain greater percentages of non-detects than conventional parameters, nutrients, or metals. Additionally, non-detects for organics were more likely, as shown for 2,4-D, to have multiple reporting limits for non-detects. The variable reporting limits may be due to the interfering matrices, low sample volumes, or different laboratory QA processes. An inter-laboratory comparison for the analytical methods used under the S8.D monitoring programs in the Puget Sound region has not been investigated, to Ecology's knowledge.

The jitter plot was also used in summarizing the contaminant load data over a gradient of % impervious cover (Figure C-2). Here, Ecology has binned or grouped the results into ranges of % impervious area by 20%. The gray dots are results that are qualified as non-detect, while the blue dots are detected concentrations. The goal of this plot is to show the distribution of contaminant loads across the range of % impervious ground cover. The plot for total copper typifies what one might expect: as the % impervious surface increases, the load of copper increases.

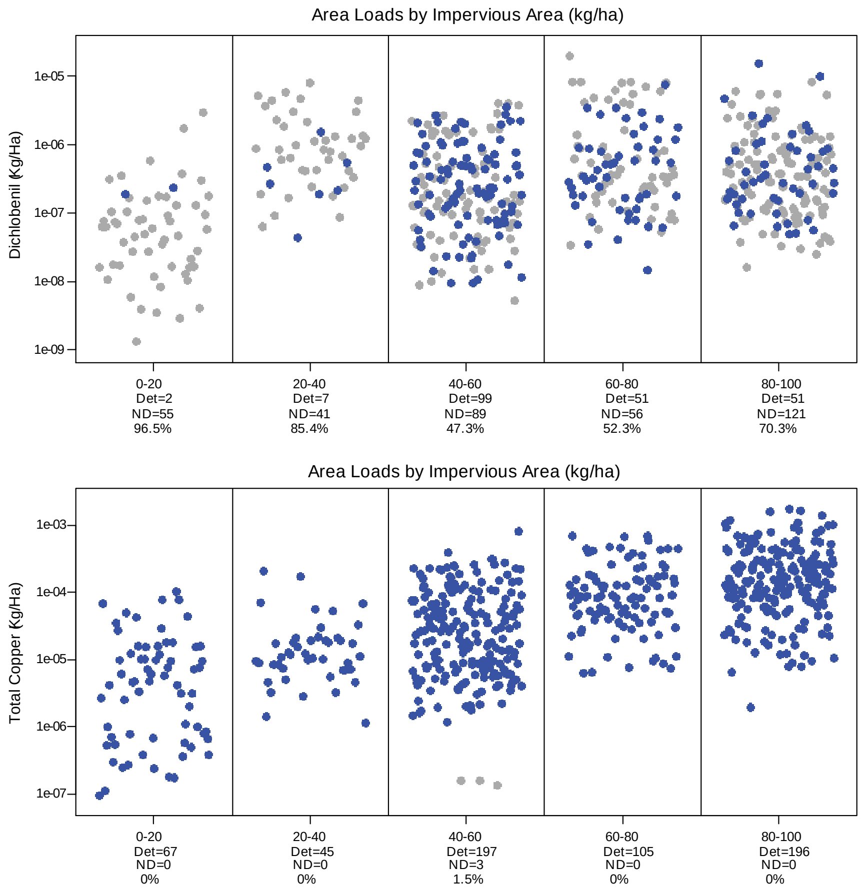


Figure C-2. Jitter plots of contaminant loads for total copper and Dichlobenil.

2. Probability Plots

Some statistical calculations assume that data follow a specific distribution. In these cases, a method is needed to check whether this assumption is valid. For example, stormwater professionals have consistently found that the concentrations of many stormwater parameters follow a log-normal distribution (EPA, 1983; Burton and Pitt, 2002; Maestre et al., 2004, 2005). A log-normal distribution results in a positive bias, meaning the average values are larger than the median values (Pitt, 2011).

Probability plots are used to visually compare a data set to a specified distribution (Helsel, 2012), in this case a log-normal distribution. The distribution is represented on the plot as a straight line, and observed data are plotted as individual points. If the data points fall near the line then they are described as reasonably fitting the log-normal distribution. If the data points show curvature or have a number of points that plot far from the line, then the data are said to differ significantly from the log-normal distribution. Parameters with few or no non-detects were tested for a normal or log-normal distribution using the Shapiro-Wilk test. This was discussed further in the *Methods* section of the report.

For all other parameters, the presence of non-detects must be properly accounted for when creating a probability plot. Although non-detects are not shown on the plot, they affect the placement of the observed data points on a probability plot. A probability plot that ignores non-detected data is invalid according to Helsel (2012). Ecology used the regression on statistic (ROS) approach to generate probability plots for this report. This approach accounts for the proportion of the data below each reporting limit and adjusts the placement of the detected data accordingly.

On these plots, the lower x-axis shows the quantile while the upper x-axis represents the percentiles of the data distribution (Figure C-3). The y-axis shows the concentrations (typically in log scale). The detected data are shown as black dots. The non-detect values are ranked, and the positional range and count of data points associated with the non-detects is taken into consideration, but are not shown on the plot.

These plots use the entire data set and do not divide the data by land use. This is particularly useful in describing stormwater baseline characterization conditions.

In the examples shown in Figure C-3, only total copper appears to “fit” the straight line well over the entire distribution of the data. This is a visual indication that total copper is the only log-normally distributed parameter in this example. The Shapiro-Wilks test indicates the fecal coliform, total phosphorus, and dichlobenil data are distribution-free.

Probability plots accurately present the median, as well as other percentiles presented on the upper x-axis of the entire data set. For example, the median values for fecal coliform, total phosphorus, and total copper appear to fall at the middle point of the detected data. This makes sense, since Figure C-1 showed that the majority of their data were made up of detected records.

On the other hand, the median for Dichlobenil is near the lower limit of much of the detected data. This also is logical, because in Figure C-1 76% of the 2,4-D data points were non-detect. Therefore, in Figure C-3 the median value falls in the area of the plot where there are few to no data points showing.

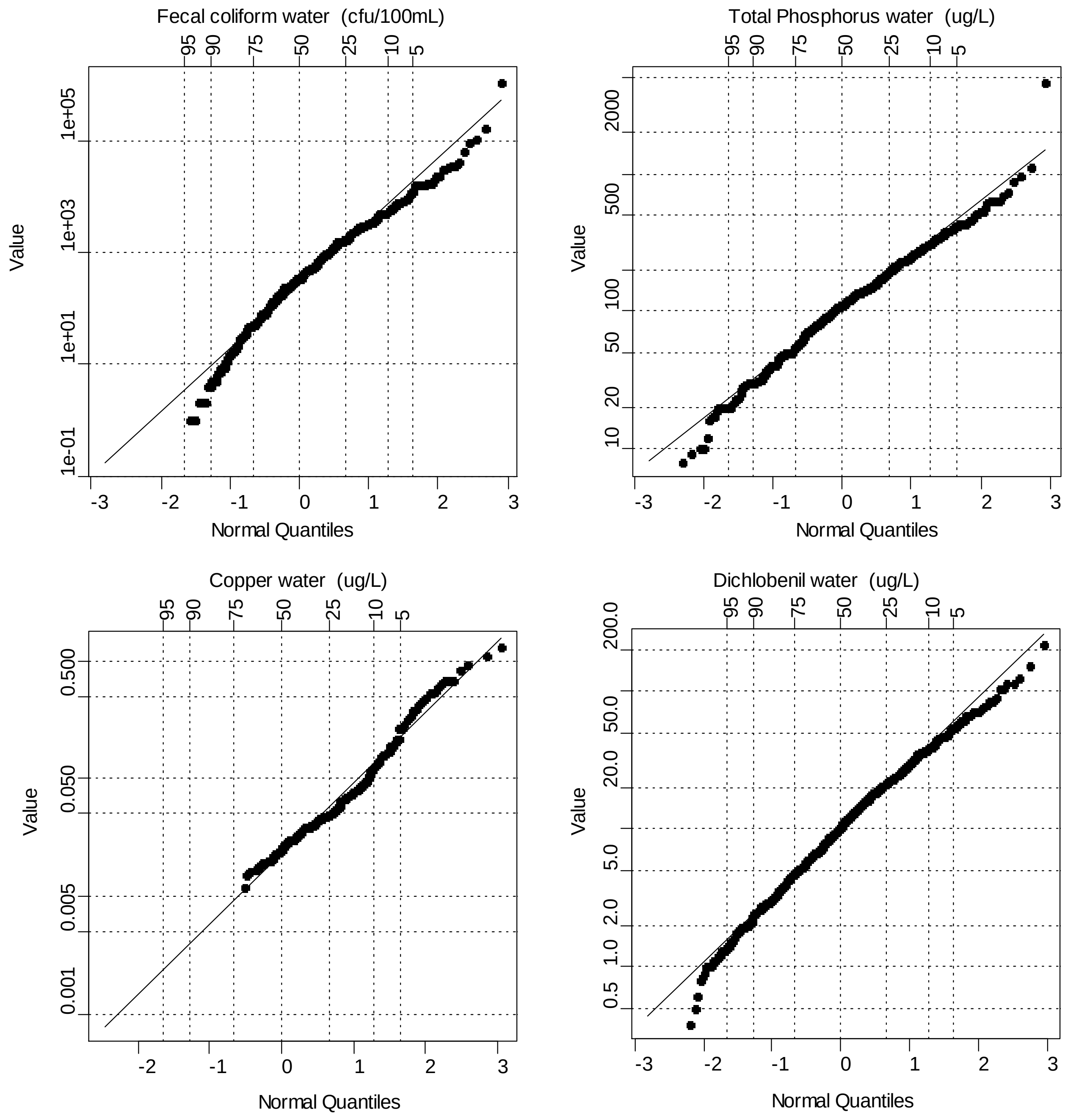


Figure C-3. Probability plots for four example parameters.

3. Plots of Non-Detects

To understand differences in laboratory reporting levels, Ecology plotted non-detect thresholds reported by the permittees. Non-detect data are shown in these plots as line segments extending from zero to the laboratory reporting level. The color of the line segment indicates which laboratory performed the analysis. Laboratory names were removed and represented by a number. The focus of this plot is not to identify permittees or their laboratories, but rather to illustrate the number of laboratories and the numerous reporting limits reported.

Within each plot, the non-detect data are spaced evenly and sorted from lowest to highest reporting level. Plots with few points show the lines distinctly, whereas plots with a large number of data points show no spaces between the lines. Examples are shown in Figure C-4.

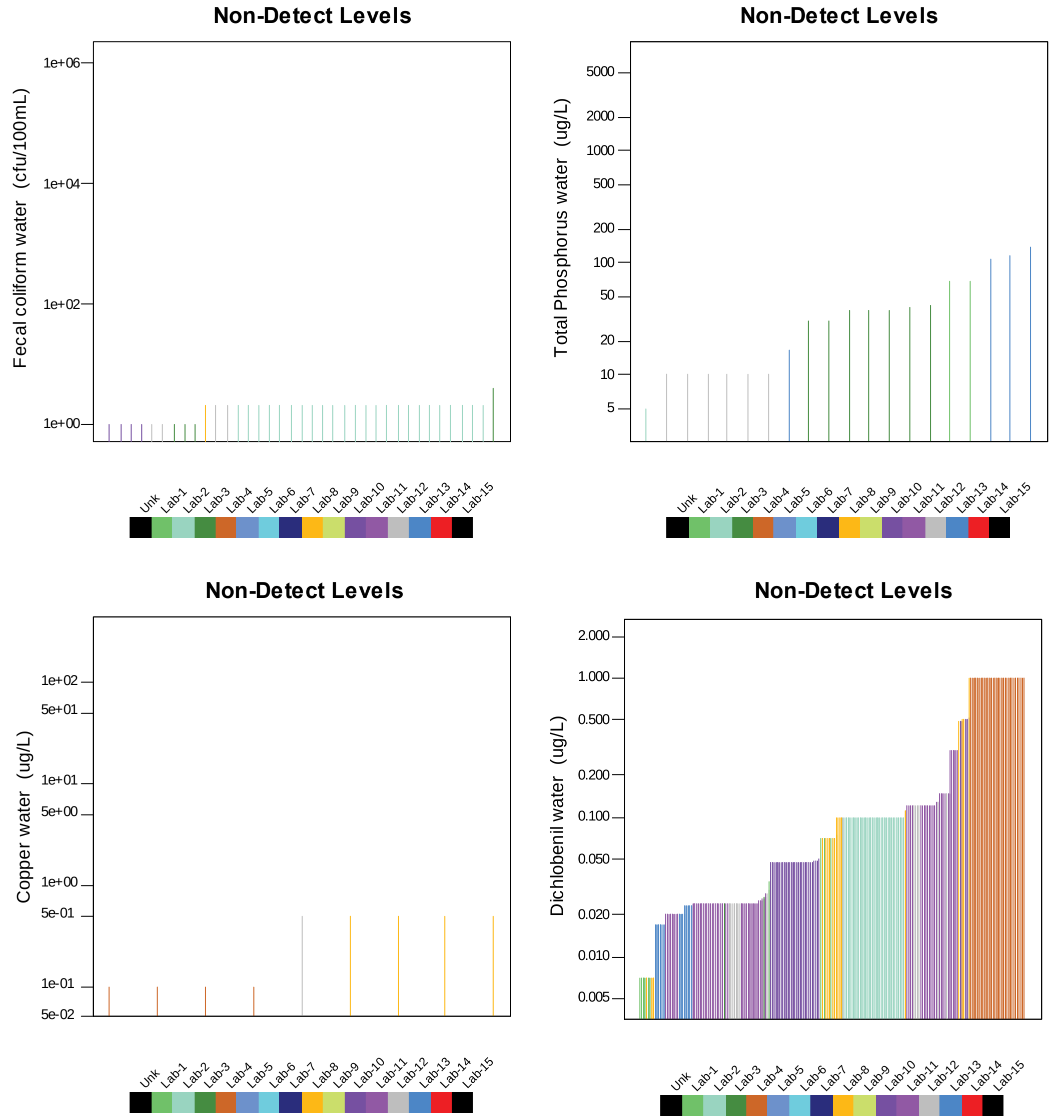


Figure C-4. Non-detect plots for four example parameters.

These examples illustrate both the frequency a parameter was not detected and the variability in the reporting limit threshold for the non-detect data. Recall that variability comes from different samples' matrices, sampling dates, handling techniques, and laboratories. The parameter data in Appendix F did not contain this plot if there were no non-detect data.

4. Empirical Distribution Function (EDF)

These plots (Figure C-5) help identify differences in concentrations among the four land-use types. EDF plots of the observed data are constructed by ranking the data from smallest to largest (Helsel, 2012). EDF plots are also known as the Kaplan-Meier (KM) Curves. The graph shows the likelihood of any given sample concentration to occur in the population of the data set by percentiles. Line type and color indicates land use, as shown in the plot legend.

On these plots, Ecology swapped axes from the usual convention in order to allow comparison with the jitter plots and box plots. Only the detect values are actually plotted, but their positions are influenced by both detections and non-detections. This is a preferred method to display data sets that contain non-detects, as opposed to the traditional box and whisker plots that use only detected values. EDF plots were not shown if there were less than five detected values for any given parameter, and in this case, the data plots (Appendix F) will show the message: "Not Plotted (Less than 5 detections)".

These four example parameters begin to illustrate the impact of the surrounding land use on the water quality of stormwater.

In the case of fecal coliform, the EDF curve for industrial is similar to commercial but quite different from low-density residential. A vertical dashed line was placed on the fecal coliform plot to illustrate where the median value (50%) occurs by land use. A horizontal dashed line was placed to show that fecal concentrations of 100 cfu/100 mL or higher occur approximately >95% of the time for the industrial land use, > 75% for commercial, > 65% for high-density residential, and > 40% of the time for low-density land use.

For total phosphorus, there is less difference observed among the four land-use types.

For Dichlobenil, the EDF for high-density residential shows both a higher proportion of detections and consistently higher concentrations. The data for low-density residential land use reflects the large number of non-detects (98%) and low concentrations in the detected samples. When many non-detects occur at the same reporting level, this shows up in the EDF plot as a long horizontal line segment.

EDF plots were also created for each parameter load as kg ha^{-1}. These are part of the plot summaries for the loading per unit area in Appendix H. Data qualifiers associated with the parameter concentrations were incorporated into the Kaplan-Meier analysis with the load value.

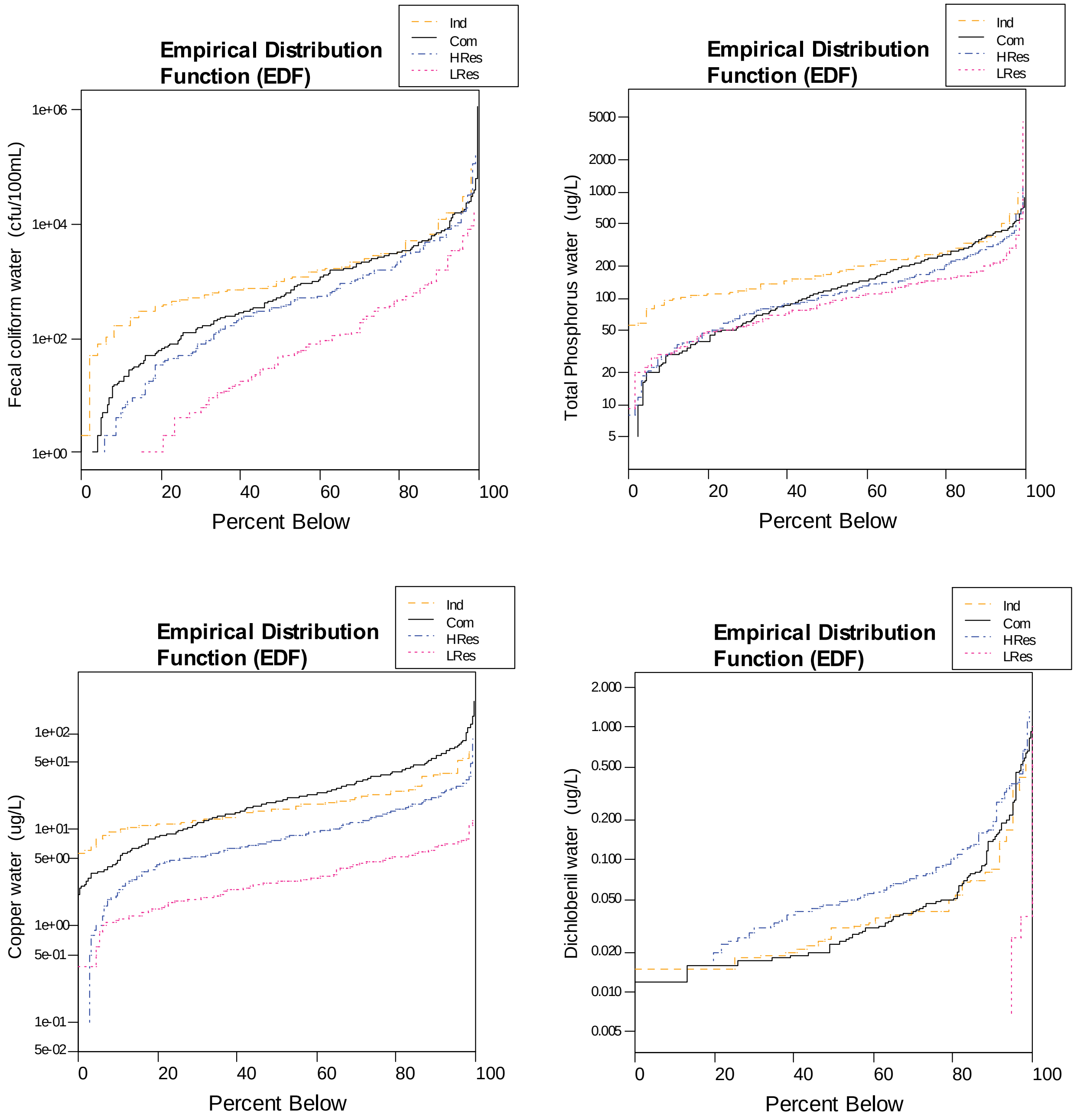


Figure C-5. EDF plots based on KM for four example parameters.

5. Box Plot by Land Use

Standard box and whisker plots were created to compare concentrations between land-use types (Figure C-6). This type of box plot is described in Helsel and Hirsch (2002). The box extends from the 25th to the 75th percentile and is split with a heavy line at the 50th percentile. Whiskers extend to the last observation within 1.5 times of the box height (prior to log transformation). Observations beyond this are shown as individual hollow circles. Thus, half of the data should fall within the box, a quarter of the data should lie above the box, and a quarter of the data should lie below the box. The box plots were created using the entire data set and make no distinction between detected and non-detected values. That is, all data values were included as if they were detections.

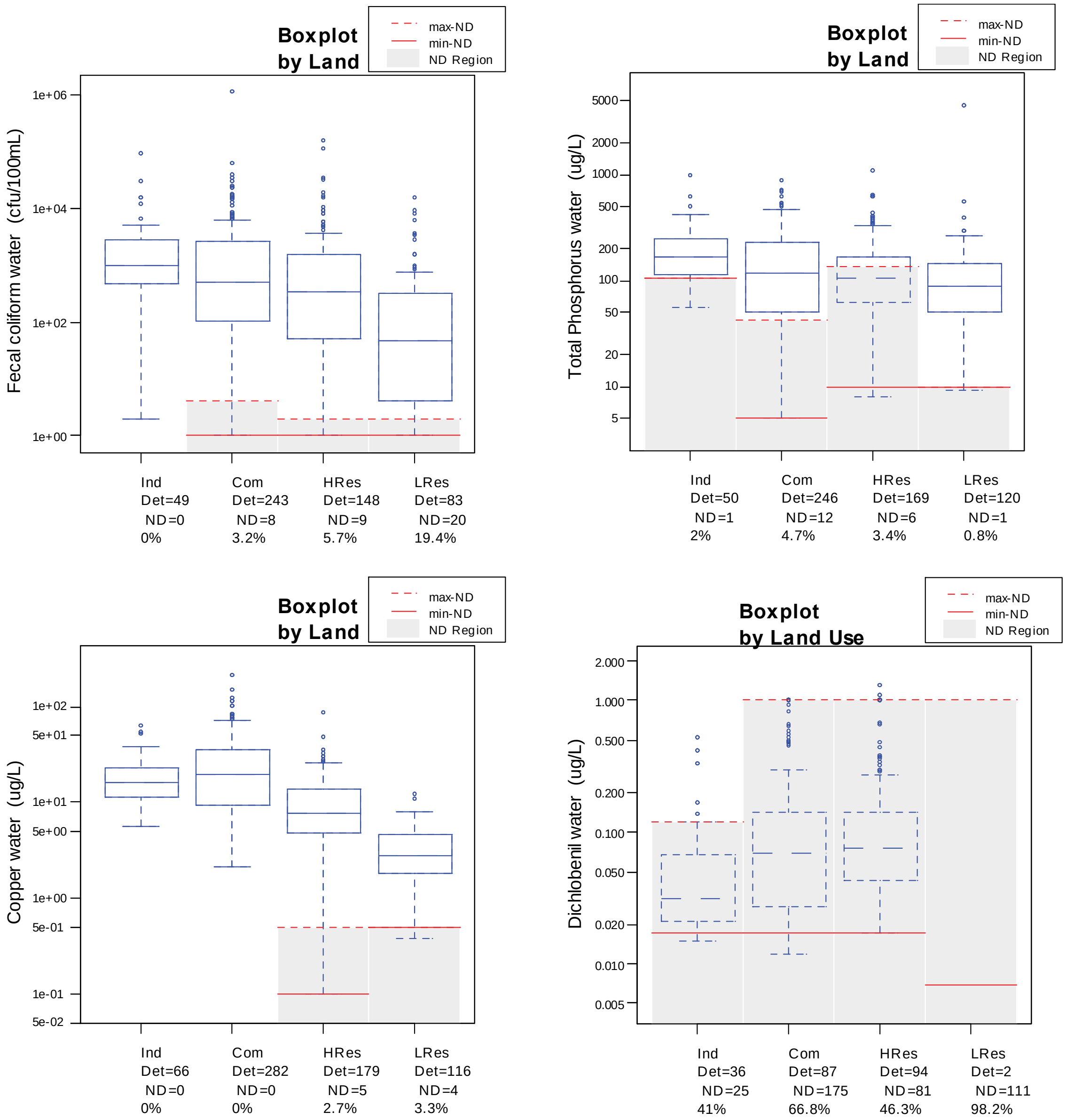


Figure C-6. Box and whisker plots of the detected data by land use for four example parameters.

As discussed in Helsel (2012), only the portions of the box plot which lie above the maximum non-detect limit are known exactly. To illustrate the region where the non-detected thresholds would influence the box plots, the visual of a gray "curtain" is used to represent the range of non-detects, as if it were pulled up over the box plot to illustrate where uncertainty still remains in the data set. The box outline is dashed under the gray curtain to reflect this uncertainty. Red horizontal lines also indicate the maximum and minimum non-detect thresholds.

Helsel (2012) recommends calculating the portion of the box plot using either KM or ROS statistics to estimate the 25th-50th-75th percentiles. This was not done for this report, so very little weight should be given to portions of the box plot in the shaded region. In some cases, the shaded region may be caused by only one or two non-detects. In these cases, the box plot may be only slightly affected. Each case must be assessed individually.

Similar to EDF plots (Figure C-5), box plots (C-6) illustrate how the surrounding land uses impact water quality of stormwater. In the case of fecal coliform, the box (25th and 75th) and median values (line) for industrial is quite different than the box for low-density residential. Visually the reader can see that the open circles range up to almost the same values, despite the land use categories. Box plots by land use were not calculated if there were less than 5 detected values for any given parameter. Data plots (Appendix E) will show the message: "Not Plotted (No land use has 5 or more detections)".

The box plot graphs and the EDF plots show similar patterns for fecal coliform and total phosphorus, with industrial and commercial areas showing higher concentrations than the residential land uses. If a parameter was detected in all samples or had relatively few non-detects, then the EDF and box plots will show the same information. For parameters where non-detects account for a larger percentages of the data set, the box plot is not presenting the same information as the EDFs. This means that the box plots are misleading for data sets that comprise medium to large percentages of non-detect data, as is the case for Dichlobenil and many of the organic parameters monitored.

Box plots were also used to summarize the contaminant loads by mass (kg) and area (kg ha^{-1}) over the land-use categories. The same approach and tools were used to construct the box plots for the load data, including the non-detect "curtain" which was calculated using the data qualifiers from the concentration data.

6. Box Plot by Season

These box and whisker plots (Figure C-7) are identical to the box plots by land use (Figure C-6), except that they are broken up by season. Seasons are as follows: Winter was Jan-Mar, spring was Apr-Jun, summer was July-Sept, and fall was Oct-Dec.

Box plots by season were not calculated if there were less than 5 detected values for any given parameter. Data plots (Appendix D) will show the message: "Not Plotted (No season has 5 or more detections)".

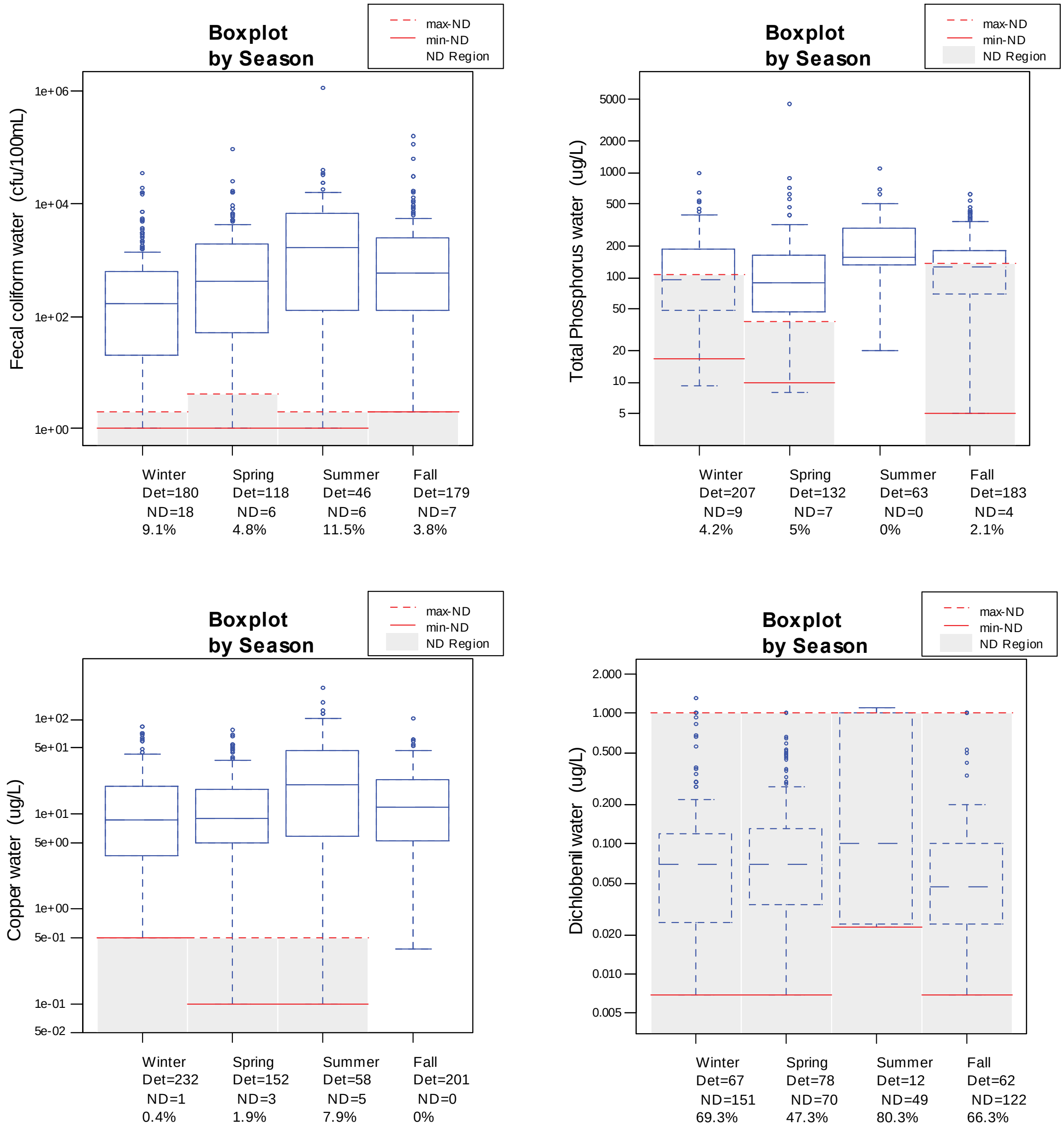


Figure C-7. Box and whisker plots of the detected data by season for four example parameters.

Statistical tests were carried out for the contaminant data on whether there was a significant difference between dry and wet seasons. The *dry* season is the months of May and June and the summer season in the box plot, and the *wet* season is the rest of the year. There is therefore more detailed information on seasonal differences shown in the box plot than described by the simple Wilcoxon test for significant differences. The observation that many of the parameters have higher concentrations during the dry season can be seen by the position of the summer median values for each of the example parameters (Figure C-7). However, this observation becomes more uncertain for the Dichlobenil data. Indeed, the Wilcoxon test describes the wet and dry season as being not significantly different.

Seasonal differences in storm-event contaminant loads (kg ha^{-1}) are also summarized using the box plots (Appendix H).

Case C Parameter – Data Sheet

In the data plots, many of the graphs are not shown, and the message “Not Plotted (Case C)” is given. Figure C-8 gives an example data sheet for a Case C parameter, triclopyr.

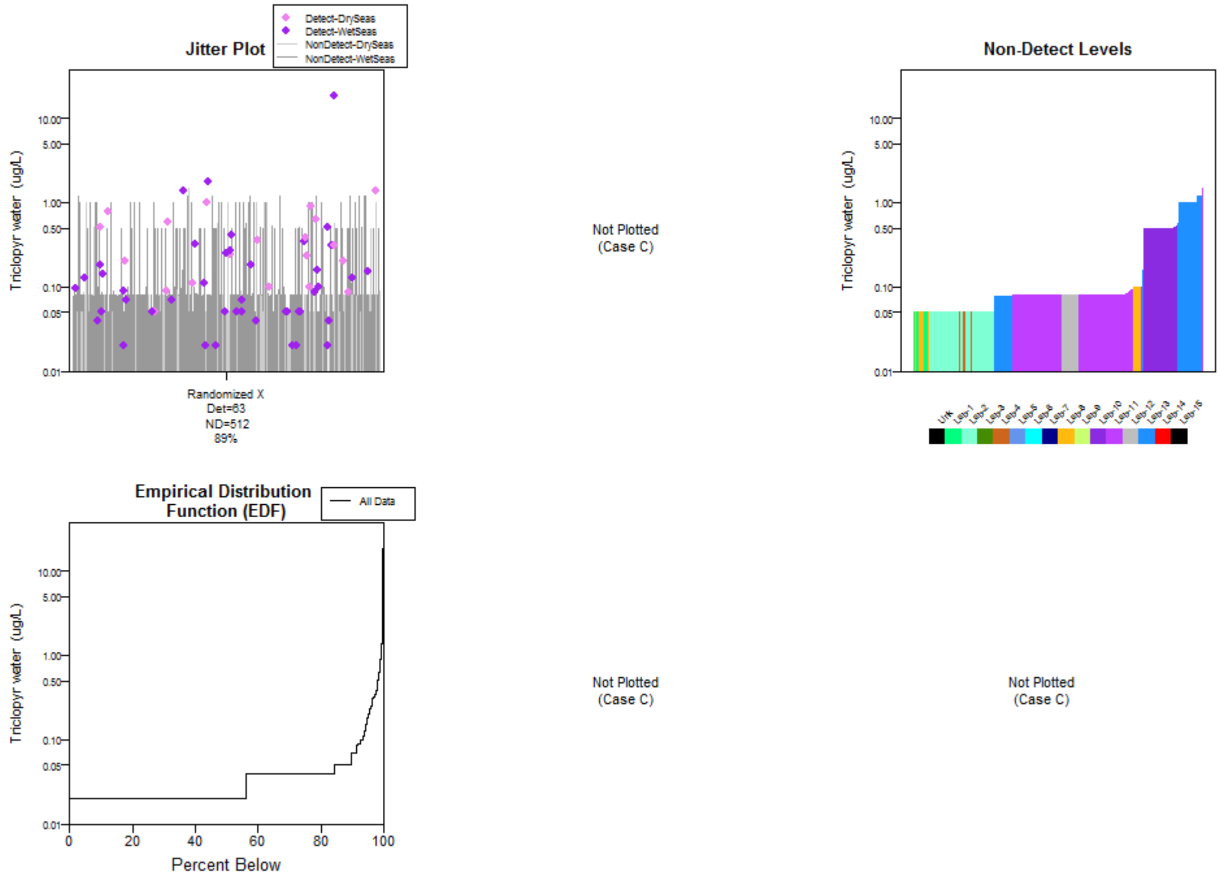


Figure C-8. Six plots for the parameter, triclopyr, in stormwater.

Triclopyr is an herbicide typically used in weed control. The previous *PS Toxics Study* found detectable concentrations in ~ 50% of the samples from commercial, industrial, and residential land uses, which was not the case in this stormwater study. It is soluble in water and breaks down fairly rapidly. Data sets that contain a large frequency of non-detects, such as for triclopyr, do not have enough detected values to warrant further analysis. The three plots that give the most information about the non-detections are retained. The jitter plot shows that there were 63 detected concentrations and that there were 512 non-detects. The plot of non-detect thresholds shows that many reporting limits were reported. The EDF plot shows that >90% of data was non-detect, and when detections were made, they varied from 0.1 to 18.3 ug/L.

Appendix D. Tables for Database Description

Table D-1. Distribution results for parameters with detection rates >95%.

Water	Sediment
Log-normal	***Normal***
1-Methylnaphthalene water (ug/L)	Dimethyl phthalate solid/sediment (ug/Kg)
Ammonia water (ug/L)	Heavy Fuel Oil solid/sediment (ug/Kg)
Butyl benzyl phthalate water (ug/L)	Total Benzofluoranthenes solid/sediment (ug/Kg)
Copper water (ug/L)	
Di-N-Octyl Phthalate water (ug/L)	***Log-normal***
Diesel Fuel water (ug/L)	1-Methylnaphthalene solid/sediment (ug/Kg)
Heavy Fuel Oil water (ug/L)	2-Methylnaphthalene solid/sediment (ug/Kg)
Lube Oil water (ug/L)	Acenaphthylene solid/sediment (ug/Kg)
Motor Oil water (ug/L)	Butyl benzyl phthalate solid/sediment (ug/Kg)
PCB-aroclor 1254 water (ug/L)	Di-N-Octyl Phthalate solid/sediment (ug/Kg)
Pentachlorophenol water (ug/L)	Dibutyl phthalate solid/sediment (ug/Kg)
Precipitation water (in)	Diesel Fuel solid/sediment (ug/Kg)
Prometon water (ug/L)	Fines solid/sediment (%)
Total PCB water (ug/L)	p-Cresol solid/sediment (ug/Kg)
Total Phthalate water (ug/L)	PCB-aroclor 1254 solid/sediment (ug/Kg)
Total TPHDx water (ug/L)	Pentachlorophenol solid/sediment (ug/Kg)
Turbidity water (NTU)	Phenol solid/sediment (ug/Kg)
Zinc water (ug/L)	Total PCB solid/sediment (ug/Kg)
	Total Phthalate solid/sediment (ug/Kg)
Non-parametric	Total TPHDx solid/sediment (ug/Kg)
2-Methylnaphthalene water (ug/L)	
2,4-D water (ug/L)	***Non-parametric***
Acenaphthene water (ug/L)	Acenaphthene solid/sediment (ug/Kg)
Acenaphthylene water (ug/L)	Anthracene solid/sediment (ug/Kg)
Anthracene water (ug/L)	Benz(a)anthracene solid/sediment (ug/Kg)
Arsenic water dissolved (ug/L)	Benzo(a)pyrene solid/sediment (ug/Kg)
Benz(a)anthracene water (ug/L)	Benzo(b)fluoranthene solid/sediment (ug/Kg)
Benzo(a)pyrene water (ug/L)	Benzo(g,h,i)perylene solid/sediment (ug/Kg)
Benzo(b)fluoranthene water (ug/L)	Benzo(k)fluoranthene solid/sediment (ug/Kg)
Benzo(b,k)fluoranthene water (ug/L)	Benzofluoranthenes, Total solid/sediment (ug/Kg)
Benzo(g,h,i)perylene water (ug/L)	Bis(2-ethylhexyl) phthalate solid/sediment (ug/Kg)
Benzo(k)fluoranthene water (ug/L)	Cadmium solid/sediment (ug/Kg)
Benzofluoranthenes, Total water (ug/L)	Chrysene solid/sediment (ug/Kg)
Biochemical Oxygen Demand water (ug/L)	Copper solid/sediment (ug/Kg)
Bis(2-ethylhexyl) phthalate water (ug/L)	CPAH solid/sediment (ug/Kg)
Cadmium water (ug/L)	Dibenzo(a,h)anthracene solid/sediment (ug/Kg)

Water	Sediment
Cadmium water dissolved (ug/L)	Fluoranthene solid/sediment (ug/Kg)
Calcium water (ug/L)	Fluorene solid/sediment (ug/Kg)
Chloride water (ug/L)	HPAH solid/sediment (ug/Kg)
Chrysene water (ug/L)	Gravel solid/sediment (%)
Conductivity water (uS/cm)	HPAH solid/sediment (ug/Kg)
Copper water dissolved (ug/L)	Indeno(1,2,3-cd)pyrene solid/sediment (ug/Kg)
CPAH water (ug/L)	Lead solid/sediment (ug/Kg)
Dibenzo(a,h)anthracene water (ug/L)	LPAH solid/sediment (ug/Kg)
Dibutyl phthalate water (ug/L)	Mercury solid/sediment (ug/Kg)
Dichlobenil water (ug/L)	Motor Oil solid/sediment (ug/Kg)
Diesel Range Organics water (ug/L)	Naphthalene solid/sediment (ug/Kg)
Diethyl phthalate water (ug/L)	Phenanthrene solid/sediment (ug/Kg)
Dimethyl phthalate water (ug/L)	Pyrene solid/sediment (ug/Kg)
Fecal coliform water (cfu/100mL)	Sand solid/sediment (%)
Fluoranthene water (ug/L)	Solids solid/sediment (%)
Fluorene water (ug/L)	Total Organic Carbon solid/sediment (%)
Gasoline Range Organics water (ug/L)	Total PAH solid/sediment (ug/Kg)
Hardness as CaCO3 water (ug/L)	Zinc solid/sediment (ug/Kg)
HPAH water (ug/L)	
Indeno(1,2,3-cd)pyrene water (ug/L)	
Lead water (ug/L)	
Lead water dissolved (ug/L)	
LPAH water (ug/L)	
Magnesium water (ug/L)	
Mecoprop water (ug/L)	
Mercury water (ug/L)	
Mercury water dissolved (ug/L)	
Naphthalene water (ug/L)	
Nitrite-Nitrate water dissolved (ug/L)	
Ortho-phosphate water dissolved (ug/L)	
pH water (pH)	
Phenanthrene water (ug/L)	
Pyrene water (ug/L)	
Sampled-Event Flow Volume water (m3)	
Storm Event Flow Volume water (m3)	
Surfactants water (ug/L)	
Total Benzofluoranthenes water (ug/L)	
Total Kjeldahl Nitrogen water (ug/L)	
Total PAH water (ug/L)	
Total Phosphorus water (ug/L)	
Total Suspended Solids water (ug/L)	
Triclopyr water (ug/L)	
Zinc water dissolved (ug/L)	

Table D-2. Summary of data qualifiers by parameter and matrix.
Those parameters with < 5% detection are highlighted with a gray-shaded box.

Parameter	Matrix	% detection	No qualifier	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
1-Methylnaphthalene	Sediment	40.4%	20	0	0	0	0	1	0	0	0	0	0	29	2	0
1-Methylnaphthalene	Water	**3.8%**	10	0	0	0	0	1	0	0	0	0	0	272	7	0
2-Methylnaphthalene	Sediment	47.4%	28	0	0	0	0	8	0	0	1	0	0	37	4	0
2-Methylnaphthalene	Water	17.2%	62	0	0	0	0	44	2	0	1	0	0	444	78	3
2-Nitrophenol	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	17	6	0
2,4-D	Sediment	8.3%	1	0	0	0	0	0	0	0	0	0	0	8	3	0
2,4-D	Water	16.9%	74	13	0	0	0	15	0	0	0	0	0	458	44	0
2,4-Dichlorophenol	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	18	6	0
2,4-Dimethylphenol	Sediment	7.1%	3	0	0	0	0	0	0	0	0	0	0	35	4	0
2,4,5-Trichlorophenol	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	18	6	0
2,4,6-Trichlorophenol	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	17	6	0
4-Chloro-3-Methylphenol	Sediment	**4.8%**	1	0	0	0	0	0	0	0	0	0	0	17	3	0
4-Nitrophenol	Sediment	**4.8%**	1	0	0	0	0	0	0	0	0	0	0	13	7	0
Acenaphthene	Sediment	54.4%	34	0	0	0	0	9	0	0	0	0	0	34	2	0
Acenaphthene	Water	9.8%	25	0	0	0	0	37	0	0	0	0	0	480	92	0
Acenaphthylene	Sediment	32.9%	24	0	0	0	0	2	0	0	0	0	0	47	6	0
Acenaphthylene	Water	6.5%	11	1	0	0	0	28	0	0	1	0	0	513	80	0
Ammonia	Water	100.0%	71	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthracene	Sediment	73.4%	43	0	0	0	0	12	0	0	3	0	0	20	1	0
Anthracene	Water	11.2%	38	1	0	0	0	26	0	0	6	0	0	484	79	0
Arsenic	Water	100.0%	0	0	0	0	0	1	0	0	15	0	0	0	0	0
Benz(a)anthracene	Sediment	88.4%	53	0	0	0	0	8	0	0	0	0	0	8	0	0
Benz(a)anthracene	Water	34.4%	113	2	0	0	0	58	0	0	3	0	0	288	47	0
Benzene	Water	**0.8%**	1	0	0	0	0	0	0	0	0	0	0	115	4	0
Benzo(a)pyrene	Sediment	82.3%	51	0	0	0	0	14	0	0	0	0	0	13	1	0
Benzo(a)pyrene	Water	28.4%	133	1	0	0	0	41	0	0	4	0	0	379	73	0
Benzo(b)fluoranthene	Sediment	80.0%	25	0	0	0	0	11	0	0	0	0	0	9	0	0
Benzo(b)fluoranthene	Water	30.4%	87	1	0	0	0	21	0	0	0	0	0	198	52	0

Parameter	Matrix	% detection	No qualifier	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Benzo(b,k)fluoranthene	Sediment	100.0%	4	0	0	0	0	5	0	0	0	0	0	0	0	0
Benzo(b,k)fluoranthene	Water	49.2%	35	0	0	0	0	27	0	0	0	0	0	63	1	0
Benzo(g,h,i)perylene	Sediment	88.7%	51	0	0	0	0	12	0	0	0	0	0	8	0	0
Benzo(g,h,i)perylene	Water	40.0%	188	2	0	0	0	60	1	0	2	0	0	313	67	0
Benzo(k)fluoranthene	Sediment	71.1%	23	0	0	0	0	8	0	0	1	0	0	13	0	0
Benzo(k)fluoranthene	Water	24.0%	68	1	0	0	0	14	0	0	3	0	0	210	63	0
Benzofluoranthenes, Total	Sediment	100.0%	34	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzofluoranthenes, Total	Water	45.6%	59	0	0	0	0	4	0	0	5	0	0	79	2	0
Biochemical Oxygen Demand	Water	78.4%	368	14	0	0	0	40	0	0	0	0	0	98	18	0
Bis(2-ethylhexyl) phthalate	Sediment	92.7%	42	0	0	0	0	9	0	0	0	0	0	3	1	0
Bis(2-ethylhexyl) phthalate	Water	61.9%	202	7	0	0	0	175	0	1	0	0	0	154	83	0
BTEX	Water	**2.5%**	3	0	0	0	0	0	0	0	0	0	0	113	4	0
Butyl benzyl phthalate	Sediment	56.1%	24	0	0	0	0	8	0	0	0	0	0	22	3	0
Butyl benzyl phthalate	Water	22.6%	45	3	0	0	0	87	0	0	8	0	0	467	23	0
Cadmium	Sediment	90.0%	56	0	0	0	0	7	0	0	9	0	0	8	0	0
Cadmium	Water	63.0%	431	34	0	0	0	292	0	0	45	0	0	393	79	0
Calcium	Water	100.0%	352	0	0	0	0	3	0	0	0	0	0	0	0	0
Chloride	Water	98.0%	502	21	0	0	0	16	0	0	1	0	0	11	0	0
Chlorpyrifos	Sediment	**1.9%**	0	0	0	0	0	1	0	0	0	0	0	45	7	0
Chlorpyrifos	Water	**0.2%**	1	0	0	0	0	0	0	0	0	0	0	577	65	1
Chrysene	Sediment	92.4%	56	0	0	0	0	17	0	0	0	0	0	6	0	0
Chrysene	Water	45.9%	230	2	0	0	0	57	0	0	2	0	0	288	55	0
Conductivity	Water	99.8%	585	21	0	0	1	29	0	0	0	0	0	1	0	0
Copper	Sediment	100.0%	72	0	0	0	0	6	0	0	0	0	0	0	0	0
Copper	Water	97.9%	871	30	0	0	1	285	0	0	41	0	0	15	11	0
CPAH	Sediment	93.9%	46	0	0	0	0	31	0	0	0	0	0	5	0	0
CPAH	Water	51.3%	187	0	0	0	0	143	0	0	0	0	0	272	41	0
Di-N-Octyl Phthalate	Sediment	28.6%	12	0	0	0	0	4	0	0	0	0	0	35	5	0
Di-N-Octyl Phthalate	Water	11.2%	41	3	0	0	0	25	0	1	1	0	0	502	59	0
Diazinon	Sediment	**1.9%**	0	0	0	0	0	1	0	0	0	0	0	46	5	0
Diazinon	Water	**0.9%**	3	0	0	0	0	3	0	0	0	0	0	573	64	1

Parameter	Matrix	% detection	No qualifier	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Dibenzo(a,h)anthracene	Sediment	73.4%	45	0	0	0	0	10	0	0	2	1	0	18	3	0
Dibenzo(a,h)anthracene	Water	13.9%	63	0	0	0	0	19	0	0	6	0	0	457	89	0
Dibutyl phthalate	Sediment	28.1%	9	0	0	0	0	6	0	0	1	0	0	35	6	0
Dibutyl phthalate	Water	31.8%	39	3	0	0	0	149	0	0	10	0	0	393	39	0
Dichlobenil	Sediment	40.0%	5	0	0	0	0	1	0	0	0	0	0	7	2	0
Dichlobenil	Water	35.8%	110	2	0	0	0	107	0	0	0	0	0	343	48	1
Diesel Fuel	Sediment	100.0%	22	0	0	0	0	0	0	0	0	0	0	0	0	0
Diesel Fuel	Water	46.8%	35	0	0	0	0	1	0	0	0	0	0	41	0	0
Diesel Range Organics	Sediment	75.0%	9	0	0	0	0	0	0	0	0	0	0	3	0	0
Diesel Range Organics	Water	57.5%	186	1	0	0	0	92	0	0	0	0	1	205	2	0
Diethyl phthalate	Sediment	5.4%	1	0	0	0	0	2	0	0	0	0	0	47	6	0
Diethyl phthalate	Water	30.6%	85	1	0	0	0	104	0	1	3	0	0	409	31	0
Dimethyl phthalate	Sediment	19.6%	4	0	0	0	0	7	0	0	0	0	0	39	6	0
Dimethyl phthalate	Water	14.8%	22	3	0	0	0	60	0	0	9	0	0	511	29	0
Ethylbenzene	Water	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	116	4	0
Fecal coliform	Water	93.4%	470	3	1	2	0	47	0	0	0	0	0	34	3	0
Fines	Sediment	100.0%	72	0	0	0	0	1	0	0	0	0	0	0	0	0
Fluoranthene	Sediment	93.7%	66	0	0	0	0	8	0	0	0	0	0	5	0	0
Fluoranthene	Water	59.1%	314	3	0	0	0	55	0	0	2	0	0	216	43	0
Fluorene	Sediment	59.0%	38	0	0	0	0	7	0	0	1	0	0	31	1	0
Fluorene	Water	12.6%	34	0	0	0	0	43	0	0	3	0	0	475	79	0
Gasoline Range Organics	Water	10.4%	4	0	0	0	0	47	0	0	0	0	0	374	66	0
Gravel	Sediment	93.2%	66	0	0	0	0	2	0	0	0	0	0	5	0	0
Hardness as CaCO3	Water	99.7%	611	21	0	0	1	7	0	0	0	0	0	2	0	0
Heavy Fuel Oil	Sediment	100.0%	12	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Fuel Oil	Water	78.5%	136	1	0	0	0	95	0	0	0	0	2	60	4	0
HPAH	Sediment	96.7%	66	0	0	0	0	21	0	0	0	0	0	3	0	0
HPAH	Water	67.3%	259	0	0	0	0	173	0	0	0	0	0	188	22	0
Indeno(1,2,3-cd)pyrene	Sediment	86.1%	55	0	0	0	0	12	0	0	1	0	0	10	1	0
Indeno(1,2,3-cd)pyrene	Water	28.7%	132	1	0	0	0	43	0	0	6	0	0	374	78	0
Lead	Sediment	97.5%	62	0	0	0	0	16	0	0	0	0	0	2	0	0

Parameter	Matrix	% detection	No qualifier	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Lead	Water	89.9%	936	41	0	0	0	104	0	0	57	0	0	101	27	0
LPAH	Sediment	94.2%	58	0	0	0	0	23	0	0	0	0	0	5	0	0
LPAH	Water	61.0%	220	0	0	0	0	172	0	0	0	0	0	219	32	0
Lube Oil	Water	41.6%	37	0	0	0	0	0	0	0	0	0	0	52	0	0
Magnesium	Water	100.0%	353	0	0	0	0	2	0	0	0	0	0	0	0	0
Malathion	Sediment	**1.9%**	0	0	0	0	0	1	0	0	0	0	0	44	8	0
Malathion	Water	**1.1%**	4	0	0	0	0	3	0	0	0	0	0	569	66	1
Mecoprop	Sediment	8.3%	0	0	0	0	0	1	0	0	0	0	0	9	2	0
Mecoprop	Water	10.4%	41	7	0	0	0	16	0	0	0	0	0	498	54	0
Mercury	Sediment	82.4%	42	0	0	0	0	10	0	0	4	0	0	12	0	0
Mercury	Water	15.8%	121	0	0	0	0	19	0	0	2	0	0	672	85	0
Motor Oil	Sediment	100.0%	22	0	0	0	0	0	0	0	0	0	0	0	0	0
Motor Oil	Water	81.9%	84	0	0	0	0	2	0	0	0	0	0	19	0	0
Naphthalene	Sediment	59.5%	36	0	0	0	0	9	0	0	2	0	0	29	3	0
Naphthalene	Water	37.1%	126	0	0	0	0	91	0	0	16	0	0	339	54	2
Nitrite-Nitrate	Water	96.1%	455	13	0	0	0	87	0	0	6	0	0	23	0	0
o-Cresol	Sediment	18.6%	7	0	0	0	0	1	0	0	0	0	0	32	3	0
Oil and grease	Water	5.7%	2	0	0	0	0	0	0	0	0	0	0	33	0	0
Ortho-phosphate	Water	92.2%	400	14	0	0	0	130	0	0	0	0	0	44	2	0
p-Cresol	Sediment	76.7%	27	0	0	0	0	5	0	0	1	0	0	9	1	0
p-Cresol	Water	7.7%	2	0	0	0	0	0	0	0	0	0	0	24	0	0
PCB-aroclor 1016	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	32	1	0
PCB-aroclor 1016	Water	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	27	0	0
PCB-aroclor 1221	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	32	1	0
PCB-aroclor 1221	Water	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	27	0	0
PCB-aroclor 1232	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	32	1	0
PCB-aroclor 1232	Water	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	27	0	0
PCB-aroclor 1242	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	32	1	0
PCB-aroclor 1242	Water	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	27	0	0
PCB-aroclor 1248	Sediment	6.1%	2	0	0	0	0	0	0	0	0	0	0	30	1	0
PCB-aroclor 1248	Water	**3.7%**	1	0	0	0	0	0	0	0	0	0	0	26	0	0

Parameter	**Matrix**	**% detection**	**No qualifier**	**C**	**E**	**G**	**j**	**J**	**JG**	**JL**	**JT**	**JTL**	**L**	**U**	**UJ**	**UJG**
PCB-aroclor 1254	Sediment	45.5%	12	0	0	0	0	2	0	0	1	0	0	17	1	0
PCB-aroclor 1254	Water	51.9%	14	0	0	0	0	0	0	0	0	0	0	12	1	0
PCB-aroclor 1260	Sediment	27.3%	5	0	0	0	0	4	0	0	0	0	0	23	1	0
PCB-aroclor 1260	Water	25.9%	6	0	0	0	0	1	0	0	0	0	0	20	0	0
Pentachlorophenol	Sediment	24.7%	15	0	0	0	0	4	0	0	0	0	0	55	3	0
Pentachlorophenol	Water	25.4%	109	8	0	0	0	31	0	0	2	0	0	408	33	0
pH	Water	100.0%	221	0	0	0	0	3	0	0	0	0	0	0	0	0
Phenanthrene	Sediment	93.6%	63	0	0	0	0	10	0	0	0	0	0	5	0	0
Phenanthrene	Water	51.8%	276	1	0	0	0	48	0	0	3	0	0	258	47	0
Phenol	Sediment	42.9%	17	0	0	0	0	4	0	0	0	0	0	27	1	0
Phenol	Water	30.8%	7	0	0	0	0	0	0	0	1	0	0	18	0	0
Precipitation	Water	100.0%	592	3	0	0	0	0	0	0	0	0	0	0	0	0
Prometon	Sediment	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	12	3	0
Prometon	Water	**3.6%**	10	1	0	0	0	10	0	0	1	0	0	505	78	2
Pyrene	Sediment	94.9%	64	0	0	0	0	11	0	0	0	0	0	4	0	0
Pyrene	Water	63.3%	335	2	0	0	0	61	0	0	3	0	0	199	33	0
Sampled-Event Flow Volume	Water	100.0%	574	26	0	0	0	0	0	0	0	0	0	0	0	0
Sand	Sediment	100.0%	72	0	0	0	0	1	0	0	0	0	0	0	0	0
Solids	Sediment	100.0%	79	0	0	0	0	3	0	0	0	0	0	0	0	0
Storm Event Flow Volume	Water	100.0%	626	1	0	0	0	0	0	0	0	0	0	0	0	0
Surfactants	Water	63.4%	335	10	0	0	0	40	0	0	0	0	0	173	49	0
Toluene	Water	**2.5%**	3	0	0	0	0	0	0	0	0	0	0	113	4	0
Total Benzofluoranthenes	Sediment	88.5%	51	0	0	0	0	18	0	0	0	0	0	9	0	0
Total Benzofluoranthenes	Water	37.8%	180	0	0	0	0	63	0	0	0	0	0	341	59	0
Total Kjeldahl Nitrogen	Water	89.6%	353	21	0	0	0	149	0	0	1	0	0	58	3	0
Total Organic Carbon	Sediment	100.0%	78	0	0	0	0	2	0	0	0	0	0	0	0	0
Total PAH	Sediment	98.8%	61	0	0	0	0	24	0	0	0	0	0	1	0	0
Total PAH	Water	72.9%	264	0	0	0	0	205	0	0	0	0	0	158	16	0
Total PCB	Sediment	51.5%	11	0	0	0	0	6	0	0	0	0	0	15	1	0
Total PCB	Water	55.6%	14	0	0	0	0	1	0	0	0	0	0	12	0	0
Total Phosphorus	Sediment	100.0%	3	0	0	0	0	0	0	0	0	0	0	0	0	0

Parameter	Matrix	% detection	No qualifier	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Total Phosphorus	Water	96.7%	495	15	0	0	0	73	0	0	2	0	0	16	4	0
Total Phthalate	Sediment	88.1%	46	0	0	0	0	13	0	0	0	0	0	6	2	0
Total Phthalate	Water	76.8%	220	0	0	0	0	274	0	0	0	0	0	143	6	0
Total Suspended Solids	Water	99.4%	578	21	0	0	1	21	0	0	0	0	0	3	1	0
Total TPHDx	Sediment	100.0%	38	0	0	0	0	0	0	0	0	0	0	0	0	0
Total TPHDx	Water	72.7%	309	0	0	0	0	112	0	0	0	0	0	158	0	0
Total Xylenes	Water	**0.8%**	1	0	0	0	0	0	0	0	0	0	0	115	4	0
TPHGx	Water	**2.9%**	1	0	0	0	0	0	0	0	0	0	0	34	0	0
Triclopyr	Sediment	8.3%	1	0	0	0	0	0	0	0	0	0	0	8	3	0
Triclopyr	Water	11.0%	32	6	0	0	0	25	0	0	0	0	0	461	50	1
Turbidity	Water	100.0%	462	21	0	0	0	65	0	0	0	0	0	0	0	0
Zinc	Sediment	100.0%	61	0	0	0	0	19	0	0	0	0	0	0	0	0
Zinc	Water	98.2%	901	42	0	0	1	264	0	0	8	0	0	15	7	0

C = This flag applies to pesticide and PCB Aroclor results when the identification has been confirmed by GC/MS.

E = Reported result is an estimate because it exceeds the calibration range.

G = Expected/scheduled analyses could not be performed.

j or J = Analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

L = Off-scale high. Actual value is known to be greater than value given. To be used when the concentration of the analyte is above the acceptable level for quantitation (exceeds the linear range or highest calibration standard) and the calibration curve is known to exhibit a negative deflection.

T = Value reported is less than the laboratory method detection limit. The value is reported for informational purposes only and shall not be used in statistical analysis.

U = Analyte was not detected at or above the reported sample quantitation limit.

UJ = Analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.

Multiple qualifiers may apply (e.g. JT).

Table D-3. Summary of data qualifiers by parameter and land use.
Those parameters with < 5% detection are highlighted with a gray-shaded box.

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
1-Methylnaphthalene	COM	**3.2%**	5	0	0	0	0	0	0	0	0	0	0	146	4	0
1-Methylnaphthalene	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	60	1	0
1-Methylnaphthalene	IND	18.8%	5	0	0	0	0	1	0	0	0	0	0	24	2	0
1-Methylnaphthalene	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	42	0	0
2-Methylnaphthalene	COM	20.9%	31	0	0	0	0	25	1	0	1	0	0	197	23	0
2-Methylnaphthalene	HDR	15.0%	17	0	0	0	0	9	1	0	0	0	0	123	28	2
2-Methylnaphthalene	IND	37.5%	14	0	0	0	0	10	0	0	0	0	0	35	5	0
2-Methylnaphthalene	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	89	22	1
2,4-D	COM	12.3%	24	4	0	0	0	4	0	0	0	0	0	208	20	0
2,4-D	HDR	33.7%	40	8	0	0	0	9	0	0	0	0	0	108	4	0
2,4-D	IND	**3.6%**	2	0	0	0	0	0	0	0	0	0	0	50	3	0
2,4-D	LDR	9.2%	8	1	0	0	0	2	0	0	0	0	0	92	17	0
Acenaphthene	COM	11.9%	16	0	0	0	0	17	0	0	0	0	0	215	30	0
Acenaphthene	HDR	**4.4%**	1	0	0	0	0	7	0	0	0	0	0	137	35	0
Acenaphthene	IND	31.3%	8	0	0	0	0	12	0	0	0	0	0	39	5	0
Acenaphthene	LDR	**0.9%**	0	0	0	0	0	1	0	0	0	0	0	89	22	0
Acenaphthylene	COM	7.2%	4	1	0	0	0	14	0	0	1	0	0	233	25	0
Acenaphthylene	HDR	6.1%	4	0	0	0	0	7	0	0	0	0	0	143	26	0
Acenaphthylene	IND	15.6%	3	0	0	0	0	7	0	0	0	0	0	47	7	0
Acenaphthylene	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	90	22	0
Ammonia	COM	100.0%	24	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammonia	HDR	100.0%	23	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammonia	IND	100.0%	24	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthracene	COM	18.0%	32	1	0	0	0	17	0	0	0	0	0	204	24	0
Anthracene	HDR	5.0%	4	0	0	0	0	3	0	0	2	0	0	145	26	0
Anthracene	IND	10.9%	1	0	0	0	0	6	0	0	0	0	0	52	5	0
Anthracene	LDR	**4.5%**	1	0	0	0	0	0	0	0	4	0	0	83	24	0
Arsenic	COM	100.0%	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Arsenic	LDR	100.0%	0	0	0	0	0	1	0	0	14	0	0	0	0	0
Benz(a)anthracene	COM	38.5%	66	2	0	0	0	23	0	0	1	0	0	135	12	0
Benz(a)anthracene	HDR	29.6%	21	0	0	0	0	21	0	0	0	0	0	83	17	0
Benz(a)anthracene	IND	20.3%	4	0	0	0	0	9	0	0	0	0	0	49	2	0
Benz(a)anthracene	LDR	43.9%	22	0	0	0	0	5	0	0	2	0	0	21	16	0
Benzene	COM	**2.8%**	1	0	0	0	0	0	0	0	0	0	0	34	1	0
Benzene	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	36	2	0
Benzene	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	45	1	0
Benzo(a)pyrene	COM	39.4%	77	1	0	0	0	30	0	0	1	0	0	149	19	0
Benzo(a)pyrene	HDR	16.8%	24	0	0	0	0	5	0	0	1	0	0	122	27	0
Benzo(a)pyrene	IND	17.2%	6	0	0	0	0	5	0	0	0	0	0	48	5	0
Benzo(a)pyrene	LDR	26.1%	26	0	0	0	0	1	0	0	2	0	0	60	22	0
Benzo(b)fluoranthene	COM	46.3%	61	1	0	0	0	14	0	0	0	0	0	78	10	0
Benzo(b)fluoranthene	HDR	18.3%	10	0	0	0	0	7	0	0	0	0	0	56	20	0
Benzo(b)fluoranthene	IND	50.0%	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Benzo(b)fluoranthene	LDR	15.0%	15	0	0	0	0	0	0	0	0	0	0	63	22	0
Benzo(b,k)fluoranthene	COM	64.3%	18	0	0	0	0	9	0	0	0	0	0	15	0	0
Benzo(b,k)fluoranthene	HDR	46.2%	13	0	0	0	0	11	0	0	0	0	0	28	0	0
Benzo(b,k)fluoranthene	IND	34.4%	4	0	0	0	0	7	0	0	0	0	0	20	1	0
Benzo(g,h,i)perylene	COM	53.4%	114	2	0	0	0	29	1	0	2	0	0	115	14	0
Benzo(g,h,i)perylene	HDR	30.6%	35	0	0	0	0	20	0	0	0	0	0	99	26	0
Benzo(g,h,i)perylene	IND	37.5%	14	0	0	0	0	10	0	0	0	0	0	35	5	0
Benzo(g,h,i)perylene	LDR	23.2%	25	0	0	0	0	1	0	0	0	0	0	64	22	0
Benzo(k)fluoranthene	COM	35.4%	44	1	0	0	0	12	0	0	1	0	0	91	15	0
Benzo(k)fluoranthene	HDR	11.8%	8	0	0	0	0	2	0	0	1	0	0	56	26	0
Benzo(k)fluoranthene	IND	50.0%	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Benzo(k)fluoranthene	LDR	16.0%	15	0	0	0	0	0	0	0	1	0	0	62	22	0
Benzofluoranthenes, Total	COM	58.3%	36	0	0	0	0	4	0	0	2	0	0	29	1	0
Benzofluoranthenes, Total	HDR	22.9%	7	0	0	0	0	0	0	0	1	0	0	27	0	0
Benzofluoranthenes, Total	IND	23.3%	7	0	0	0	0	0	0	0	0	0	0	22	1	0
Benzofluoranthenes, Total	LDR	91.7%	9	0	0	0	0	0	0	0	2	0	0	1	0	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Biochemical Oxygen Demand	COM	90.5%	204	5	0	0	0	10	0	0	0	0	0	21	2	0
Biochemical Oxygen Demand	HDR	82.0%	101	7	0	0	0	15	0	0	0	0	0	21	6	0
Biochemical Oxygen Demand	IND	93.3%	36	0	0	0	0	6	0	0	0	0	0	3	0	0
Biochemical Oxygen Demand	LDR	37.6%	27	2	0	0	0	9	0	0	0	0	0	53	10	0
Bis(2-ethylhexyl) phthalate	COM	77.2%	127	4	0	0	0	74	0	1	0	0	0	43	18	0
Bis(2-ethylhexyl) phthalate	HDR	58.9%	47	3	0	0	0	56	0	0	0	0	0	49	25	0
Bis(2-ethylhexyl) phthalate	IND	63.5%	25	0	0	0	0	15	0	0	0	0	0	20	3	0
Bis(2-ethylhexyl) phthalate	LDR	29.5%	3	0	0	0	0	30	0	0	0	0	0	42	37	0
BTEX	COM	**2.8%**	1	0	0	0	0	0	0	0	0	0	0	34	1	0
BTEX	HDR	5.3%	2	0	0	0	0	0	0	0	0	0	0	34	2	0
BTEX	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	45	1	0
Butyl benzyl phthalate	COM	25.6%	35	1	0	0	0	31	0	0	4	0	0	199	7	0
Butyl benzyl phthalate	HDR	23.3%	5	2	0	0	0	32	0	0	3	0	0	131	7	0
Butyl benzyl phthalate	IND	15.6%	0	0	0	0	0	10	0	0	0	0	0	53	1	0
Butyl benzyl phthalate	LDR	17.9%	5	0	0	0	0	14	0	0	1	0	0	84	8	0
Cadmium	COM	72.2%	255	14	0	0	0	100	0	0	30	0	0	129	25	0
Cadmium	HDR	59.1%	84	17	0	0	0	104	0	0	7	0	0	125	22	0
Cadmium	IND	64.4%	52	0	0	0	0	33	0	0	0	0	0	47	0	0
Cadmium	LDR	46.1%	40	3	0	0	0	55	0	0	8	0	0	92	32	0
Calcium	COM	100.0%	153	0	0	0	0	1	0	0	0	0	0	0	0	0
Calcium	HDR	100.0%	93	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcium	IND	100.0%	31	0	0	0	0	1	0	0	0	0	0	0	0	0
Calcium	LDR	100.0%	75	0	0	0	0	1	0	0	0	0	0	0	0	0
Chloride	COM	99.1%	210	8	0	0	0	7	0	0	0	0	0	2	0	0
Chloride	HDR	95.1%	139	10	0	0	0	4	0	0	1	0	0	8	0	0
Chloride	IND	100.0%	49	0	0	0	0	1	0	0	0	0	0	0	0	0
Chloride	LDR	99.1%	104	3	0	0	0	4	0	0	0	0	0	1	0	0
Chlorpyrifos	COM	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	250	22	1
Chlorpyrifos	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	165	22	0
Chlorpyrifos	IND	**1.6%**	1	0	0	0	0	0	0	0	0	0	0	60	3	0
Chlorpyrifos	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	102	18	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Chrysene	COM	63.3%	147	2	0	0	0	27	0	0	0	0	0	93	9	0
Chrysene	HDR	33.3%	36	0	0	0	0	22	0	0	2	0	0	97	23	0
Chrysene	IND	40.6%	19	0	0	0	0	7	0	0	0	0	0	37	1	0
Chrysene	LDR	25.9%	28	0	0	0	0	1	0	0	0	0	0	61	22	0
Conductivity	COM	99.6%	251	8	0	0	0	16	0	0	0	0	0	1	0	0
Conductivity	HDR	100.0%	162	10	0	0	1	7	0	0	0	0	0	0	0	0
Conductivity	IND	100.0%	62	0	0	0	0	4	0	0	0	0	0	0	0	0
Conductivity	LDR	100.0%	110	3	0	0	0	2	0	0	0	0	0	0	0	0
Copper	COM	99.1%	433	12	0	0	0	102	0	0	0	0	0	1	4	0
Copper	HDR	96.3%	243	12	0	0	1	66	0	0	14	0	0	9	4	0
Copper	IND	99.2%	127	0	0	0	0	3	0	0	0	0	0	0	1	0
Copper	LDR	96.8%	68	6	0	0	0	114	0	0	27	0	0	5	2	0
CPAH	COM	65.8%	117	0	0	0	0	68	0	0	0	0	0	92	4	0
CPAH	HDR	42.2%	32	0	0	0	0	44	0	0	0	0	0	88	16	0
CPAH	IND	43.8%	11	0	0	0	0	17	0	0	0	0	0	35	1	0
CPAH	LDR	34.7%	27	0	0	0	0	14	0	0	0	0	0	57	20	0
Di-N-Octyl Phthalate	COM	14.1%	27	2	0	0	0	9	0	1	0	0	0	222	16	0
Di-N-Octyl Phthalate	HDR	13.4%	7	1	0	0	0	15	0	0	1	0	0	138	17	0
Di-N-Octyl Phthalate	IND	9.4%	6	0	0	0	0	0	0	0	0	0	0	49	9	0
Di-N-Octyl Phthalate	LDR	**1.8%**	1	0	0	0	0	1	0	0	0	0	0	93	17	0
Diazinon	COM	**0.7%**	2	0	0	0	0	0	0	0	0	0	0	248	22	1
Diazinon	HDR	**1.6%**	1	0	0	0	0	2	0	0	0	0	0	162	22	0
Diazinon	IND	**1.6%**	0	0	0	0	0	1	0	0	0	0	0	61	2	0
Diazinon	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	102	18	0
Dibenzo(a,h)anthracene	COM	21.6%	43	0	0	0	0	16	0	0	1	0	0	192	26	0
Dibenzo(a,h)anthracene	HDR	6.1%	7	0	0	0	0	2	0	0	2	0	0	133	36	0
Dibenzo(a,h)anthracene	IND	**1.6%**	1	0	0	0	0	0	0	0	0	0	0	58	5	0
Dibenzo(a,h)anthracene	LDR	14.3%	12	0	0	0	0	1	0	0	3	0	0	74	22	0
Dibutyl phthalate	COM	27.4%	28	3	0	0	0	44	0	0	1	0	0	186	15	0
Dibutyl phthalate	HDR	37.8%	6	0	0	0	0	58	0	0	4	0	0	105	7	0
Dibutyl phthalate	IND	35.9%	0	0	0	0	0	23	0	0	0	0	0	39	2	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Dibutyl phthalate	LDR	30.4%	5	0	0	0	0	24	0	0	5	0	0	63	15	0
Dichlobenil	COM	33.2%	53	0	0	0	0	34	0	0	0	0	0	153	21	1
Dichlobenil	HDR	53.7%	43	2	0	0	0	49	0	0	0	0	0	75	6	0
Dichlobenil	IND	59.0%	12	0	0	0	0	24	0	0	0	0	0	22	3	0
Dichlobenil	LDR	**1.8%**	2	0	0	0	0	0	0	0	0	0	0	93	18	0
Diesel Fuel	COM	46.8%	35	0	0	0	0	1	0	0	0	0	0	41	0	0
Diesel Range Organics	COM	62.9%	80	1	0	0	0	24	0	0	0	0	0	61	1	0
Diesel Range Organics	HDR	55.2%	58	0	0	0	0	32	0	0	0	0	1	73	1	0
Diesel Range Organics	IND	64.0%	30	0	0	0	0	2	0	0	0	0	0	18	0	0
Diesel Range Organics	LDR	49.5%	18	0	0	0	0	34	0	0	0	0	0	53	0	0
Diethyl phthalate	COM	26.3%	36	0	0	0	0	36	0	1	0	0	0	191	14	0
Diethyl phthalate	HDR	33.9%	20	1	0	0	0	37	0	0	3	0	0	111	8	0
Diethyl phthalate	IND	20.3%	2	0	0	0	0	11	0	0	0	0	0	49	2	0
Diethyl phthalate	LDR	42.0%	27	0	0	0	0	20	0	0	0	0	0	58	7	0
Dimethyl phthalate	COM	12.9%	17	3	0	0	0	14	0	0	2	0	0	229	13	0
Dimethyl phthalate	HDR	15.0%	0	0	0	0	0	25	0	0	2	0	0	145	8	0
Dimethyl phthalate	IND	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	58	6	0
Dimethyl phthalate	LDR	27.7%	5	0	0	0	0	21	0	0	5	0	0	79	2	0
Ethylbenzene	COM	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	35	1	0
Ethylbenzene	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	36	2	0
Ethylbenzene	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	45	1	0
Fecal coliform	COM	96.8%	222	1	1	1	0	18	0	0	0	0	0	8	0	0
Fecal coliform	HDR	94.3%	133	0	0	0	0	15	0	0	0	0	0	7	2	0
Fecal coliform	IND	100.0%	46	0	0	1	0	2	0	0	0	0	0	0	0	0
Fecal coliform	LDR	80.6%	69	2	0	0	0	12	0	0	0	0	0	19	1	0
Fluoranthene	COM	72.6%	178	3	0	0	0	20	0	0	0	0	0	72	4	0
Fluoranthene	HDR	53.9%	74	0	0	0	0	22	0	0	1	0	0	65	18	0
Fluoranthene	IND	73.4%	36	0	0	0	0	11	0	0	0	0	0	17	0	0
Fluoranthene	LDR	25.9%	26	0	0	0	0	2	0	0	1	0	0	62	21	0
Fluorene	COM	15.5%	23	0	0	0	0	19	0	0	1	0	0	210	25	0
Fluorene	HDR	8.3%	3	0	0	0	0	11	0	0	1	0	0	137	28	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Fluorene	IND	32.8%	8	0	0	0	0	13	0	0	0	0	0	40	3	0
Fluorene	LDR	**0.9%**	0	0	0	0	0	0	0	0	1	0	0	88	23	0
Gasoline Range Organics	COM	9.6%	0	0	0	0	0	18	0	0	0	0	0	149	20	0
Gasoline Range Organics	HDR	12.3%	2	0	0	0	0	17	0	0	0	0	0	108	28	0
Gasoline Range Organics	IND	31.8%	2	0	0	0	0	12	0	0	0	0	0	25	5	0
Gasoline Range Organics	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	92	13	0
Hardness as CaCO3	COM	99.3%	267	8	0	0	0	4	0	0	0	0	0	2	0	0
Hardness as CaCO3	HDR	100.0%	170	10	0	0	1	0	0	0	0	0	0	0	0	0
Hardness as CaCO3	IND	100.0%	64	0	0	0	0	1	0	0	0	0	0	0	0	0
Hardness as CaCO3	LDR	100.0%	110	3	0	0	0	2	0	0	0	0	0	0	0	0
Heavy Fuel Oil	COM	93.9%	72	1	0	0	0	20	0	0	0	0	0	6	0	0
Heavy Fuel Oil	HDR	78.8%	40	0	0	0	0	37	0	0	0	0	1	19	2	0
Heavy Fuel Oil	IND	73.7%	9	0	0	0	0	5	0	0	0	0	0	4	1	0
Heavy Fuel Oil	LDR	60.5%	15	0	0	0	0	33	0	0	0	0	1	31	1	0
HPAH	COM	77.5%	151	0	0	0	0	66	0	0	0	0	0	63	0	0
HPAH	HDR	62.2%	53	0	0	0	0	59	0	0	0	0	0	59	9	0
HPAH	IND	82.8%	27	0	0	0	0	26	0	0	0	0	0	11	0	0
HPAH	LDR	42.4%	28	0	0	0	0	22	0	0	0	0	0	55	13	0
eno(1,2,3-cd)pyrene	COM	39.2%	79	1	0	0	0	28	0	0	1	0	0	148	21	0
eno(1,2,3-cd)pyrene	HDR	19.4%	25	0	0	0	0	8	0	0	2	0	0	114	31	0
eno(1,2,3-cd)pyrene	IND	17.2%	5	0	0	0	0	6	0	0	0	0	0	49	4	0
eno(1,2,3-cd)pyrene	LDR	24.1%	23	0	0	0	0	1	0	0	3	0	0	63	22	0
Lead	COM	96.4%	451	16	0	0	0	39	0	0	27	0	0	19	1	0
Lead	HDR	86.3%	254	20	0	0	0	22	0	0	13	0	0	41	8	0
Lead	IND	83.3%	100	0	0	0	0	10	0	0	0	0	0	21	1	0
Lead	LDR	83.4%	131	5	0	0	0	33	0	0	17	0	0	20	17	0
LPAH	COM	70.8%	142	0	0	0	0	57	0	0	0	0	0	75	7	0
LPAH	HDR	53.3%	36	0	0	0	0	60	0	0	0	0	0	73	11	0
LPAH	IND	70.3%	22	0	0	0	0	23	0	0	0	0	0	18	1	0
LPAH	LDR	44.1%	20	0	0	0	0	32	0	0	0	0	0	53	13	0
Lube Oil	COM	94.4%	34	0	0	0	0	0	0	0	0	0	0	2	0	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Lube Oil	HDR	10.0%	3	0	0	0	0	0	0	0	0	0	0	27	0	0
Lube Oil	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	23	0	0
Magnesium	COM	100.0%	153	0	0	0	0	1	0	0	0	0	0	0	0	0
Magnesium	HDR	100.0%	93	0	0	0	0	0	0	0	0	0	0	0	0	0
Magnesium	IND	100.0%	32	0	0	0	0	0	0	0	0	0	0	0	0	0
Magnesium	LDR	100.0%	75	0	0	0	0	1	0	0	0	0	0	0	0	0
Malathion	COM	**1.8%**	3	0	0	0	0	2	0	0	0	0	0	244	22	1
Malathion	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	164	23	0
Malathion	IND	**1.6%**	0	0	0	0	0	1	0	0	0	0	0	60	3	0
Malathion	LDR	**0.8%**	1	0	0	0	0	0	0	0	0	0	0	101	18	0
Mecoprop	COM	5.5%	10	2	0	0	0	3	0	0	0	0	0	231	25	0
Mecoprop	HDR	24.7%	25	5	0	0	0	12	0	0	0	0	0	120	8	0
Mecoprop	IND	**1.8%**	1	0	0	0	0	0	0	0	0	0	0	51	3	0
Mecoprop	LDR	5.0%	5	0	0	0	0	1	0	0	0	0	0	96	18	0
Mercury	COM	22.3%	103	0	0	0	0	17	0	0	1	0	0	362	60	0
Mercury	HDR	7.3%	9	0	0	0	0	1	0	0	1	0	0	130	9	0
Mercury	IND	6.1%	7	0	0	0	0	1	0	0	0	0	0	124	0	0
Mercury	LDR	**2.7%**	2	0	0	0	0	0	0	0	0	0	0	56	16	0
Motor Oil	COM	75.0%	47	0	0	0	0	1	0	0	0	0	0	16	0	0
Motor Oil	HDR	84.2%	15	0	0	0	0	1	0	0	0	0	0	3	0	0
Motor Oil	IND	100.0%	22	0	0	0	0	0	0	0	0	0	0	0	0	0
Naphthalene	COM	36.2%	66	0	0	0	0	33	0	0	1	0	0	157	19	0
Naphthalene	HDR	37.6%	26	0	0	0	0	36	0	0	5	0	0	90	20	1
Naphthalene	IND	46.0%	22	0	0	0	0	7	0	0	0	0	0	30	4	0
Naphthalene	LDR	33.3%	12	0	0	0	0	15	0	0	10	0	0	62	11	1
Nitrite-Nitrate	COM	90.8%	186	6	0	0	0	35	0	0	0	0	0	23	0	0
Nitrite-Nitrate	HDR	100.0%	133	6	0	0	0	23	0	0	6	0	0	0	0	0
Nitrite-Nitrate	IND	100.0%	43	0	0	0	0	9	0	0	0	0	0	0	0	0
Nitrite-Nitrate	LDR	100.0%	93	1	0	0	0	20	0	0	0	0	0	0	0	0
Oil and grease	COM	5.7%	2	0	0	0	0	0	0	0	0	0	0	33	0	0
Ortho-phosphate	COM	90.4%	169	4	0	0	0	53	0	0	0	0	0	22	2	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Ortho-phosphate	HDR	90.1%	115	7	0	0	0	33	0	0	0	0	0	17	0	0
Ortho-phosphate	IND	94.4%	44	0	0	0	0	7	0	0	0	0	0	3	0	0
Ortho-phosphate	LDR	98.2%	72	3	0	0	0	37	0	0	0	0	0	2	0	0
p-Cresol	COM	25.0%	2	0	0	0	0	0	0	0	0	0	0	6	0	0
p-Cresol	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	7	0	0
p-Cresol	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	11	0	0
PCB-aroclor 1016	COM	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	8	0	0
PCB-aroclor 1016	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	10	0	0
PCB-aroclor 1016	IND	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	9	0	0
PCB-aroclor 1221	COM	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	8	0	0
PCB-aroclor 1221	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	10	0	0
PCB-aroclor 1221	IND	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	9	0	0
PCB-aroclor 1232	COM	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	8	0	0
PCB-aroclor 1232	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	10	0	0
PCB-aroclor 1232	IND	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	9	0	0
PCB-aroclor 1242	COM	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	8	0	0
PCB-aroclor 1242	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	10	0	0
PCB-aroclor 1242	IND	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	9	0	0
PCB-aroclor 1248	COM	12.5%	1	0	0	0	0	0	0	0	0	0	0	7	0	0
PCB-aroclor 1248	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	10	0	0
PCB-aroclor 1248	IND	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	9	0	0
PCB-aroclor 1254	COM	100.0%	8	0	0	0	0	0	0	0	0	0	0	0	0	0
PCB-aroclor 1254	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	10	0	0
PCB-aroclor 1254	IND	66.7%	6	0	0	0	0	0	0	0	0	0	0	2	1	0
PCB-aroclor 1260	COM	50.0%	3	0	0	0	0	1	0	0	0	0	0	4	0	0
PCB-aroclor 1260	HDR	10.0%	1	0	0	0	0	0	0	0	0	0	0	9	0	0
PCB-aroclor 1260	IND	22.2%	2	0	0	0	0	0	0	0	0	0	0	7	0	0
Pentachlorophenol	COM	40.5%	93	8	0	0	0	3	0	0	2	0	0	151	5	0
Pentachlorophenol	HDR	12.9%	8	0	0	0	0	13	0	0	0	0	0	122	20	0
Pentachlorophenol	IND	9.1%	0	0	0	0	0	5	0	0	0	0	0	50	0	0
Pentachlorophenol	LDR	16.2%	8	0	0	0	0	10	0	0	0	0	0	85	8	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
pH	COM	100.0%	72	0	0	0	0	1	0	0	0	0	0	0	0	0
pH	HDR	100.0%	85	0	0	0	0	1	0	0	0	0	0	0	0	0
pH	IND	100.0%	64	0	0	0	0	1	0	0	0	0	0	0	0	0
Phenanthrene	COM	62.8%	155	1	0	0	0	18	0	0	0	0	0	92	11	0
Phenanthrene	HDR	46.7%	59	0	0	0	0	23	0	0	2	0	0	81	15	0
Phenanthrene	IND	68.8%	39	0	0	0	0	5	0	0	0	0	0	20	0	0
Phenanthrene	LDR	23.2%	23	0	0	0	0	2	0	0	1	0	0	65	21	0
Phenol	COM	37.5%	3	0	0	0	0	0	0	0	0	0	0	5	0	0
Phenol	HDR	42.9%	3	0	0	0	0	0	0	0	0	0	0	4	0	0
Phenol	LDR	18.2%	1	0	0	0	0	0	0	0	1	0	0	9	0	0
Precipitation	COM	100.0%	219	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation	HDR	100.0%	125	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation	IND	100.0%	33	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation	LDR	100.0%	91	3	0	0	0	0	0	0	0	0	0	0	0	0
Prometon	COM	**0.8%**	0	0	0	0	0	2	0	0	0	0	0	230	27	1
Prometon	HDR	6.9%	6	1	0	0	0	5	0	0	0	0	0	135	26	1
Prometon	IND	10.0%	4	0	0	0	0	2	0	0	0	0	0	51	3	0
Prometon	LDR	**1.8%**	0	0	0	0	0	1	0	0	1	0	0	89	22	0
Pyrene	COM	75.1%	182	2	0	0	0	24	0	0	0	0	0	64	5	0
Pyrene	HDR	58.9%	80	0	0	0	0	24	0	0	2	0	0	62	12	0
Pyrene	IND	81.3%	46	0	0	0	0	6	0	0	0	0	0	12	0	0
Pyrene	LDR	31.3%	27	0	0	0	0	7	0	0	1	0	0	61	16	0
Sampled-Event Flow Volume	COM	100.0%	257	8	0	0	0	0	0	0	0	0	0	0	0	0
Sampled-Event Flow Volume	HDR	100.0%	154	10	0	0	0	0	0	0	0	0	0	0	0	0
Sampled-Event Flow Volume	IND	100.0%	66	0	0	0	0	0	0	0	0	0	0	0	0	0
Sampled-Event Flow Volume	LDR	100.0%	97	8	0	0	0	0	0	0	0	0	0	0	0	0
Storm Event Flow Volume	COM	100.0%	272	0	0	0	0	0	0	0	0	0	0	0	0	0
Storm Event Flow Volume	HDR	100.0%	173	0	0	0	0	0	0	0	0	0	0	0	0	0
Storm Event Flow Volume	IND	100.0%	66	0	0	0	0	0	0	0	0	0	0	0	0	0
Storm Event Flow Volume	LDR	100.0%	115	1	0	0	0	0	0	0	0	0	0	0	0	0
Surfactants	COM	78.6%	181	7	0	0	0	21	0	0	0	0	0	48	9	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Surfactants	HDR	58.4%	86	3	0	0	0	12	0	0	0	0	0	53	19	0
Surfactants	IND	75.0%	39	0	0	0	0	3	0	0	0	0	0	14	0	0
Surfactants	LDR	29.5%	29	0	0	0	0	4	0	0	0	0	0	58	21	0
Toluene	COM	**2.8%**	1	0	0	0	0	0	0	0	0	0	0	34	1	0
Toluene	HDR	5.3%	2	0	0	0	0	0	0	0	0	0	0	34	2	0
Toluene	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	45	1	0
Total Benzofluoranthenes	COM	52.3%	115	0	0	0	0	32	0	0	0	0	0	125	9	0
Total Benzofluoranthenes	HDR	27.8%	29	0	0	0	0	21	0	0	0	0	0	110	20	0
Total Benzofluoranthenes	IND	29.7%	12	0	0	0	0	7	0	0	0	0	0	43	2	0
Total Benzofluoranthenes	LDR	22.9%	24	0	0	0	0	3	0	0	0	0	0	63	28	0
Total Kjeldahl Nitrogen	COM	86.5%	159	8	0	0	0	51	0	0	0	0	0	34	0	0
Total Kjeldahl Nitrogen	HDR	91.6%	102	10	0	0	0	40	0	0	1	0	0	12	2	0
Total Kjeldahl Nitrogen	IND	98.1%	37	0	0	0	0	15	0	0	0	0	0	1	0	0
Total Kjeldahl Nitrogen	LDR	89.4%	55	3	0	0	0	43	0	0	0	0	0	11	1	0
Total PAH	COM	82.9%	159	0	0	0	0	74	0	0	0	0	0	47	1	0
Total PAH	HDR	65.6%	48	0	0	0	0	70	0	0	0	0	0	55	7	0
Total PAH	IND	84.4%	26	0	0	0	0	28	0	0	0	0	0	9	1	0
Total PAH	LDR	54.2%	31	0	0	0	0	33	0	0	0	0	0	47	7	0
Total PCB	COM	100.0%	7	0	0	0	0	1	0	0	0	0	0	0	0	0
Total PCB	HDR	10.0%	1	0	0	0	0	0	0	0	0	0	0	9	0	0
Total PCB	IND	66.7%	6	0	0	0	0	0	0	0	0	0	0	3	0	0
Total Phosphorus	COM	95.3%	216	6	0	0	0	23	0	0	1	0	0	12	0	0
Total Phosphorus	HDR	96.6%	138	6	0	0	0	25	0	0	0	0	0	2	4	0
Total Phosphorus	IND	98.0%	40	0	0	0	0	10	0	0	0	0	0	1	0	0
Total Phosphorus	LDR	99.2%	101	3	0	0	0	15	0	0	1	0	0	1	0	0
Total Phthalate	COM	82.2%	123	0	0	0	0	108	0	0	0	0	0	50	0	0
Total Phthalate	HDR	74.4%	49	0	0	0	0	85	0	0	0	0	0	41	5	0
Total Phthalate	IND	81.3%	21	0	0	0	0	31	0	0	0	0	0	11	1	0
Total Phthalate	LDR	65.3%	27	0	0	0	0	50	0	0	0	0	0	41	0	0
Total Suspended Solids	COM	99.6%	252	8	0	0	0	10	0	0	0	0	0	0	1	0
Total Suspended Solids	HDR	99.4%	157	10	0	0	1	8	0	0	0	0	0	1	0	0

Parameter	Land use	% detection	No qualifiers	C	E	G	j	J	JG	JL	JT	JTL	L	U	UJ	UJG
Total Suspended Solids	IND	100.0%	62	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Suspended Solids	LDR	98.3%	107	3	0	0	0	3	0	0	0	0	0	2	0	0
Total TPHDx	COM	80.2%	173	0	0	0	0	29	0	0	0	0	0	50	0	0
Total TPHDx	HDR	70.7%	77	0	0	0	0	41	0	0	0	0	0	49	0	0
Total TPHDx	IND	88.9%	42	0	0	0	0	6	0	0	0	0	0	6	0	0
Total TPHDx	LDR	50.0%	17	0	0	0	0	36	0	0	0	0	0	53	0	0
Total Xylenes	COM	**2.8%**	1	0	0	0	0	0	0	0	0	0	0	34	1	0
Total Xylenes	HDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	36	2	0
Total Xylenes	LDR	**0.0%**	0	0	0	0	0	0	0	0	0	0	0	45	1	0
TPHGx	COM	**2.9%**	1	0	0	0	0	0	0	0	0	0	0	34	0	0
Triclopyr	COM	6.4%	13	0	0	0	0	3	0	0	0	0	0	208	26	0
Triclopyr	HDR	17.0%	10	5	0	0	0	12	0	0	0	0	0	121	10	1
Triclopyr	IND	5.7%	3	0	0	0	0	0	0	0	0	0	0	42	8	0
Triclopyr	LDR	15.0%	6	1	0	0	0	10	0	0	0	0	0	90	6	0
Turbidity	COM	100.0%	215	8	0	0	0	22	0	0	0	0	0	0	0	0
Turbidity	HDR	100.0%	122	10	0	0	0	17	0	0	0	0	0	0	0	0
Turbidity	IND	100.0%	41	0	0	0	0	1	0	0	0	0	0	0	0	0
Turbidity	LDR	100.0%	84	3	0	0	0	25	0	0	0	0	0	0	0	0
Zinc	COM	100.0%	443	16	0	0	0	87	0	0	0	0	0	0	0	0
Zinc	HDR	97.4%	253	20	0	0	1	54	0	0	8	0	0	8	1	0
Zinc	IND	99.2%	128	0	0	0	0	1	0	0	0	0	0	0	1	0
Zinc	LDR	94.5%	77	6	0	0	0	122	0	0	0	0	0	7	5	0

Table D-4. Summary of data cases for each parameter by matrix and land use.
The % non-detect is shown in parentheses beside the Case letter.

Parameter	Commercial	High-density residential	Industrial	Low-density residential
1-Methylnaphthalene sediment (ug/Kg)	A (48.6)	C (100)	C (100)	B (60)
1-Methylnaphthalene water (ug/L)	C (96.8)	C (100)	C (81.2)	C (100)
2-Methylnaphthalene sediment (ug/Kg)	A (37.8)	B (62.5)	C (83.3)	C (81.8)
2-Methylnaphthalene water (ug/L)	B (79.1)	C (85)	B (62.5)	C (100)
2-Nitrophenol sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
2,4-D sediment (ug/Kg)	C (100)	C (100)	C (96.4)	B (80)
2,4-D water (ug/L)	C (87.7)	B (66.3)	C (100)	C (90.8)
2,4-Dichlorophenol sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
2,4-Dimethylphenol sediment (ug/Kg)	C (84.2)	C (100)	C (100)	C (100)
2,4,5-Trichlorophenol sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
2,4,6-Trichlorophenol sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
4-Chloro-3-Methylphenol sediment (ug/Kg)	C (91.7)	C (100)	C (100)	C (100)
4-Nitrophenol sediment (ug/Kg)	C (100)	C (100)		B (66.7)
Acenaphthene sediment (ug/Kg)	A (23.9)	B (68.8)	C (83.3)	C (81.8)
Acenaphthene water (ug/L)	C (88.1)	C (95.6)	B (68.8)	C (99.1)
Acenaphthylene sediment (ug/Kg)	A (43.5)	C (100)	C (100)	C (100)
Acenaphthylene water (ug/L)	C (92.8)	C (93.9)	C (84.4)	C (100)
Ammonia water (ug/L)	A (0)	A (0)	A (0)	
Anthracene sediment (ug/Kg)	A (10.9)	A (37.5)	A (16.7)	C (81.8)
Anthracene water (ug/L)	C (82)	C (95)	C (89.1)	C (95.5)
Arsenic water dissolved (ug/L)	A (0)			A (0)
Benz(a)anthracene sediment (ug/Kg)	A (0)	A (23.1)	A (16.7)	A (50)
Benz(a)anthracene water (ug/L)	B (61.5)	B (70.4)	B (79.7)	B (56.1)
Benzene water (ug/L)	C (97.2)	C (100)		C (100)
Benzo(a)pyrene sediment (ug/Kg)	A (2.2)	A (31.2)	A (16.7)	B (63.6)
Benzo(a)pyrene water (ug/L)	B (60.6)	C (83.2)	C (82.8)	B (73.9)
Benzo(b)fluoranthene sediment (ug/Kg)	A (3.8)	A (22.2)	A (0)	B (66.7)
Benzo(b)fluoranthene water (ug/L)	B (53.7)	C (81.7)	A (50)	C (85)
Benzo(b,k)fluoranthene sediment (ug/Kg)	A (0)	A (0)	A (0)	
Benzo(b,k)fluoranthene water (ug/L)	A (35.7)	B (53.8)	B (65.6)	
Benzo(g,h,i)perylene sediment (ug/Kg)	A (0)	A (23.1)	A (0)	B (62.5)
Benzo(g,h,i)perylene water (ug/L)	A (46.6)	B (69.4)	B (62.5)	B (76.8)
Benzo(k)fluoranthene sediment (ug/Kg)	A (7.7)	A (44.4)	A (0)	B (77.8)
Benzo(k)fluoranthene water (ug/L)	B (64.6)	C (88.2)	A (50)	C (84)
Benzofluoranthenes, Total sediment (ug/Kg)	A (0)	A (0)	A (0)	A (0)
Benzofluoranthenes, Total water (ug/L)	A (41.7)	B (77.1)	B (76.7)	A (8.3)
Biochemical Oxygen Demand water (ug/L)	A (9.5)	A (18)	A (6.7)	B (62.4)
Bis(2-ethylhexyl) phthalate sediment (ug/Kg)	A (0)	A (6.2)	A (0)	A (27.3)
Bis(2-ethylhexyl) phthalate water (ug/L)	A (22.8)	A (41.1)	A (36.5)	B (70.5)

Parameter	Commercial	High-density residential	Industrial	Low-density residential
BTEX water (ug/L)	C (97.2)	C (94.7)		C (100)
Butyl benzyl phthalate sediment (ug/Kg)	A (37.5)	A (50)	A (33.3)	B (54.5)
Butyl benzyl phthalate water (ug/L)	B (74.4)	B (76.7)	C (84.4)	C (82.1)
Cadmium sediment (ug/Kg)	A (4.3)	A (29.4)	A (0)	A (9.1)
Cadmium water (ug/L)	A (16.5)	A (30.6)	A (16.7)	B (50.4)
Cadmium water dissolved (ug/L)	A (39.3)	B (51.4)	B (54.5)	B (57.4)
Calcium water (ug/L)	A (0)	A (0)	A (0)	A (0)
Calcium water dissolved (ug/L)	A (0)			
Chloride water (ug/L)	A (0.9)	A (4.9)	A (0)	A (0.9)
Chlorpyrifos sediment (ug/Kg)	C (95.2)	C (100)	C (100)	C (100)
Chlorpyrifos water (ug/L)	C (100)	C (100)	C (98.4)	C (100)
Chrysene sediment (ug/Kg)	A (0)	A (6.2)	A (0)	A (45.5)
Chrysene water (ug/L)	A (36.7)	B (66.7)	B (59.4)	B (74.1)
Conductivity water (uS/cm)	A (0.4)	A (0)	A (0)	A (0)
Copper sediment (ug/Kg)	A (0)	A (0)	A (0)	A (0)
Copper water (ug/L)	A (0)	A (2.7)	A (0)	A (3.3)
Copper water dissolved (ug/L)	A (1.9)	A (4.8)	A (1.5)	A (2.9)
CPAH sediment (ug/Kg)	A (0)	A (6.2)	A (0)	A (36.4)
CPAH water (ug/L)	A (33.5)	B (57.8)	B (56.2)	B (66.1)
Di-N-Octyl Phthalate sediment (ug/Kg)	B (60.9)	C (81.2)	A (33.3)	C (100)
Di-N-Octyl Phthalate water (ug/L)	C (85.9)	C (86.6)	C (90.6)	C (98.2)
Diazinon sediment (ug/Kg)	C (95)	C (100)	C (100)	C (100)
Diazinon water (ug/L)	C (99.3)	C (98.4)	C (98.4)	C (100)
Dibenzo(a,h)anthracene sediment (ug/Kg)	A (13)	A (37.5)	A (33.3)	B (63.6)
Dibenzo(a,h)anthracene water (ug/L)	B (78.4)	C (93.9)	C (98.4)	C (85.7)
Dibutyl phthalate sediment (ug/Kg)	B (58.3)	C (93.8)	A (50)	C (81.8)
Dibutyl phthalate water (ug/L)	B (72.6)	B (62.2)	B (64.1)	B (69.6)
Dichlobenil sediment (ug/Kg)	A (20)	B (75)		C (83.3)
Dichlobenil water (ug/L)	B (66.8)	A (46.3)	A (41)	C (98.2)
Diesel Fuel sediment (ug/Kg)	A (0)			
Diesel Fuel water (ug/L)	B (53.2)			
Diesel Range Organics sediment (ug/Kg)	A (50)	A (0)	A (0)	
Diesel Range Organics water (ug/L)	A (37.1)	A (44.8)	A (36)	B (50.5)
Diethyl phthalate sediment (ug/Kg)	C (91.3)	C (100)	C (83.3)	C (100)
Diethyl phthalate water (ug/L)	B (73.7)	B (66.1)	B (79.7)	B (58)
Dimethyl phthalate sediment (ug/Kg)	B (65.2)	C (93.8)	C (83.3)	C (90.9)
Dimethyl phthalate water (ug/L)	C (87.1)	C (85)	C (100)	B (72.3)
Ethylbenzene water (ug/L)	C (100)	C (100)		C (100)
Fecal coliform water (cfu/100mL)	A (3.2)	A (5.7)	A (0)	A (19.4)
Fines sediment (%)	A (0)	A (0)	A (0)	A (0)
Fluoranthene sediment (ug/Kg)	A (0)	A (12.5)	A (0)	A (27.3)

Parameter	Commercial	High-density residential	Industrial	Low-density residential
Fluoranthene water (ug/L)	A (27.4)	A (46.1)	A (26.6)	B (74.1)
Fluorene sediment (ug/Kg)	A (17.4)	B (66.7)	C (83.3)	C (81.8)
Fluorene water (ug/L)	C (84.5)	C (91.7)	B (67.2)	C (99.1)
Gasoline Range Organics water (ug/L)	C (90.4)	C (87.7)	B (68.2)	C (100)
Gravel sediment (%)	A (4.7)	A (13.3)	A (0)	A (10)
Hardness as CaCO3 water (ug/L)	A (0.7)	A (0)	A (0)	A (0)
Heavy Fuel Oil sediment (ug/Kg)	A (0)	A (0)	A (0)	A (39.5)
Heavy Fuel Oil water (ug/L)	A (6.1)	A (21.2)	A (26.3)	
HPAH sediment (ug/Kg)	A (0)	A (5.3)	A (0)	A (15.4)
HPAH water (ug/L)	A (21.7)	A (37.8)	A (17.2)	B (60.7)
Indeno(1,2,3-cd)pyrene sediment (ug/Kg)	A (2.2)	A (18.8)	A (16.7)	B (54.5)
Indeno(1,2,3-cd)pyrene water (ug/L)	B (60.8)	C (80.6)	C (82.8)	B (75.9)
Lead sediment (ug/Kg)	A (0)	A (5.9)	A (0)	A (9.1)
Lead water (ug/L)	A (0)	A (2.2)	A (0)	A (1.8)
Lead water dissolved (ug/L)	A (7.3)	A (25.1)	A (33.3)	A (32.1)
LPAH sediment (ug/Kg)	A (2.1)	A (5.6)	A (14.3)	A (15.4)
LPAH water (ug/L)	A (28.4)	A (46.7)	A (29.7)	B (56.2)
Lube Oil water (ug/L)	A (5.6)	C (90)		C (100)
Magnesium water (ug/L)	A (0)	A (0)	A (0)	A (0)
Magnesium water dissolved (ug/L)	A (0)			
Malathion sediment (ug/Kg)	C (95.2)	C (100)	C (100)	C (100)
Malathion water (ug/L)	C (98.2)	C (100)	C (98.4)	C (99.2)
Mecoprop sediment (ug/Kg)	C (100)	C (100)		B (80)
Mecoprop water (ug/L)	C (94.5)	B (75.3)	C (98.2)	C (95)
Mercury sediment (ug/Kg)	A (13)	A (33.3)	A (0)	A (42.9)
Mercury water (ug/L)	B (69)	C (89.3)	C (87.9)	C (97.3)
Mercury water dissolved (ug/L)	C (86.8)	C (96)	C (100)	C (97.3)
Motor Oil sediment (ug/Kg)	A (0)			
Motor Oil water (ug/L)	A (25)	A (15.8)	A (0)	
Naphthalene sediment (ug/Kg)	A (17.4)	B (75)	B (66.7)	B (72.7)
Naphthalene water (ug/L)	B (63.8)	B (62.4)	B (54)	B (66.7)
Nitrite-Nitrate water dissolved (ug/L)	A (9.2)	A (0)	A (0)	A (0)
o-Cresol sediment (ug/Kg)	B (70)	C (81.8)	C (100)	C (100)
Oil and grease water (ug/L)	C (94.3)			
Ortho-phosphate water dissolved (ug/L)	A (9.6)	A (9.9)	A (5.6)	A (1.8)
p-Cresol sediment (ug/Kg)	A (10)	A (18.2)	A (50)	A (50)
p-Cresol water (ug/L)	B (75)	C (100)		C (100)
PCB-aroclor 1016 sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
PCB-aroclor 1016 water (ug/L)	C (100)	C (100)	C (100)	
PCB-aroclor 1221 sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
PCB-aroclor 1221 water (ug/L)	C (100)	C (100)	C (100)	

Parameter	Commercial	High-density residential	Industrial	Low-density residential
PCB-aroclor 1232 sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
PCB-aroclor 1232 water (ug/L)	C (100)	C (100)	C (100)	
PCB-aroclor 1242 sediment (ug/Kg)	C (100)	C (100)	C (100)	C (100)
PCB-aroclor 1242 water (ug/L)	C (100)	C (100)	C (100)	
PCB-aroclor 1248 sediment (ug/Kg)	C (94.7)	C (83.3)	C (100)	C (100)
PCB-aroclor 1248 water (ug/L)	C (87.5)	C (100)	C (100)	
PCB-aroclor 1254 sediment (ug/Kg)	A (36.8)	C (100)	A (50)	C (100)
PCB-aroclor 1254 water (ug/L)	A (0)	C (100)	A (33.3)	
PCB-aroclor 1260 sediment (ug/Kg)	B (63.2)	C (100)	B (66.7)	C (100)
PCB-aroclor 1260 water (ug/L)	A (50)	C (90)	B (77.8)	
Pentachlorophenol sediment (ug/Kg)	B (69.6)	B (80)	B (80)	C (90.9)
Pentachlorophenol water (ug/L)	B (59.5)	C (87.1)	C (90.9)	C (83.8)
pH water (pH)	A (0)	A (0)	A (0)	
Phenanthrene sediment (ug/Kg)	A (2.2)	A (6.7)	A (16.7)	A (18.2)
Phenanthrene water (ug/L)	A (37.2)	B (53.3)	A (31.2)	B (76.8)
Phenol sediment (ug/Kg)	A (40.9)	B (69.2)	B (80)	B (66.7)
Phenol water (ug/L)	B (62.5)	B (57.1)		C (81.8)
Precipitation water (in)	A (0)	A (0)	A (0)	A (0)
Prometon sediment (ug/Kg)	C (100)	C (100)		C (100)
Prometon water (ug/L)	C (99.2)	C (93.1)	C (90)	C (98.2)
Pyrene sediment (ug/Kg)	A (0)	A (12.5)	A (0)	A (18.2)
Pyrene water (ug/L)	A (24.9)	A (41.1)	A (18.8)	B (68.8)
Sampled-Event Flow Volume water (m3)	A (0)	A (0)	A (0)	A (0)
Sand sediment (%)	A (0)	A (0)	A (0)	A (0)
Solids sediment (%)	A (0)	A (0)	A (0)	A (0)
Storm Event Flow Volume water (m3)	A (0)	A (0)	A (0)	A (0)
Surfactants water (ug/L)	A (21.4)	A (41.6)	A (25)	B (70.5)
Toluene water (ug/L)	C (97.2)	C (94.7)		C (100)
Total Benzofluoranthenes sediment (ug/Kg)	A (2.2)	A (12.5)	A (0)	B (54.5)
Total Benzofluoranthenes water (ug/L)	A (47.1)	B (72.2)	B (70.3)	B (75.9)
Total Kjeldahl Nitrogen water (ug/L)	A (13.5)	A (8.4)	A (1.9)	A (10.6)
Total Organic Carbon sediment (%)	A (0)	A (0)	A (0)	A (0)
Total PAH sediment (ug/Kg)	A (0)	A (0)	A (0)	A (9.1)
Total PAH water (ug/L)	A (16.2)	A (34.4)	A (15.6)	A (48.2)
Total PCB sediment (ug/Kg)	A (31.6)	C (83.3)	A (50)	C (100)
Total PCB water (ug/L)	A (0)	C (90)	A (33.3)	
Total Phosphorus sediment (ug/Kg)	A (0)			
Total Phosphorus water (ug/L)	A (4.7)	A (3.4)	A (2)	A (0.8)
Total Phthalate sediment (ug/Kg)	A (7.1)	A (11.8)	A (18.2)	A (18.2)
Total Phthalate water (ug/L)	A (18)	A (25.6)	A (18.8)	A (36.6)
Total Suspended Solids water (ug/L)	A (0.4)	A (0.6)	A (0)	A (1.7)

Parameter	Commercial	High-density residential	Industrial	Low-density residential
Total TPHDx sediment (ug/Kg)	A (0)	A (0)	A (0)	
Total TPHDx water (ug/L)	A (19.8)	A (29.3)	A (11.1)	A (50)
Total Xylenes water (ug/L)	C (97.2)	C (100)		C (100)
TPHGx water (ug/L)	C (97.1)			
Triclopyr sediment (ug/Kg)	C (100)	C (100)		B (80)
Triclopyr water (ug/L)	C (93.6)	C (83)	C (94.3)	C (85)
Turbidity water (NTU)	A (0)	A (0)	A (0)	A (0)
Zinc sediment (ug/Kg)	A (0)	A (0)	A (0)	A (0)
Zinc water (ug/L)	A (0)	A (2.2)	A (0)	A (1.8)
Zinc water dissolved (ug/L)	A (0)	A (3)	A (1.5)	A (9.5)

Appendix E. Hydrology

Table E-1. Percentage of the storms sampled per year for each catchment.
Minimum and maximum percent and number of storms.

Location_ID	2009 min	2009 max	2009 count	2010 min	2010 max	2010 count	2011 min	2011 max	2011 count	2012 min	2012 max	2012 count	2013 min	2013 max	2013 count
GM34921	-	-	-	24.2	100	9	12	99.8	15	96.5	99	5	-	-	-
KICCOMS8D_OUT	36.2	74	3	21.8	97.5	8	30.1	97.2	9	76.8	99.7	5	97.8	100	6
KICHDRS8D_OUT	16.3	91.3	3	12	100	7	20.4	97.1	6	50.2	96.1	4	71.4	71.4	1
KICLDRS8D_OUT	83.4	100	3	7.5	94.5	12	2.3	100	9	99.5	99.5	1	90.1	100	3
LDR010	-	-	-	33	95.5	7	3.7	93.3	8	42.4	94.5	8	-	-	-
MH5171	-	-	-	85	100	6	7.9	99.7	15	26.8	99.2	6	-	-	-
PIECOMM_OUT	-	-	-	53.6	95.3	4	63.5	97.2	9	85.6	94.3	5	66.4	89.5	3
PIEHIRES_OUT	-	-	-	76.3	76.3	1	73.5	98	5	89.8	89.8	1	81.8	81.8	1
PIELORES_OUT	-	-	-	90.1	90.1	1	59.5	96	7	64.3	85.5	4	86.8	97.4	3
POSOUTFALL_6057	77.8	100	9	61.7	100	16	53	99.7	12	73.1	97.8	3	-	-	-
POT564S8D_OUT	91	99.7	3	73.9	98.4	7	25.9	100	11	15.6	56.8	8	-	-	-
SEAC1S8D_OUT	71.5	100	3	100	100	14	100	100	12	61.5	100	5	-	-	-
SEAI1S8D_OUT	100	100	3	71.6	100	13	100	100	12	100	100	5	-	-	-
SEAR1S8D_OUT	100	100	5	100	100	13	100	100	10	100	100	7	-	-	-
SNO_COM	95	99.8	5	16.7	99.7	12	76.8	99.4	11	72.6	98.1	8	-	-	-
SNO_HDR	83.1	99.3	7	48.8	97.1	13	82.1	98.2	10	70.8	98	8	-	-	-
SNO_LDR	24.3	94	5	35.6	91.7	13	29.5	97.8	15	32.7	95.9	6	-	-	-
TAC001S8D_OF235	95.5	100	5	33.6	100	16	79.4	100	12	32.2	98.1	8	-	-	-
TAC003S8D_OF245	46.9	100	4	56.1	89.8	10	61.4	100	11	26.6	95.3	8	-	-	-
TFWFD1	83.5	100	5	25.7	100	11	30.3	93.9	11	55.7	89	8	-	-	-

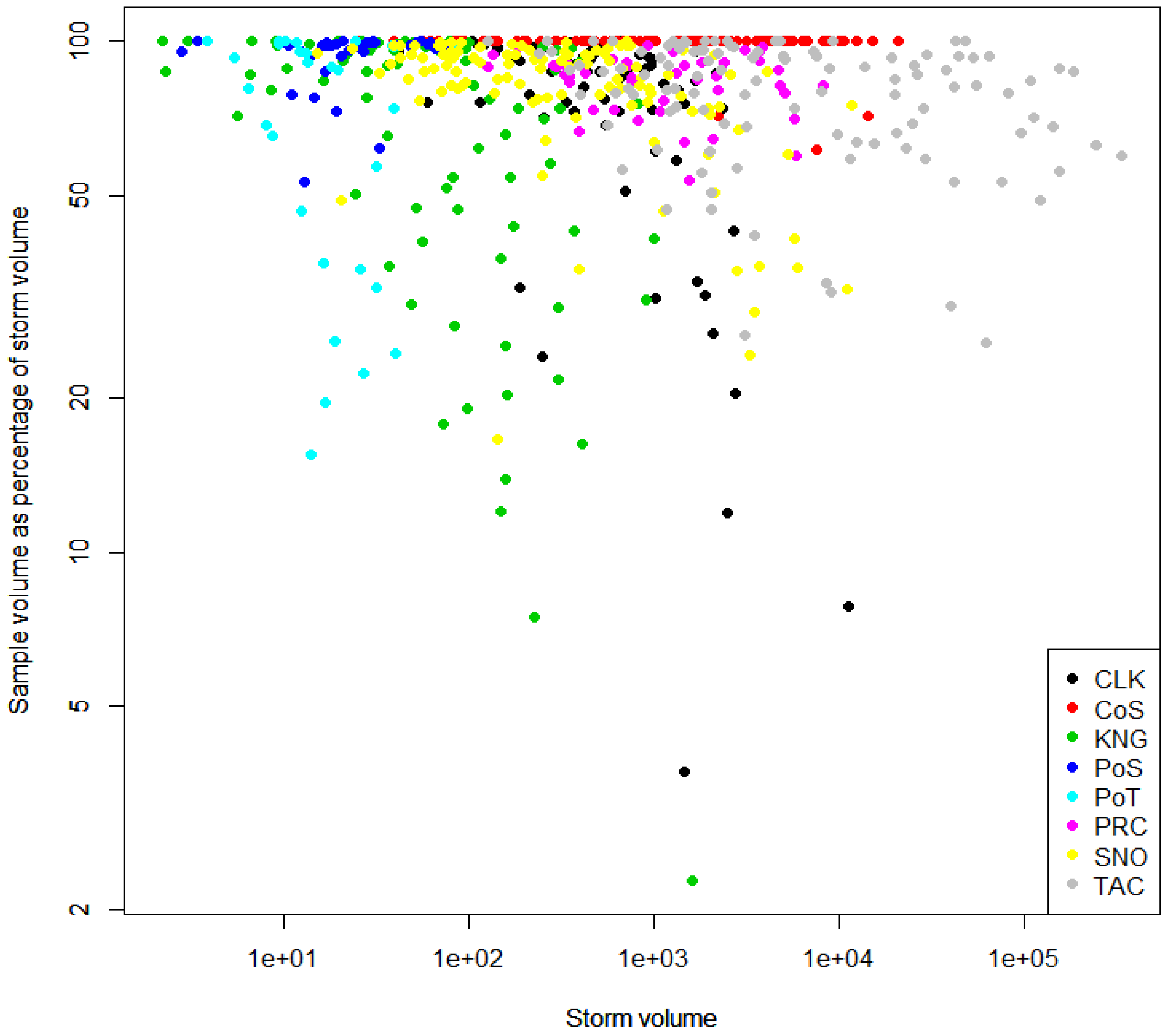


Figure E-1. Log-log scatterplot of sample volume against storm volume. Permittees are identified as unique colors.

CLK = Clark County
CoS = City of Seattle
KNG = King County
PoS = Port of Seattle
PoT = Port of Tacoma
PRC = Pierce County
SNO = Snohomish County
TAC = City of Tacoma

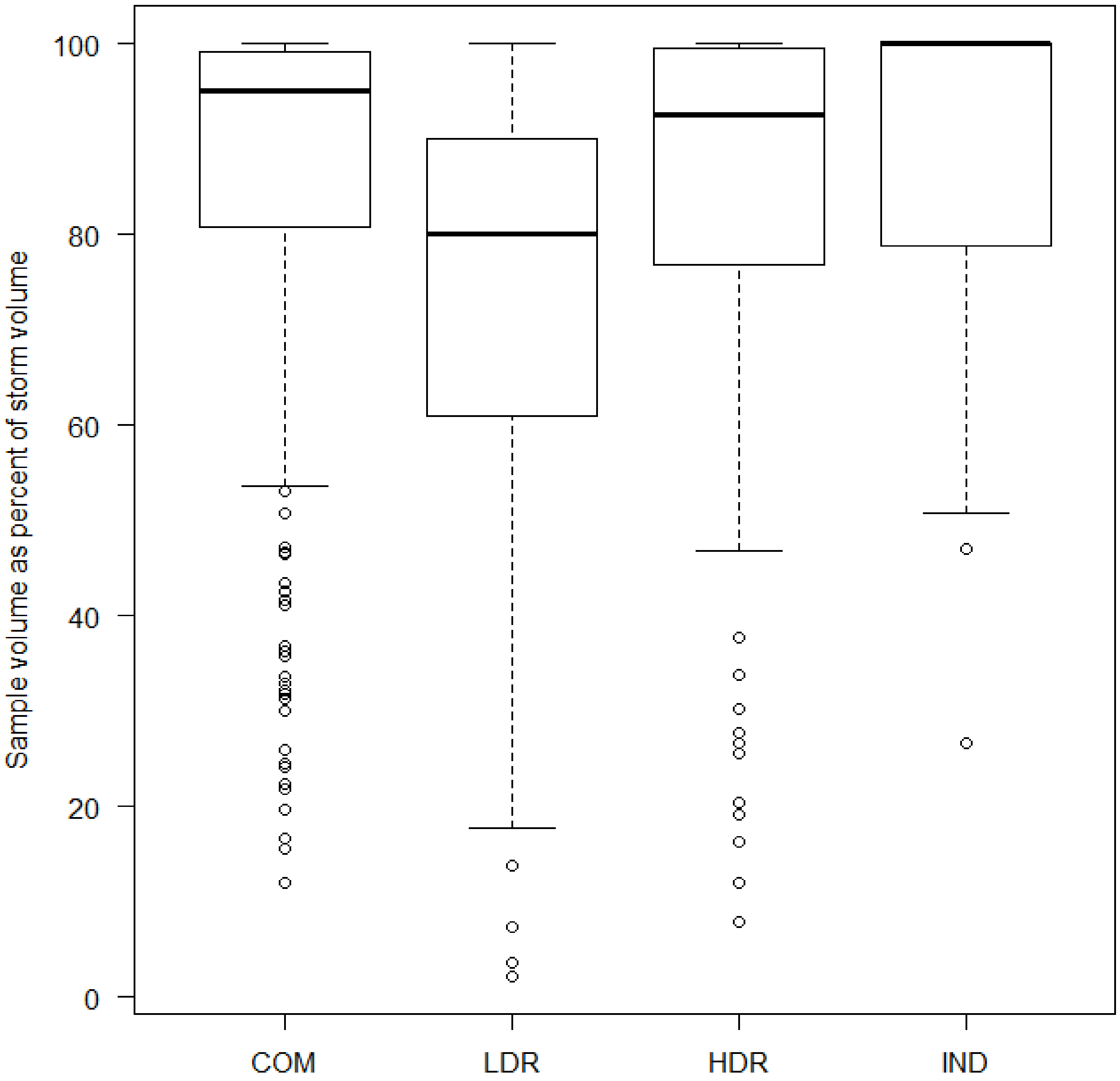


Figure E-2. Box plot of the percent of the storm volume captured by the sample, categorized by land use.

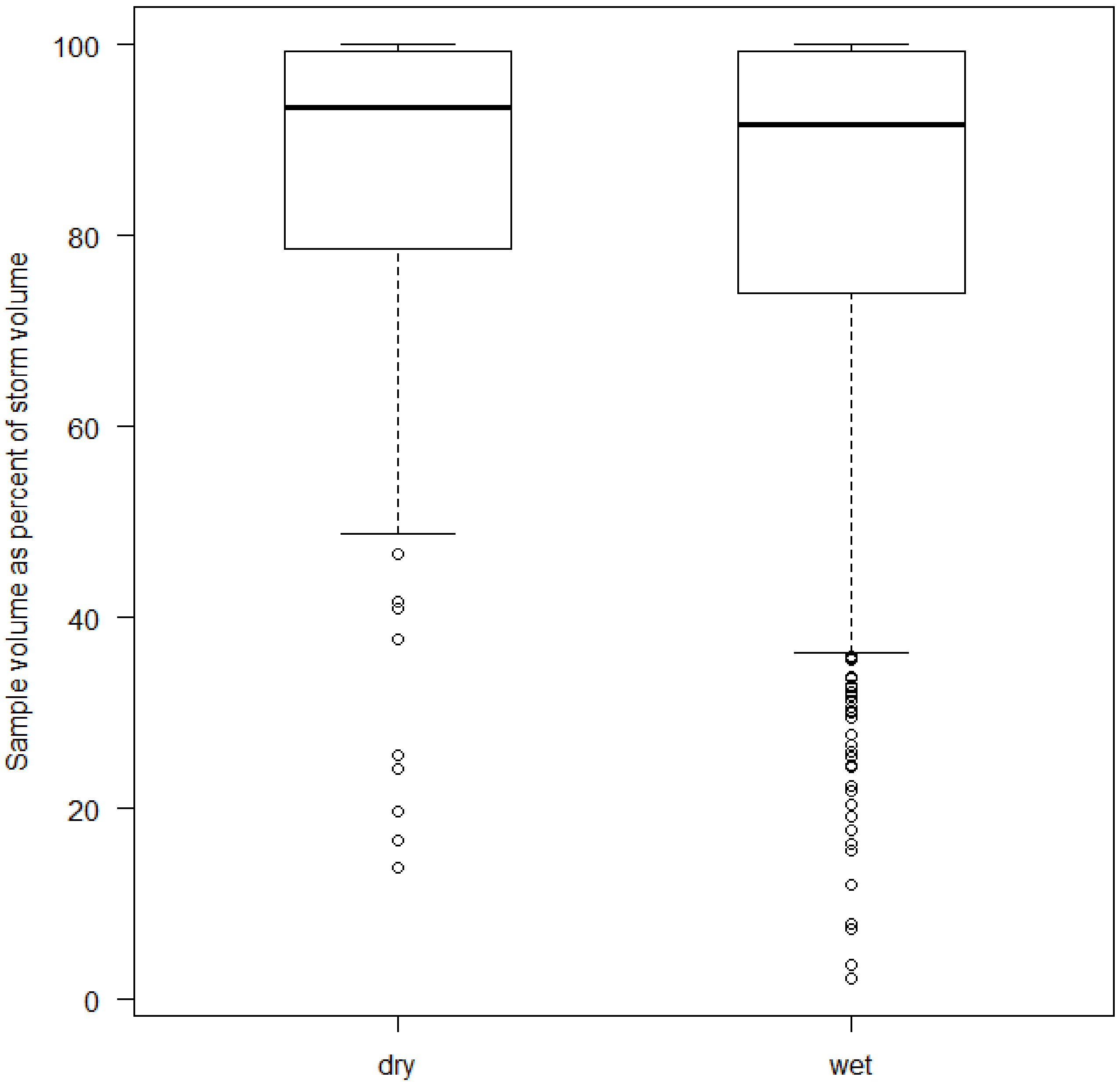


Figure E-3. Box plot of the percent of the storm volume captured by the sample, categorized by wet and dry season.

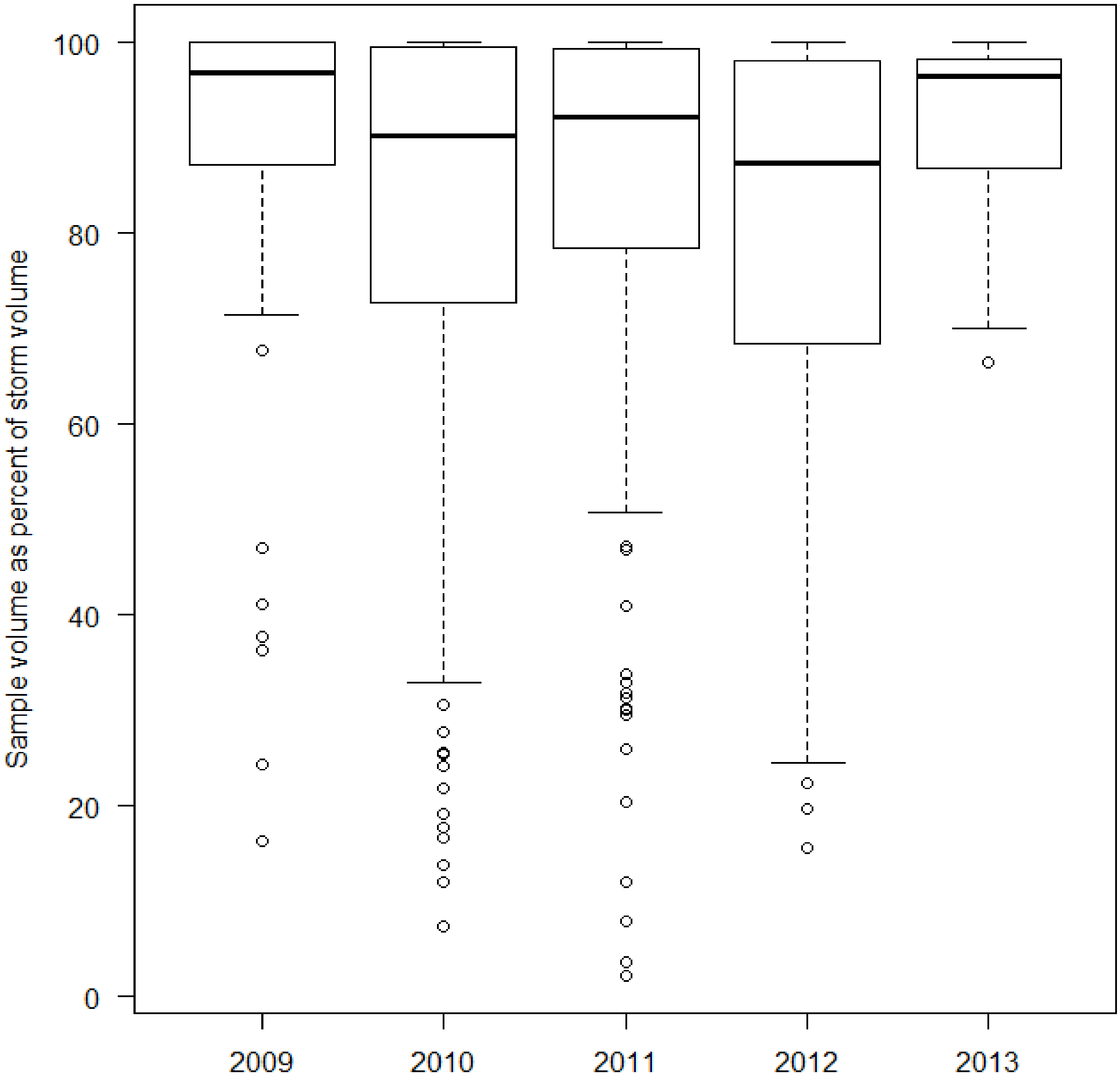


Figure E-4. Box plot of the percent of the storm volume captured by the sample, categorized by sample year.

Appendix F. Data Plots for Contaminant Concentrations

Appendix F (172 pages) is available only online.

It is linked to this report at https://fortress.wa.gov/ecy/publications/SummaryPages/1503001.html

Appendix G. Contaminant Concentrations

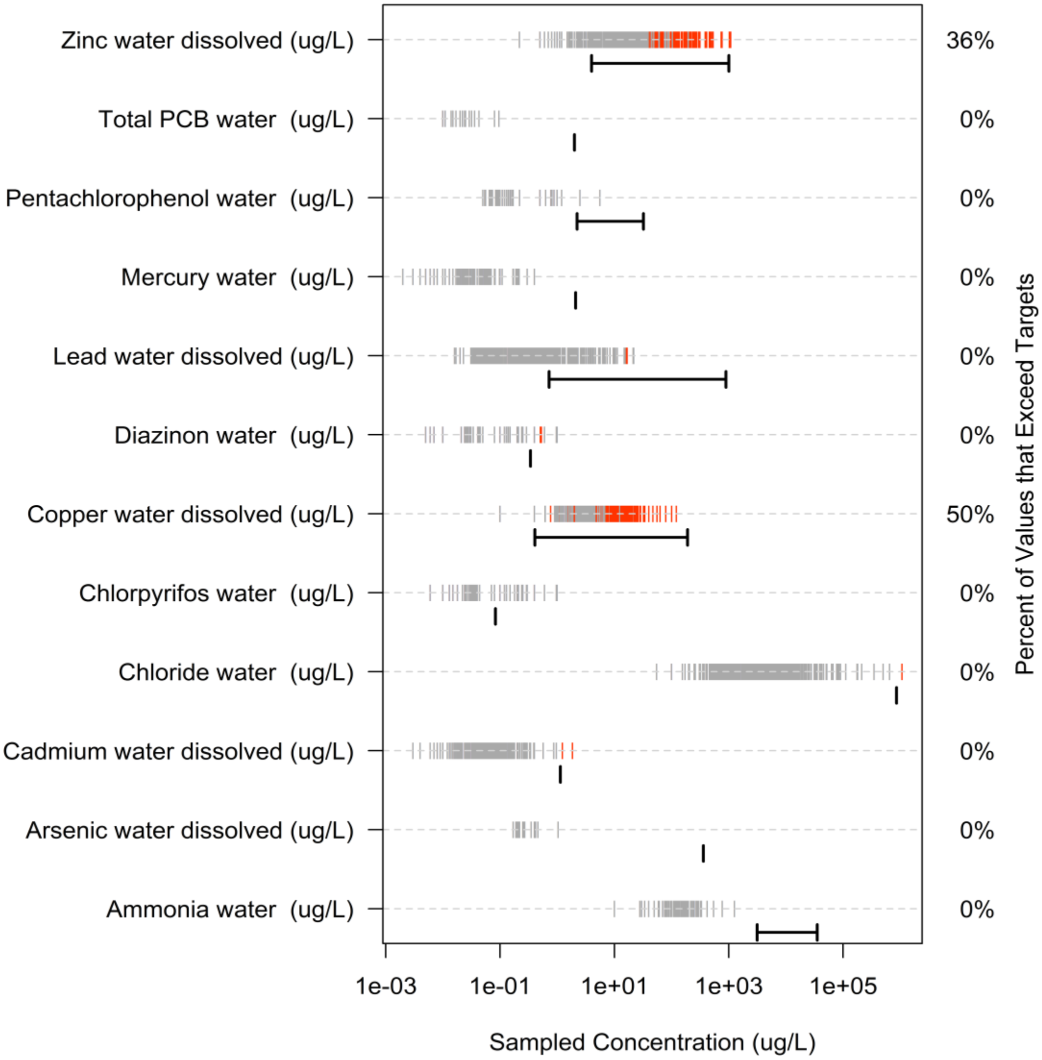


Figure G-1. Range of concentrations compared with water quality standards for the protection of aquatic life (acute criteria).

Vertical gray bars are concentrations that do not exceed criteria, and vertical red bars exceed the target. The range of criteria calculated for parameters with pH or hardness dependent criteria is highlighted by the black bar. The percent of samples which exceed the criteria is documented on the secondary y-axis.

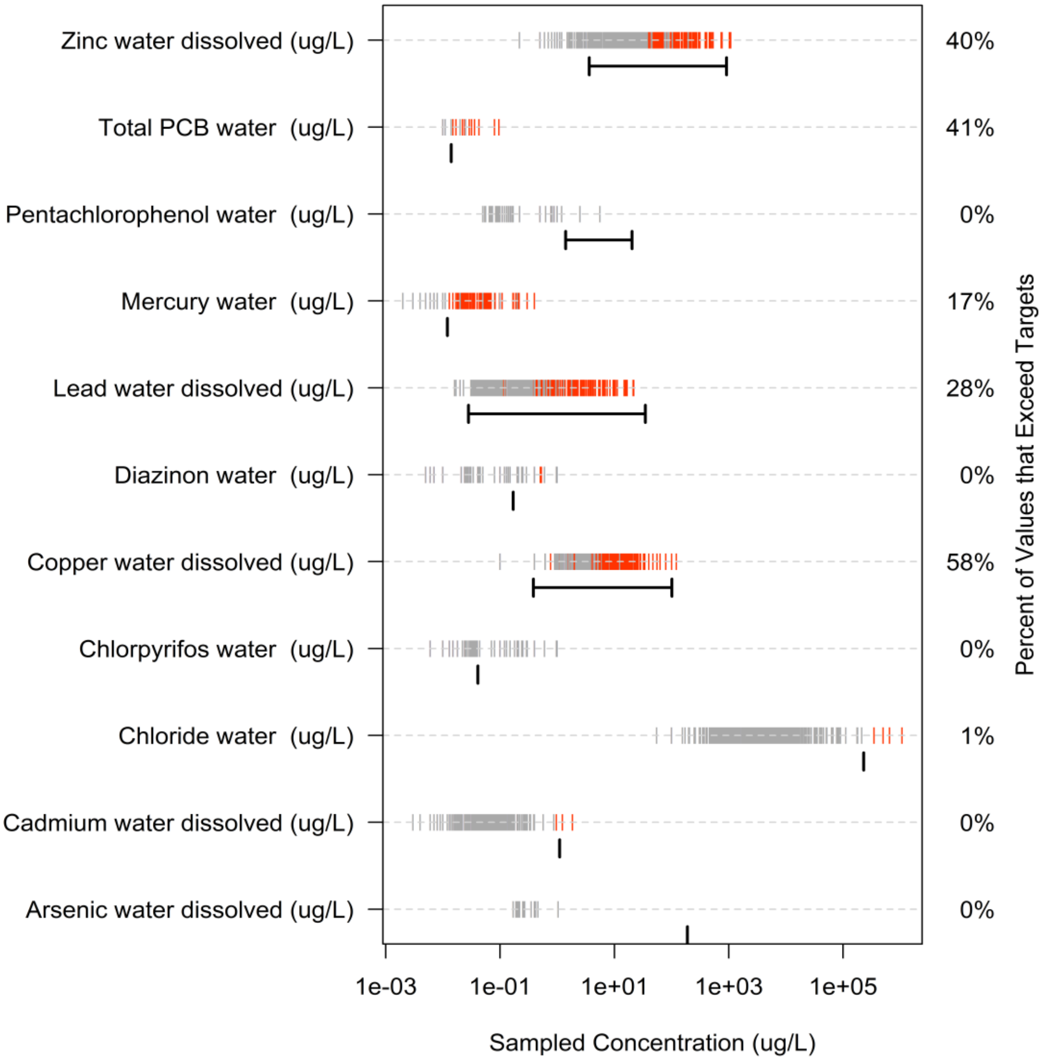


Figure G-2. Range of concentrations compared with water quality criteria for the protection of aquatic life (chronic criteria).

Vertical gray bars are concentrations that do not exceed criteria, and vertical red bars exceed the target. The range of criteria calculated for parameters with pH or hardness dependent criteria is highlighted by the black bar. The percent of samples which exceed the criteria is documented on the secondary y-axis.

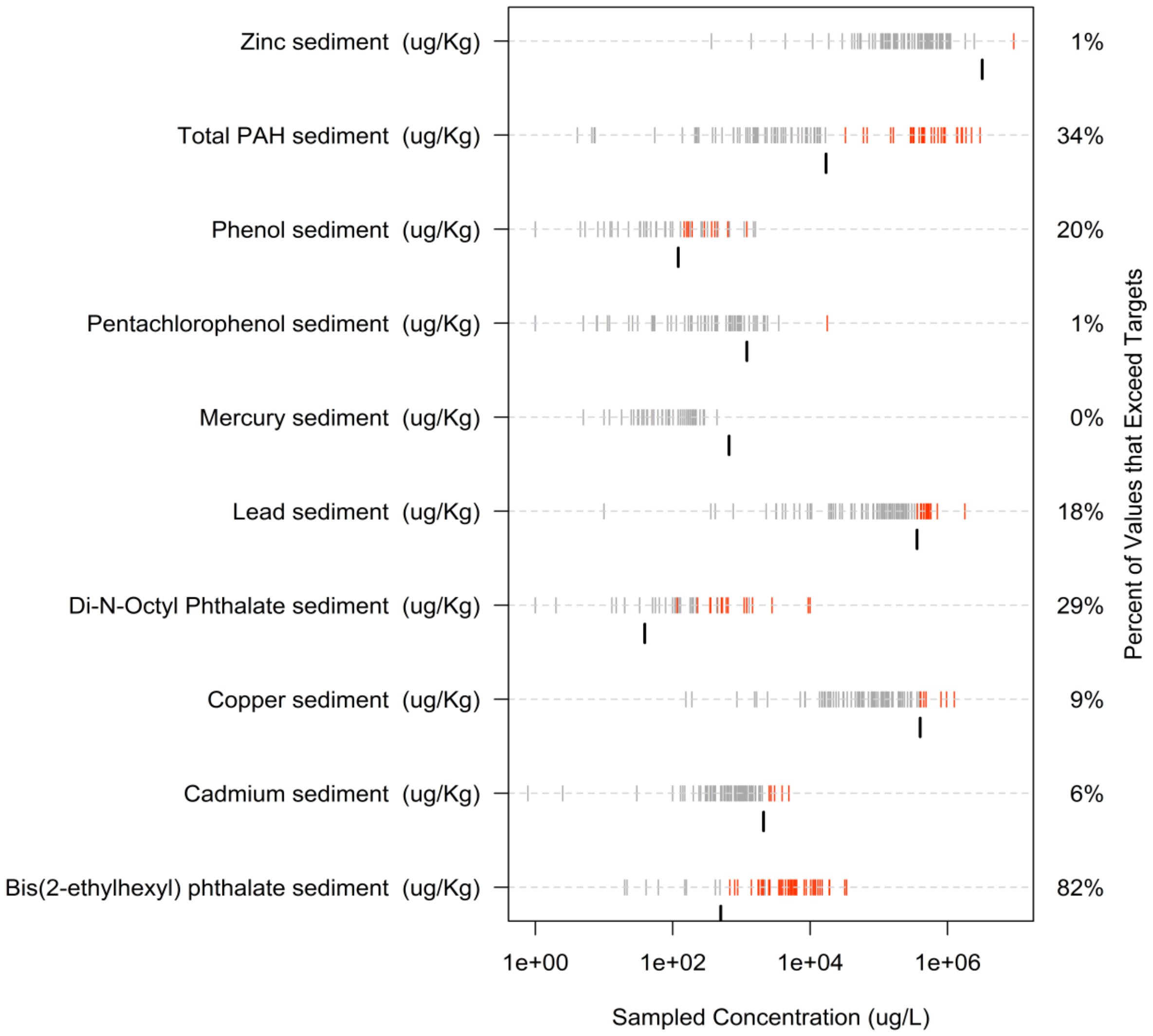


Figure G-3. Range of concentrations compared with sediment cleanup objectives.

Vertical gray bars are concentrations that do not exceed criteria, and vertical red bars exceed the target. The target is highlighted by the black bar. The percent of samples which exceed the criteria is documented on the secondary y-axis.

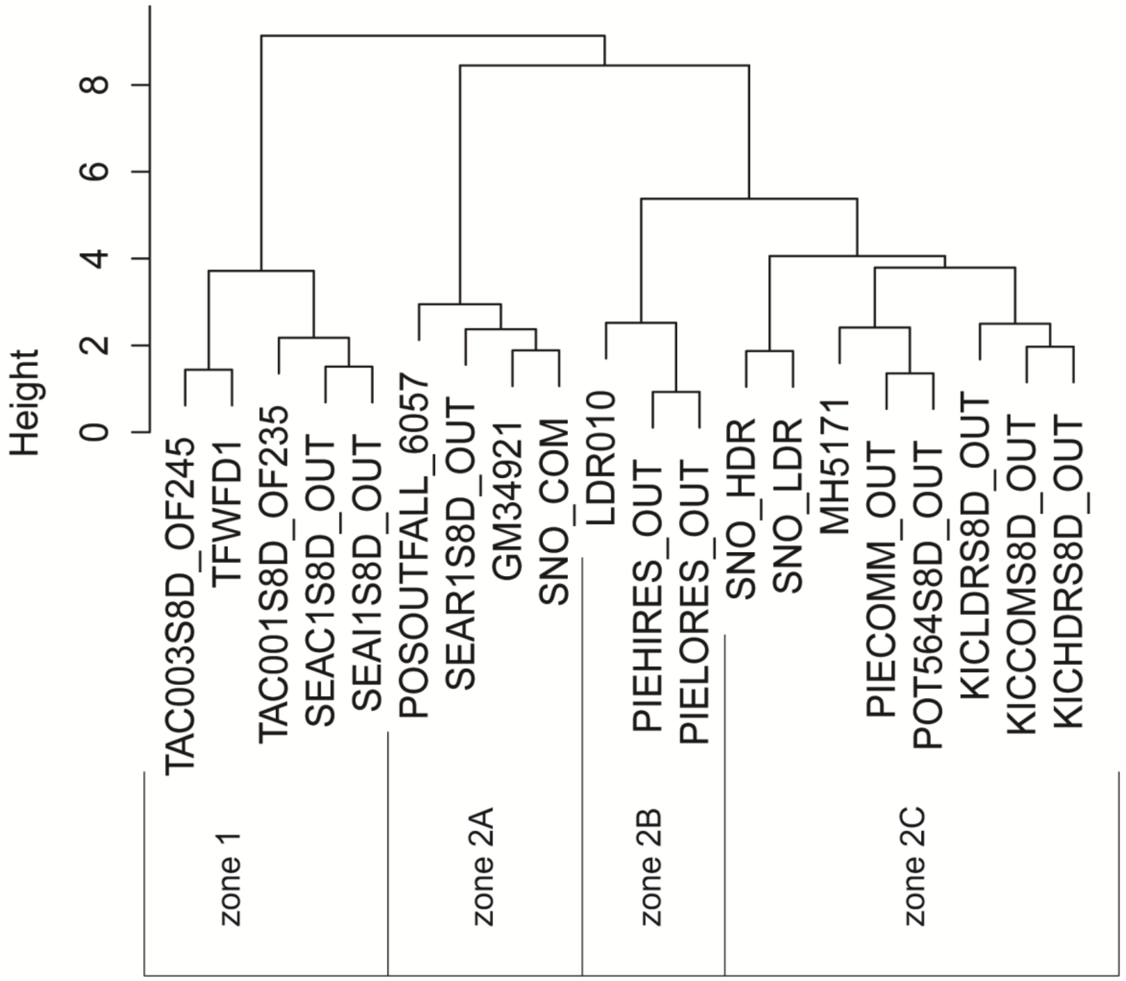


Figure G-4. Dendrogram of the cluster analysis of stormwater concentrations using Ward's method.

Sample sites are grouped based on water concentrations of the parameters used in the PCA. Zones are groups of similar sites.

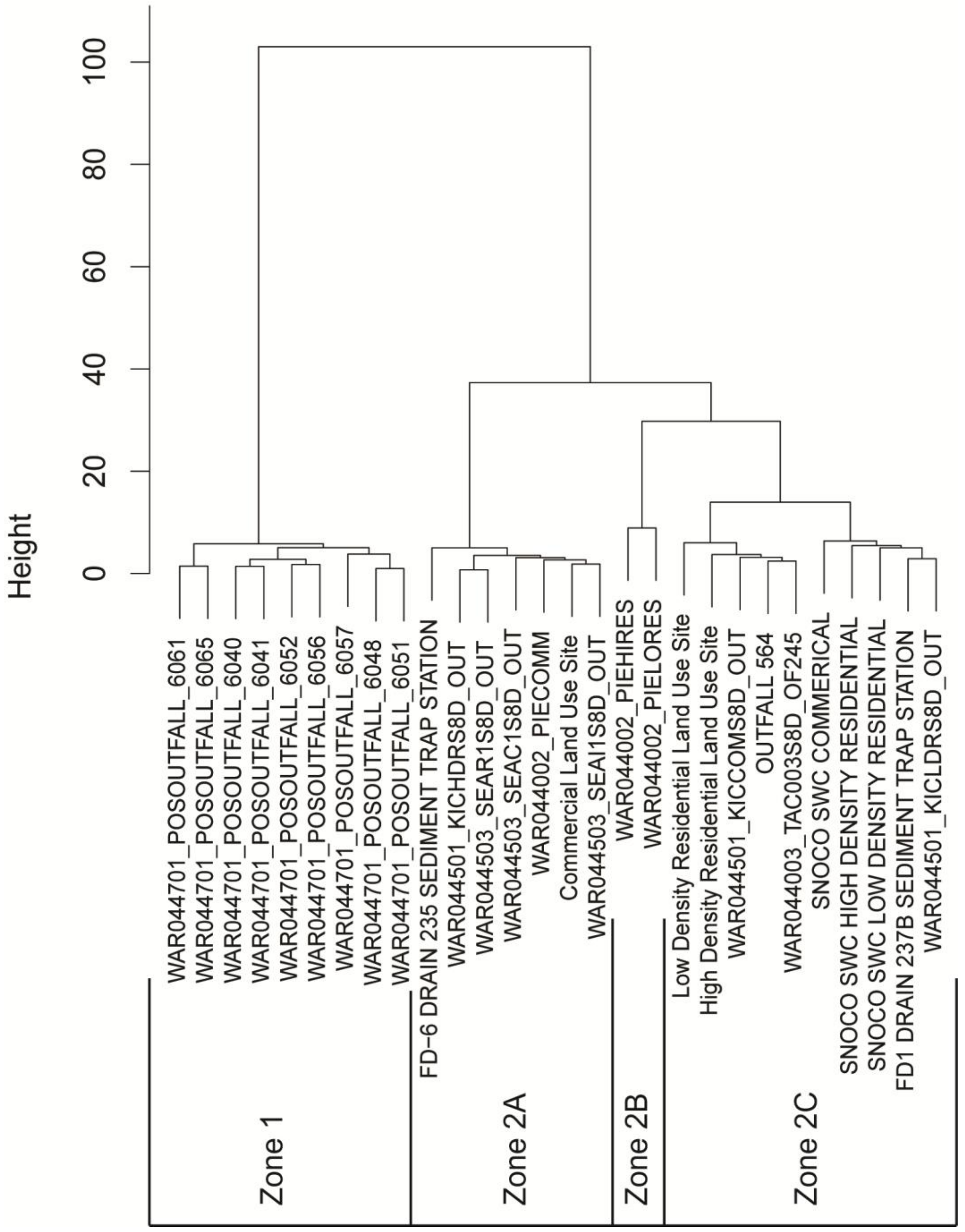


Figure G-5. Dendrogram of the cluster analysis of stormwater sediment concentrations using Ward's method.

Sample sites are grouped based on water concentrations of the parameters used in the PCA. Zones are groups of similar sites.

The following Appendix G tables are available only online as zip files.

They are linked to this report at
https://fortress.wa.gov/ecy/publications/SummaryPages/1503001.html

Table G-1. Statistical summary of contaminant concentrations by parameter and media.

Table G-2. Statistical summary of contaminant concentrations by parameter, media, and land use.

Table G-3. Statistical summary of contaminant concentrations by parameter, media, and season.

Appendix H. Data Plots for Contaminant Loads

Appendix H (89 pages) is available only online.

It is linked to this report at https://fortress.wa.gov/ecy/publications/SummaryPages/1503001.html

Appendix I. Contaminant Loads

The following Appendix I tables are available only online as zip files.

They are linked to this report at
https://fortress.wa.gov/ecy/publications/SummaryPages/1503001.html

Table I-1. Statistical summary of contaminant mass loads (kg) by parameter.

Table I-2. Statistical summary of contaminant mass loads (kg) by parameter and land use.

Table I-3. Statistical summary of contaminant mass loads (kg) by parameter and season.

Table I-4. Statistical summary of contaminant load per area (kg ha^{-1}).

Table I-5. Statistical summary of contaminant load per area (kg ha^{-1}) by parameter and land use.

Table I-6. Statistical summary of contaminant load per area (kg ha^{-1}) by parameter and season.

Appendix J. Glossary, Acronyms, and Abbreviations

Glossary

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the total maximum daily load (TMDL) program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Exceed criterion or standard: Did not meet (or violated) the criterion or standard.

Fecal coliform: That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Parameter: A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Percentile: A statistical number obtained from a distribution of a data set.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

PS Toxics Study: Control of Toxic Chemicals in Puget Sound: Phase 3 Data and Load Estimates (Herrera, 2011).

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Total suspended solids (TSS): Portion of solids retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

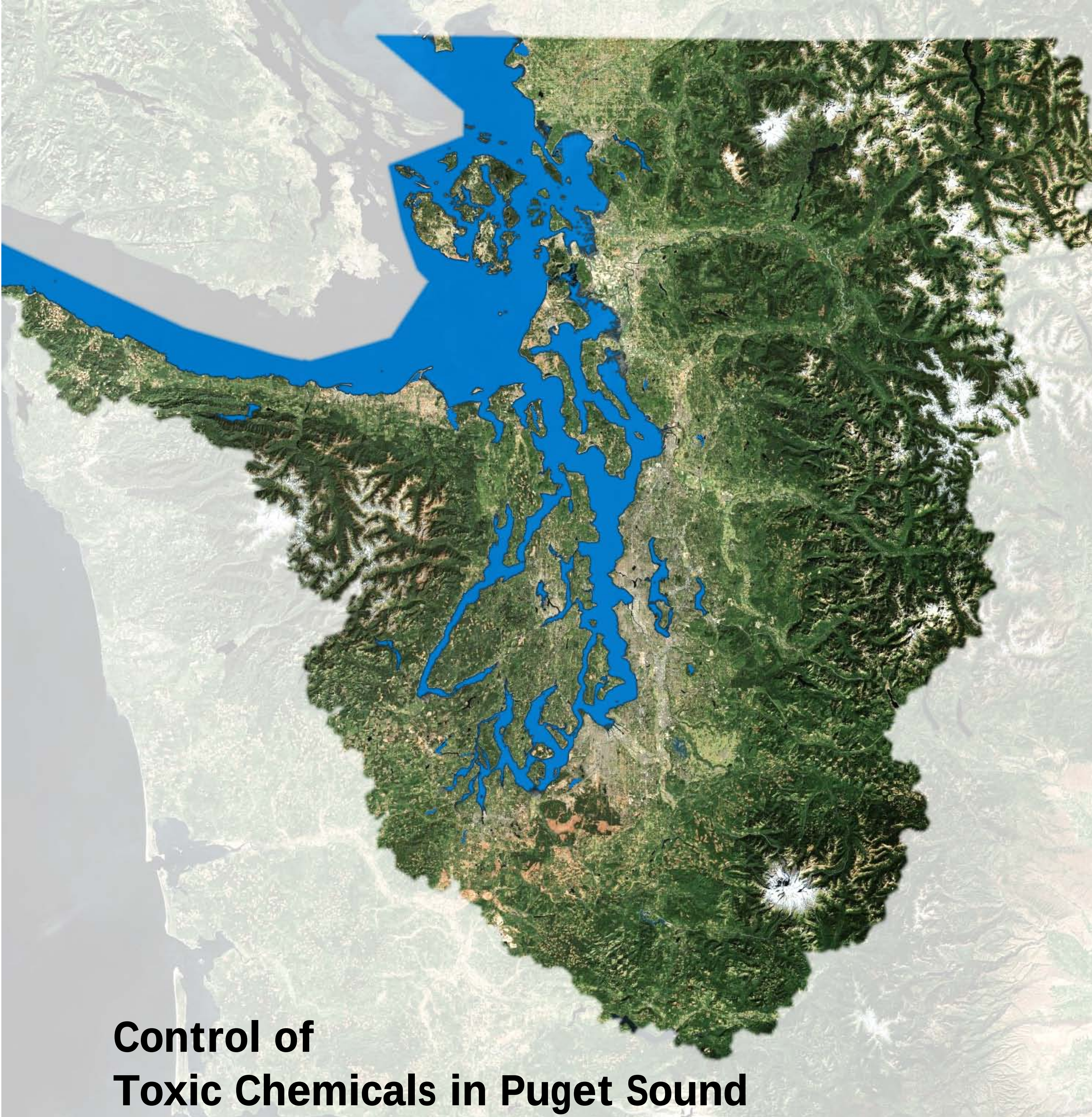
Acronyms and Abbreviations

BEHP	bis(2-Ethylhexyl) phthalate
BMP	Best management practice
BOD	Biological oxygen demand
BTEX	Benzene, toluene, ethylbenzene, and xylene
Ecology	Washington State Department of Ecology
EDF	Empirical Distribution Function
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
HPAH	High molecular weight PAH
KM	Kaplan-Meier
LPAH	Low molecular weight PAH
MDL	Method detection limit
MLE	Maximum Likelihood Estimation
MQO	Measurement quality objective
NOAA	National Oceanic and Atmospheric Administration
NPDES	(See Glossary above)
NSQD	National Stormwater Quality Database
NURP	National Urban Runoff Program
NWTPH	Northwest Total Petroleum Hydrocarbon
PAH	Polycyclic aromatic hydrocarbon
PCA	Principal components analysis
PCB	Polychlorinated biphenyl
QA	Quality assurance
QC	Quality control
RL	Reporting limit
ROS	Regression on Order Statistics

SCO	Sediment Cleanup Objective
SMS	Sediment Management Standard
SVOC	Semi-volatile organic compound
TIA	Total impervious area
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
TPH	Total petroleum hydrocarbon
TSS	(See Glossary above)
WAC	Washington Administrative Code
WQP	Water Quality Program

Units of Measurement

°C	degrees centigrade
cfu	colony forming units
dw	dry weight
ha	hectare
kg	kilograms, a unit of mass equal to 1,000 grams
mg	milligram
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
s.u.	standard units
ug/Kg	micrograms per kilogram (parts per billion)
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity



Control of Toxic Chemicals in Puget Sound

Summary Technical Report for Phase 3: Loadings from POTW Discharge of Treated Wastewater

DEPARTMENT OF ECOLOGY
State of Washington

HERRERA
ENVIRONMENTAL CONSULTANTS

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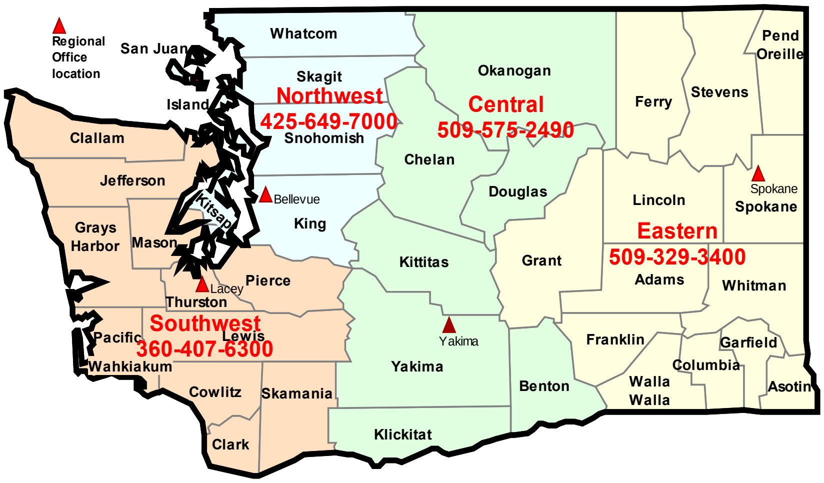

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Summary Technical Report

Control of Toxic Chemicals in Puget Sound Phase 3: Loadings from POTW Discharge of Treated Wastewater

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List of Abbreviations and Acronyms

ARI	Analytical Resources, Inc.
BNAs	base/neutral/acid extractable compounds
DDT	dichlorodiphenyltrichloroethane
DMR	discharge monitoring report
E & E	Ecology and Environment, Inc.
ECD	electron capture detector
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
GC	gas chromatograph
GC/ECD	gas chromatography/electron capture detector
GC/HRMS	gas chromatography/high-resolution mass spectrometry
GC/MS	gas chromatography/mass spectrometry
Herrera	Herrera Environmental Consultants, Inc.
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
kg/yr	kilograms per year
L	liter
LC/MS/MS	liquid chromatography-tandem mass spectrometry
MBR	membrane bioreactor
MDL	method detection limit
MEL	Manchester Environmental Laboratory
mgd	million gallons per day
mgy	million gallons per year
ml	milliliter
MS	mass spectrometer
ng/L	nanogram/liter (parts per trillion)
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl

List of Abbreviations and Acronyms
(continued)

PFC	perfluorinated compound
PFOA	perfluoroorganic acid
PFOS	perfluorosulfonate
pg/L	picograms per liter (parts per quadrillion)
POTW	publicly owned treatment works
PPCPs	pharmaceuticals and personal care products
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
ROS	regression on order statistics
SIM	selected ion monitoring
STP	Sewage Treatment Plant
µg/L	micrograms per liter (parts per billion)
U.S. EPA	United States Environmental Protection Agency
UV	ultraviolet
WWTP	wastewater treatment plant

Executive Summary

The project team's purpose was to improve the estimates of toxic chemical loadings to Puget Sound by targeted assessment of National Pollutant Discharge Elimination System (NPDES) permitted publicly owned treatment works (POTWs). Our goals were (1) to screen treated wastewater discharges for toxic chemicals that POTW operators do not routinely monitor, and (2) to improve the loading estimates for certain toxic chemicals by employing more sensitive analytical methods.

The project team identified and collected treated wastewater samples from ten POTWs of varying types of treatment process, size, and source of wastewater, distributed around the Puget Sound Basin. Two of the POTWs discharged to freshwater rivers, and the rest to Puget Sound marine waters. Together, the ten sampled POTWs discharged an average of about 48 percent of the total treated municipal wastewater discharged by all Ecology-permitted POTWs in the Puget Sound Basin. Although we collected samples only twice from each POTW (in February and July 2009), these 20 samples represented the aggregate of all treated wastewater discharged by the 106 permitted POTWs of the Puget Sound Basin.

The project team analyzed the wastewater samples for the following classes of toxic chemicals, using methods that yielded significantly lower than typical reporting limits:

- Polycyclic aromatic hydrocarbons (PAHs)
- Phthalates
- Other base/neutral/acid (BNA) extractable compounds
- Pesticides
- Herbicides
- Polybrominated diphenyl ethers (PBDEs)
- Perfluorinated compounds (PFCs)
- Polychlorinated biphenyls (PCBs)
- Metals (copper, lead, and zinc)

Following data review and validation, this project generated a total of 4,579 valid analytical results that characterized treated wastewater discharged from POTWs into the Puget Sound Basin. Toxic chemicals from each chemical class were detected in at least one sample from each of the ten sampled POTWs. We detected a total of 230 chemicals, not counting PBDE and PCB homologs. In order to evaluate the reasonableness of the results from this study, we compared the total concentrations of phthalates, PFCs, and PCBs discharged from the ten subject POTWs with those reportedly discharged to or from other POTWs in the state. The results of this study were similar to the results of those several other previous studies.

The project team determined individual annual loading rates of each of the chemicals from each of the ten sampled POTWs. Although the small number of samples precluded drawing any conclusions regarding specific POTWs, a few general findings were apparent.

- The majority of the PAHs discharged from most of the POTWs consisted primarily of five chemicals (fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene).

- The majority of the phthalates discharged from each of the ten POTWs consisted of bis(2-ethylhexyl) phthalate.

- The POTWs discharged only relatively small amounts of about a dozen pesticides and herbicides.

- Although the POTWs discharged many PBDEs, only three of them (BDE-047, BDE-099, and BDE-209) comprised almost all of the total loadings from each.

- Similarly, the POTWs discharged most of the PFCs that were analyzed, but only four of the PFCs (perfluorohexanoate, perfluorononanoate, perfluorooctane sulfonate, and perfluorooctanoate) comprised most of the total loadings from each POTW.

- Generally, as the total loadings of PCBs increased from any given POTW, so did the number of different PCB congeners that were discharged. Most of the PCB congeners were distributed among the tri-, tetra-, and penta-chlorobiphenyl homolog groups.

The project team also estimated the total loadings from POTWs to the surface waters of the Puget Sound Basin of 68 chemicals, plus two homolog groups and seven chemical classes. Chemical classifications are useful because they often indicate which chemicals might share a single source, affect environmental receptors in a similar manner, or all be amenable to particular treatments or other control actions. These estimated loadings were divided to represent the input from each of the 14 geographically distinct study areas of the basin. Due to the limited number of sampling events and atypical weather during the sampling period, we did not discern seasonal variations in loadings.

The results from this study greatly extended our understanding of chemical loadings from POTWs and were consistent with the results from Phase 2 and other recent studies conducted by Ecology and others. Future determination of the most effective and efficient actions for controlling or managing toxic threats should include evaluation of the effects of the chemicals, the new loading estimates of those chemicals, and the many other interdependent variables that characterize the pathways that facilitate chemical movement through the environment to Puget Sound.

1. Background and Purpose

1.1 Context of This Project

The Washington State Department of Ecology (Ecology) and several other groups have been working with the U.S. Environmental Protection Agency (EPA) and the Puget Sound Partnership (PSP) to restore the environmental health of Puget Sound by 2020 (PSP, 2010). This multi-year effort has required development of strategies, actions, and performance measures for restoring the Puget Sound ecosystem. Ecology has teamed with several partner organizations to study toxic chemical loadings to Puget Sound to understand the relative contributions from sources of contaminants in the Puget Sound ecosystem (Ecology, 2010). The main objectives of the "Control of Toxic Chemicals in Puget Sound" projects have included:

- Identify toxic chemicals that have harmed or threaten to harm the Puget Sound ecosystem or the beneficial uses which humans obtain from the Sound.

- Estimate the loading rates of key contaminants from their sources through their major pathways to Puget Sound.

- Provide information that will support development of a strategy to identify the actions, practices, and policies necessary to protect and restore the overall health of the Puget Sound ecosystem.

Accomplishing these objectives requires an understanding of the complex inter-relationships among the following three distinct elements of the Puget Sound ecosystem:

- The sources of pollutants.
- The pathways those pollutants take through the environment.
- The effects of those pollutants on the ecosystem.

It is important to clarify the difference between sources and pathways.

The term *source* may apply in a variety of ways with regard to chemicals in the environment. For the purpose of this project, the term source is defined as the location, object, or activity from which a pollutant is released to environmental media or released in a form that can be mobilized and transported through an environmental *pathway*. The term *primary source* identifies the initial release of a pollutant, as distinct from a *secondary source*, such as an old toxic chemical spill site, atmospheric deposition, or a publicly owned wastewater treatment plant (POTW). However, these secondary sources are more accurately described as pathways because they transport and mobilize chemicals from one location to another, or (in the case of POTWs) act as a focal point for chemical collection. Often, as also is the case for POTWs, pollutants moving along a pathway are degraded, destroyed, or permanently rendered harmless through designed or natural treatment processes.

The following examples illustrate the distinction between primary sources and secondary sources:

- Examples of *Primary Sources*:
    - Polycyclic aromatic hydrocarbons released to air from wood or petroleum burning.
    - Copper released to air, stormwater, and roadside ditches from brake pad wear.
    - Unmetabolized pharmaceuticals discharged from homes into sanitary wastewaters.
    - PCBs released to soil from transformer leakage.
    - Triclopyr applied to roadside ditches to control weeds.

- Examples of *Secondary Sources*, which are typically also pathways:
    - Atmospheric deposition of pollutants onto the surface of land or waterbodies.
    - Stormwater discharged from a municipal outfall into a stream.
    - Treated wastewater discharged from a POTW.
    - Contaminated soil leachate entering either groundwater or surface water.
    - Forest fire releasing back into the air the mercury that the growing vegetation had previously absorbed.

The toxic effects of a chemical depend on the dose (or exposure concentration), the duration of exposure, the timing of the exposure (e.g., at what stage of the lifecycle exposure occurs), the synergism and antagonism among multiple toxicants, and the harmful result of the exposure (e.g., temporary functional impairment, reduced reproductive capacity, shortened lifespan, and death). Given the goal of protecting the entire Puget Sound ecosystem, when evaluating relative toxic effects, Ecology must also consider the impacts of chemicals on the dependencies and interactions among species, such as through food chain relationships and altered predator avoidance behaviors.

Thus, while estimates of total loadings are important data, they are not particularly meaningful when considered in isolation. Loadings do not directly translate into threats, such that reducing the loading by half would reduce the threat by half. Determining the most effective and efficient actions for controlling or managing toxic threats must include evaluation of many interdependent variables and options. Management actions may occur at several different points along the pathways that facilitate chemical movement through the environment. For example, a control action may be to eliminate the initial release of the chemical by banning the primary source. Alternately, a more efficient method to reduce the threat from a chemical may be to treat a contaminated medium at a location where the pathways of several chemicals converge. Another approach for managing a toxic threat may be to establish a management zone for a small area, for example by prohibiting shellfish harvest within the vicinity of a POTW outfall. In some cases, targeting some of the available resources on limited goals may be preferable so that the remaining resources will be sufficient to ensure that other critical areas always remain healthy and usable. Final policy decisions for how to control and manage the chemicals that enter the Puget Sound ecosystem must include consideration of all these factors along with the various estimates of chemical loading.

These toxic chemical loading projects have been conducted in three phases, which are described in the following subsections. The Phase 1 study provided initial estimates of toxic chemical loadings to Puget Sound. Phase 2 projects improved those loading estimates. Phase 3 activities, of which this project is one component, target priority sources to collect and analyze environmental samples and improve the numerical model of the Sound (the Puget Sound box model) with the new data. The results of Phase 3 will help to enable Ecology and the PSP to assign the threats from toxic chemicals to specific sources and to select and implement actions to clean up and prevent contamination from those sources posing the greatest risks to Puget Sound.

Phase 1 – Initial Estimate of Toxic Chemical Loadings to Puget Sound

The purpose of this project was to assemble preliminary estimates of loadings of the most important toxic chemicals to Puget Sound via the presumed nine major pathways. These pathways were: surface runoff, aerial deposition onto Puget Sound, wastewater discharge, combined sewer overflows, direct spills to aquatic systems, groundwater discharges to marine surface waters, exchanges with the Pacific Ocean, leaching or biologically-induced movement from contaminated sediments, and migration of contaminated biota into Puget Sound. Based on data already available for the first five of these, the authors estimated the loadings of 17 chemicals (or classes of chemicals) from 14 hydrologically-based study areas that comprised the Puget Sound Basin. Depending on the contaminant, the main pathways were surface runoff and direct deposition from the air to the Sound (Hart Crowser, Inc., et al., 2007).

Phase 2 – Improve Loading Estimates

Two critical informational needs were to better understand and quantify the sources of toxic contaminants that enter Puget Sound and to improve the understanding of how toxics move within the ecosystem once they are there. The seven different projects in Phase 2 built upon the initial Phase 1 study to address these needs, and their results are available (Ecology, 2010a).

One of the Phase 2 projects focused on improving the loading estimates from permitted point source dischargers of wastewater within the Puget Sound Basin (EnviroVision Corporation, et al., 2008). While the available data were limited, the authors found that the contributions of toxic chemicals from wastewater dischargers (both publicly and privately owned) were small relative to the total loadings from all the major loading sources to Puget Sound, ranging from 1.4 to 7.0 percent of the total. The data also suggested that publicly owned treatment works (POTWs) discharged significantly more of some toxic chemicals than did the privately owned industrial point source dischargers.

Phase 3 – Targeting Priority Toxic Sources

In Phase 3, six of the 11 projects included the collection and analysis of environmental samples from within the Puget Sound Basin so that Ecology and its partners could further improve estimates of loadings from specific sources. The other projects focused on improving the Puget Sound box model with the new data and the synthesis and reporting of the results from all three phases to date. Results of the studies completed to date are available (Ecology, 2010a).

Two of the Phase 3 projects focused on POTWs regulated by Ecology through the National Pollution Elimination System (NPDES) permit program. One of these projects consisted of collecting and analyzing samples of wastewater for pharmaceuticals and personal care products

(PPCPs) (Lubliner, et al., 2010). The authors found differences in the removal efficiency of PPCPs among wastewater treatment plant processes, and that advanced nutrient reduction and tertiary filtration may provide additional PPCP removal. The other Phase 3 project that focused on POTWs is the project addressed by this report.

1.2 Purpose of This Project

One of the recommendations from one of the Phase 2 projects was:

> "If better estimates of toxic chemical loadings are necessary, Ecology should collect targeted samples and analyze them using methods that produce smaller MDLs. Also, as Ecology identifies emerging potential threats from other toxic chemicals (for example, polybrominated diphenyl ethers, fluorinated organic compounds, bisphenol A, and pharmaceuticals and personal care products), Ecology should (or should require permittees to) collect and analyze wastewater samples for those newly identified pollutants." (EnviroVision, et al., 2008)

The purpose of this project was to improve the estimates of toxic chemical loadings to Puget Sound by targeting POTWs and collecting and analyzing representative samples of the treated wastewater that they discharge. The goals of this project were (1) to screen treated wastewater discharges for toxic chemicals that POTW operators do not routinely monitor, and (2) to improve loading estimates for certain toxic chemicals by employing more sensitive analytical methods.

2. Methods

The project team consisted of the following organizations:

- Washington State Department of Ecology (Ecology)
- Herrera Environmental Consultants, Inc. (Herrera)
- Ecology and Environment, Inc. (E & E)
- Analytical Resources, Inc. (ARI)
- Axys Analytical Services, Ltd. (Axys)
- Pacific Rim Laboratories, Inc. (Pacific Rim)

Ecology was the project lead. E & E worked under contract to Ecology and was responsible for coordination of field and laboratory activities and quality assurance review of the analytical data. Herrera worked under subcontract to E & E and was responsible for sample collection and loading calculations. ARI worked under subcontract to Herrera and provided clean sample containers. Axys and Pacific Rim worked under subcontract to the Ecology Manchester Environmental Laboratory (MEL) and conducted the analyses of polybrominated diphenyl ethers, perfluorinated compounds, and polychlorinated biphenyls. MEL conducted the analyses of all the other parameters.

2.1 General Approach

The project team expected that variations in the following factors might drive differences in the loading rates of the various toxic chemicals discharged from POTWs:

- Types of treatment processes employed by the POTW.
- Rate of flow through the POTW.
- Activities of the sources in the POTW service area (e.g., residential or industrial).
- Time of day.
- Season of year.

Assessing these factors would have involved collecting samples from several POTWs that represented each type of treatment, at several different flow rates, for a variety of upstream sources located in different areas of the Puget Sound Basin, and collecting many samples from each POTW to establish how the loading rates of toxic chemicals varied at different times of the day and during the seasons of the year. However, due to a limited budget, the project team needed to produce a limited scope of work that balanced all of these factors, while maximizing the amount of usable data that this project would produce.

2.1.1 Selection of Pollutants

Ecology requires NPDES-permitted POTWs to periodically analyze their treated effluents for Priority Pollutant chemicals using standard analytical methodology and to report that data to Ecology. Review of that data in Phase 2 (EnviroVision, et al., 2008) found that most organic analytes were not detected in the effluents discharged from the POTWs using then standard analytical methods. These organic compounds included:

- Polycyclic aromatic hydrocarbons (PAHs)
- Phthalates
- Other base/neutral/acid (BNA) extractable compounds
- Pesticides
- Herbicides
- Polychlorinated biphenyls (PCBs)

In addition, Ecology was aware that several new classes of toxic chemicals were emerging as potentially harmful components of POTW effluent. These chemicals included:

- Polybrominated diphenyl ethers (PBDEs)
- Perfluorinated compounds (PFCs)
- Pharmaceuticals and personal care products (PPCPs)

The project team chose to analyze the wastewater discharges for 390 of the compounds contained within these chemical classes, excluding PPCPs. We did not focus on PPCPs in this study because another toxics loading project was evaluating these chemicals (Lubliner, et al., 2010). The project team also analyzed the treated wastewaters for total copper, lead, and zinc to enable a better comparison of the results from this study with the previous loading estimates derived in Phase 2 (EnviroVision, et al., 2008). We employed analytical methods that were more sensitive than those which POTW operators have been required to use so that we might detect smaller concentrations of the target pollutants (i.e., to decrease the "minimum detection limits" – MDLs). We analyzed for PCBs in only the samples collected in February, and only for six of the POTWs (Bremerton STP, City of Tacoma (Central No. 1), Everett STP (Outfall 100), King County West Point, Pierce County Chambers Creek STP, and Shelton STP).

2.1.2 Selection of POTWs

General POTW Characteristics

POTWs receive the following types of wastewater for treatment:

- Raw sewage from residential toilets, showers, and sinks, including wastes from laundry, dishwashing, and food preparation activities.

- A wide variety of wastes from industrial, commercial, and institutional facilities which may or may not undergo pretreatment prior to discharge to the POTW.

- Unless collected and conveyed separately, stormwater runoff from streets, rooftops, and other impervious surfaces.

Once wastewater reaches a POTW, it undergoes treatment before it is discharged to the environment, typically a surface water body. The treatment process can involve three stages: primary, secondary, and tertiary treatment. Occasionally where stormwater and sanitary lines are combined, large storm events can produce an influx of stormwater in excess of plant capacity that overwhelms the treatment system, resulting in the combined stormwater and sewage bypassing the treatment plant and discharging directly to surface waters untreated. This is a "combined sewer overflow" event and, except for the potentially severely impacted local areas, does not constitute a large part of the total loading of toxic chemicals to Puget Sound (Hart Crowser, et al., 2007).

For treating wastewater, the primary treatment stage employs a mechanical or physical process designed to remove solids and immiscible fats and oils. This may be accomplished in large settling tanks (usually referred to as sedimentation tanks or primary clarifiers) where solids and immiscible materials either float to the top or sink to the bottom. POTWs may also use preliminary screens to separate large objects before wastewater enters the settling tanks. The top product is skimmed off with a raking mechanism and is processed for disposal. The bottom product (or sludge) is scraped into a hopper where it is further dewatered before disposal to a landfill, biosludge composter, or waste fuel incinerator. Sludge can also be processed along with other compostable waste (grass clippings, leaves, food waste, and some cardboard products) and be sold as a biosolid fertilizer.

The purpose of secondary treatment is to meet federal and state secondary effluent standards by substantially degrading the biological or organic content of the liquid sewage effluent. These standards target biological oxygen demand and total suspended solids, typically using aerobic biological processes. The essential elements that drive the secondary treatment process are oxygen and biota, consisting of bacteria and protozoa that are capable of consuming the soluble organic contaminants (e.g., sugars, fats, and other hydrocarbons). The biota require a substrate in which they can thrive and bind much of the less soluble fractions into flocculent. Flocculation is a process of contact and adhesion whereby the particles of dispersion form larger-size clusters. Secondary clarifiers separate the flocculated solids from the wastewater stream, producing an additional sludge product that is processed in similar ways as the primary sludge product.

Some POTWs use treatment processes with the intent to address specific pollutants (e.g., organic nitrogen and phosphorus) beyond those specified in secondary water quality standards (biological oxygen demand, total suspended solids, and fecal coliform). They may employ multiple treatment processes for removing specific target pollutants. Sometimes this is called "tertiary treatment."

Prior to discharge to the environment, treated wastewater requires disinfection to inactivate pathogens that were not destroyed earlier in the treatment process. Disinfection is the additional step used to decrease the number of microorganisms. While the traditional and most common disinfection method is chlorination, ultraviolet (UV) and ozone are alternate methods.

Representative POTWs of the Puget Sound Basin

Under the NPDES permit program, Ecology has permitted approximately 106 POTWs to discharge treated wastewater in the Puget Sound Basin. Ecology had discharge flow information available in its NPDES permit management database (Ecology, 2010b) for the years 2007 through 2009 for all 106 POTWs except for the ten relatively smaller facilities operated by the U.S. Navy, U.S. Army, or Tribes. Appendix A identifies the total population of 96 candidate POTWs that the project team considered for this study. Of these 96 POTWs, 83 had flow data for all 36 months, seven had flow data for at least 24 months but less than 36, five had flow data for at least 12 months but less than 24, and one had flow data for less than 12 months. The data were sufficient for determining average flows, and were comparable to the flows used for the prior Phase 2 loading estimation by EnviroVision, et al. (2008). The total discharge volume to the Puget Sound Basin employed for the Phase 2 estimation was 130,061 mgy, while the total volume employed in this study was 124,142 mgy.

Although the project team hoped to select a sufficient number of POTWs to represent the entire range of operating variables in Puget Sound Basin, due to the limited budget the number of POTWs that we could sample was limited to ten. Although all the variations of size, age, type of treatment process, and type of source cannot be adequately compared through evaluation of only ten facilities, by providing some representation of each we expected to cover a relatively wide range of conditions. Access to the facilities and their current operating status (e.g., no plant upgrades ongoing or planned between the two sampling events) also contributed to the final selection. Table 1 identifies the POTWs that we selected as the subjects of this study.

The project team selected POTWs to represent a flow-weighted cross-section of the 96 candidate POTWs. The percentages of the total flows to Puget Sound from the selected POTWs were roughly comparable to those of all 96 POTWs. These percentages were for small POTWs (<1 mgd) 0.5% for the ten selected POTWs versus 3.8% for all 96 Puget Sound POTWs, for medium POTWs (1 to 10 mgd) 6.0% versus 23.2%, and for large POTWs (>10 mgd) 93.5% versus 73.0%, respectively. Since the five largest sampled POTWs discharged about 46% of the total treated effluent discharged by the POTWs in the Puget Sound Basin, the project team determined that this distribution of facilities adequately represented the actual flows to the Sound. Table 2 shows the similarity between the distributions of the total flows among all 96 small, medium, and large POTWs and the distributions among the ten POTWs sampled in this project.

Nine of the ten selected POTWs used an activated sludge secondary treatment process. The remaining facility (Everett STP (Outfall 100)) was a trickling filter/solids contact system. Since at least 66 percent of the POTWs in the Puget Sound Basin used activated sludge for secondary treatment, weighting the selection toward this treatment process was appropriate.

Four POTWs in the Puget Sound Basin employed treatment processes to address pollutants beyond those specified in the secondary effluent standards. We sampled one of these, the Sumner STP, for this study. Since only four Ecology-permitted POTWs that discharged to surface waters in the Puget Sound Basin employed a membrane bioreactor (MBR) (Carnation WWTP, Duvall STP, Port Orchard WWTP, and Seashore Villa STP), and their discharges have been relatively small, with a combined total flow of 2.34 mgd, we sampled none of the MBR-equipped facilities for this study.

For disinfection, seven of the selected facilities used chlorine, and the remaining operations used UV. This distribution adequately represented the types of disinfection employed in the Puget Sound Basin because most of the older facilities there still use chlorine, while newer facilities often rely on UV.

In terms of source activities in the POTW service areas, five of the selected POTWs received a significant amount of industrial influent, two received minor amounts, and three treated practically only sanitary waste from their primarily residential service areas. The selected POTWs were distributed among seven of the 14 study areas in the Puget Sound Basin to ensure representative geographic coverage (Figure 1).

2.1.3 Seasonal and Temporal Sampling

The project team sampled each POTW twice. To maximize the potential seasonal variation in loading rates, we scheduled collection of those two samples to represent significantly different weather conditions: winter (wet season) and summer (dry season), in February and July 2009, respectively. As mentioned previously, we analyzed PCBs only once for six selected POTWs, in February 2009.

The limited budget prevented the project team from tracking the variation in loading rates that may occur during the course of a given day because doing so would have required analyses of many more samples. However, we did account for potential variations during a typical weekday by analyzing 24-hour composited samples collected Mondays through Fridays.

2.2 Field Methods

This section summarizes how the project team collected representative samples of treated wastewater from the ten POTWs. Additional details may be found in the Quality Assurance Project Plan (QAPP) (E & E and Herrera, 2009).

The project team conducted a site visit to each facility to assess site access, select the most appropriate locations for collecting samples, and evaluate equipment installation needs. The following bullet items describe the general sampling site location at each POTW.

- Bellingham STP – Automated and grab samples were collected from the outfall flume downstream of the chlorination and dechlorination facility.

- Bremerton STP – Automated and grab samples were collected from contact tanks downstream of the chlorination and dechlorination facility, just upstream of the outfall.

- Burlington WWTP – Automated and grab samples were collected from the inlet to the outfall pipe downstream of the UV radiation treatment.

- City of Tacoma (Central No. 1) – Automated and grab samples were collected from the contact tank near the outfall.

- Everett STP (Outfall 100) – The automated sample was collected by way of an access stand pipe located downstream of the first chlorination facility. This represented the permit compliance point for the Everett POTW for all parameters except residual chlorine and fecal coliform. This location was upstream of the comingling with the Marysville STP effluent and upstream of a pump station where additional chlorination may occur.

The grab sample was collected from a sampling spigot located downstream of this pump station at the compliance point for residual chlorine and fecal coliform. Grab samples could not be collected from the same location as the automated samples due to physical constraints.

- Gig Harbor STP – Automated and grab samples were collected from a mixed effluent contact tank downstream of the chlorination and dechlorination facility. The grab samples were collected slightly downstream of the automated sampler location.
- King County West Point – Automated and grab samples were collected from the effluent wet well downstream of the chlorination and dechlorination facility.
- Pierce County Chambers Creek STP – Automated and grab samples were collected from the contact tank mixing area downstream of the chlorination and dechlorination facility, just upstream of the outfall.
- Shelton STP – Automated and grab samples were collected from contact tanks downstream of the chlorination and dechlorination facility.
- Sumner STP – Automated and grab samples were collected near the outfall.

The project team collected all 20 treated wastewater samples as specified in the QAPP (E & E and Herrera, 2009). The 24-hour composite samples represented the treated effluent discharged during one full weekday. Tables 3 and 4 provide the specific sampling schedules for each of the ten POTWs, winter and summer, respectively. We used automated samplers to collect time-weighted composite samples for all analytes except PFCs and metals. Since parts of the automated sampling equipment were composed of Teflon and glass, we collected the aliquots for PFCs and metals analyses as discrete grab samples in appropriate containers. We collected these grab samples at two times to represent both the high and low daily flow at each POTW. We sampled all ten POTWs within a narrow time frame so that the samples represented similar weather conditions.

The project team cleaned the sample bottles (including the 9-liter [L] glass jar, the 1-L polypropylene bottle, and the 500-milliliter [ml] Teflon bottle for metals) as described in the QAPP (E & E and Herrera, 2009). Sample bottles and tubing were kept tightly sealed, and the ends of the tubing were covered with aluminum foil and placed into a pre-marked sealable plastic bag until installation at the facility.

The project team programmed the automated, refrigerated sampling devices (ISCO Avalanche®) to collect a 175-ml aliquot every 30 minutes, for a total of 48 sample aliquots collected from each POTW over the 24-hour sampling period. On the scheduled sampling day, we installed each sampling device at the site and verified the program. We then operated the sampling device manually, collecting and discharging effluent, to rinse the intake hosing and verify that the device collected 175 ml of effluent. To verify that the program had started and the automatic sampling device was working correctly, before moving to the next POTW, we waited while the ISCO-Avalanche collected at least two sample aliquots.

Upon completion of the automated collection of the 24-hour composite sample, project personnel checked the equipment to verify that no sampling errors had occurred. We capped the sample jar, removed it from the sampling device, and placed it on ice. At this time, we manually operated the sampling device to collect an aliquot of effluent to verify that 175 ml of effluent was still being collected.

The project team transported bottles for the grab portions of each sample in single resealable plastic bags. We collected grab samples from all the POTWs using the modified one-person clean hands/dirty hands procedure. In most cases it was necessary to use an extension pole and attach the sample bottle with zip ties to reach the effluent stream. We then rinsed the extension pole with deionized water before using it at the next POTW.

Once project personnel had collected both the grab and composite aliquots, we immediately capped, labeled, and put them on ice in a cooler. We then transported the samples to the Ecology Field Operations Center in Lacey and refrigerated them until delivering them the following morning to MEL for analysis.

Winter sampling occurred during the week of February 9, 2009. However, the project team resampled two of the POTWs (Tacoma Central and Chambers Creek) the following week due to the partial failure of two of the automated samplers and damage to the field duplicate sample. Thus the grab samples for these two POTWs were not collected on the same day as the composites. We successfully collected the entire set of 48 aliquots at nine of the ten facilities. However, the Burlington POTW shut down in the final hour of the sampling effort and resulted in collection of only 47 aliquots from this facility.

Summer sampling occurred during the week of July 13, 2009. All 48 aliquot were collected at all ten POTWs, and there were no irregularities associated with this event.

The project team obtained daily flow rate information from the operators of each of the POTWs for the days when samples were collected. We also reviewed the flow data that the POTWs had submitted to Ecology via their discharge monitoring reports for the 3 years from January 2007 through December 2009.

2.3 Laboratory Methods

The Ecology MEL analyzed the wastewater samples for all of the targeted toxic chemicals except PBDEs, PFCs, and PCBs. Pacific Rim analyzed its portion of the samples for PBDEs and PCBs. Axys analyzed its portion of the samples for PFCs. The analytical methods identified in the following subsection are described in detail in U.S. EPA 1999a, 2004, and 2007.

2.3.1 Analytical Methods

PAHs were analyzed using U.S. EPA SW-846 Method 8270 SIM. Method 8270 SIM is a modification of Method 8270. Selected ion monitoring (SIM) enhances sensitivity by setting the mass spectrometer (MS) to detect specific ions rather than a range of ions. Sensitivity is generally increased by a factor of 10 over standard MS measurements. The primary disadvantage of SIM is a loss of qualitative information (unable to compare spectra).

BNAs and herbicides were analyzed using U.S. EPA SW-846 Method 8270. BNA extractable compounds included the phthalates chemical class. Samples were analyzed by gas chromatography/mass spectrometry (GC/MS) following extraction and, if necessary, appropriate sample cleanup and derivatization procedures. Sample extracts were injected into a gas chromatograph (GC) equipped with a capillary column that utilized a temperature program to separate analytes that were then detected with an MS. Analytes were identified by comparing electron impact spectra to the spectra of known standards. Analytes were quantified by comparing the response of a major ion relative to an internal standard using a calibration curve developed for each analyte.

Pesticides were analyzed using U.S. EPA SW-846 Method 8081. Samples were analyzed by gas chromatography/electron capture detector (GC/ECD) following extraction and, if necessary, appropriate sample cleanup procedures. Sample extracts were injected into a GC equipped with a capillary column, which utilized a temperature program to separate analytes that were then detected with an electron capture detector (ECD). Analytes were identified by comparing the retention time of target compounds with retention times of known standards on two dissimilar columns. Analytes were quantified by comparing the sample peak response using a calibration curve developed for each target compound.

PBDEs were analyzed using U.S. EPA method GC/HRMS 1614. Samples were analyzed using gas chromatography/high-resolution mass spectrometry (GC/HRMS) following extraction and, if necessary, appropriate sample cleanup procedures. Sample extracts were injected into a GC equipped with a capillary column, which utilized a temperature program to separate analytes that were then detected with an HRMS. Individual compounds (i.e., congeners) were identified by comparing the retention time and ion-abundance ratio of target compounds and associated labeled analog compounds with retention times and ion-abundance ratios of known standards. Congeners were quantified using the isotopic dilution quantitation technique, comparing the area of the quantification ion to that of the 13C-labeled standard and correcting for response factors.

PFCs were analyzed using Axys Method MLA-060 (Axys Analytical Services, Ltd., 2008). Samples were analyzed by liquid chromatography-tandem mass spectrometry (LC/MS/MS) following solid-phase extraction and selective elution procedures. Sample extracts were analyzed on a high-performance liquid chromatograph coupled to a triple quadrupole mass spectrometer. Target compounds were quantified using the internal standard method, comparing the area of the quantification ion to that of the 13C-labeled standard and correcting for response factors.

PCBs were analyzed using U.S. EPA method GC/HRMS 1668A. Samples were analyzed using gas chromatography/high-resolution mass spectrometry (GC/HRMS) following extraction and, if necessary, appropriate sample cleanup procedures. Sample extracts were injected into a GC equipped with a capillary column, which utilized a temperature program to separate analytes that were then detected with an HRMS. Individual compounds (i.e., congeners) were identified by comparing the retention time and ion-abundance ratio of target compounds and associated labeled analog compounds with retention times and ion-abundance ratios of known standards. Congeners were quantified using the isotopic dilution quantitation technique, comparing the area of the quantification ion to that of the 13C-labeled standard and correcting for response factors.

Metals were analyzed using U.S. EPA Method 200.8. Samples were analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) following acid extraction. Sample extracts injected into the ICP-MS were quantified by comparing instrument response to a calibration curve developed for each analyte. Results were reported for total (unfiltered) copper, lead, and zinc.

2.3.2 Data Review and Validation

The project team conducted data review and validation in general accordance with the detailed quality control (QC) procedures documented in the MEL Quality Assurance Manual (Manchester Environmental Laboratory, 2007) and Lab Users Manual (Manchester Environmental Laboratory, 2008), and in each subcontracted laboratory's quality assurance (QA) manual. One QC target for this project was for each laboratory to extract and analyze all the samples collected during each event in a single batch. By doing this, a single set of QC parameters would be applicable to all samples collected during each sampling event.

2.4 Data Analysis

2.4.1 Quality Assurance Review

The project team validated analytical data to verify they met project data quality objectives and to identify any limitations of the data, following the process outlined in Ecology QA1 review guidelines (PTI Environmental Services, 1989). Validation consisted of comparing calibration, accuracy, and precision results to the QC criteria listed in the method, the laboratory standard operating procedure, and the QAPP. If no QA guidelines existed for specific analytes, then the project team used applicable U.S. EPA national and regional data review guidelines (U.S. EPA, 1999b).

Since the Ecology MEL employs standardized analyte lists that partially overlap, they analyzed the following six chemicals with more than one method.

- 2,3,4,6-Tetrachlorophenol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- Dacthal
- Hexachlorobenzene
- Pentachlorophenol

For example, the laboratory used U.S. EPA Method SW-846 8270 (for semivolatile [BNA extractable] organic compounds by GC/MS) and 8270 (chlorinated herbicides by solid-phase extraction and GC/MS) to quantify the amount of pentachlorophenol in the samples. Thus, the laboratory reported more than one result for these six chemicals (i.e., two results for each sample). For each chemical, the project team selected only one of the results for use in estimating loadings – the one obtained with the more sensitive method which provided the smaller reporting limit.

The generally accepted practice is that concentrations between the method detection limit (MDL) and the reporting limit are reported as detected but not quantified, due to the potential for misuse of low-level data with relatively high quantitative uncertainty. However, for this investigation concentrations of all analytes reported between the MDL and reporting limit have been quantified and annotated with a "J" qualifier (estimated concentration), indicating a higher level of uncertainty in the quantitative value. Statistical evaluations of data whose uncertainties are "high" can lead to erroneous conclusions, especially if the sample populations are limited in size or are highly censored (high percentages of non-detect data – results where analytes are not present at detectable concentrations).

For this study, only wastewater sample results quantified at concentrations at least three times greater than the corresponding results in the method blank and in the field blank samples were considered "detected." Wastewater sample results that were not at least three times greater than the corresponding results in the method blank were qualified with a "U" to indicate "not detected." Wastewater sample results that were not at least three times greater than the corresponding results in the field or rinseate blank samples were qualified with a "UFB" to indicate "not detected due to contamination of the field or rinseate blank" for the purposes of this project only. The qualifier "U" subsequently replaced "UFB" in the data uploaded to the Ecology Environmental Information Management (EIM) system database.

2.4.2 Estimated Discharge from POTWs

The project team reviewed the wastewater discharge rates reported for January 2007 through December 2009 by the 96 POTWs listed in Appendix A (raw data in Ecology, 2010b), and determined the average annual discharge rate for each POTW. For estimating chemical loadings, we employed the average flows self-reported by the POTWs via their discharge monitoring reports.

2.4.3 Estimated Loadings of Toxic Chemicals from Each of the Ten POTWs

Using the toxic chemical concentration data obtained through this study, the project team developed annual loading rates for each of the ten sampled POTWs. We calculated annual loading rates by multiplying the average annual discharge rate from each facility by the average concentration for each toxic chemical. The average concentration depended on the number of detect and non-detect values from the two sampling events. We used the following procedures to compute annual loading rates for each POTW:

- If a chemical were detected during both sampling events, an average concentration was computed using the two detect values. We then used this average in the subsequent loading calculation.

- If a chemical were analyzed during only one sampling event and were detected, we used the reported concentration in the subsequent loading calculation.

- If a chemical were analyzed during both sampling events and were detected during only one of them, we computed an average concentration using the detect value and one-half the reporting limit for the non-detect value. We then used this average in the subsequent loading calculation.

- If a chemical were analyzed during both sampling events and were not detected during either of them, we did not generate a loading estimate.

2.4.4 Estimated Total Loadings to Puget Sound

The project team computed annual loading rates of each toxic chemical or chemical class for each of the 14 study areas in Puget Sound by multiplying the average annual volume of treated wastewater discharged from all the POTWs located in each study area by a representative concentration for each toxic chemical or chemical class. The average annual discharge volume for each study area was the sum of the discharge volumes from the POTWs located within the area. Table 6 identifies the average annual total discharge of wastewater from POTWs for each study area and compares the values used in this Phase 3 study with those that were used and that should have been used in the Phase 2 study (EnviroVision, et al., 2008). The discharge volumes were quite similar after correction for the mis-location of several POTWs in the Phase 2 study.

In determining some of the representative concentrations, the project team employed Regression on Order Statistics (ROS) to account for non-detect results, as described in the calculation steps provided later in this section. ROS is a commonly used procedure for estimating summary statistics from data sets that contain below-detection-limit (censored) observations (Helsel, 2005). The procedure first computes the Weibull-type plotting positions of the combined uncensored and censored observations. A linear regression model is then generated from the plotting positions of the uncensored observations and their normal quantiles. This linear regression model is the basis for estimating the concentration of the censored observations as a function of their normal quantiles. Finally, the observed uncensored values are combined with the modeled censored values to estimate summary statistics for the entire population. In this application, the project team used ROS to estimate summary statistics (i.e., 5th, 25th, 50th, 75th, and 95th percentiles) for individual and classes of toxic chemicals.

The project team compared the summary statistics derived from the treatment of non-detect results using the ROS method with those derived from three simpler substitution methods. They employed substitutions of non-detect data with zero, half the reporting limit, and the full reporting limit.

Individual Chemicals

To obtain representative concentrations for each toxic chemical, the project team pooled the data from samples collected at all ten POTWs during both the winter and summer sampling events. After pooling the data, we used different procedures to obtain a representative concentration for each chemical. The selected procedure for each chemical depended on the total number of results and the number of detect and non-detect values. We used the following steps to calculate representative concentrations if ten or more results were available for a given chemical:

1. Compute the detection frequency for each chemical by dividing the number of detect values by the total number of valid values, after excluding from both counts any rejected results. The number of valid values varied for each chemical because some values were rejected for quality assurance reasons, and some chemicals were analyzed a different number of times. Appendix D summarizes these detection frequencies.

2. Screen the frequencies from Step 1 to identify only those chemicals that had a detection frequency of 50 percent or greater. Given that the maximum number of results possible for any chemical was 20, this 50 percent detection frequency was the minimum likely to provide meaningful loading rate estimates.

3. Calculate the 5th, 25th, 50th, 75th, and 95th percentiles from the subset of chemicals identified in Step 2 using ROS, a statistical method for calculating summary statistics on censored datasets. Appendix E summarizes these percentiles.

4. Use the 25th, 50th, and 75th percentiles from Step 3 as the representative concentrations in the loading calculations to provide a measure of the central tendency and overall variability of the loading rates.

If fewer than ten results were available for a given chemical, the project team used the following steps to compute representative concentrations:

1. Compute the detection frequency for each chemical by dividing the number of detect values by the total number of valid values, after excluding from both counts any rejected results. The number of valid values varied for each chemical because some values were rejected for quality assurance reasons, and some chemicals were analyzed a different number of times. Appendix D summarizes these detection frequencies.

2. Screen the frequencies from Step 1 to identify only those chemicals that had a detection frequency of 65 percent or greater. For chemicals with fewer than ten results, this 65 percent detection frequency was the minimum likely to provide meaningful loading rate estimates.

3. Calculate the 5th, 25th, 50th, 75th, and 95th percentiles for each of the chemicals identified in Step 2, substituting one-half the reporting limit for all non-detect values in the data. Appendix E summarizes these percentiles.

4. Use the 25th, 50th, and 75th percentiles from Step 3 as the representative concentrations in the loading calculations to provide a measure of the central tendency and overall variability of the loading rates.

Further statistical and loading calculations employed only those chemicals selected by one of the two options described above.

Classes of Toxic Chemicals

Chemical classifications reflect the general internal structure of a group of chemicals or the reactive groups attached to that general structure. Aggregating chemicals into groups or classes with similar structures or reactive groups is sometimes useful because chemical classifications often indicate that the chemicals within such a group might share a single source, behave or affect environmental receptors in a similar manner, or all be amenable to particular treatments or other control actions that remove them from the waste stream.

The specific analytical method by which a chemical may be measured need not correspond with how that chemical may be "classified." For this study, the project team grouped the toxic chemicals of concern into classifications that did not necessarily reflect the analytical method that the laboratories used. Thus, for example, although pentachlorophenol is one of the BNA extractable analytes and is also detectable using the chlorinated herbicides method, we reported it, only once, as a member of the class of other BNA extractables and used the herbicide result because it was derived from the more sensitive analytical method.

The project team grouped the toxic chemicals into the 11 different classes listed below. Where we had sufficient data, we calculated the summary statistics and loading rates for individual chemicals. Where we had sufficient data, we also calculated the summary statistics and loading rates for certain chemical classes, comprised of specific individual compounds, as shown below. A "congener" is an example of a specific compound. For this project, a "homolog" is the group of compounds that contains a specific number of chlorine or bromine atoms. For example, the dibrominated diphenyl ether homolog group consists of the three individual congeners BDE-007, BDE-010, and BDE-015. Carcinogenic PAHs (cPAHs) constituted a subset of the heavy PAHs (HPAHs). A complete list of the chemicals and classes is provided in Appendix C.

Chemical Class	Number of Chemicals	Loading for Chemicals	Loading for Class
PAHs (light, heavy, and carcinogenic)	16 (6, 10, 7)	Yes	Yes
Phthalates	6	Yes	Yes
Other Base/Neutral/Acid Extractables	55	Yes	No
Pesticides	34	Yes	No
Herbicides	18	Yes	No
PBDEs (congeners)	38	Yes	Yes
PBDEs (homologs)	9	Yes	No
PFCs	13	Yes	Yes
PCBs (congeners)	209	Yes	Yes
PCBs (homologs)	10	Yes	No
Metals (copper, lead, and zinc)	3	Yes	No

To determine a representative concentration for each toxic chemical class, the project team pooled the data from all the samples collected from all ten POTWs during both the winter and summer sampling events. We summed the reported concentrations of each chemical within each class of chemicals for each sampling event at each POTW. We used the following steps to derive representative concentrations for each class of toxic chemicals:

1. For these summations, substitute zero for all non-detect values of individual chemicals unless all the reported values of the individual chemicals of a given chemical class/event/POTW combination were non-detects. In that case, use the highest reporting limit of all the individual chemicals within that chemical class/event/POTW combination to represent the non-detect concentration for that chemical class/event/POTW combination.

2. If none of the summed concentrations for a chemical class were non-detect, calculate the 5th, 25th, 50th, 75th, and 95th percentiles from those summed concentrations. If any of the

summed concentrations were non-detect, calculate the 5th, 25th, 50th, 75th, and 95th percentiles using ROS. Appendix E summarizes these percentiles.

3. Use the 25th, 50th, and 75th percentiles from Step 2 as the representative concentrations in the loading calculations to provide a measure of the central tendency and overall variability of the loading rates.

3. Results

3.1 Field Work

Table 5 shows the average daily flows for 2007 through 2009 compared with the average of measured discharge flow rates that each POTW operator provided for the two sampling events, and presents the annual flows that we used in calculating toxic chemical loadings. The flow values that the project team selected for loading calculations were based on the more representative monthly monitoring results reported by the POTWs to Ecology to comply with their NPDES permits.

3.2 Laboratory Work

3.2.1 Review of Data Quality

Appendix B contains copies of the Data Usability Summary Reports that document the results of the Level 1 data quality review. Brief descriptions of the data quality are provided below for each analytical method.

Polycyclic Aromatic Hydrocarbons

The Ecology MEL analyzed samples from February and July for PAHs using U.S. EPA Method SW-846 Method 8270D SIM (Polycyclic Aromatic Hydrocarbons by GC/MS) in accordance with the QAPP. The 320 PAH results generally met the project data quality objectives for reporting and QC limits. The project team qualified 35 percent of the results with a "J" qualifier to indicate uncertainty in the quantitative measurements. Of the results that indicated a detectable amount of pollutant ("detect results"), 52 percent were qualified with a "J."

Base/Neutral/Acid Extractable Compounds

The Ecology MEL analyzed samples from February and July for BNAs using U.S. EPA Method SW-846 Method 8270 (Semivolatile Organic Compounds by GC/MS) in accordance with the QAPP. BNA extractable compounds included the phthalates chemical class. The 1,160 BNA results generally met the project data quality objectives for reporting and QC limits. The project team qualified 30 percent of the results with a "J" qualifier to indicate uncertainty in the quantitative measurements. Of the detect results, 60 percent were qualified with a "J." Four of the detect results were also qualified as tentatively identified when qualitative QC criteria were not met. We rejected 70 results for failing to meet QC criteria (6.0 percent of the total possible BNA results). The following ten compounds had rejected results:

- 2,4-Dimethylphenol........... 2 Rejects
- 2-Nitroaniline .... 5 Rejects
- 3,3'-Dichlorobenzidine......11 Rejects
- 3-Nitroaniline .... 5 Rejects
- 4-Chloroaniline..................20 Rejects
- 4-Nitroaniline ....10 Rejects
- 4-Nonylphenol.......................... 4 Rejects
- bis(2-Chloroethoxy) methane... 5 Rejects
- Bisphenol A.............................. 5 Rejects
- Caffeine .... 3 Rejects

The Ecology MEL analyzed all of the required BNAs with the exception of benzidine (in both events) and N-nitrosodimethylamine (in July). In both February and July, the laboratory also provided data for the following five chemicals, not specified in the QAPP.

- 2-Methylphenol
- 4-Methylphenol
- Caffeine
- Triclosan
- Triethyl citrate

In July only, the laboratory provided data for the following five chemicals, also not specified in the QAPP.

- 3B-Coprostanol
- Benzoic acid
- Benzyl alcohol
- Cholesterol
- 2-Chloroethanol phosphate (3:1)

The BNA data met the project data quality objectives, although the reporting limits for several of the analytes were slightly greater than the values identified in the QAPP.

Pesticides

The Ecology MEL analyzed samples from February and July for pesticides using U.S. EPA Method SW-846 Method 8081 (Chlorinated Pesticide Compounds by GC/ECD) in accordance with the QAPP. The 650 pesticide results generally met the project data quality objectives for reporting and QC limits. The project team qualified 43 percent of the results with a "J" qualifier to indicate uncertainty in the quantitative measurements. Of the detect results, 62 percent were qualified with a "J."

In July only, the Ecology MEL provided data for the following seven chemicals that were not specified in the QAPP.

- 2,4'-DDD
- 2,4'-DDE
- 2,4'-DDT
- Chlordane, technical
- DDMU
- Mirex
- Pentachloroanisole

Herbicides

The Ecology MEL analyzed samples from February and July for herbicides using U.S. EPA Method SW-846 Method 535/8270 (Chlorinated Herbicides by Solid-Phase Extraction and GC/MS) in accordance with the QAPP. The 360 herbicide results generally met the project data quality objectives for reporting and QC limits. The project team qualified 12 percent of the results with a "J" qualifier to indicate uncertainty in the quantitative measurements. Of the detect results, 79 percent were qualified with a "J." Eleven of the detect results were also qualified as tentatively identified when qualitative QC criteria were not met. We rejected five results for failing to meet QC criteria (1.4 percent of the total possible herbicide results). The following four compounds had rejected results:

- 2,4-DB..................1 Reject
- Acifluorfen...........1 Reject
- Dinoseb ....1 Reject
- Picloram .... 2 Rejects

Polybrominated Diphenyl Ethers
Pacific Rim analyzed samples from February and July for PBDE congeners using U.S. EPA SW-846 Method 1614 (Brominated Diphenyl Ethers in Water, Soil, Sediment, and Tissue by HRGC/HRMS) rather than U.S. EPA Method 1668 as specified in the QAPP. This variation was acceptable because it provided equivalent or better data than required to meet project data quality objectives.

The 710 PBDE results generally met the project data quality objectives for reporting and QC limits. The project team qualified 37 percent of the results with a "J" qualifier to indicate uncertainty in the quantitative measurements. Of the detect results, 23 percent were qualified with a "J." Ten of the detect results were also qualified as tentatively identified when qualitative QC criteria were not met.

Pacific Rim analyzed all the required congeners, except that in both February and July the results for BDE-197 and BDE-204 were reported as a total value rather than separately, and in February the results for BDE-049 and BDE-071 were reported as a total value rather than separately. The inability of the laboratory to separate these very similar congeners did not negatively impact the data usability. In addition, Pacific Rim provided data for the following three congeners that were not specified in the QAPP.

- BDE-007
- BDE-010
- BDE-015

Perfluorinated Organic Compounds
Axys analyzed samples from February and July for PFCs using Method MLA-060 (Analytical Procedure for Perfluorinated Organic Compounds in Aqueous Samples by LC-MS/MS) in accordance with the QAPP. In addition, the laboratory provided data for perfluorooctane sulfonamide (PFOSA).

Although the 260 PFC results complied with all other project data quality objectives, Axys employed reporting limits that were approximately an order of magnitude greater than the reporting limits identified in the QAPP. While this made no difference for detected congeners, and the quality of the non-detect results was acceptable, a possibility exists that the actual total concentrations of PFCs, and thus their loadings to Puget Sound, was greater than the estimate provided by this study.

Polychlorinated Biphenyls
Pacific Rim analyzed samples from February for PCB congeners using U.S. EPA Method 1668 (Chlorinated Biphenyl Congeners by HRGC/HRMS) in accordance with the QAPP. The 1,134 PCB results generally met the project data quality objectives for reporting and QC limits. The project team qualified less than 0.1 percent of the results with a "J" qualifier to indicate uncertainty in the quantitative measurements. None of the detect results were qualified with a "J." Seventeen of the detect results were also qualified as tentatively identified when qualitative QC criteria were not met.

Metals
The Ecology MEL analyzed samples for total metals (copper, lead, and zinc) using U.S. EPA Method 200.8 (Inductively Coupled Plasma – Mass Spectrometry) in accordance with the QAPP. The 60 metals results met the project data quality objectives for reporting and QC limits, and none of them were qualified.

3.2.2 Summary of Analytical Results

Excluding duplicate and field blank/rinseate samples, this project generated a total of 4,579 valid analytical results that characterized 20 samples of treated wastewater from ten subject POTWs (two samples from each POTW). Through data review and validation, the project team qualified 95 results as non-detects (with the "UFB" qualifier) due to potential contamination during handling based on the results of field/rinseate samples. A detectable amount of target analyte was present from every class of toxic chemicals that the project team assessed in one or more of the treated wastewater discharges. We detected a total of 230 chemicals, not counting PBDE and PCB homologs (212 chemicals if PCB co-elutants are considered individual analytes). Except for the PFC class, the range (i.e., variability) of the total concentrations of each chemical class among the POTWs was greater in summer than in winter. Appendix C summarizes all of the results from the chemical analyses. Appendix D summarizes for each analyzed chemical the number of valid results and the percentage of those results that indicated the detectable presence of that chemical. Table 7 shows the number of chemicals detected within each of the chemical classes. Note that all data provided in the text, tables, and appendices are precise to only two significant figures.

Polycyclic Aromatic Hydrocarbons
The project team analyzed for 16 PAHs, consisting of six low molecular weight compounds (LPAHs) and ten high molecular weight compounds (HPAHs). The greatest number of PAHs detected in any of the 20 samples was eight, and the largest single PAH concentration was 0.37 micrograms per liter (μg/L) of naphthalene. The most frequently detected PAHs were fluorene, fluoranthene, phenanthrene, and pyrene.

Each one of the six LPAHs was detected in effluent samples from at least one POTW. LPAHs were detected in all but four samples and in all but one POTW, and the largest concentration of total LPAHs in any sample was 0.79 μg/L. For the ten samples collected in February, the number of detected LPAHs ranged from zero to five, and the largest sum of the LPAHs was 0.14 μg/L. For the ten samples collected in July, the number of detected LPAHs ranged from zero to six, and the largest sum of the LPAHs was 0.79 μg/L.

Seven of the ten HPAHs were detected in effluent samples from at least one POTW. HPAHs were detected in all but two samples, those from a single POTW. The number of detected HPAHs ranged from zero to five, and the largest sum of the HPAHs was 0.076 μg/L. For the ten samples collected in February, the number of detected HPAHs ranged from zero to four, and the largest sum of the HPAHs ranged was 0.047 μg/L. For the ten samples collected in July, the number of detected HPAHs ranged from zero to five, and the largest sum of the HPAHs was 0.076 μg/L.

The effluent samples from only two POTWs contained detectable carcinogenic PAHs (cPAHs).

Phthalates

The project team analyzed for six phthalates. For the ten samples collected in February, the number of detected phthalates ranged from one to three, and the sum of phthalates ranged from 0.31 to 3.4 µg/L. For the ten samples collected in July, only bis(2-ethylhexyl) phthalate phthalate was detected, at concentrations ranging from 0.19 to 5.3 µg/L.

Other Base/Neutral/Acid Extractables

The project team analyzed 55 semi-volatile compounds (BNA extractables) that were not grouped within another chemical class. Thirty of these compounds were detected in the wastewater samples, and each of the 20 samples contained detectable concentrations of from four to 15 of them. The three chemicals that typically showed the greatest concentrations were 3B-coprostanol, caffeine, and cholesterol. When these three compounds were excluded (due to absent analyses or rejected results for the February samples), the results for the remaining 27 compounds did not indicate the existence of a seasonal pattern.

Pesticides

The project team analyzed 20 samples for 34 pesticides and detected six. Endosulfan I and alpha-BHC were detected only in winter, at three and two POTWs, respectively. Chlorpyriphos, pentachloroanisole, and toxaphene were detected only in summer, at one, three, and two POTWs, respectively. Hexachlorobenzene was detected in the wastewater from one POTW in the summer, and from another POTW in the winter.

Herbicides

The project team analyzed 20 samples for 18 herbicides and detected only five, generally more frequently in the summer than in the winter. Detectable concentrations of MCPP and triclopyr were present in only five of the wastewater samples. Detectable concentrations of 2,4-D; Dicamba I; and MCPA were present in three samples.

Polybrominated Diphenyl Ethers

Congeners

The project team analyzed for 38 PBDE congeners, with six of them co-eluting with another congener, producing three combinations. Considering the co-eluting congener combinations to be individual analytes, for the ten samples collected in February, the number of detected PBDEs ranged from 11 to 25, and the sum of PBDEs ranged from 9,100 to 125,000 picograms per liter (pg/L). For the ten samples collected in July, the number of detected PBDEs ranged from 11 to 31, and the sum of PBDEs ranged from 8,600 to 135,000 pg/L.

Homologs

The project team calculated concentrations for the nine PBDE homologs based upon the congener data. PBDEs from each homolog group were detected, and four of the homolog groups were detected in every sample (the hexa-, penta-, tetra-, and tri-BDEs).

Perfluorinated Compounds

The project team analyzed for 13 PFCs and detected from six to ten of these toxic chemicals in each of the wastewater samples. The four compounds that were typically present in the greatest concentrations were perfluorohexanoate (maximum of 52 nanograms per liter (ng/L)), perfluorononanoate (maximum of 134 ng/L), perfluorooctane sulfonate (maximum of 55 ng/L), and perfluorooctanoate (maximum of 70 ng/L). All 20 samples contained detectable concentrations of these four chemicals.

Polychlorinated Biphenyls

Congeners

The project team analyzed the six wastewater samples collected in February for 209 PCB congeners, with 37 of them co-eluting in one or another of 17 combinations. Considering the 17 co-eluting congener combinations to be individual analytes, the number of detected PCB congeners ranged from five to 105, and the sum of PCB congeners ranged from 69 to 15,400 pg/L. Every effluent sample contained PCBs.

Homologs

The MEL calculated concentrations for the ten PCB homologs based upon the congener data. PCBs in each homolog group were detected, and eight of the homologs were detected in at least half of the samples.

Metals

The project team detected copper, lead, and zinc in all 20 samples of wastewater. The smallest reported concentrations were 2.6 µg/L for copper, 0.15 µg/L for lead, and 13 µg/L for zinc. The two greatest concentrations of copper were in the wastewaters from the King County West Point and Sumner POTWs (14 and 17 µg/L, respectively). The two greatest concentrations of lead were in the wastewaters from the Everett STP and City of Tacoma (Central No. 1) POTWs (1.2 and 0.72 µg/L, respectively). The two greatest concentrations of zinc were in the wastewaters from the Gig Harbor STP (95 and 76 µg/L, for summer and winter, respectively).

Summary Statistics

Using the calculation methods described in Section 2.4.4, the project team quantified the variability of the results of each chemical and class of chemicals for which Puget Sound-wide loadings were later calculated. Appendix E summarizes these summary statistics, listing the expected concentration of each chemical and class of chemicals at the 5th, 25th, 50th, 75th, and 95th percentiles.

When comparing the methods for handling non-detect data, the project team found that the median concentrations obtained by substituting half the reporting limit were the most similar to those derived by the ROS method. Of the 63 chemicals and chemical classes where ROS was used, the corresponding median concentrations for 60 of them were the same or within a 10% relative difference, and for two others were within a 15% relative difference. Substituting half the reporting limit gave median values slightly larger than the ROS method for 4-methylphenol (58% relative difference). These results were consistent with those of Antweiler and Taylor, 2008. Appendix F contains additional details of this comparison.

3.3 Estimated Loadings of Toxic Chemicals from Each of the POTWs

The project team multiplied the average flows of wastewater discharge shown in Table 5 by the chemical concentrations selected as described in Section 2.4.3 to estimate rough annual loading rates from each of the ten subject POTWs. Appendix G summarizes the annual loadings from each POTW to the Puget Sound Basin.

Polycyclic Aromatic Hydrocarbons
Of the 16 PAHs analyzed among the ten POTWs, the number of PAHs detected in the discharge from any given POTW ranged from two to eight. Only five chemicals (fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) comprised almost all of the total PAH loadings (61 to 100 percent) from nine of the POTWs. The effluent from one of the POTWs (Everett (outfall 100)) contained five PAHs not usually found in the other discharges, among which were four cPAHs.

Phthalates
Of the six phthalates analyzed among the ten POTWs, the number of phthalates detected at any given POTW ranged from one to three. All ten POTWs discharged bis(2-ethylhexyl) phthalate, which constituted 52 to 100 percent of their total loadings of phthalates via treated effluent.

Other Base/Neutral/Acid Extractables
Of the 55 miscellaneous BNA extractable chemicals discharged by the ten subject POTWs, the project team detected seven of them in all 20 samples of wastewater. These were 1,4-dichlorobenzene; 2,4,6-trichlorophenol; 2-chloroethanol phosphate; cholesterol; dibenzofuran; triclosan; and triethyl citrate. The three chemicals discharged in the greatest amounts were 3B-coprostanol (ranging from not detectable to 1,100 kilograms per year (kg/year)), caffeine (ranging from not detectable to 54 kg/year), and cholesterol (ranging from 14 to 1,500 kg/year).

Pesticides
Of the ten POTWs, the treated wastewater discharges of three of them contained no detectable amount of the 34 analyzed pesticides. Only five chemicals (chlorpyriphos, endosulfan I, hexachlorobenzene, pentachloroanisole, and toxaphene) comprised 96 to 100 percent of the total pesticide loadings from each of the other seven POTWs.

Herbicides
Of the ten POTWs, the treated wastewater discharges of three of them contained no detectable amount of the 18 analyzed herbicides. Only four chemicals (2,4-D; MCPA; MCPP; and triclopyr) comprised 84 to 100 percent of the total herbicide loadings from each of the other seven POTWs.

Polybrominated Diphenyl Ethers
Congeners
Of the 38 PBDEs analyzed among the ten POTWs, the number of PBDEs detected at any given POTW ranged from 18 to 32 (when considering the three co-eluting congener combinations as

individual analytes). Only three congeners (BDE-047, BDE-099, and BDE-209) comprised 69 to 82 percent of the total PBDE loadings from each of the ten POTWs.

Homologs

The two homologs that constituted the greatest portion of the PBDE loadings (from 45 to 81 percent) were the penta- and tetra-bromodiphenyl ethers. Decabromodiphenyl ether represented 43 percent of the total loading discharged by the Gig Harbor STP. The Everett STP (Outfall 100), King County West Point, and City of Tacoma (Central No. 1) facilities discharged the largest amounts of PBDEs annually, from 2.6 to 64 times as much as any of the other POTWs.

Perfluorinated Compounds

Of the 13 PFCs analyzed among the ten POTWs, the number detected at any given POTW ranged from eight to ten. Five of these compounds were detected in every one of the 20 sample analyzed. Only four chemicals (perfluorohexanoate, perfluorononanoate, perfluorooctane sulfonate, and perfluorooctanoate) comprised 56 to 87 percent of the total PFCs discharged from each of the POTWs.

Polychlorinated Biphenyls

Congeners

Of the 209 PCB congeners analyzed among the six sampled POTWs, the number detected at any given POTW ranged from five to 105 (when considering the 17 co-eluting congener combinations as individual analytes). The variety of congeners detected at a given POTW generally corresponded with their total loadings. The five congeners that the six POTWs discharged in the greatest amounts were PCBs-004, 052/064, 118, and 138. The total loading of these five congeners constituted about 19 percent of the total loading of PCB congeners.

Homologs

Of the ten homolog groups, the number detected at the six sampled POTWs ranged from one to nine. For three of the POTWs, the tetra-, penta-, and hexa-chlorobiphenyl homologs constituted 63 to 70 percent of their discharges. For the Shelton STP, the tri-, tetra-, and hepta-chlorobiphenyl homologs constituted 94 percent of its discharge. For the Pierce County Chambers Creek STP, the di-, tri, and tetra-chlorobiphenyl homologs constituted 93 percent of its discharge.

Metals

The ranges of the loadings of the three analyzed metals from the ten sampled POTWs varied considerably. The median annual loading of copper was 59 kg/year, within an 180-fold high-to-low range. The median annual loading of lead was 4.3 kg/year, within a 90-fold high-to-low range. The median annual loading of zinc was 240 kg/year, within a 48-fold high-to-low range.

3.4 Estimated Total Loadings to Puget Sound

Based on the total number of valid analyses and the frequencies of detection, the project team identified 68 individual chemicals, discounting PBDE and PCB homologs, for which we could reliably estimate total loadings to Puget Sound (using the method described in Section 2.4.4).

The data also allowed calculation of estimates for the total loadings of 13 PBDE and PCB homologs and seven chemical classes. Appendix E identifies the summary statistics (the 5th, 25th, 50th, 75th, and 95th percentiles) for these individual chemicals and chemical classes. Appendix H summarizes the estimated loadings of these chemicals and chemical classes in the 14 study areas of Puget Sound (25th, 50th, and 75th percentiles only).

Since the available data required the grouping of chemical results from all ten of the subject POTWs, the areal distribution of loadings to the Puget Sound Basin directly corresponded to the total discharge rates from the POTWs within each study area. Since no POTWs were located within the Elliott Bay study area, the loadings from that study area were zero. The following bullets identify the estimated ranges of total loadings for toxic chemical classes and the three metals to the Puget Sound Basin from all the POTWs in the 14 study areas, shown as from the 25th to the 75th percentiles. Appendix H presents additional details along with the loading estimates for the other chemicals.

- Total PAHs: 7.6 to 46 kg/year.
  LPAHs comprised from 43 to 76 percent of the total PAHs annually discharged to Puget Sound. The amount of LPAHs ranged from 3.3 to 35 kg/year.

- Total phthalates: 220 to 910 kg/year.
  Bis(2-ethylhexyl) phthalate comprised 80 to 100 percent of the total phthalates annually discharged to Puget Sound. The amount of bis(2-ethylhexyl) phthalate ranged from 220 to 900 kg/year.

- Total PBDEs: 7.0 to 21 kg/year.
  From 71 to 79 percent of the PBDE congeners annually discharged to Puget Sound were BDE-047, BDE-099, and BDE-209, constituents within the tetra-, penta-, and deca-bromodiphenyl ether homolog groups, respectively.

- Total PFCs: 31 to 59 kg/year.
  From 39 to 49 percent of the PFCs annually discharged to Puget Sound consisted of perfluorohexanoate and perfluorooctanoate.

- Total PCBs: 0.13 to 1.8 kg/year.
  Approximately 55 percent of the PCB congeners annually discharged to Puget Sound were distributed among the tri-, tetra-, and penta-chlorobiphenyl homolog groups.

- Copper: 2,500 to 5,500 kg/year.

- Lead: 140 to 250 kg/year.

- Zinc: 16,000 to 24,000 kg/year.

4. Discussion

4.1 Comparison with Results from Phase 2

Most of the difference in estimated loadings between the Phase 2 study in 2008 and this Phase 3 study appeared to be due to variations in the concentrations rather than total discharge volume of treated wastewater. Table 6 shows the similarity between the Phase 2 and Phase 3 studies of the average total flows from POTWs to the 14 Puget Sound study areas.

Based on the limited suite of NPDES self-monitoring analytes and the use of standard analytical reporting limits (i.e., larger than those used for this study), the Phase 2 study provided estimates of total loadings for seven chemicals: copper, lead, mercury, zinc, chloroform, bis(2-ethylhexyl) phthalate, and phenolics. The total estimated loadings of copper and zinc to Puget Sound from this study were about 70 and 97 percent, respectively, of the Phase 2 study estimates. The estimated loadings of lead and bis(2-ethylhexyl)phthalate from this study were 18 and 17 percent, respectively, of the Phase 2 study estimates. For each of the 14 Puget Sound study areas, Table 8 compares the loading rate estimates of the four chemicals that we assessed in Phase 2 with the results from this study.

In general, the current study has improved and extended the results from Phase 2, and has clearly demonstrated that POTWs discharge toxic chemicals in their treated wastewater effluents.

4.2 Comparison with Results from Other Studies

The project team evaluated whether the results from this study for these particular ten POTWs were similar to or differed from the discharges of treated effluents from other POTWs in Washington State. We focused primarily on PCBs, which are legacy pollutants, and PFCs, which are pollutants of emerging concern.

Polychlorinated Biphenyls
PCBs are the class of toxic organic chemicals for which Ecology had the greatest amount of historical data. The following studies addressed historical discharges of PCBs from POTWs:

• Albion, Colfax, Pullman	Lubliner, 2009.
• College Place, Walla Walla	Lubliner, 2007.
• Liberty Lake, Spokane	Golding, 2002.
• Okanogan, Omak, Oroville	Serdar, 2003.
• 18 POTWs in the Yakima River watershed	Johnson, et al., 2009.

For all of these studies, the analytical laboratories employed methods that reduced the final detection limits to values lower than normal, similar to this study. Figure 2 illustrates the total concentrations of PCBs discharged from these facilities and shows that the results found in this study were similar to results from elsewhere. This study found that the concentrations of total PCBs from the Everett STP (Outfall 100) and City of Tacoma (Central No. 1) facilities were greater than the other POTWs shown in Figure 2. However, these results were based upon only a single composite sample from each facility. Further analyses are required to support any conclusions.

Ten of the PCB congeners (and their three co-elutants) detected most frequently and at the greatest concentrations in this study were the same PCB congeners that Ross, et al. (2000) found at the greatest concentrations in blubber tissue samples from the northern and southern resident populations of Orca whales. These ten congeners were PCBs-052, 099, 101, 105, 118, 138, 149, 153, 180, and 187. They and their co-elutants were among the top 12 percent of all PCB congeners ranked according to the greatest average concentration discharged from the six POTWs and among the top 25 percent frequency of detection, and contributed 31 percent of the total average concentration of all the PCB congeners. Four of the 21 congeners for which Ecology estimated loadings were among the ten that Ross, et al. identified as the greatest in the Orca whales. These congeners and their two co-elutants comprised from 9.7 to 23 percent of the total loading of PCBs from POTWs to Puget Sound.

Since the manufacture of PCBs ceased several decades ago, the frequent detection of PCBs in POTW wastewaters indicated that legacy contamination remains a significant source of PCBs. The presence of PCBs in a variety of building materials (e.g., caulking, paint, insulation, roofing, siding, and asphalt) is an ongoing source that slowly and continually releases small amounts of PCBs into the environment and the regional wastewater infrastructure. The U.S. EPA (1997) summarized data that indicated that 32 to 65 metric tons of PCBs had been incorporated into caulking materials alone in the Puget Sound region (Ecology, 2011 in preparation). Since PCBs degrade very slowly and adhere to organic matter, the majority of residual PCBs appear to have bound to particles, and some have become trapped in wastewater systems (i.e., in the sediments in the piping). Therefore, uncontrolled construction or cleaning activities may mobilize these residuals and release additional pulses of PCBs into the environment for many more years.

Perfluorinated Compounds

Ecology has only recently begun to acquire monitoring data concerning PFCs in wastewater discharges. A recent study (Furl and Meredith, 2010) assessed the PFCs discharged in 2008 from four Washington state POTWs. Figure 3 illustrates the concentrations of total PFCs discharged from those four facilities and compares them with the results from the ten POTWs sampled in this study. The results from the two studies were similar. Almost all the total PFC concentrations in the treated wastewaters were between 50 and 200 ng/L.

Phthalates

Information about discharges of phthalates from POTWs in Washington state is limited. One study estimated the loading of bis(2-ethylhexyl) phthalate to POTWs in the Puget Sound region (Washington Toxics Coalitions and People for Puget Sound, 2009). Based upon analyses of residential dust and laundry wastewaters, the authors determined that approximately 959 kg of bis(2-ethylhexyl) phthalate flows annually from residences to POTWs in the Puget Sound region. This loading is consistent with our estimate in this study that POTWs discharge from 220 to 900 kg of bis(2-ethylhexyl) phthalate. The smaller amount discharged from POTWs than discharged to POTWs likely indicates that POTWs successfully treat or remove some of the phthalates in their wastewaters.

4.3 Seasonal Comparisons

The original intent for collecting treated effluent samples in February and July was to characterize possible differences in the concentrations and loadings of toxic chemicals during the wet and dry seasons. The project team suspected that a greater amount of precipitation and a higher groundwater table in the winter might increase the flow to POTWs and possibly affect the contaminant loads entering the POTWs and the degree of treatment they experienced prior to discharge. Also seasonal differences in the activities of wastewater producers may have caused the loadings of certain toxic chemicals to vary from one part of the year to another.

Unfortunately, the weather did not cooperate, and January to early February 2009 was an unusually dry period. Although some precipitation did occur in mid-February when samples were collected, the flow volumes from several of the POTWs were less in February than in July (Table 5).

Given that the measured effluent concentrations and flows varied substantially among the POTWs and that one day of sampling could not represent an entire season, this study could not distinguish a seasonal pattern. However, the winter samples from the three largest facilities (based on flow) contained from two to seven times as many detected PAHs and total concentrations from four to 19 times as great as the other POTWs. Whether this variation was due to a seasonal difference is not clear. Additional study may be warranted in the future.

4.4 Limitations

1. Based on 4,579 valid concentration results for toxic chemicals in 20 samples of wastewater, the results represented only a small portion of the total amount of wastewater treated and discharged by the POTWs in the Puget Sound Basin. Some comparisons are:

    - The Puget Sound Basin contained 106 permitted POTWs, and flow information was available for 96 of them.
      However, the project team collected samples from only ten POTWs and based loading estimates for the entire Sound on only 20 samples (six samples for PCBs).

    - The total flow from the 96 Puget Sound POTWs was approximately 124,140 mgy.
      However, the project team collected samples from POTWs whose discharges totaled 59,900 mgy (Table 5) – only 48 percent of the total POTW discharge to the Sound.

    - The rates of toxic chemical loadings from POTW discharges vary day-to-day throughout the year.
      However, the project team collected samples that represented only two days of the year (one day for PCBs).

2. Almost 73 percent of the analytical results were "non-detects." As a consequence, the project team did not estimate loadings from all 96 Puget Sound POTWs for 303 of the total 371 individual chemicals that we analyzed, not counting the PBDE and PCB homologs and

PCB co-elutants. However, a non-detect result did not mean that the amount of a particular chemical in a given wastewater sample was zero. Thus, this study could not support conclusions about whether any of these 303 chemicals were or were not threats to the health of the Puget Sound ecosystem.

3. The project team used the ROS method to “fill in” values for 48 individual chemicals, eight homolog groups, and seven chemical classes for which only some of the results were non-detect (less than 35 percent for individual chemicals with fewer than ten results, and less than 50 percent for the other individual chemicals). Therefore, the concentration summary statistics in Appendix E and the loading estimates in Appendix H were accurate only to the extent that the assumptions behind the ROS method were true for these data.

5. Conclusions

The goals of this project were (1) to screen treated wastewater discharges for toxic chemicals that POTW operators do not routinely monitor, and (2) to improve the loading estimates for certain toxic chemicals by employing more sensitive analytical methods.

This study developed improved estimates for the loadings of toxic chemicals discharged from permitted POTWs into the surface waters of the Puget Sound Basin. These new loading estimates are improved and more accurate than the Phase 2 estimates because the project team:

(a) Sampled from facilities that employed a wide variety of treatment techniques.
(b) Applied uniform and approved methods for sampling and analyses.
(c) Used more recent data than in prior studies.
(d) Covered a much broader list of chemicals than normally monitored.
(e) Employed more sensitive analytical methods than normally used.

POTWs are a significant secondary source of toxic chemicals. The results from this study will support development and prioritization of future control actions to improve and protect the Puget Sound ecosystem.

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Tables

Table 1. Characteristics of the Ten Subject POTWs

POTW Name	Permit Number	Study Area	Treatment Process	Industrial Influent	Max Month Avg Design Flow (MGD)	Representative Flow (MGD)
Bellingham STP	WA0023744	Strait of Georgia	Secondary oxygen-activated sludge with chlorine.	Yes	37	12.3
Bremerton STP	WA0029289	Sinclair-Dyes Inlet	Secondary activated sludge with chlorine.	Yes	10.1	4.30
Burlington WWTP	WA0020150	Whidbey Basin	Secondary activated sludge with UV disinfection.	Negligible	3.79	1.64
City of Tacoma (Central No.1)	WA0037087	Commencement Bay	Secondary activated sludge with chlorine.	Yes	60	19.9
Everett STP (Outfall 100)	WA0024490	Port Gardner	Trickling filter and solids contact with chlorine.	Yes	21.0	10.6
Gig Harbor STP	WA0023957	South Sound East	Secondary activated sludge with chlorine.	Negligible	1.6	0.809
King County West Point	WA0029181	Main Basin	Secondary activated sludge with chlorine.	Yes	215	92.5
Pierce County Chambers Creek STP	WA0039624	South Sound East	Secondary activated sludge (aerobic and anoxic) with UV.	Minimal	28.7	17.9
Shelton STP	WA0023345	South Sound East	Secondary activated sludge in oxidation ditch with chlorine.	Negligible	4.02	1.99
Sumner STP	WA0023353	Commencement Bay	Activated sludge with UV disinfection and anaerobic sludge digestion.	Minimal	4.59	2.01

Key:

MGD = Million gallons per day.
POTW = Publicly Owned Treatment Works.
STP = Sewage Treatment Plant.
UV = Ultraviolet.
WWTP = Wastewater Treatment Plant.

Table 2. Comparison of Sampled POTWs with All POTWs in the Puget Sound Basin

Size of the Average Flow	POTWs in the Puget Sound Basin (a)			POTWs Sampled in This Project		
	Number	Total Flow from POTWs Considered (MGY)	Percentage of Total Flow	Number	Total Flow from POTWs Sampled (MGY)	Percentage of Total Flow
Small (<1 MGD)	60	4,710	3.8%	1	295	0.5%
Medium (1 to 10 MGD)	29	28,770	23.2%	4	3,630	6.0%
Large (>10 MGD)	7	90,660	73.0%	5	56,900 (b)	93.5%
Total =	96	124,140	100.0%	10	60,800 (c)	100.0%

Key:

The precision of the data in this table is only two significant figures.

The flows may not add up due to rounding.

The flows are based upon the average monthly flows self-reported by each POTW from January 2007 through December 2009 (Ecology, 2010b).

MGD = Million gallons per day.
MGY = Million gallons per year.
POTW = Publicly Owned Treatment Works.
(a) = Excluding the ten small facilities operated by the U.S. Army and Navy and the Tribes.
(b) = Includes only the sampled Outfall 100 at the Everett STP.
(c) = This value differs from the corresponding total in Table 5 due to rounding.

Table 3. Summary of Winter Samples

POTW Name	Composite Samples					Grab Samples	
	Volume Submitted to Laboratory (Liter)	Number of Aliquots	Start (date/time)	End (date/time)	Collected (date/time)	Grab 1 (date/time)	Grab 2 (date/time)
Bellingham STP	8.4	48	2/11/09 09:35	2/12/09 09:06	2/12/09 09:30	2/11/09 07:15	2/12/09 10:40
Bremerton STP	8.3	48	02/09/09 09:30	2/10/09 09:01	2/10/09 10:00	02/09/09 08:45	2/10/09 10:45
Burlington WWTP	9	47	2/09/09 10:40	2/10/09 10:10	2/10/09 10:40	2/10/09 0735	2/10/09 10:10
City of Tacoma (Central No. 1)	8.4	48	2/18/09 10:44	2/19/09 10:15	2/19/09 10:30	2/11/09 05:45	2/12/09 14:15
Field Duplicate	8.4	48	2/18/09 11:08	2/19/09 10:39	2/19/09 10:45	NA	NA
Lab Duplicate	8.4	48	2/18/09 11:30	2/19/09 11:03	2/19/09 11:15	NA	NA
Everett STP (Outfall 100)	8.5	48	2/11/2009 12:06	2/12/09 11:37	2/12/2009 12:40	2/11/09 12:20	2/12/09 13:00
Gig Harbor STP	8.3	48	2/09/09 07:05	2/10/09 06:35	2/12/09 12:15	2/09/09 05:55	2/10/09 12:25
King County West Point	8.8	48	2/09/2009 07:20	2/10/2009 06:50	2/10/2009 12:30	2/09/09 05:30	02/09/09 13:35
Field Duplicate	NA	NA	NA	NA	NA	2/09/09 05:30	02/09/09 13:35
Lab Duplicate	NA	NA	NA	NA	NA	2/09/09 05:30	02/09/09 13:35
Pierce County Chambers Creek STP	8.4	48	2/18/09 14:34	2/19/09 14:05	2/19/09 14:30	2/11/09 07:30	2/12/09 16:30
Shelton STP	8.4	48	2/09/09 12:37	2/10/09 12:08	2/10/09 16:00	2/09/09 12:10	2/10/09 06:00
Sumner STP	8.4	48	2/11/09 10:00	2/12/09 09:30	2/12/2009 12:00	2/11/09 10:40	2/12/09 06:15

Key:

NA = Not applicable.

POTW = Publicly Owned Treatment Works.

STP = Sewage Treatment Plant.

WWTP = Wastewater Treatment Plant.

Table 4. Summary of Summer Samples

POTW Name	Composite Samples					Grab Samples	
	Volume Submitted to Laboratory (Liter)	Number of Aliquots	Start (date/time)	End (date/time)	Collected (date/time)	Grab 1 (date/time)	Grab 2 (date/time)
Bellingham STP	9	48	7/15/2009 07:10	7/16/2009 07:20	7/16/2009 09:20	7/15/2009 07:20	7/16/2009 09:24
Bremerton STP	9	48	7/13/2009 10:00	7/14/2009 09:30	7/14/2009 09:30	7/13/2009 08:35	7/14/2009 10:30
Burlington WWTP	9	48	7/13/2009 11:25	7/14/2009 10:54	7/14/2009 08:15	7/13/2009 10:00	7/14/2009 08:20
City of Tacoma (Central No. 1)	9	48	7/15/2009 06:50	7/16/2009 06:10	7/16/2009 07:30	7/15/2009 06:00	7/16/2009 14:40
Everett STP (Outfall 100)	9	48	7/15/2009 10:59	7/16/2009 10:29	7/16/2009 12:28	7/15/2009 10:30	7/16/2009 12:37
Gig Harbor STP	9	48	7/13/2009 06:28	7/14/2009 06:00	7/14/2009 11:30	7/13/2009 06:00	7/14/2009 12:15
King County West Point	9	48	7/13/2009 07:44	7/14/2009 07:12	7/14/2009 13:25	7/13/2009 05:55	7/14/2009 13:30
Field Duplicate	9	48	7/13/2009 07:50	7/14/2009 07:17	7/14/2009 13:25	7/13/2009 05:40	NA
Pierce County Chambers Creek STP	9	48	7/15/2009 15:30	7/16/2009 15:00	7/16/2009 16:00	7/16/2009 07:25	7/16/2009 16:14
Shelton STP	9	48	7/14/2009 07:50	7/15/2009 07:20	7/15/2009 12:45	7/13/2009 12:45	7/14/2009 07:30
Sumner STP	9	48	7/16/2009 06:30	7/17/2009 06:00	7/17/2009 06:00	7/15/2009 10:35	7/16/2009 06:15

Key:

NA = Not applicable.
POTW = Publicly Owned Treatment Works.
STP = Sewage Treatment Plant.
WWTP = Wastewater Treatment Plant.

Table 5. Average Flow Volumes for the Ten POTWs

	Phase 2 (a) (MGD / MGY)	Self-Reported via DMRs (b) (MGD)	Phase 3 (this study)			
			February Event (MGD)	July Event (MGD)	Average (MGD / MGY)	Value Used for Loading Estimates (MGD / MGY)
Bellingham STP	12.1 / 4,430	12.3 (c)	10.94	9.98 (d)	10.5 / 3,820	12.3 / 4,490
Bremerton STP	5.04 / 1,840	4.30 (e)	3.71	4.91	4.31 / 1,570	4.30 / 1,570
Burlington WWTP	1.56 / 569	1.64 (e)	no data	no data	no data	1.64 / 599
City of Tacoma (Central No. 1)	19.7 / 7,190	19.9 (e)	17.28	16.25	16.8 / 6,120	19.9 / 7,260
Everett STP (Outfall 100)	12.6 / 4,620	10.6 (e)	11.98	14.58	13.3 / 4,470 (f)	10.6 / 3,870
Gig Harbor STP	0.800 / 292	0.809 (e)	0.7133	0.6725	0.693 / 253	0.809 / 295
King County West Point	102 / 37,400	92.5 (g)	110.9	66.24	88.6 / 32,300	92.5 / 33,800
Pierce County Chambers Creek STP	17.8 / 6,480	17.9 (e)	8.52	15.72	12.1 / 4,420	17.9 / 6,530
Shelton STP	2.13 / 776	1.99 (e)	2.13	no data	2.13 / 777 (h)	1.99 / 726
Sumner STP	1.89 / 690	2.01 (e)	1.95	1.96	1.96 / 714	2.01 / 734

Key:

DMR = Discharge Monitoring Report required by NPDES permit.

MGD = Million gallons per day.

MGY = Million gallons per year.

POTW = Publicly Owned Treatment Works.
STP = Sewage Treatment Plant.
WWTP = Wastewater Treatment Plant.
(a) = From EnviroVision, et al., 2008.
(b) = From Ecology PARIS database of permittee-reported monitoring results (Ecology, 2010b).
(c) = December 2007 through December 2009.
(d) = Average of daily flows for July 15 and 16, 2009 (Wendling, 2010).
(e) = January 2007 through December 2009.
(f) = Annual flow was adjusted to account for an average of 29 days per year out of service.
(g) = July 2009 through December 2009.
(h) = Only one data point.

Table 6. Average Total POTW Flow Volumes for the 14 Puget Sound Study Areas

Study Area	Average Total POTW Flows (MGY)			Comparison Phase 3 versus Phase 2 (corrected) (percent)
	Phase 2	Phase 2 (corrected)	Phase 3 (this study)	
Admiralty Inlet	338	338	332	- 1.8
Commencement Bay	12,126	12,162	12,169	+ 0.058
Elliott Bay	0	0	0	0
Hood Canal (North)	4	270	73.4	- 73.
Hood Canal (South)	0	5.9	5.9	0
Main Basin	77,329	77,161	72,543	- 6.0
Port Gardner	12,634	12,935	11,736	- 9.3
San Juan Islands	1,529	858	828	- 3.5
Sinclair-Dyes Inlet	3,798	3,796	3,624	- 4.5
South Sound (East)	7,832	7,062	7,097	- 0.50
South Sound (West)	4,243	4,904	4,731	- 3.5
Strait of Georgia	5,943	5,943	6,068	- 2.1
Strait of Juan de Fuca	1,160	1,160	1,110	- 4.3
Whidbey Basin	3,126	3,701	3,825	- 3.4
Total =	**130,061**	**130,296**	**124,142**	**- 4.7**

Key:

The precision of the data in this table is only two significant figures.
Values may not appear to sum correctly due to rounding.

MGY = Million gallons per year.

POTW = Publicly Owned Treatment Works.

The POTWs reassigned to their correct Study Areas were:

Alderbrook Resort and Spa
Carnation WWTP
Granite Falls STP STP
Messenger House Care Center
North Bend STP
Oak Harbor STP

Olympic Water and Sewer, Inc.
Penn Cove WWTP
Pope Resources
Rainier State School
Shelton STP
Taylor Bay STP

Table 7. Number of Chemicals Detected within Each Chemical Class

Chemical Class	Number of Chemicals			
	Analyzed	Detected (a)	Detected >= 50% (b)	Detected >= 65% (b)
Polycyclic Aromatic Hydrocarbons (PAHs)	16	13	4	nc
Phthalates	6	4	1	nc
Other Base/Neutral/Acid Extractables	55	30	(c)	nc
Pesticides	34	6	0	nc
Herbicides	18	5	0	nc
Polybrominated Diphenyl Ethers (PBDE Congeners)	38	33	18	nc
Polybrominated Diphenyl Ethers (PBDE Homologs)	9	9	8	nc
Perfluorinated Compound (PFCs)	13	12	9	nc
Polychlorinated Biphenyls (Congeners) (PCB Congeners)	209	124	nc	21
Polychlorinated Biphenyls (Homologs) (PCB Homologs)	10	10	nc	5
Metals (Copper, Lead, and Zinc)	3	3	nc	nc

Key:

nc = Not calculated.
(a) = Derived from data in Appendix C; used for determining loadings by chemical class.
(b) = Derived from Percent Detection column in Appendix D; used for determining loadings for individual chemicals.
(c) = Total loading rates were not determined for these groups of chemicals.

Table 8. Comparison of Estimated Loadings from Phase 1 and Phase 2

Study Area	Copper				Lead				Zinc				bis(2-Ethylhexyl) Phthalate			
	Phase 2 (a) Best Estimate (kg/year)	Phase 3 (this study)			Phase 2 (a) Best Estimate (kg/year)	Phase 3 (this study)			Phase 2 (a) Best Estimate (kg/year)	Phase 3 (this study)			Phase 2 (a) Best Estimate (kg/year)	Phase 3 (this study)		
		25th Percentile (kg/year)	50th Percentile (kg/year)	75th Percentile (kg/year)		25th Percentile (kg/year)	50th Percentile (kg/year)	75th Percentile (kg/year)		25th Percentile (kg/year)	50th Percentile (kg/year)	75th Percentile (kg/year)		25th Percentile (kg/year)	50th Percentile (kg/year)	75th Percentile (kg/year)
Admiralty Inlet	1.32E+01	6.69E+00	1.16E+01	1.47E+01	1.41E+00	3.74E-01	4.96E-01	6.79E-01	5.88E+01	4.29E+01	5.08E+01	6.37E+01	4.16E+00	5.78E-01	1.18E+00	2.42E+00
Elliott Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commencement Bay	5.25E+02	2.45E+02	4.25E+02	5.40E+02	1.07E+02	1.37E+01	1.82E+01	2.49E+01	2.03E+03	1.57E+03	1.86E+03	2.33E+03	1.85E+02	2.12E+01	4.31E+01	8.87E+01
Hood Canal (North)	1.60E-01	1.48E+00	2.56E+00	3.26E+00	1.70E-02	8.27E-02	1.10E-01	1.50E-01	7.00E-01	9.48E+00	1.12E+01	1.41E+01	5.00E-02	1.28E-01	2.60E-01	5.35E-01
Hood Canal (South)	0	1.18E-01	2.05E-01	2.61E-01	0	6.61E-03	8.78E-03	1.20E-02	0	7.58E-01	8.98E-01	1.13E+00	0	1.02E-02	2.08E-02	4.28E-02
Main Basin	3.81E+03	1.46E+03	2.53E+03	3.22E+03	3.19E+02	8.17E+01	1.08E+02	1.48E+02	9.29E+03	9.37E+03	1.11E+04	1.39E+04	5.58E+02	1.26E+02	2.57E+02	5.29E+02
Port Gardner	2.75E+02	2.36E+02	4.10E+02	5.21E+02	1.53E+02	1.32E+01	1.75E+01	2.40E+01	1.07E+03	1.52E+03	1.79E+03	2.25E+03	3.41E+02	2.04E+01	4.15E+01	8.55E+01
San Juan Islands	6.74E+01	1.67E+01	2.89E+01	3.67E+01	3.04E+00	9.32E-01	1.24E+00	1.69E+00	1.71E+02	1.07E+02	1.27E+02	1.59E+02	6.73E+00	1.44E+00	2.93E+00	6.03E+00
Sinclair-Dyes Inlet	6.08E+01	7.30E+01	1.26E+02	1.61E+02	2.01E+02	4.08E+00	5.42E+00	7.41E+00	1.12E+03	4.68E+02	5.54E+02	6.95E+02	1.01E+02	6.31E+00	1.28E+01	2.64E+01
South Sound (East)	5.64E+02	1.43E+02	2.48E+02	3.15E+02	1.57E+02	7.99E+00	1.06E+01	1.45E+01	2.19E+03	9.17E+02	1.09E+03	1.36E+03	3.76E+02	1.24E+01	2.51E+01	5.17E+01
South Sound (West)	2.87E+02	9.53E+01	1.65E+02	2.10E+02	1.00E+01	5.33E+00	7.07E+00	9.67E+00	1.43E+03	6.11E+02	7.24E+02	9.07E+02	6.57E+02	8.24E+00	1.67E+01	3.45E+01
Strait of Georgia	4.93E+02	1.22E+02	2.12E+02	2.69E+02	9.62E+01	6.83E+00	9.07E+00	1.24E+01	1.38E+03	7.84E+02	9.28E+02	1.16E+03	3.04E+02	1.06E+01	2.15E+01	4.42E+01
Strait of Juan de Fuca	4.54E+01	2.24E+01	3.87E+01	4.93E+01	4.83E+00	1.25E+00	1.66E+00	2.27E+00	2.02E+02	1.43E+02	1.70E+02	2.13E+02	9.98E+00	1.93E+00	3.93E+00	8.09E+00
Whidbey Basin	9.55E+01	7.71E+01	1.33E+02	1.70E+02	1.07E+01	4.31E+00	5.72E+00	7.82E+00	6.49E+02	4.94E+02	5.85E+02	7.33E+02	2.78E+01	6.66E+00	1.35E+01	2.79E+01
Puget Sound Total	**6.23E+03**	**2.50E+03**	**4.33E+03**	**5.51E+03**	**1.06E+03**	**1.40E+02**	**1.86E+02**	**2.54E+02**	**1.96E+04**	**1.60E+04**	**1.90E+04**	**2.38E+04**	**2.57E+03**	**2.16E+02**	**4.39E+02**	**9.05E+02**

Key:

The precision of the data in this table is only two significant figures.

The loadings from POTWs to the Elliott Bay Study Area was zero because this area of Puget Sound had no POTWs discharging to it.

kg/year = Kilograms per year.

(a) = From EnviroVision, et al., 2008; and Maroncelli, James, 2009.
The estimated loadings were based on: (1) Replacement of non-detect results with one-half the method detection limit or method reporting limit;
and (2) Extrapolations for those POTWs without analytical results by using the median concentration of all POTWs.

Figures

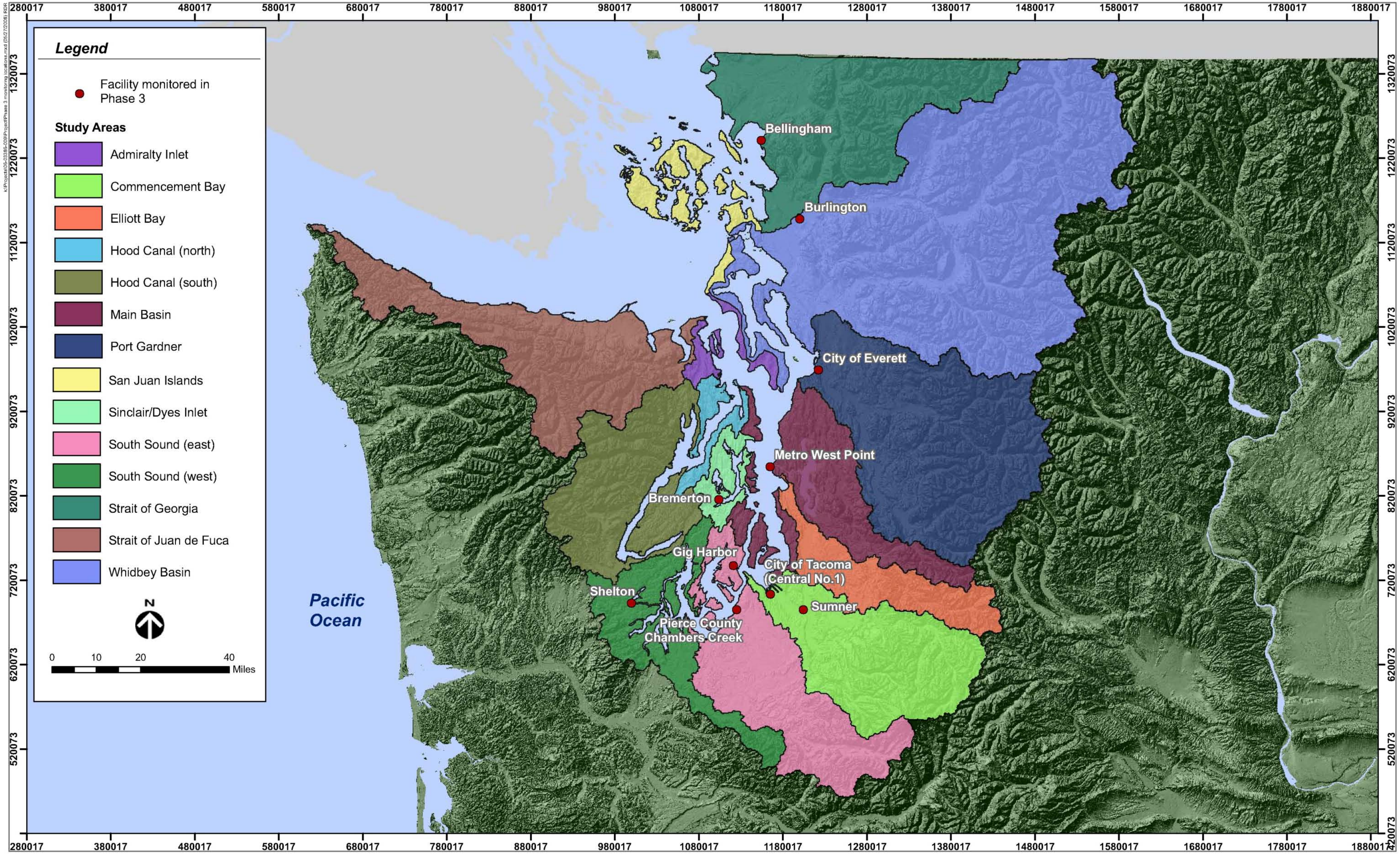

Figure 1. Location Map of the Ten Publicly Owned Treatment Works.

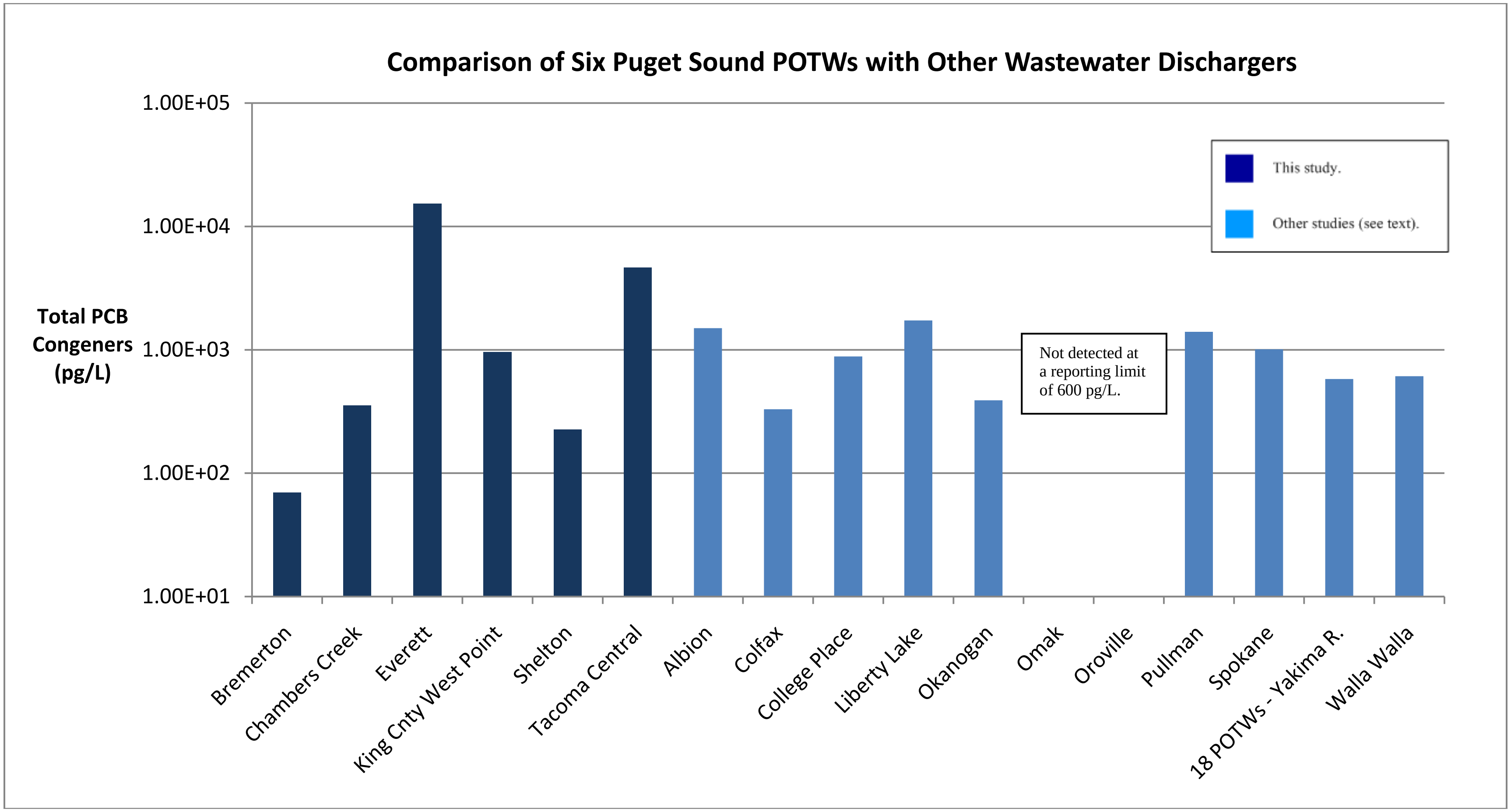

Figure 2. Comparison of Average Total PCB Results among Several POTWs

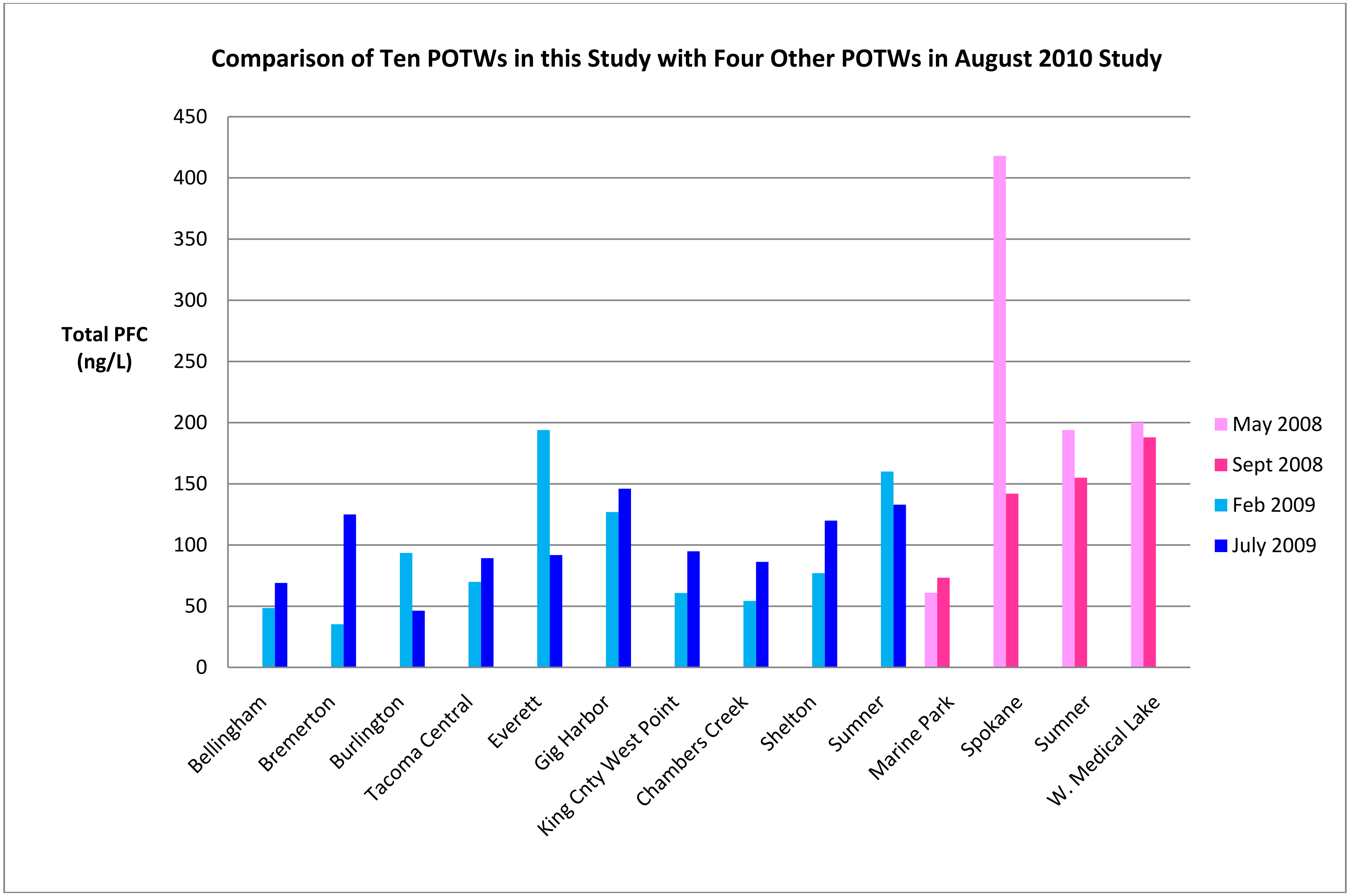

Figure 3. Comparison of Average Total PFC Results among Several POTWs

Appendix A.

List of the POTWs in the Puget Sound Basin

Appendix A. List of POTWs in the Puget Sound Basin

Study Area	POTW Name	Permit Number	Average Flow: Reported 2007 - 2009 (MGD)
Admiralty Inlet	Port Townsend STP (Biosolids Facility)	WA0037052	0.9089
Commencement Bay	Buckley STP	WA0023361	0.5633
	Carbonado STP	WA0020834	0.02422
	Cherrywood Mobile Home Manor	WA0037079	0.01175
	City of Tacoma Central No. 1	WA0037087	19.87
	City of Tacoma North No. 3	WA0037214	4.475
	Enumclaw STP	WA0020575	1.572
	Orting STP	WA0020303	0.5762
	Puyallup STP	WA0037168	4.039
	Rainier State School	WA0037923	0.112
	South Prairie STP	WA0040479	0.02736
	Sumner STP	WA0023353	2.006
	Wilkeson STP	WA0023281	0.04119
Elliott Bay	none		
Hood Canal (north)	Olympic Water and Sewer, Inc.	WA0021202	0.1893
	Pope Resources (a)	WA0022292	0.0118
Hood Canal (south)	Alderbrook Resort and Spa	WA0037753	0.01607
Main Basin	Alderwood WTP	WA0020826	2.085
	Bainbridge Island City WWTP	WA0020907	0.5251
	Edmonds STP	WA0024058	5.488
	Kitsap County Kingston WWTP	WA0032077	0.1042
	Kitsap County Manchester	WA0023701	0.2066
	Lakehaven Utility District (Lakota STP)	WA0022624	5.2
	Lynnwood STP	WA0024031	4.065
	King County Renton (South Treatment Plant)	WA0029581	74.9
	King County West Point	WA0029181	92.46
	Messenger House Care Center	WA0023469	0.005892
	Midway Sewer District	WA0020958	4.136
	Miller Creek WWTP	WA0022764	2.797
	Mukilteo Water District (Olympus Terrace STP)	WA0023396	1.609
	Redondo WWTP	WA0023451	2.694
	Salmon Creek WWTP (Burien)	WA0022772	2.25
	Vashon STP	WA0022527	0.09314

Appendix A. List of POTWs in the Puget Sound Basin

Study Area	POTW Name	Permit Number	Average Flow: Reported 2007 - 2009 (MGD)
Port Gardner	Carnation WWTP	WA0032182	0.0907
	Duvall STP	WA0029513	0.5366
	Everett STP (all outfalls)	WA0024490	20.02
	Granite Falls STP	WA0021130	0.2921
	Lake Stevens Sewer District	WA0020893	2.12
	Marysville STP	WA0022497	4.538
	Monroe WWTP	WA0020486	1.526
	North Bend STP	WA0029351	0.4658
	Snohomish STP	WA0029548	1.192
	Snoqualmie WWTP	WA0022403	0.9815
	Sultan WWTP	WA0023302	0.3696
San Juan Islands	Anacortes WWTP	WA0020257	1.821
	Eastsound Orcas Village	WA0030911	0.003354
	Eastsound Water District	WA0030571	0.09869
	Fisherman Bay STP	WA0030589	0.01658
	Friday Harbor STP	WA0023582	0.2696
	Roche Harbor Resort	WA0021822	0.03388
	Rosario WWTP	WA0029891	0.0241
Sinclair/Dyes Inlet	Bremerton STP	WA0029289	4.304
	Kitsap County Central Kitsap	WA0030520	3.83
	Kitsap County Sewer District 7	WA0030317	0.08297
	Port Orchard WWTP	WA0020346	1.704
South Sound (east)	Eatonville STP	WA0037231	0.2073
	Gig Harbor STP	WA0023957	0.8088
	Pierce County Chambers Creek STP	WA0039624	17.89
	WA DOC McNeil Island STP	WA0040002	0.2264
	Yelm STP	WA0040762	0.2986
South Sound (west)	Boston Harbor STP	WA0040291	0.03061
	Carlyon Beach STP	WA0037915	0.02169
	Hartstene Pointe STP	WA0038377	0.06468
	LOTT WWTP	WA0037061	10.77
	Rustlewood STP	WA0038075	0.02942
	Seashore Villa STP	WA0037273	0.01229
	Shelton STP	WA0023345	1.988
	Tamoshan STP	WA0037290	0.02594
	Taylor Bay STP	WA0037656	0.01095

Appendix A. List of POTWs in the Puget Sound Basin

Study Area	POTW Name	Permit Number	Average Flow: Reported 2007 - 2009 (MGD)
Strait of Georgia	Bellingham STP	WA0023744	12.3
	Birch Bay STP	WA0029556	0.849
	Blaine STP	WA0022641	0.539
	Everson STP	WA0020435	0.2556
	Ferndale STP	WA0022454	1.533
	Lynden STP	WA0022578	1.131
	WA Parks Larrabee State Park	WA0023787	0.006589
Strait of Juan de Fuca	Clallam Bay STP	WA0024431	0.02675
	Port Angeles STP	WA0023973	2.324
	Sekiu STP	WA0024449	0.06453
	Sequim STP	WA0022349	0.4912
	WA DOC Clallam Bay Corrections Center	WA0039845	0.1314
Whidbey Basin	Arlington STP	WA0022560	1.203
	Burlington WWTP	WA0020150	1.637
	Concrete STP	WA0020851	0.08774
	Coupeville STP	WA0029378	0.1628
	Indian Ridge Youth Camp	WA0029424	0.00005325
	La Conner STP	WA0022446	0.2365
	Langley STP	WA0020702	0.07734
	Mt Vernon WWTP	WA0024074	3.674
	Oak Harbor STP	WA0020567	1.839
	Penn Cove WWTP	WA0029386	0.02442
	Seattle City Light Diablo	WA0029858	0.006129
	Seattle City Light Newhalem	WA0029670	0.005357
	Sedro Woolley STP	WA0023752	0.8123
	Skagit County Sewer District 2 (Big Lake)	WA0030597	0.1318
	Stanwood STP	WA0020290	0.5494
	Warm Beach Campground & Conference Center	WA0029904	0.02604
Puget Sound Total =		**MGY =**	**124,143**

Key:

The precision of the data in this table is only two significant figures.

MGD = Million gallons per day.

MGY = Million gallons per year.

POTW = Publicly Owned Treatment Works.

(a) = Although the Pope Resources facility treats Port Gardner's sanitary wastewater, it is privately owned.

Appendix B.

Data Usability Summary Reports

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: March 31, 2008	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance level 1 review (QA1) (PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Matrix	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0902008	Water	Sumner	0902008-01	02/12/2009		None
0902008	Water	Gig Harbor	0902008-02	02/10/2009		None
0902008	Water	Shelton	0902008-03	02/10/2009		None
0902008	Water	Everett	0902008-04	02/12/2009		None
0902008	Water	Burlington	0902008-05	02/10/2009		None
0902008	Water	Bremerton	0902008-06	02/10/2009		None
0902008	Water	Tacoma	0902008-07	02/19/2009	MS/MSD	None
0902008	Water	Chambers Creek	0902008-08	02/19/2009		None
0902008	Water	Metro West Point	0902008-09	02/10/2009		None
0902008	Water	Bellingham	0902008-10	02/12/2009		None
0902008	Water	Field Blank	0902008-11	02/12/2009		None

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Orders	Matrix	Test Method	Method Name	Number of Samples
0902008	Water	SW846 8270 SIM	Polycyclic Aromatic Hydrocarbons by Gas Chromatography/Mass Spectrometry-SIM	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes
Did coolers arrive at lab between 0 °C and 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes
Frequency of Field QC Samples Correct? Field Duplicate – Not required. Field Blank – 1/20 samples. MS/MSD samples – 1/20 samples.	Yes
Case narrative present and complete?	Yes
Any holding time violations?	No - All samples were prepared and analyzed within holding times.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);

- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7).

The PAH data was originally reviewed Dickey Huntamer, Manchester Environmental Laboratory (MEL) on March 10, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided by the laboratory.

Polycyclic Aromatic Hydrocarbons (PAHs) by GC/MS SIM

Description	Notes and Qualifiers
Any compounds present in method and field blanks?	Yes, refer to Table 3.
For samples, if associated results are <5 times the method blank or <3 times the field blank then "U" flag data.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes.
Surrogate standard recovery values for samples, MS/MSD, method blanks, and LCS/LCSD samples within laboratory QC limits?	No, please refer to Table 4. No action was taken for one surrogate outlier.
Internal standard recovery values for samples, MS/MSD, method blanks, and LCS/LCSD samples within laboratory QC limits?	Yes.
MS/MSD percent recovery values within laboratory QC criteria?	Yes.
MS/MSD relative percent difference values within QC criteria (see Table 4) of <35%?	Yes.
LCS percent recovery values within laboratory QC criteria (see Table 5)? If the value is high with no positive values in the associated data; then no data qualification is required.	Yes.
Is initial calibration for target compounds <20 % RSD or curve fit?	Yes
Is initial calibration verification standard for target compounds <30 %?	Yes.
Is continuing calibration for target compounds < 20%?	Yes
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	No

Summary of Potential Impacts on Data Usability

Major Concerns

None

Minor Concerns

Samples results below the PQL are reported at the PQL and flagged not detected (U) due to method blank contamination. Matrix spike (B09B138-MS1, parent sample Tacoma) percent recovery values were outside QC limits, the sample results were qualified (refer to Table 4). Laboratory control sample percent recovery values were outside QC limits, associated samples were qualified (refer to Table 5).

Table 3 - List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL	MDL
SW846 8270SIM	B09B099-BLK1	MBLK	1-Methylnaphthalene	0.0048	J	µg/L	0.010	0.0016
SW846 8270SIM	B09B099-BLK1	MBLK	2-Methylnaphthalene	0.0048	J	µg/L	0.010	0.0015

Method	SampleID	SampType	Analyte	Result	Qual	Units	PQL	MDL
SW846 8270SIM	B09B099-BLK1	MBLK	Naphthalene	0.0051	J	µg/L	0.010	0.0011
SW846 8270SIM	B09B115-BLK1	MBLK	1-Methylnaphthalene	0.0048	J	µg/L	0.010	0.0016
SW846 8270SIM	B09B115-BLK1	MBLK	2-Methylnaphthalene	0.0048	J	µg/L	0.010	0.0015
SW846 8270SIM	B09B115-BLK1	MBLK	Fluorene	0.0015	J	µg/L	0.010	0.0014
SW846 8270SIM	B09B115-BLK1	MBLK	Naphthalene	0.0051	J	µg/L	0.010	0.0011
SW846 8270SIM	B09B139-BLK1	MBLK	1-Methylnaphthalene	0.0052	J	µg/L	0.010	0.0016
SW846 8270SIM	B09B139-BLK1	MBLK	2-Methylnaphthalene	0.0049	J	µg/L	0.010	0.0015
SW846 8270SIM	B09B139-BLK1	MBLK	Fluorene	0.0027	J	µg/L	0.010	0.0014
SW846 8270SIM	B09B139-BLK1	MBLK	Naphthalene	0.0053	J	µg/L	0.010	0.0011
SW846 8270SIM	B09B139-BLK1	MBLK	Phenanthrene	0.0022	J	µg/L	0.010	

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	SampleID	Analyte	Result	Qual
SW846 8270SIM	Gig Harbor	1-Methylnaphthalene	0.012	U
SW846 8270SIM	Gig Harbor	2-Methylnaphthalene	0.0094	U
SW846 8270SIM	Shelton	1-Methylnaphthalene	0.0084	U
SW846 8270SIM	Shelton	2-Methylnaphthalene	0.0090	U
SW846 8270SIM	Shelton	Naphthalene	0.025	U
SW846 8270SIM	Burlington	1-Methylnaphthalene	0.012	U
SW846 8270SIM	Burlington	2-Methylnaphthalene	0.0082	U
SW846 8270SIM	Bremerton	1-Methylnaphthalene	0.012	U
SW846 8270SIM	Bremerton	2-Methylnaphthalene	0.011	U
SW846 8270SIM	Metro Point West	1-Methylnaphthalene	0.020	U
SW846 8270SIM	Metro Point West	2-Methylnaphthalene	0.022	U
SW846 8270SIM	Sumner	1-Methylnaphthalene	0.012	U
SW846 8270SIM	Sumner	2-Methylnaphthalene	0.0090	U
SW846 8270SIM	Everett	Naphthalene	0.018	U
SW846 8270SIM	Bellingham	1-Methylnaphthalene	0.0099	U
SW846 8270SIM	Bellingham	2-Methylnaphthalene	0.010	U
SW846 8270SIM	Field Blank	Naphthalene	0.017	U
SW846 8270SIM	Tacoma	1-Methylnaphthalene	0.015	U
SW846 8270SIM	Tacoma	2-Methylnaphthalene	0.018	U
SW846 8270SIM	Tacoma	Phenanthrene	0.0080	U
SW846 8270SIM	Chambers Creek	2-Methylnaphthalene	0.014	U

Table 4 - List of Samples with Surrogates outside Control Limits

Method	SampleID	Analyte	Percent Recovery	QC Limit	Sample Qualification
SW846 8270SIM	Everett	Benzo(a)pyrene- d12	43	50 - 150	None
SW846 8270SIM	Tacoma	Benzo(a)pyrene- d12	42	50 - 150	None
SW846 8270SIM	Tacoma MS	Benzo(a)pyrene- d12	28	50 - 150	None
SW846 8270SIM	Tacoma MSD	Benzo(a)pyrene- d12	34	50 - 150	None
SW846 8270SIM	Chambers Creek	Benzo(a)pyrene- d12	34	50 - 150	None

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits

None

Table 6 - List LCS Percent Recovery Values outside Control Limits

None

Table 7 –Samples that were Reanalyzed

None

Key:
A = Analyte
NC = Not Calculated
ND = Not Detected
PQL = Practical Quantitation Limit
RPD = Relative Percent Difference

Data Validation Qualifiers:

Code	Description
B	Analyte detected in sample and method blank. Reported result is sample concentration without blank correction or associated quantitation limit.
JG	Analyte was positively identified. Value may be greater than the reported estimate.
JK	Analyte was positively identified. Reported result is an estimate with unknown bias.
JL	Analyte was positively identified. Value may be less than the reported estimate.
JT	Analyte was positively identified. Reported result is an estimate below the associated quantitation limit but above the MDL.
JTG	Analyte was positively identified. Value may be greater than the reported result, which is an estimate below the associated quantitation limit but above the MDL.
JTK	Analyte was positively identified. Reported result is an estimate with unknown bias, below the associated quantitation limit but above the MDL.
JTL	Analyte was positively identified. Value may be less than the reported result which is an estimate below associated quantitation limit but above MDL.
NJ	There is evidence that the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate.
NJT	There is evidence the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate below the associated quantitation limit but above the MDL.
NU	There is evidence the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported result.
NUJ	There is evidence the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported estimate.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJ	Analyte was not detected at or above the reported estimate
UJG	Analyte was not detected at or above the reported estimate with likely low bias.
UJK	Analyte was not detected at or above the reported estimate with unknown bias.
UJL	Analyte was not detected at or above the reported estimate with likely high bias.

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Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Gig Harbor**

Work Order: 0902008	Lab ID #: 0902008-02	Batch ID: B09B099
Project Officer: Maroncelli, Jim	Collected: 2/10/2009	Prepared: 2/12/2009
Initial Vol: 1500 mL	Prep Method: SW3510A	Analyzed: 2/18/2009
Final Vol: 1 mL	Analysis Method: SW8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	1-Methylnaphthalene	0.012	~~JT~~ U	0.0067	0.0010
91-58-7	2-Chloronaphthalene	0.0067	U	0.0067	0.0008
91-57-6	2-Methylnaphthalene	0.0094	~~JT~~ U	0.0067	0.0010
83-32-9	Acenaphthene	0.0067	U	0.0067	0.0016
208-96-8	Acenaphthylene	0.0067	U	0.0067	0.0009
120-12-7	Anthracene	0.0067	U	0.0067	
56-55-3	Benzo(a)anthracene	0.0067	U	0.0067	0.0007
50-32-8	Benzo(a)pyrene	0.0067	U	0.0067	0.0007
205-99-2	Benzo(b)fluoranthene	0.0067	U	0.0067	0.0012
191-24-2	Benzo(ghi)perylene	0.0067	U	0.0067	0.0007
207-08-9	Benzo(k)fluoranthene	0.0067	U	0.0067	0.0014
86-74-8	Carbazole	0.0067	U	0.0067	0.0010
218-01-9	Chrysene	0.0067	U	0.0067	0.0008
53-70-3	Dibenzo(a,h)anthracene	0.0067	U	0.0067	0.0010
132-64-9	Dibenzofuran	0.0067	U	0.0067	0.0008
206-44-0	Fluoranthene	0.0067	U	0.0067	0.0010
86-73-7	Fluorene	0.0067	U	0.0067	0.0009
193-39-5	Indeno(1,2,3-cd)pyrene	0.0067	U	0.0067	0.0021
91-20-3	**Naphthalene**	**0.13**		0.0067	0.0007
85-01-8	**Phenanthrene**	**0.0061**	JT	0.0067	
129-00-0	**Pyrene**	**0.0043**	JT	0.0067	0.0011
483-65-8	Retene	0.0067	U	0.0067	

① 10APRIL20

Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.254		0.267	95	30-115
93951-97-4	Acenaphthylene-D8	0.209		0.267	78	50-150
1719-06-8	Anthracene-D10	0.224		0.267	84	50-150
63466-71-7	Benzo(a)pyrene-D12	0.141		0.267	53	50-150
81103-79-9	Fluorene-D10	0.214		0.267	80	50-150
1718-52-1	Pyrene-D10	0.254		0.267	95	50-150
1718-51-0	Terphenyl-D14	0.181		0.267	68	18-137

Authorized by: ______________________

Release Date: 3/26/09

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Final Analysis Report for
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Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Shelton**

Work Order: 0902008	Lab ID #: 0902008-03	Batch ID: B09B099
Project Officer: Maroncelli, Jim	Collected: 2/10/2009	Prepared: 2/12/2009
Initial Vol: 1580 mL	Prep Method: SW3510A	Analyzed: 2/18/2009
Final Vol: 1 mL	Analysis Method: SW8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	1-Methylnaphthalene	0.0084	~~UJ~~ u	0.0063	0.0010
91-58-7	**2-Chloronaphthalene**	**0.0047**	JT	0.0063	0.0008
91-57-6	2-Methylnaphthalene	0.0090	~~UJ~~ u	0.0063	0.0009
83-32-9	Acenaphthene	0.0063	U	0.0063	0.0015
208-96-8	Acenaphthylene	0.0063	U	0.0063	0.0009
120-12-7	Anthracene	0.0063	U	0.0063	
56-55-3	Benzo(a)anthracene	0.0063	U	0.0063	0.0007
50-32-8	Benzo(a)pyrene	0.0063	U	0.0063	0.0007
205-99-2	Benzo(b)fluoranthene	0.0063	U	0.0063	0.0011
191-24-2	Benzo(ghi)perylene	0.0063	U	0.0063	0.0006
207-08-9	Benzo(k)fluoranthene	0.0063	U	0.0063	0.0014
86-74-8	Carbazole	0.0063	U	0.0063	0.0009
218-01-9	Chrysene	0.0063	U	0.0063	0.0008
53-70-3	Dibenzo(a,h)anthracene	0.0063	U	0.0063	0.0010
132-64-9	**Dibenzofuran**	**0.0056**	JT	0.0063	0.0007
206-44-0	Fluoranthene	0.0063	U	0.0063	0.0009
86-73-7	**Fluorene**	**0.0057**	JT	0.0063	0.0009
193-39-5	Indeno(1,2,3-cd)pyrene	0.0063	U	0.0063	0.0019
91-20-3	**Naphthalene**	**0.025**	u	0.0063	0.0007
85-01-8	**Phenanthrene**	**0.0051**	JT	0.0063	
129-00-0	Pyrene	0.0063	U	0.0063	0.0011
483-65-8	Retene	0.0063	U	0.0063	

①
10 April

Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.223		0.253	88	30-115
93951-97-4	Acenaphthylene-D8	0.196		0.253	77	50-150
1719-06-8	Anthracene-D10	0.213		0.253	84	50-150
63466-71-7	Benzo(a)pyrene-D12	0.181		0.253	72	50-150
81103-79-9	Fluorene-D10	0.195		0.253	77	50-150
1718-52-1	Pyrene-D10	0.231		0.253	91	50-150
1718-51-0	Terphenyl-D14	0.198		0.253	78	18-137

Authorized by: ____________ Release Date: 5/20/09

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Project: Phase 3: Priority Pollutant Scans of Ten POTWs

Field ID: Burlington

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1660 mL
Final Vol: 1 mL

Lab ID #: 0902008-05
Collected: 2/10/2009
Prep Method: SW3510A
Analysis Method: SW8270

Batch ID: B09B099
Prepared: 2/12/2009
Analyzed: 2/19/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	1-Methylnaphthalene	0.0097	~~UJ~~ U	0.0060	0.0009
91-58-7	2-Chloronaphthalene	0.0060	U	0.0060	0.0007
91-57-6	2-Methylnaphthalene	0.0082	~~UJ~~ U	0.0060	0.0009
83-32-9	Acenaphthene	0.0060	U	0.0060	0.0015
208-96-8	Acenaphthylene	0.0060	U	0.0060	0.0008
120-12-7	Anthracene	0.0060	U	0.0060	
56-55-3	Benzo(a)anthracene	0.0060	U	0.0060	0.0007
50-32-8	Benzo(a)pyrene	0.0060	U	0.0060	0.0006
205-99-2	Benzo(b)fluoranthene	0.0060	U	0.0060	0.0011
191-24-2	Benzo(ghi)perylene	0.0060	U	0.0060	0.0006
207-08-9	Benzo(k)fluoranthene	0.0060	U	0.0060	0.0013
86-74-8	Carbazole	0.0060	U	0.0060	0.0009
218-01-9	Chrysene	0.0060	U	0.0060	0.0007
53-70-3	Dibenzo(a,h)anthracene	0.0060	U	0.0060	0.0009
132-64-9	**Dibenzofuran**	**0.0061**		0.0060	0.0007
206-44-0	**Fluoranthene**	**0.0037**	J T	0.0060	0.0009
86-73-7	**Fluorene**	**0.011**		0.0060	0.0008
193-39-5	Indeno(1,2,3-cd)pyrene	0.0060	U	0.0060	0.0019
91-20-3	**Naphthalene**	**0.027**		0.0060	0.0007
85-01-8	Phenanthrene	0.0060	U	0.0060	
129-00-0	**Pyrene**	**0.0045**	J T	0.0060	0.0010
483-65-8	Retene	0.0060	U	0.0060	

10APRIL200

Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.219		0.241	91	30-115
93951-97-4	Acenaphthylene-D8	0.185		0.241	77	50-150
1719-06-8	Anthracene-D10	0.209		0.241	87	50-150
63466-71-7	Benzo(a)pyrene-D12	0.164		0.241	68	50-150
81103-79-9	Fluorene-D10	0.183		0.241	76	50-150
1718-52-1	Pyrene-D10	0.220		0.241	91	50-150
1718-51-0	Terphenyl-D14	0.184		0.241	76	18-137

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Release Date: 3/26/09

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Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Bremerton**

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1540 mL
Final Vol: 1 mL

Lab ID #: 0902008-06
Collected: 2/10/2009
Prep Method: SW3510A
Analysis Method: SW8270

Batch ID: B09B099
Prepared: 2/12/2009
Analyzed: 2/19/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	**1-Methylnaphthalene**	**0.012**	u	0.0065	0.0010
91-58-7	2-Chloronaphthalene	0.0065	U	0.0065	0.0008
91-57-6	**2-Methylnaphthalene**	**0.011**	u	0.0065	0.0010
83-32-9	Acenaphthene	0.0065	U	0.0065	0.0016
208-96-8	Acenaphthylene	0.0065	U	0.0065	0.0009
120-12-7	Anthracene	0.0065	U	0.0065	
56-55-3	Benzo(a)anthracene	0.0065	U	0.0065	0.0007
50-32-8	Benzo(a)pyrene	0.0065	U	0.0065	0.0007
205-99-2	Benzo(b)fluoranthene	0.0065	U	0.0065	0.0012
191-24-2	Benzo(ghi)perylene	0.0065	U	0.0065	0.0006
207-08-9	Benzo(k)fluoranthene	0.0065	U	0.0065	0.0014
86-74-8	Carbazole	0.0065	U	0.0065	0.0009
218-01-9	Chrysene	0.0065	U	0.0065	0.0008
53-70-3	Dibenzo(a,h)anthracene	0.0065	U	0.0065	0.0010
132-64-9	**Dibenzofuran**	**0.0062**	JT	0.0065	0.0008
206-44-0	**Fluoranthene**	**0.0037**	JT	0.0065	0.0009
86-73-7	**Fluorene**	**0.0069**		0.0065	0.0009
193-39-5	Indeno(1,2,3-cd)pyrene	0.0065	U	0.0065	0.0020
91-20-3	**Naphthalene**	**0.040**		0.0065	0.0007
85-01-8	**Phenanthrene**	**0.0054**	JT	0.0065	
129-00-0	**Pyrene**	**0.0060**	JT	0.0065	0.0011
483-65-8	Retene	0.0065	U	0.0065	

① 10 April 20

Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.233		0.26	90	30-115
93951-97-4	Acenaphthylene-D8	0.192		0.26	74	50-150
1719-06-8	Anthracene-D10	0.227		0.26	87	50-150
63466-71-7	Benzo(a)pyrene-D12	0.156		0.26	60	50-150
81103-79-9	Fluorene-D10	0.194		0.26	75	50-150
1718-52-1	Pyrene-D10	0.243		0.26	94	50-150
1718-51-0	Terphenyl-D14	0.191		0.26	74	18-137

Authorized by: ______________________

Release Date: 3/26/09

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Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Metro West Point**

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1700 mL
Final Vol: 1 mL

Lab ID #: 0902008-09
Collected: 2/10/2009
Prep Method: SW3510A
Analysis Method: SW8270

Batch ID: B09B099
Prepared: 2/12/2009
Analyzed: 2/19/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	**1-Methylnaphthalene**	**0.020**	u	0.0059	0.0009
91-58-7	2-Chloronaphthalene	0.0059	U	0.0059	0.0007
91-57-6	**2-Methylnaphthalene**	**0.022**	u	0.0059	0.0009
83-32-9	**Acenaphthene**	**0.012**		0.0059	0.0014
208-96-8	**Acenaphthylene**	**0.0051**	JT	0.0059	0.0008
120-12-7	**Anthracene**	**0.0039**	JT	0.0059	
56-55-3	Benzo(a)anthracene	0.0059	U	0.0059	0.0006
50-32-8	Benzo(a)pyrene	0.0059	U	0.0059	0.0006
205-99-2	Benzo(b)fluoranthene	0.0059	U	0.0059	0.0011
191-24-2	Benzo(ghi)perylene	0.0059	U	0.0059	0.0006
207-08-9	Benzo(k)fluoranthene	0.0059	U	0.0059	0.0013
86-74-8	Carbazole	0.0059	U	0.0059	0.0008
218-01-9	Chrysene	0.0059	U	0.0059	0.0007
53-70-3	Dibenzo(a,h)anthracene	0.0059	U	0.0059	0.0009
132-64-9	**Dibenzofuran**	**0.021**		0.0059	0.0007
206-44-0	**Fluoranthene**	**0.0075**		0.0059	0.0009
86-73-7	**Fluorene**	**0.025**		0.0059	0.0008
193-39-5	**Indeno(1,2,3-cd)pyrene**	**0.0047**	JT	0.0059	0.0018
91-20-3	**Naphthalene**	**0.044**		0.0059	0.0007
85-01-8	**Phenanthrene**	**0.016**		0.0059	
129-00-0	**Pyrene**	**0.014**		0.0059	0.0010
483-65-8	Retene	0.0059	U	0.0059	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.224		0.235	95	30-115
93951-97-4	Acenaphthylene-D8	0.193		0.235	82	50-150
1719-06-8	Anthracene-D10	0.199		0.235	84	50-150
63466-71-7	Benzo(a)pyrene-D12	0.118		0.235	50	50-150
81103-79-9	Fluorene-D10	0.195		0.235	83	50-150
1718-52-1	Pyrene-D10	0.207		0.235	88	50-150
1718-51-0	Terphenyl-D14	0.145		0.235	62	18-137

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Release Date: 5/26/09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
PAHs SIM list

Project: Phase 3: Priority Pollutant Scans of Ten POTWs

Field ID: Sumner

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1615 mL
Final Vol: 1 mL

Lab ID #: 0902008-01
Collected: 2/12/2009
Prep Method: SW3510A
Analysis Method: SW8270

Batch ID: B09B115
Prepared: 2/17/2009
Analyzed: 2/18/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	1-Methylnaphthalene	0.012	~~UJ~~ U	0.0062	0.0010
91-58-7	2-Chloronaphthalene	0.0062	U	0.0062	0.0008
91-57-6	2-Methylnaphthalene	0.0090	~~UJ~~ U	0.0062	0.0009
83-32-9	**Acenaphthene**	**0.0055**	J	0.0062	0.0015
208-96-8	**Acenaphthylene**	**0.0032**	J	0.0062	0.0009
120-12-7	Anthracene	0.0062	U	0.0062	
56-55-3	Benzo(a)anthracene	0.0062	U	0.0062	0.0007
50-32-8	Benzo(a)pyrene	0.0062	U	0.0062	0.0007
205-99-2	Benzo(b)fluoranthene	0.0062	U	0.0062	0.0011
191-24-2	Benzo(ghi)perylene	0.0062	U	0.0062	0.0006
207-08-9	Benzo(k)fluoranthene	0.0062	U	0.0062	0.0013
86-74-8	Carbazole	0.0062	U	0.0062	0.0009
218-01-9	Chrysene	0.0062	U	0.0062	0.0007
53-70-3	Dibenzo(a,h)anthracene	0.0062	U	0.0062	0.0009
132-64-9	**Dibenzofuran**	**0.0081**		0.0062	0.0007
206-44-0	**Fluoranthene**	**0.0049**	J	0.0062	0.0009
86-73-7	**Fluorene**	**0.0090**		0.0062	0.0008
193-39-5	Indeno(1,2,3-cd)pyrene	0.0062	U	0.0062	0.0019
91-20-3	**Naphthalene**	**0.030**		0.0062	0.0007
85-01-8	**Phenanthrene**	**0.0060**	J	0.0062	
129-00-0	**Pyrene**	**0.0043**	J	0.0062	0.0010
483-65-8	Retene	0.0062	U	0.0062	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.216		0.248	87	30-115
93951-97-4	Acenaphthylene-D8	0.180		0.248	73	50-150
1719-06-8	Anthracene-D10	0.207		0.248	83	50-150
63466-71-7	Benzo(a)pyrene-D12	0.179		0.248	72	50-150
81103-79-9	Fluorene-D10	0.178		0.248	72	50-150
1718-52-1	Pyrene-D10	0.226		0.248	91	50-150
1718-51-0	Terphenyl-D14	0.204		0.248	82	18-137

Authorized by: ______________ Release Date: 3/26/09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
PAHs SIM list

Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Everett**

Work Order: 0902008	Lab ID #: 0902008-04	Batch ID: B09B115
Project Officer: Maroncelli, Jim	Collected: 2/12/2009	Prepared: 2/17/2009
Initial Vol: 1520 mL	Prep Method: SW3510A	Analyzed: 2/18/2009
Final Vol: 1 mL	Analysis Method: SW8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	1-Methylnaphthalene	0.0066	U	0.0066	0.0010
91-58-7	2-Chloronaphthalene	0.0066	U	0.0066	0.0008
91-57-6	2-Methylnaphthalene	0.0066	U	0.0066	0.0010
83-32-9	Acenaphthene	0.0066	U	0.0066	0.0016
208-96-8	Acenaphthylene	0.0066	U	0.0066	0.0009
120-12-7	Anthracene	0.0066	U	0.0066	
56-55-3	Benzo(a)anthracene	0.0066	U	0.0066	0.0007
50-32-8	Benzo(a)pyrene	0.0066	U	0.0066	0.0007
205-99-2	Benzo(b)fluoranthene	0.0066	U	0.0066	0.0012
191-24-2	**Benzo(ghi)perylene**	**0.0059**	JT	0.0066	0.0007
207-08-9	Benzo(k)fluoranthene	0.0066	U	0.0066	0.0014
86-74-8	Carbazole	0.0066	U	0.0066	0.0009
218-01-9	Chrysene	0.0066	U	0.0066	0.0008
53-70-3	Dibenzo(a,h)anthracene	0.0066	U	0.0066	0.0010
132-64-9	Dibenzofuran	0.0066	U	0.0066	0.0008
206-44-0	**Fluoranthene**	**0.0087**		0.0066	0.0010
86-73-7	Fluorene	0.0066	U	0.0066	0.0009
193-39-5	**Indeno(1,2,3-cd)pyrene**	**0.016**		0.0066	0.0020
91-20-3	**Naphthalene**	**0.018**	U	0.0066	0.0007
85-01-8	Phenanthrene	0.0066	U	0.0066	
129-00-0	**Pyrene**	**0.016**		0.0066	0.0011
483-65-8	Retene	0.0066	U	0.0066	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.252		0.263	96	30-115
93951-97-4	Acenaphthylene-D8	0.194		0.263	74	50-150
1719-06-8	Anthracene-D10	0.206		0.263	78	50-150
63466-71-7	Benzo(a)pyrene-D12	0.113		0.263	43	50-150
81103-79-9	Fluorene-D10	0.201		0.263	76	50-150
1718-52-1	Pyrene-D10	0.198		0.263	75	50-150
1718-51-0	Terphenyl-D14	0.139		0.263	53	18-137

Authorized by: ______________________ Release Date: 3/26/09

Washington State Department of Ecology
Manchester Environmental Laboratory
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PAHs SIM list

Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Bellingham**

Work Order: 0902008	Lab ID #: 0902008-10	Batch ID: B09B115
Project Officer: Maroncelli, Jim	Collected: 2/12/2009	Prepared: 2/17/2009
Initial Vol: 1650 mL	Prep Method: SW3510A	Analyzed: 2/18/2009
Final Vol: 1 mL	Analysis Method: SW8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	**1-Methylnaphthalene**	**0.0099**	u	0.0061	0.0010
91-58-7	**2-Chloronaphthalene**	**0.0086**		0.0061	0.0007
91-57-6	**2-Methylnaphthalene**	**0.010**	u	0.0061	0.0009
83-32-9	Acenaphthene	0.0061	U	0.0061	0.0015
208-96-8	Acenaphthylene	0.0061	U	0.0061	0.0008
120-12-7	Anthracene	0.0061	U	0.0061	
56-55-3	Benzo(a)anthracene	0.0061	U	0.0061	0.0007
50-32-8	Benzo(a)pyrene	0.0061	U	0.0061	0.0006
205-99-2	Benzo(b)fluoranthene	0.0061	U	0.0061	0.0011
191-24-2	Benzo(ghi)perylene	0.0061	U	0.0061	0.0006
207-08-9	Benzo(k)fluoranthene	0.0061	U	0.0061	0.0013
86-74-8	Carbazole	0.0061	U	0.0061	0.0009
218-01-9	Chrysene	0.0061	U	0.0061	0.0007
53-70-3	Dibenzo(a,h)anthracene	0.0061	U	0.0061	0.0009
132-64-9	**Dibenzofuran**	**0.011**		0.0061	0.0007
206-44-0	**Fluoranthene**	**0.0084**		0.0061	0.0009
86-73-7	**Fluorene**	**0.011**		0.0061	0.0008
193-39-5	Indeno(1,2,3-cd)pyrene	0.0061	U	0.0061	0.0019
91-20-3	**Naphthalene**	**0.037**		0.0061	0.0007
85-01-8	**Phenanthrene**	**0.011**		0.0061	
129-00-0	**Pyrene**	**0.0078**		0.0061	0.0010
483-65-8	Retene	0.0061	U	0.0061	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.211		0.242	87	30-115
93951-97-4	Acenaphthylene-D8	0.176		0.242	73	50-150
1719-06-8	Anthracene-D10	0.208		0.242	86	50-150
63466-71-7	Benzo(a)pyrene-D12	0.134		0.242	55	50-150
81103-79-9	Fluorene-D10	0.182		0.242	75	50-150
1718-52-1	Pyrene-D10	0.217		0.242	90	50-150
1718-51-0	Terphenyl-D14	0.159		0.242	66	18-137

Authorized by: _______________ Release Date: 3/26/09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
PAHs SIM list

Project: Phase 3: Priority Pollutant Scans of Ten POTWs **Field ID: Field Blank**

Work Order: 0902008	Lab ID #: 0902008-11	Batch ID: B09B115
Project Officer: Maroncelli, Jim	Collected: 2/12/2009	Prepared: 2/17/2009
Initial Vol: 1505 mL	Prep Method: SW3510A	Analyzed: 2/18/2009
Final Vol: 1 mL	Analysis Method: SW8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	1-Methylnaphthalene	0.0066	U	0.0066	0.0010
91-58-7	2-Chloronaphthalene	0.0066	U	0.0066	0.0008
91-57-6	2-Methylnaphthalene	0.0066	U	0.0066	0.0010
83-32-9	Acenaphthene	0.0066	U	0.0066	0.0016
208-96-8	Acenaphthylene	0.0066	U	0.0066	0.0009
120-12-7	Anthracene	0.0066	U	0.0066	
56-55-3	Benzo(a)anthracene	0.0066	U	0.0066	0.0007
50-32-8	Benzo(a)pyrene	0.0066	U	0.0066	0.0007
205-99-2	Benzo(b)fluoranthene	0.0066	U	0.0066	0.0012
191-24-2	Benzo(ghi)perylene	0.0066	U	0.0066	0.0007
207-08-9	Benzo(k)fluoranthene	0.0066	U	0.0066	0.0014
86-74-8	Carbazole	0.0066	U	0.0066	0.0010
218-01-9	Chrysene	0.0066	U	0.0066	0.0008
53-70-3	Dibenzo(a,h)anthracene	0.0066	U	0.0066	0.0010
132-64-9	Dibenzofuran	0.0066	U	0.0066	0.0008
206-44-0	Fluoranthene	0.0066	U	0.0066	0.0010
86-73-7	Fluorene	0.0066	U	0.0066	0.0009
193-39-5	Indeno(1,2,3-cd)pyrene	0.0066	U	0.0066	0.0020
91-20-3	**Naphthalene**	**0.017**	u	0.0066	0.0007
85-01-8	Phenanthrene	0.0066	U	0.0066	
129-00-0	Pyrene	0.0066	U	0.0066	0.0011
483-65-8	Retene	0.0066	U	0.0066	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.227		0.266	86	30-115
93951-97-4	Acenaphthylene-D8	0.221		0.266	83	50-150
1719-06-8	Anthracene-D10	0.215		0.266	81	50-150
63466-71-7	Benzo(a)pyrene-D12	0.226		0.266	85	50-150
81103-79-9	Fluorene-D10	0.207		0.266	78	50-150
1718-52-1	Pyrene-D10	0.230		0.266	87	50-150
1718-51-0	Terphenyl-D14	0.221		0.266	83	18-137

Authorized by: ______________ Release Date: 2/26/09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
PAHs SIM list

Project: Phase 3: Priority Pollutant Scans of Ten POTWs — Field ID: Tacoma

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1360 mL
Final Vol: 1 mL

Lab ID #: 0902008-07
Collected: 2/19/2009
Prep Method: SW3510A
Analysis Method: SW8270

Batch ID: B09B139
Prepared: 2/24/2009
Analyzed: 2/24/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	**1-Methylnaphthalene**	**0.015**	u	0.0074	0.0012
91-58-7	2-Chloronaphthalene	0.0074	U	0.0074	0.0009
91-57-6	2-Methylnaphthalene	0.0082	~~UJ~~ u	0.0074	0.0011
83-32-9	**Acenaphthene**	**0.011**		0.0074	0.0018
208-96-8	**Acenaphthylene**	**0.0058**	J	0.0074	0.0010
120-12-7	Anthracene	0.0074	U	0.0074	
56-55-3	Benzo(a)anthracene	0.0074	U	0.0074	0.0008
50-32-8	Benzo(a)pyrene	0.0074	U	0.0074	0.0008
205-99-2	Benzo(b)fluoranthene	0.0074	U	0.0074	0.0013
191-24-2	Benzo(ghi)perylene	0.0074	U	0.0074	0.0007
207-08-9	Benzo(k)fluoranthene	0.0074	U	0.0074	0.0016
86-74-8	Carbazole	0.0074	U	0.0074	0.0011
218-01-9	Chrysene	0.0074	U	0.0074	0.0009
53-70-3	Dibenzo(a,h)anthracene	0.0074	U	0.0074	0.0011
132-64-9	**Dibenzofuran**	**0.019**		0.0074	0.0009
206-44-0	**Fluoranthene**	**0.015**		0.0074	0.0011
86-73-7	**Fluorene**	**0.022**		0.0074	0.0010
193-39-5	Indeno(1,2,3-cd)pyrene	0.0074	U	0.0074	0.0023
91-20-3	**Naphthalene**	**0.036**		0.0074	0.0008
85-01-8	**Phenanthrene**	**0.0080**	u	0.0074	
129-00-0	**Pyrene**	**0.018**		0.0074	0.0012
483-65-8	Retene	0.0074	U	0.0074	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.287		0.294	97	30-115
93951-97-4	Acenaphthylene-D8	0.246		0.294	84	50-150
1719-06-8	Anthracene-D10	0.245		0.294	83	50-150
63466-71-7	Benzo(a)pyrene-D12	0.123		0.294	42	50-150
81103-79-9	Fluorene-D10	0.251		0.294	85	50-150
1718-52-1	Pyrene-D10	0.249		0.294	85	50-150
1718-51-0	Terphenyl-D14	0.162		0.294	55	18-137

Authorized by: ______________ Release Date: 3/26/09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
PAHs SIM list

Project: Phase 3: Priority Pollutant Scans of Ten POTWs Field ID: Chambers Creek

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1540 mL
Final Vol: 1 mL

Lab ID #: 0902008-08
Collected: 2/19/2009
Prep Method: SW3510A
Analysis Method: SW8270

Batch ID: B09B139
Prepared: 2/24/2009
Analyzed: 2/24/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
90-12-0	**1-Methylnaphthalene**	**0.025**		0.0065	0.0010
91-58-7	2-Chloronaphthalene	0.0065	U	0.0065	0.0008
91-57-6	**2-Methylnaphthalene**	**0.014**	u	0.0065	0.0010
83-32-9	**Acenaphthene**	**0.014**		0.0065	0.0016
208-96-8	Acenaphthylene	0.0065	U	0.0065	0.0009
120-12-7	Anthracene	0.0065	U	0.0065	
56-55-3	Benzo(a)anthracene	0.0065	U	0.0065	0.0007
50-32-8	Benzo(a)pyrene	0.0065	U	0.0065	0.0007
205-99-2	Benzo(b)fluoranthene	0.0065	U	0.0065	0.0012
191-24-2	Benzo(ghi)perylene	0.0065	U	0.0065	0.0006
207-08-9	Benzo(k)fluoranthene	0.0065	U	0.0065	0.0014
86-74-8	Carbazole	0.0065	U	0.0065	0.0009
218-01-9	Chrysene	0.0065	U	0.0065	0.0008
53-70-3	Dibenzo(a,h)anthracene	0.0065	U	0.0065	0.0010
132-64-9	**Dibenzofuran**	**0.016**		0.0065	0.0008
206-44-0	**Fluoranthene**	**0.0085**		0.0065	0.0009
86-73-7	**Fluorene**	**0.018**		0.0065	0.0009
193-39-5	Indeno(1,2,3-cd)pyrene	0.0065	U	0.0065	0.0020
91-20-3	**Naphthalene**	**0.063**		0.0065	0.0007
85-01-8	**Phenanthrene**	**0.016**		0.0065	
129-00-0	**Pyrene**	**0.0068**		0.0065	0.0011
483-65-8	Retene	0.0065	U	0.0065	

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Surrogate Recovery:

CAS#	Analyte	Result	Qualifier	Spike Level	% Recovery	%Rec.Limits
321-60-8	2-Fluorobiphenyl	0.232		0.26	89	30-115
93951-97-4	Acenaphthylene-D8	0.194		0.26	75	50-150
1719-06-8	Anthracene-D10	0.226		0.26	87	50-150
63466-71-7	Benzo(a)pyrene-D12	0.124		0.26	48	50-150
81103-79-9	Fluorene-D10	0.194		0.26	75	50-150
1718-52-1	Pyrene-D10	0.231		0.26	89	50-150
1718-51-0	Terphenyl-D14	0.163		0.26	63	18-137

Authorized by: Release Date: 3/26/09

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: October 14, 2009	**Completed by: Mark Woodke**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0907021	Gig Harbor	0907021-01	07/14/2009	Batch	
0907021	Bremerton	0907021-02	07/14/2009		
0907021	West Point	0907021-04	07/14/2009		
0907021	Burlington	0907021-05	07/14/2009		
0907021	Tacoma	0907021-06	07/16/2009		
0907021	Chambers Creek	0907021-07	07/16/2009		
0907021	Sumner	0907021-08	07/17/2009		
0907021	Bellingham	0907021-09	07/16/2009		
0907021	Everett	0907021-10	07/16/2009		
0907021	Shelton	0907021-13	07/15/2009		
0907021	Rinsate	0907021-12	07/10/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0907021	Water	EPA 8270D SIM	Polycyclic Aromatic Hydrocarbons by GC/MS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Assumed based on the data review memoranda by Dickey Huntamer.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	Yes according to the data review memorandum by Dickey Huntamer. Sample extracts for Gig Harbor and Burlington were re-analyzed after the extraction holding time. Associated sample results were qualified estimated biased low (JG or UJG).

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7)

The semivolatile organic analyses (BNAs) data was originally reviewed by Dickey Huntamer, Manchester Environmental Laboratory (MEL) on October 22, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Polycyclic Aromatic Hydrocarbons by GC/MS-SIM	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 3)?	Yes.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data. Qualification also applies to TICs.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes
Surrogate recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	No
Surrogate recovery values for samples and MS/MSD within laboratory QC limits? All samples should be re-analyzed for VOCs? Samples should be re-analyzed if >1 BN and/or AP for SVOCs is out.	No
MS/MSD percent recovery values within laboratory QC criteria (see Table 5)?	No – Several compounds were outside QC limits. The analytes were qualified in the parent sample “JG” and “UJG” for low MS/MSD recovery. If both MS/MSD percent recovery values were below 10%, then non-detect results were flagged as rejected “REJ”.
MS/MSD relative percent difference values within QC criteria (see Table 5) of <35%?	No – Several compounds were outside QC limits. The analytes were qualified in the parent sample “JK” and “UJK” for relative percent difference outliers.
LCS percent recovery values within Laboratory QC criteria (see Table 6)?	No – Several compounds were outside QC limits. All analytes were qualified in associated samples “JG” and “UJG” for low LCS/LCSD recovery. If LCS/LCSD percent recovery values were below 10%, then non-detect results were flagged as rejected “REJ”.
Do internal standards areas and retention time meet criteria? If not was sample re-analyzed to establish matrix?	No, several IS were outside QC limits in all samples except Burlington; associated sample results were flagged as estimated by Dickey Huntamer.
Is initial calibration for target compounds <20 % RSD or curve fit?	No – several compounds were above the QC limit, all associated samples results were qualified “JK or UJK”.
Is continuing calibration for target compounds < 20%?	No – several compounds were above the QC limit, all associated samples results were qualified “JK or UJK”.

Polycyclic Aromatic Hydrocarbons by GC/MS-SIM	
Description	**Notes and Qualifiers**
Were any samples re-analyzed or diluted (see Table 7)? For any sample re-analysis and dilutions is only one reportable result by flagged?	Yes.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Analytes were detected in the method and field blanks. The associated sample results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U. Several MS/MSD compound percent recovery values were outside QC limits. The analytes were qualified in the parent sample "JG" and "UJG" for low MS/MSD recovery. If both MS/MSD percent recovery values were below 10%, then non-detect results were flagged as rejected "REJ". Several LCS/LCSD compound percent recovery values were outside QC limits. All analytes were qualified in associated samples "JG" and "UJG" for low LCS/LCSD recovery. If both LCS/LCSD percent recovery values were below 10%, then non-detect results were flagged as rejected "REJ". Several compounds were above the initial and continuing calibrations QC limit, all associated samples results were qualified estimated quantities (UJK, JH, JTK, or JK). Sample results greater than MDL and less than PQL are flagged estimated (JT). Sample results associated with internal standard outliers were qualified as estimated quantities with an unknown bias (JK or UJK). Sample results associated with holding time exceedances were qualified as estimated quantities with a low bias (JG or UJG).

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
SW846 8270	B09G136-BLK1	MBLK	Carbazole	0.012	J	µg/L	0.010
SW846 8270	B09G203-BLK1	MBLK	Carbazole	0.013		µg/L	0.010

Table 3A - List of Samples Qualified for Method Blank Contamination
None

Table 4 - List of Samples with Surrogates outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	QC Limit	Sample Qualification
SW846 8270	Chambers Creek	2-Fluorobiphenyl	12	30 - 115	None
SW846 8270	Bellingham	2-Fluorobiphenyl	9	30 – 115	None
SW846 8270	Shelton	2-Fluorobiphenyl	17	30 – 115	None
SW846 8270	B09G136-MS1	2-Fluorobiphenyl	17	30 – 115	None
SW846 8270	B09G203-BLK1	2-Fluorobiphenyl	25	30 – 115	None
SW846 8270	B09G203-BS1	2-Fluorobiphenyl	17	30 – 115	None
SW846 8270	Rinsate	2-Fluorobiphenyl	124	30 – 115	None
SW846 8270	Chambers Creek	Acenaphthylene-d8	29	50 - 150	None
SW846 8270	Bellingham	Acenaphthylene-d8	28	50 - 150	None
SW846 8270	Everett	Acenaphthylene-d8	39	50 - 150	None
SW846 8270	Shelton	Acenaphthylene-d8	30	50 - 150	None

Method	Sample ID	Analyte	Percent Recovery	QC Limit	Sample Qualification
SW846 8270	B09G136-MS1	Acenaphthylene-d8	27	50 - 150	None
SW846 8270	B09G203-BLK1	Acenaphthylene-d8	32	50 - 150	None
SW846 8270	B09G203-BS1	Acenaphthylene-d8	35	50 - 150	None
SW846 8270	B09G136-MS1	Anthracene-d10	49	50 - 150	None
SW846 8270	Gig Harbor	Benzo(a)pyrene-d12	37	50 - 150	None
SW846 8270	Bremerton	Benzo(a)pyrene-d12	44	50 - 150	None
SW846 8270	West Point	Benzo(a)pyrene-d12	49	50 - 150	None
SW846 8270	Burlington	Benzo(a)pyrene-d12	37	50 - 150	None
SW846 8270	Tacoma	Benzo(a)pyrene-d12	47	50 - 150	None
SW846 8270	B09G136-MS1	Benzo(a)pyrene-d12	49	50 - 150	None
SW846 8270	B09G136-MSD1	Benzo(a)pyrene-d12	48	50 - 150	None

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	West Point MS/MSD	Naphthalene	0/18	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	2-Methylnaphthalene	4/18	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	1-Methylnaphthalene	4/18	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	2-Chloronaphthalene	3/9	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	Acenaphthene	5/23	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	Indeno(1,2,3-cd)pyrene	48/44	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	Dibenzo(a,h)anthracene	44/41	NA	50 – 150	JG/UJG
SW846 8270	West Point MS/MSD	Benzo(g,h,i)perylene	45/42	NA	50 – 150	JG/UJG
SW846 8270	West Point MS	Acenaphthylene	17	NA	50 – 150	None
SW846 8270	West Point MS	Dibenzofuran	17	NA	50 – 150	None
SW846 8270	West Point MS	Fluorene	35	NA	50 – 150	None
SW846 8270	West Point MS	Phenanthrene	42	NA	50 – 150	None
SW846 8270	West Point MS	Anthracene	37	NA	50 – 150	None
SW846 8270	West Point MS/MSD	Naphthalene	Not Calculated	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	2-Methylnaphthalene	127	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	1-Methylnaphthalene	130	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	2-Chloronaphthalene	89	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Acenaphthylene	111	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Acenaphthene	125	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Dibenzofuran	111	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Fluorene	70	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Phenanthrene	53	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Anthracene	72	40	NA	JK/UJK
SW846 8270	West Point MS/MSD	Retene	64	40	NA	JK/UJK

Table 6 - List LCS Percent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	B09G136-BS1/BSD1	Naphthalene	10/16	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	2-Methylnaphthalene	11/16	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	1-Methylnaphthalene	11/17	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	2-Chloronaphthalene	9/11	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	Acenaphthylene	28/45	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	Acenapthene	12/18	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	Dibenzofuran	27/43	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	Indeno(1,2,3-cd)pyrene	44/42	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	Dibenzo(a,h)anthracene	43/41	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1/BSD1	Benzo(g,h,i)perylene	45/43	NA	50 – 150	JG/UJG
SW846 8270	B09G136-BS1	Fluorene	43	NA	50 – 150	None
SW846 8270	B09G136-BS1	Phenanthrene	48	NA	50 – 150	None
SW846 8270	B09G136-BS1	Anthracene	44	NA	50 – 150	None
SW846 8270	B09G136-BS1/BSD1	Naphthalene	NA	43	<40	JK/UJK
SW846 8270	B09G136-BS1/BSD1	2-Methylnaphthalene	NA	40	<40	JK/UJK
SW846 8270	B09G136-BS1/BSD1	1-Methylnaphthalene	NA	41	<40	JK/UJK
SW846 8270	B09G136-BS1/BSD1	Acenaphthylene	NA	45	<40	JK/UJK
SW846 8270	B09G136-BS1/BSD1	Acenaphthene	NA	42	<40	JK/UJK
SW846 8270	B09G136-BS1/BSD1	Dibenzofuran	NA	43	<40	JK/UJK

Table 7 –Samples that were Reanalyzed

Sample ID	Reason for Reanalysis
Gig Harbor	Sample was reanalyzed due to initial poor analysis.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
T	The associated positive result is less than the quantitation limit.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: June 12, 2009	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0902008	Sumner	0902008-01	02/12/2009		
0902008	Gig Harbor	0902008-02	02/10/2009		
0902008	Shelton	0902008-03	02/10/2009		
0902008	Everett	0902008-04	02/12/2009		
0902008	Burlington	0902008-05	02/10/2009		
0902008	Bremerton	0902008-06	02/10/2009		
0902008	Tacoma	0902008-07	02/19/2009	MS/MSD	
0902008	Chambers Creek	0902008-08	02/19/2009		
0902008	Metro West Point	0902008-09	02/10/2009		
0902008	Bellingham	0902008-10	02/12/2009		
0902008	Field Blank	0902008-11	02/12/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0902008	Water	EPA 8270	Semivolatile Organic Compounds by GC/MS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, according to the data review memoranda by Dickey Huntamer.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	Yes, according to the data review memoranda by Dickey Huntamer. Sample extracts for Sumner, Everett, and Field blank were analyzed after the extraction holding time. Associated sample results were qualified estimated biased low (JG or UJG).

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7)

The semivolatile organic analyses (BNAs) data was originally reviewed by Dickey Huntamer, Manchester Environmental Laboratory (MEL) on May 22, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Semivolatile Organics (including organotins) by GCMS	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 2)?	Yes.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data. Qualification also applies to TICs.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes
Surrogate recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	Yes
Surrogate recovery values for samples and MS/MSD within laboratory QC limits? All samples should be re-analyzed for VOCs? Samples should be re-analyzed if >1 BN and/or AP for SVOCs is out.	Yes
MS/MSD percent recovery values within laboratory QC criteria (see Table 4)?	No – Several compounds were outside QC limits. The analytes were qualified in the parent sample “JG” and “UJG” for low MS/MSD recovery. If MS/MSD percent recovery values were below 10%, then non-detect results were flagged as rejected “REJ”.
MS/MSD relative percent difference values within QC criteria (see Table 4) of <35%?	No – Several compounds were outside QC limits. No action was taken.
LCS percent recovery values within Laboratory QC criteria (see Table 5)?	No – Several compounds were outside QC limits. All analytes were qualified in associated samples “JG” and “UJG” for low LCS/LCSD recovery. If LCS/LCSD percent recovery values were below 10%, then non-detect results were flagged as rejected “REJ”.
Do internal standards areas and retention time meet criteria? If not was sample re-analyzed to establish matrix (see Table 6)?	No, several IS were low in samples Sumner, Everett, Bellingham, and Field blank; associated sample results were flagged as estimated, biased high (UJ or J) by Dickey Huntamer.
Is initial calibration for target compounds <20 % RSD or curve fit?	No – several compounds were above the QC limit, all associated samples results were qualified “JK or UJK”.
Is continuing calibration for target compounds < 20%?	No – several compounds were above the QC limit, all associated samples results were qualified “JK or UJK”.

Semivolatile Organics (including organotins) by GCMS	
Description	**Notes and Qualifiers**
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	Yes.

Summary of Potential Impacts on Data Usability

Major Concerns

None

Minor Concerns

Analytes were detected in the method and field blanks. The associated amples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U. Several MS/MSD compound percent recovery valuess were outside QC limits. The analytes were qualified in the parent sample "JG" and "UJG" for low MS/MSD recovery. If MS/MSD percent recovery values were below 10%, then non-detect results were flagged as rejected "REJ". Several LCS/LCSD compound percent recovery values were outside QC limits. All analytes were qualified in associated samples "JG" and "UJG" for low LCS/LCSD recovery. If LCS/LCSD percent recovery values were below 10%, then non-detect results were flagged as rejected "REJ". Several IS recovery were low in samples Sumner, Everett, Bellingham, and Field blank; associated sample results were flagged as estimated, biased high (UJ or J) y Dickey Huntamer. Several compounds were above the initial and continuing calibrations QC limit, all associated samples results were qualified estimated, bias unknown (UJK, JTK, or JK). Sample results greater than MDL and less than PQL are flagged estimated (JT).

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
SW846 8270	B09B100-BLK1	MBLK	Di-n-butylphthalate	0.25	J	µg/L	0.25
SW846 8270	B09B100-BLK1	MBLK	Bis(2-hexylethyl)phthalate	0.007	J	µg/L	0.50
SW846 8270	B09B116-BLK1	MBLK	Butylbenzylphthalate	0.62	J	µg/L	0.50
SW846 8270	B09B116-BLK1	MBLK	Bis(2-hexylethyl)phthalate	0.78	J	µg/L	0.50
SW846 8270	Field Blank	FBLK	1,2-Dichlorobenzene	0.02	J	µg/L	0.16
SW846 8270	Field Blank	FBLK	1,3-Dichlorobenzene	0.01	J	µg/L	0.16
SW846 8270	Field Blank	FBLK	4-Nonylphenol	0.28	J	µg/L	0.64
SW846 8270	Field Blank	FBLK	Bis(2-hexylethyl)phthalate	0.47	J	µg/L	0.32
SW846 8270	Field Blank	FBLK	Dimethylphthalate	0.58	J	µg/L	0.32
SW846 8270	Field Blank	FBLK	Phenol	0.19	J	µg/L	0.64

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	Sample ID	Analyte	Result	Qual
SW846 8270	Sumner	1,2-Dichlorobenzene	0.15	U
SW846 8270	Sumner	Butylbenzylphthalate	0.62	U
SW846 8270	Sumner	Bis(2-hexylethyl)phthalate	1.1	U
SW846 8270	Sumner	Phenol	0.62	U
SW846 8270	Gig Harbor	1,2-Dichlorobenzene	0.16	U
SW846 8270	Gig Harbor	1,3-Dichlorobenzene	0.16	U
SW846 8270	Gig Harbor	Di-n-butylphthalate	0.22	U
SW846 8270	Gig Harbor	Bis(2-hexylethyl)phthalate	1.4	U

Method	Sample ID	Analyte	Result	Qual
SW846 8270	Shelton	1,2-Dichlorobenzene	0.16	U
SW846 8270	Shelton	1,3-Dichlorobenzene	0.16	U
SW846 8270	Shelton	Di-n-butylphthalate	0.43	U
SW846 8270	Shelton	Bis(2-hexylethyl)phthalate	1.0	U
SW846 8270	Shelton	Phenol	0.63	U
SW846 8270	Everett	4-Nonylphenol	0.65	U
SW846 8270	Everett	Bis(2-hexylethyl)phthalate	3.4	U
SW846 8270	Everett	Phenol	0.78	U
SW846 8270	Burlington	Di-n-butylphthalate	0.24	U
SW846 8270	Burlington	Bis(2-hexylethyl)phthalate	0.53	U
SW846 8270	Burlington	Phenol	0.56	U
SW846 8270	Bremerton	Di-n-butylphthalate	0.36	U
SW846 8270	Bremerton	Bis(2-hexylethyl)phthalate	2.4	U
SW846 8270	Bremerton	Phenol	0.86	U
SW846 8270	Tacoma	4-Nonylphenol	1.0	U
SW846 8270	Tacoma	Di-n-butylphthalate	0.28	U
SW846 8270	Tacoma	Bis(2-hexylethyl)phthalate	2.8	U
SW846 8270	Tacoma	Phenol	0.72	U
SW846 8270	Chambers Creek	4-Nonylphenol	0.68	U
SW846 8270	Chambers Creek	Bis(2-hexylethyl)phthalate	1.2	U
SW846 8270	Chambers Creek	Phenol	0.68	U
SW846 8270	Metro West Point	Di-n-butylphthalate	0.38	U
SW846 8270	Metro West Point	Bis(2-hexylethyl)phthalate	1.4	U
SW846 8270	Metro West Point	Phenol	0.94	U

Table 4 - List of Samples with Surrogates outside Control Limits
None

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	Tacoma MS	Phenol	39	NA	50 – 150	None
SW846 8270	Tacoma MSD	Phenol	36	NA	50 – 150	None
SW846 8270	Tacoma MS	4-Methylphenol	41	NA	50 – 150	JG
SW846 8270	Tacoma MSD	4-Methylphenol	45	NA	50 – 150	JG
SW846 8270	Tacoma MS	4-Nitrophenol	0	NA	50 – 150	REJ
SW846 8270	Tacoma MSD	4-Nitrophenol	0	NA	50 – 150	REJ
SW846 8270	Tacoma MS	Hexachloroethane	43	NA	50 – 150	UJG
SW846 8270	Tacoma MSD	Hexachloroethane	31	NA	50 – 150	UJG
SW846 8270	Tacoma MS	Hexachlorobutadiene	49	NA	50 – 150	UJG
SW846 8270	Tacoma MSD	Hexachlorobutadiene	37	NA	50 – 150	UJG
SW846 8270	Tacoma MS	2-Nitroaniline	22	NA	50 – 150	UJG
SW846 8270	Tacoma MSD	2-Nitroaniline	37	NA	50 – 150	UJG
SW846 8270	Tacoma MSD	2-Nitroaniline	NA	43	<40	None

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	Tacoma MS	3-Nitroaniline	23	NA	50 – 150	UJG
SW846 8270	Tacoma MSD	3-Nitroaniline	39	NA	50 – 150	UJG
SW846 8270	Tacoma MSD	3-Nitroaniline	NA	46	<40	None
SW846 8270	Tacoma MS	4-Nitroaniline	0	NA	50 – 150	REJ
SW846 8270	Tacoma MSD	4-Nitroaniline	0	NA	50 – 150	REJ
SW846 8270	Tacoma MS	n-Nitrosodiphenylamine	41	NA	50 – 150	JG
SW846 8270	Tacoma MSD	n-Nitrosodiphenylamine	62	NA	50 – 150	None
SW846 8270	Tacoma MS	4-Nonylphenol	30	NA	50 – 150	None
SW846 8270	Tacoma MSD	4-Nonylphenol	39	NA	50 – 150	None
SW846 8270	Tacoma MS	Bisphenol A	3	NA	50 – 150	REJ
SW846 8270	Tacoma MSD	Bisphenol A	0	NA	50 – 150	REJ

Table 6 - List LCS Percent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	B09B100-BS1	Hexachlorocyclopentadiene	46	NA	50 – 150	UJG
SW846 8270	B09B100-BSD1	Hexachlorocyclopentadiene	51	NA	50 – 150	None
SW846 8270	B09B100-BS1	4-Chloroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B100-BSD1	4-Chloroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B100-BS1	4-Nonylphenol	0	NA	50 – 150	REJ
SW846 8270	B09B100-BSD1	4-Nonylphenol	0	NA	50 – 150	REJ
SW846 8270	B09B116-BS1	Benzyl alcohol	NA	44	<40	None
SW846 8270	B09B116-BS1	Benzoic acid	NA	64	<40	None
SW846 8270	B09B116-BS1	4-Chloroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B116-BSD1	4-Chloroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B116-BS1	3,3’-Dichlorobenzidine	0	NA	50 – 150	REJ
SW846 8270	B09B116-BSD1	3,3’-Dichlorobenzidine	0	NA	50 – 150	REJ
SW846 8270	B09B116-BS1	2-Nitroaniline	7.7	NA	50 – 150	REJ
SW846 8270	B09B116-BSD1	2-Nitroaniline	29	NA	50 – 150	None
SW846 8270	B09B116-BS1	2-Nitroaniline	NA	118	<40	None
SW846 8270	B09B116-BSD1	3-Nitroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B116-BS1	3-Nitroaniline	29	NA	50 – 150	None
SW846 8270	B09B116-BSD1	3-Nitroaniline	NA	114	<40	None
SW846 8270	B09B116-BS1	4-Nitroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B116-BSD1	4-Nitroaniline	22	NA	50 – 150	None
SW846 8270	B09B116-BS1	n-Nitrosodiphenylamine	41	NA	50 – 150	UJG or JTG
SW846 8270	B09B116-BSD1	n-Nitrosodiphenylamine	62	NA	50 – 150	UJG or JTG
SW846 8270	B09B116-BS1	n-Nitrosodiphenylamine	NA	190	<40	None
SW846 8270	B09B116-BS1	Triethyl citrate	20	NA	50 – 150	None
SW846 8270	B09B116-BSD1	Triethyl citrate	11	NA	50 – 150	None
SW846 8270	B09B116-BSD1	Triethyl citrate	NA	61	<40	None
SW846 8270	B09B116-BSD1	4-Nonylphenol	24	NA	50 – 150	UJG or JTG

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	B09B116-BS1	4-Nonylphenol	71	NA	50 – 150	UJG or JTG
SW846 8270	B09B116-BSD1	4-Nonylphenol	NA	99	<40	None
SW846 8270	B09B116-BS1	Bisphenol A	0	NA	50 – 150	REJ
SW846 8270	B09B116-BSD1	Bisphenol A	9	NA	50 – 150	REJ
SW846 8270	B09B116-BSD1	Bisphenol A	NA	100	<40	None
SW846 8270	B09B116-BS1	di-n-Ocytlphthalate	358	NA	50 – 150	JL
SW846 8270	B09B116-BSD1	di-n-Ocytlphthalate	2980	NA	50 – 150	JL
SW846 8270	B09B116-BSD1	di-n-Ocytlphthalate	NA	157	<40	None
SW846 8270	B09B146-BS1	Benzyl alcohol	0	NA	50 – 150	None
SW846 8270	B09B146-BS1	Bis(2-chloroethoxy)methane	0	NA	50 – 150	REJ
SW846 8270	B09B146-BS1	4-Chloroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B146-BS1	4-Nitrophenol	0	NA	50 – 150	None
SW846 8270	B09B146-BS1	4-Nitroaniline	0	NA	50 – 150	REJ
SW846 8270	B09B146-BS1	Bisphenol A	0	NA	50 – 150	REJ
SW846 8270	B09B146-BS1	4-Methylphenol	39	NA	50 – 150	JG
SW846 8270	B09B146-BS1	Benzoic acid	39	NA	50 – 150	None
SW846 8270	B09B146-BS1	2-Nitroaniline	8	NA	50 – 150	REJ
SW846 8270	B09B146-BS1	3-Nitroaniline	8	NA	50 – 150	REJ
SW846 8270	B09B146-BS1	Caffeine	5	NA	50 – 150	JTG
SW846 8270	B09B146-BS1	Triclosan	33	NA	50 – 150	None

Table 7 –Samples that were Reanalyzed

Sample ID	Reason for Reanalysis
Sumner	Sample was reanalyzed due to IS outliers.
Everett	Sample was reanalyzed due to IS outliers.
Bellingham	Sample was reanalyzed due to QC outliers.
Field blank	Sample was reanalyzed due to QC outliers.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: October 14, 2009	**Completed by: Mark Woodke**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0907021	Gig Harbor	0907021-01	07/14/2009		
0907021	Bremerton	0907021-02	07/14/2009		
0907021	West Point	0907021-04	07/14/2009	MS/MSD	
0907021	Burlington	0907021-05	07/14/2009		
0907021	Tacoma	0907021-06	07/16/2009		
0907021	Chambers Creek	0907021-07	07/16/2009		
0907021	Sumner	0907021-08	07/17/2009		
0907021	Bellingham	0907021-09	07/16/2009		
0907021	Everett	0907021-10	07/16/2009		
0907021	Shelton	0907021-13	07/15/2009		
0907021	Rinsate	0907021-12	07/10/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0907021	Water	EPA 8270	Semivolatile Organic Compounds by GC/MS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, assumed based on the data review memorandum by Dickey Huntamer.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	No.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blank Results (Table 3);
- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7)

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: October 14, 2009	**Completed by: Mark Woodke**

The semivolatile organic analyses (BNAs) data was originally reviewed by Dickey Huntamer, Manchester Environmental Laboratory (MEL) on September 22, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Semivolatile Organics (including organotins) by GCMS	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 2)?	Yes.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data. Qualification also applies to TICs.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes
Surrogate recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	No
Surrogate recovery values for samples and MS/MSD within laboratory QC limits? All samples should be re-analyzed for VOCs? Samples should be re-analyzed if >1 BN and/or AP for SVOCs is out.	No
MS/MSD percent recovery values within laboratory QC criteria (see Table 4)?	No – Several compounds were outside QC limits. The analytes were qualified in the parent sample “JG” and “UJG” for low MS/MSD recovery. If MS/MSD percent recovery values were below 10%, then non-detect results were flagged as rejected “REJ”.
MS/MSD relative percent difference values within QC criteria (see Table 4) of <35%?	Yes.
LCS percent recovery values within Laboratory QC criteria (see Table 5)?	No – Several compounds were outside QC limits. All analytes were qualified in associated samples “JG” and “UJG” for low LCS/LCSD recovery. If LCS/LCSD percent recovery values were below 10%, then non-detect results were flagged as rejected “REJ”.
Do internal standards areas and retention time meet criteria? If not was sample re-analyzed to establish matrix (see Table 6)?	Yes.
Is initial calibration for target compounds <20 % RSD or curve fit?	No – several compounds were above the QC limit, all associated samples results were qualified “JK or UJK”.
Is continuing calibration for target compounds < 20%?	No – several compounds were above the QC limit, all associated samples results were qualified “JK or UJK”.
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	Yes.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns

Analytes were detected in the method blanks. The associated samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged UJ. Several MS/MSD compound percent recovery values were outside QC limits. The analytes were qualified in the parent sample "JG" and "UJG" for low MS/MSD recovery. If both MS/MSD percent recovery values were below 10%, then non-detect results were flagged as rejected "REJ". Several LCS/LCSD compound percent recovery values were outside QC limits. All analytes were qualified in associated samples "JG" and "UJG" for low LCS/LCSD recovery. If both LCS/LCSD percent recovery values were below 10%, then non-detect results were flagged as rejected "REJ". Several compounds were above the initial and continuing calibrations QC limit, all associated samples results were qualified estimated, bias unknown (UJK, JTK, or JK). Sample results greater than MDL and less than PQL are flagged estimated (JT).

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
SW846 8270	B09G117-BLK1	MBLK	Di-n-butylphthalate	0.18	J	µg/L	0.25
SW846 8270	B09G161-BLK1	MBLK	Di-n-butylphthalate	0.78	J	µg/L	0.25

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	Sample ID	Analyte	Result	Qualifier
SW846 8270	Gig Harbor	Di-n-butylphthalate	0.32	UJ
SW846 8270	Bremerton	Di-n-butylphthalate	0.19	UJ
SW846 8270	West Point	Di-n-butylphthalate	0.21	UJ
SW846 8270	Burlington	Di-n-butylphthalate	0.39	UJ
SW846 8270	Tacoma	Di-n-butylphthalate	0.24	UJ
SW846 8270	Chambers Creek	Di-n-butylphthalate	0.33	UJ
SW846 8270	Sumner	Di-n-butylphthalate	0.24	UJ
SW846 8270	Bellingham	Di-n-butylphthalate	0.26	UJ
SW846 8270	Everett	Di-n-butylphthalate	0.25	UJ
SW846 8270	Shelton	Di-n-butylphthalate	0.22	UJ

Table 4 - List of Samples with Surrogates outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	QC Limit	Sample Qualification
SW846 8270	Sumner	2-Fluorobiphenyl	42	43 – 116	None
SW846 8270	B09G161-BSD1	2-Fluorophenol	139	43 – 116	None
SW846 8270	B09G161-BLK1	2-Fluorophenol	128	43 – 116	None
SW846 8270	B09G117-BLK1	2-Fluorophenol	135	43 – 116	None

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	West Point MS	Phenol	44	NA	50 – 150	JG/UJG
SW846 8270	West Point MSD	Phenol	46	NA	50 – 150	JG/UJG

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	West Point MS	Benzyl Alcohol	41	NA	50 – 150	JG/UJG
SW846 8270	West Point MSD	Benzyl Alcohol	41	NA	50 – 150	JG/UJG
SW846 8270	West Point MS	Hexachloroethane	48	NA	50 – 150	JG/UJG
SW846 8270	West Point MSD	Hexachloroethane	40	NA	50 – 150	JG/UJG
SW846 8270	West Point MS	4-Nitroaniline	12	NA	50 – 150	JG/UJG
SW846 8270	West Point MSD	4-Nitroaniline	12	NA	50 – 150	JG/UJG
SW846 8270	West Point MS	Hexachlorocyclopentadiene	39	NA	50 – 150	JG/UJG
SW846 8270	West Point MSD	Hexachlorocyclopentadiene	32	NA	50 – 150	JG/UJG
SW846 8270	West Point MS	Hexachlorobutadiene	44	NA	50 – 150	None
SW846 8270	West Point MS	N-Nitrosodiphenylamine	161	NA	50 – 150	J
SW846 8270	West Point MSD	N-Nitrosodiphenylamine	162	NA	50 – 150	J
SW846 8270	West Point MS	Cholesterol	204	NA	50 – 150	J
SW846 8270	West Point MSD	Cholesterol	217	NA	50 – 150	J
SW846 8270	West Point MS	Bisphenol A	156	NA	50 – 150	J
SW846 8270	West Point MSD	Bisphenol A	154	NA	50 – 150	J
SW846 8270	West Point MS	Coprostanol	151	NA	50 – 150	None
SW846 8270	West Point MS	4-Chloroaniline	0	NA	50 – 150	Rej
SW846 8270	West Point MSD	4-Chloroaniline	0	NA	50 – 150	Rej
SW846 8270	West Point MS	3,3’-Dichlorobenzidine	0	NA	50 – 150	Rej
SW846 8270	West Point MSD	3,3’-Dichlorobenzidine	0	NA	50 – 150	Rej

Table 6 - List LCS Percent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	B09G117-BS1	Benzyl Alcohol	47	NA	50 – 150	JG/UJG
SW846 8270	B09G117-BS1	Benzoic Acid	35	NA	50 – 150	JG/UJG

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	B09G117-BS1	Hexachlorocyclopentadiene	20	NA	50 – 150	JG/UJG
SW846 8270	B09G117-BS1	4-Chloroaniline	0	NA	50 – 150	Rej
SW846 8270	B09G117-BS1	N-Nitrosodiphenylamine	199	NA	50 – 150	J
SW846 8270	B09G117-BS1	4-Nitroaniline	191	NA	50 – 150	J
SW846 8270	B09G117-BS1	N-Nonylphenol	152	NA	50 – 150	J
SW846 8270	B09G161-BS1/-BSD1	Hexachlorocyclopentadiene	20/44	NA	50 – 150	JG/UJG
SW846 8270	B09G161-BS1/-BSD1	Benzyl alcohol	42/48	NA	50 – 150	JG/UJG
SW846 8270	B09G161-BS1/-BSD1	Benzoic acid	25/33	NA	50 – 150	JG/UJG
SW846 8270	B09G161-BS1/-BSD1	Bisphenol A	140/41	NA	50 – 150	None
SW846 8270	B09G161-BS1/-BSD1	Hexachloroethane	49/68	NA	50 – 150	None
SW846 8270	B09G161-BS1/-BSD1	4-Chloroaniline	6/0	NA	50 – 150	Rej
SW846 8270	B09G161-BS1/-BSD1	N-Nitrosodiphenylamine	189/197	NA	50 – 150	J
SW846 8270	B09G161-BS1/-BSD1	4-Nitroaniline	183/150	NA	50 – 150	J
SW846 8270	B09G161-BS1/-BSD1	N-Nonylphenol	140/145	NA	50 – 150	J
SW846 8270	B09G161-BS1	Bisphenol A	NA	108	<40	J
SW846 8270	B09G161-BS1	Hexachlorocyclopentadiene	NA	75	<40	J

Table 7 –Samples that were Reanalyzed

Sample ID	Reason for Reanalysis
B09G117-BS1	Sample was reanalyzed due to overwriting file.
B09G161-BS1	Sample was reanalyzed due to overwriting file.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
T	The associated positive result is less than the quantitation limit.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: March 31, 2008	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance level 1 review (QA1) (PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Matrix	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0902008	Water	Sumner	0902008-01	02/12/2009		None
0902008	Water	Gig Harbor	0902008-02	02/10/2009		None
0902008	Water	Shelton	0902008-03	02/10/2009		None
0902008	Water	Everett	0902008-04	02/12/2009		None
0902008	Water	Burlington	0902008-05	02/10/2009		None
0902008	Water	Bremerton	0902008-06	02/10/2009		None
0902008	Water	Tacoma	0902008-07	02/19/2009	MS/MSD	None
0902008	Water	Chambers Creek	0902008-08	02/19/2009		None
0902008	Water	Metro West Point	0902008-09	02/10/2009		None
0902008	Water	Bellingham	0902008-10	02/12/2009		None
0902008	Water	Field Blank	0902008-11	02/12/2009		None

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Orders	Matrix	Test Method	Method Name	Number of Samples
0902008	Water	SW846 8270	Acid Herbicides by Gas Chromatography/Mass Spectrometry	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes
Did coolers arrive at lab between 0 °C and 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes
Frequency of Field QC Samples Correct? Field Duplicate – Not required. Field Blank – 1/20 samples. MS/MSD samples – 1/20 samples.	Yes
Case narrative present and complete?	Yes
Any holding time violations?	No - All samples were prepared and analyzed within holding times.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- Surrogates Outside Limits (Table 4);

- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7).

The acid herbicides data was reviewed by Bob Carrell, Manchester Environmental Laboratory (MEL) on March 11, 2009. The laboratory provided the analytical summaries for samples, including QC samples. No raw data was provided by the laboratory.

Acid Herbicides by GC/MS	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks?	No.
For samples, if results are <5 times the blank then "U" flag data.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes.
Surrogate standard recovery values for samples, MS/MSD, method blanks, and LCS/LCSD samples within laboratory QC limits?	No, please refer to Table 4. No action was taken for LCS surrogate outliers.
Internal standard recovery values for samples, MS/MSD, method blanks, and LCS/LCSD samples within laboratory QC limits?	Yes.
MS/MSD percent recovery values within laboratory QC criteria?	No, please refer to Table 5.
MS/MSD relative percent difference values within QC criteria (see Table 4) of <40%?	No, please refer to Table 5. No action was taken, since results were qualified due to MS/MSD recovery.
LCS percent recovery values within laboratory QC criteria (see Table 5)? If the value is high with no positive values in the associated data; then no data qualification is required.	No, please refer to Table 6.
Is initial calibration for target compounds <20 % RSD or curve fit?	Yes
Is initial calibration verification standard for target compounds <30 %?	No, 4-nitrophenol and dinoseb were outside QC limits. No action was taken since the anayltes were not detected in the associated samples.
Is continuing calibration for target compounds < 20%?	Yes
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	No

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Matrix spike (B09B138-MS1 and –MSD, parent sample Tacoma) percent recovery values were outside QC limits, the sample results were qualified (refer to Table 4). Laboratory control sample percent recovery values were outside QC limits, associated samples were qualified (refer to Table 5).

Table 3 - List of Positive Results for Blank Samples

None

Table 3A - List of Samples Qualified for Method Blank Contamination

None

Table 4 - List of Samples with Surrogates outside Control Limits

Method	Sample ID	Analyte	Recovery	QC Limit	Sample Qualification
SW846 8270	B09B102-BS1	2,4-Dichlorophenylacetic Acid	24	40 - 130	None

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits

Method	Sample ID	Analyte	Recovery	QC Limit	Sample Qualification
SW846 8270	B09B138-MS1	2,4-DB	0	40 - 130	R
SW846 8270	B09B138-MS1	4-Nitrophenol	23	40 - 130	UJL or JL
SW846 8270	B09B138-MS1	Acifluorfen (Blazer)	0	40 - 130	R
SW846 8270	B09B138-MS1	Clopyralid	38	40 - 130	UJL or JL
SW846 8270	B09B138-MS1	Dinoseb	0	40 - 130	R
SW846 8270	B09B138-MS1	Picloram	15	40 - 130	None
SW846 8270	B09B138-MSD1	2,4-DB	0	40 - 130	R
SW846 8270	B09B138-MSD1	4-Nitrophenol	19	40 - 130	UJL or JL
SW846 8270	B09B138-MS1	Clopyralid	34	40 - 130	UJL or JL
SW846 8270	B09B138-MS1	Dinoseb	34	40 - 130	R
SW846 8270	B09B138-MS1	Picloram	0	40 - 130	R
SW846 8270	B09B138-MS1	2,4-DB	RPD = NC	40	None
SW846 8270	B09B138-MS1	Acifluorfen (Blazer)	RPD = NC	40	None
SW846 8270	B09B138-MS1	Dinoseb	RPD = NC	40	None
SW846 8270	B09B138-MS1	Picloram	RPD = NC	40	None

Table 6 - List LCS Percent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Recovery	QC Limit	Sample Qualification
SW846 8270	B09B102-BS1	2,3,4,5-Tetrachlorophenol	24	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	2,3,4,6-Tetrachlorophenol	39	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	2,4,5-T	36	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	2,4,5-Trichlorophenol	21	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	2,4,6-Trichlorophenol	26	40 - 130	UJL, JTL or JL
SW846 8270	B09B102-BS1	2,4-D	35	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	2,4-DB	23	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	4-Nitrophenol	22	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	Acifluorfen (Blazer)	34	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	Clopyralid	30	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	Dicamba I	39	40 - 130	UJL, NJTL, or JL
SW846 8270	B09B102-BS1	Diclofop-Methyl	38	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	Dinoseb	24	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	MCPA	38	40 - 130	UJL, NJTL, or JL
SW846 8270	B09B102-BS1	MCPP (Mecoprop)	38	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	Picloram	26	40 - 130	UJL or JL
SW846 8270	B09B102-BS1	Trichlopry	38	40 - 130	UJL, NJTL, or JL
SW846 8270	B09B138-BS1	Dinoseb	35	40 - 130	UJL or JL
SW846 8270	B09B148-BS1	Picloram	36	40 - 130	UJL or JL
SW846 8270	B09B148-BSD	Clopyralid	28	40 - 130	UJL or JL

Method	SampleID	Analyte	Recovery	QC Limit	Sample Qualification
SW846 8270	B09B148-BSD	Picloram	36	40 - 130	UJL or JL

Table 7 –Samples that were Reanalyzed
None

Key:
A = Analyte
NC = Not Calculated
ND = Not Detected
PQL = Practical Quantitation Limit
RPD = Relative Percent Difference

Data Validation Qualifiers:

Code	Description
B	Analyte detected in sample and method blank. Reported result is sample concentration without blank correction or associated quantitation limit.
JG	Analyte was positively identified. Value may be greater than the reported estimate.
JK	Analyte was positively identified. Reported result is an estimate with unknown bias.
JL	Analyte was positively identified. Value may be less than the reported estimate.
JT	Analyte was positively identified. Reported result is an estimate below the associated quantitation limit but above the MDL.
JTG	Analyte was positively identified. Value may be greater than the reported result, which is an estimate below the associated quantitation limit but above the MDL.
JTK	Analyte was positively identified. Reported result is an estimate with unknown bias, below the associated quantitation limit but above the MDL.
JTL	Analyte was positively identified. Value may be less than the reported result which is an estimate below associated quantitation limit but above MDL.
NJ	There is evidence that the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate.
NJT	There is evidence the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate below the associated quantitation limit but above the MDL.
NU	There is evidence the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported result.
NUJ	There is evidence the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported estimate.
NAF	Not analyzed for.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJ	Analyte was not detected at or above the reported estimate
UJG	Analyte was not detected at or above the reported estimate with likely low bias.
UJK	Analyte was not detected at or above the reported estimate with unknown bias.
UJL	Analyte was not detected at or above the reported estimate with likely high bias.

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Gig Harbor**

Work Order: 0902008	Lab ID #: 0902008-02	Batch ID: B09B102
Project Officer: Maroncelli, Jim	Collected: 2/10/2009	Prepared: 2/11/2009
Initial Vol: 995 mL	Prep Method: SW3535	Analyzed: 3/2/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.063	U JL	0.063	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.063	U JL	0.063	0.007
93-76-5	2,4,5-T	0.063	U JL	0.063	0.009
93-72-1	2,4,5-TP (Silvex)	0.063	U	0.063	0.010
95-95-4	2,4,5-Trichlorophenol	0.063	U JL	0.063	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.16**	JL	0.063	0.011
94-75-7	2,4-D	0.063	U JL	0.063	0.012
94-82-6	2,4-DB	0.063	U JL	0.063	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.063	U	0.063	0.007
100-02-7	4-Nitrophenol	0.063	U JL	0.063	0.022
62476-59-9	Acifluorfen (Blazer)	0.063	U JL	0.063	0.054
25057-89-0	Bentazon	0.063	U	0.063	0.007
1689-84-5	Bromoxynil	0.063	U JL	0.063	0.006
1702-17-6	Clopyralid	0.063	U	0.063	0.008
1861-32-1	Dacthal (DCPA)	0.063	U	0.063	0.005
1918-00-9	Dicamba I	0.063	U JL	0.063	0.007
120-36-5	Dichlorprop	0.063	U	0.063	0.009
51338-27-3	Diclofop-Methyl	0.063	U JL	0.063	0.017
88-85-7	Dinoseb	0.063	U JL	0.063	0.041
1689-83-4	Ioxynil	0.063	U	0.063	0.016
94-74-6	MCPA	0.063	U JL	0.063	0.008
93-65-2	MCPP (Mecoprop)	0.063	U JL	0.063	0.008
87-86-5	Pentachlorophenol	0.063	U	0.063	0.007
1918-02-1	Picloram	0.063	UJL	0.063	0.018
55335-06-3	Trichlopyr	0.063	U JL	0.063	0.007

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10 April 2009

Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	1.01	1.01	100	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.668	1.01	67	40-130

Authorized by: ____________

Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Shelton**

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 985 mL
Final Vol: 0.5 mL

Lab ID #: 0902008-03
Collected: 2/10/2009
Prep Method: SW3535
Analysis Method: SW 8270

Batch ID: B09B102
Prepared: 2/11/2009
Analyzed: 3/2/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.063	U JL	0.063	0.004
58-90-2	**2,3,4,6-Tetrachlorophenol**	**0.15**	JL	0.063	0.007
93-76-5	2,4,5-T	0.063	U JL	0.063	0.009
93-72-1	2,4,5-TP (Silvex)	0.063	U	0.063	0.010
95-95-4	2,4,5-Trichlorophenol	0.063	U JL	0.063	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.30**	JL	0.063	0.011
94-75-7	2,4-D	0.063	U JL	0.063	0.012
94-82-6	2,4-DB	0.063	U JL	0.063	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.063	U	0.063	0.007
100-02-7	4-Nitrophenol	0.063	U JL	0.063	0.022
62476-59-9	Acifluorfen (Blazer)	0.063	U JL	0.063	0.054
25057-89-0	Bentazon	0.063	U	0.063	0.007
1689-84-5	Bromoxynil	0.063	U	0.063	0.006
1702-17-6	Clopyralid	0.063	U JL	0.063	0.009
1861-32-1	Dacthal (DCPA)	0.063	U	0.063	0.005
1918-00-9	Dicamba I	0.063	U JL	0.063	0.007
120-36-5	Dichlorprop	0.063	U	0.063	0.009
51338-27-3	Diclofop-Methyl	0.063	U JL	0.063	0.017
88-85-7	Dinoseb	0.063	U JL	0.063	0.041
1689-83-4	Ioxynil	0.063	U	0.063	0.016
94-74-6	MCPA	0.063	U JL	0.063	0.008
93-65-2	MCPP (Mecoprop)	0.063	U JL	0.063	0.008
87-86-5	Pentachlorophenol	0.063	U	0.063	0.007
1918-02-1	Picloram	0.063	UJ JL	0.063	0.018
55335-06-3	**Trichlopyr**	**0.054**	~~NJ JL~~ NJJL	0.063	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.904	1.02	89	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.670	1.02	66	40-130

Authorized by:

Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Burlington**

Work Order: 0902008	Lab ID #: 0902008-05	Batch ID: B09B102
Project Officer: Maroncelli, Jim	Collected: 2/10/2009	Prepared: 2/11/2009
Initial Vol: 1020 mL	Prep Method: SW3535	Analyzed: 3/2/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.061	U JL	0.061	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.061	U JL	0.061	0.007
93-76-5	2,4,5-T	0.061	U JL	0.061	0.009
93-72-1	2,4,5-TP (Silvex)	0.061	U	0.061	0.010
95-95-4	2,4,5-Trichlorophenol	0.061	U JL	0.061	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.029**	J JL	0.061	0.011
94-75-7	2,4-D	0.061	U JL	0.061	0.012
94-82-6	2,4-DB	0.061	U JL	0.061	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.061	U	0.061	0.007
100-02-7	4-Nitrophenol	0.061	U JL	0.061	0.021
62476-59-9	Acifluorfen (Blazer)	0.061	U JL	0.061	0.053
25057-89-0	Bentazon	0.061	U	0.061	0.006
1689-84-5	Bromoxynil	0.061	U	0.061	0.006
1702-17-6	Clopyralid	0.061	U JL	0.061	0.008
1861-32-1	Dacthal (DCPA)	0.061	U	0.061	0.005
1918-00-9	Dicamba I	0.061	U JL	0.061	0.007
120-36-5	Dichlorprop	0.061	U	0.061	0.008
51338-27-3	Diclofop-Methyl	0.061	U JL	0.061	0.016
88-85-7	Dinoseb	0.061	U JL	0.061	0.040
1689-83-4	Ioxynil	0.061	U	0.061	0.016
94-74-6	MCPA	0.061	U JL	0.061	0.008
93-65-2	MCPP (Mecoprop)	0.061	U JL	0.061	0.008
87-86-5	**Pentachlorophenol**	**0.037**	NJT	0.061	0.007
1918-02-1	Picloram	0.061	UJL	0.061	0.017
55335-06-3	Trichlopyr	0.061	U JL	0.061	0.007

① 10 April 2009

Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.917	0.98	94	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.745	0.98	76	40-130

Authorized by: ______________________ Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Bremerton**

Work Order: 0902008	Lab ID #: 0902008-06	Batch ID: B09B102
Project Officer: Maroncelli, Jim	Collected: 2/10/2009	Prepared: 2/11/2009
Initial Vol: 995 mL	Prep Method: SW3535	Analyzed: 3/2/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.063	UJL	0.063	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.063	UJL	0.063	0.007
93-76-5	2,4,5-T	0.063	UJL	0.063	0.009
93-72-1	2,4,5-TP (Silvex)	0.063	U	0.063	0.010
95-95-4	2,4,5-Trichlorophenol	0.063	UJL	0.063	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.033**	J JL	0.063	0.011
94-75-7	2,4-D	0.063	UJL	0.063	0.012
94-82-6	2,4-DB	0.063	UJL	0.063	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.063	U	0.063	0.007
100-02-7	4-Nitrophenol	0.063	UJL	0.063	0.022
62476-59-9	Acifluorfen (Blazer)	0.063	UJL	0.063	0.054
25057-89-0	Bentazon	0.063	U	0.063	0.007
1689-84-5	Bromoxynil	0.063	U	0.063	0.006
1702-17-6	Clopyralid	0.063	UJL	0.063	0.008
1861-32-1	Dacthal (DCPA)	0.063	U	0.063	0.005
1918-00-9	Dicamba I	0.063	UJL	0.063	0.007
120-36-5	Dichlorprop	0.063	U	0.063	0.009
51338-27-3	Diclofop-Methyl	0.063	UJL	0.063	0.017
88-85-7	Dinoseb	0.063	UJL	0.063	0.041
1689-83-4	Ioxynil	0.063	U	0.063	0.016
94-74-6	MCPA	0.063	UJL	0.063	0.008
93-65-2	MCPP (Mecoprop)	0.063	UJL	0.063	0.008
87-86-5	**Pentachlorophenol**	**0.044**	NJT	0.063	0.007
1918-02-1	Picloram	0.063	UJL	0.063	0.018
55335-06-3	Trichlopyr	0.063	UJL	0.063	0.007

① 10 APRIL 2009

Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.894	1.01	89	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.724	1.01	72	40-130

Authorized by: ______ Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Metro West Point**

Work Order: 0902008	Lab ID #: 0902008-09	Batch ID: B09B102
Project Officer: Maroncelli, Jim	Collected: 2/10/2009	Prepared: 2/11/2009
Initial Vol: 1015 mL	Prep Method: SW3535	Analyzed: 3/3/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.062	U JL	0.062	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.062	U JL	0.062	0.007
93-76-5	2,4,5-T	0.062	U JL	0.062	0.009
93-72-1	2,4,5-TP (Silvex)	0.062	U	0.062	0.010
95-95-4	2,4,5-Trichlorophenol	0.062	U JL	0.062	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.046**	J JL	0.062	0.011
94-75-7	2,4-D	0.062	U JL	0.062	0.012
94-82-6	2,4-DB	0.062	U JL	0.062	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.062	U	0.062	0.007
100-02-7	4-Nitrophenol	0.062	U JL	0.062	0.021
62476-59-9	Acifluorfen (Blazer)	0.062	U JL	0.062	0.053
25057-89-0	Bentazon	0.062	U	0.062	0.006
1689-84-5	Bromoxynil	0.062	U	0.062	0.006
1702-17-6	Clopyralid	0.062	U JL	0.062	0.008
1861-32-1	Dacthal (DCPA)	0.062	U	0.062	0.005
1918-00-9	**Dicamba I**	**0.031**	NJ JL	0.062	0.007
120-36-5	Dichlorprop	0.062	U	0.062	0.008
51338-27-3	Diclofop-Methyl	0.062	U JL	0.062	0.017
88-85-7	Dinoseb	0.062	U JL	0.062	0.040
1689-83-4	Ioxynil	0.062	U	0.062	0.016
94-74-6	**MCPA**	**0.16**	NJ JL	0.062	0.008
93-65-2	MCPP (Mecoprop)	0.062	U JL	0.062	0.008
87-86-5	Pentachlorophenol	0.062	U	0.062	0.007
1918-02-1	Picloram	0.062	UJ L	0.062	0.017
55335-06-3	**Trichlopyr**	**0.051**	NJ JL	0.062	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.901	0.985	92	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.724	0.985	74	40-130

Authorized by: ____________ Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Tacoma**

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 1010 mL
Final Vol: 0.5 mL

Lab ID #: 0902008-07
Collected: 2/19/2009
Prep Method: SW3535
Analysis Method: SW 8270

Batch ID: B09B138
Prepared: 2/20/2009
Analyzed: 3/3/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.062	U	0.062	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.062	U	0.062	0.007
93-76-5	2,4,5-T	0.062	U	0.062	0.009
93-72-1	2,4,5-TP (Silvex)	0.062	U	0.062	0.010
95-95-4	2,4,5-Trichlorophenol	0.062	U	0.062	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.12**		0.062	0.011
94-75-7	2,4-D	0.062	U	0.062	0.012
94-82-6	2,4-DB		~~REJ~~ R	0.062	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.062	U	0.062	0.007
100-02-7	4-Nitrophenol	0.062	UJ L	0.062	0.021
62476-59-9	Acifluorfen (Blazer)	0.062	~~UJ~~ R	0.062	0.053
25057-89-0	Bentazon	0.062	U	0.062	0.006
1689-84-5	Bromoxynil	0.062	U	0.062	0.006
1702-17-6	Clopyralid	0.062	UJ L	0.062	0.008
1861-32-1	Dacthal (DCPA)	0.062	U	0.062	0.005
1918-00-9	Dicamba I	0.062	U	0.062	0.007
120-36-5	Dichlorprop	0.062	U	0.062	0.008
51338-27-3	Diclofop-Methyl	0.062	U	0.062	0.017
88-85-7	Dinoseb	0.062	~~UJ~~ R	0.062	0.040
1689-83-4	Ioxynil	0.062	U	0.062	0.016
94-74-6	MCPA	0.062	U	0.062	0.008
93-65-2	MCPP (Mecoprop)	0.062	U	0.062	0.008
87-86-5	Pentachlorophenol	0.062	U	0.062	0.007
1918-02-1	Picloram	0.062	~~U~~ R	0.062	0.018
55335-06-3	Trichlopyr	0.062	U	0.062	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	1.04	0.99	106	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.688	0.99	70	40-130

Authorized by: Release Date: 3-16-09

Washington State Department of Ecology
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Result_Reported_Value Result_Value_UOM Result_Reporting_Limit Result_Reporting_Limit_Type Result_Detection_Limit Result_Detection_Limit_Type Result_Data_Qualifier Result_Lab_Name

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Chambers Creek**

Work Order: 0902008	Lab ID #: 0902008-08	Batch ID: B09B138
Project Officer: Maroncelli, Jim	Collected: 2/19/2009	Prepared: 2/20/2009
Initial Vol: 980 mL	Prep Method: SW3535	Analyzed: 3/3/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.064	U	0.064	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.064	U	0.064	0.007
93-76-5	2,4,5-T	0.064	U	0.064	0.009
93-72-1	2,4,5-TP (Silvex)	0.064	U	0.064	0.010
95-95-4	2,4,5-Trichlorophenol	0.064	U	0.064	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.092**		0.064	0.011
94-75-7	2,4-D	0.064	U	0.064	0.013
94-82-6	2,4-DB	0.064	U	0.064	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.064	U	0.064	0.007
100-02-7	4-Nitrophenol	0.064	U	0.064	0.022
62476-59-9	Acifluorfen (Blazer)	0.064	U	0.064	0.055
25057-89-0	Bentazon	0.064	U	0.064	0.007
1689-84-5	Bromoxynil	0.064	U	0.064	0.006
1702-17-6	Clopyralid	0.064	U	0.064	0.009
1861-32-1	Dacthal (DCPA)	0.064	U	0.064	0.005
1918-00-9	Dicamba I	0.064	U	0.064	0.007
120-36-5	Dichlorprop	0.064	U	0.064	0.009
51338-27-3	Diclofop-Methyl	0.064	U	0.064	0.017
88-85-7	Dinoseb	0.064	U JL	0.064	0.042
1689-83-4	Ioxynil	0.064	U	0.064	0.016
94-74-6	MCPA	0.064	U	0.064	0.008
93-65-2	**MCPP (Mecoprop)**	**0.23**		0.064	0.008
87-86-5	Pentachlorophenol	0.064	U	0.064	0.007
1918-02-1	Picloram	0.064	~~UJ~~ U	0.064	0.018
55335-06-3	Trichlopyr	0.064	U	0.064	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	1.06	1.02	104	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.776	1.02	76	40-130

Authorized by: ____________ Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Sumner**

Work Order: 0902008	Lab ID #: 0902008-01	Batch ID: B09B148
Project Officer: Maroncelli, Jim	Collected: 2/12/2009	Prepared: 2/17/2009
Initial Vol: 1010 mL	Prep Method: SW3535	Analyzed: 3/3/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.062	U	0.062	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.062	U	0.062	0.007
93-76-5	2,4,5-T	0.062	U	0.062	0.009
93-72-1	2,4,5-TP (Silvex)	0.062	U	0.062	0.010
95-95-4	2,4,5-Trichlorophenol	0.062	U	0.062	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.057**	**J** T	0.062	0.011
94-75-7	2,4-D	0.062	U	0.062	0.012
94-82-6	2,4-DB	0.062	U	0.062	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.062	U	0.062	0.007
100-02-7	4-Nitrophenol	0.062	U	0.062	0.021
62476-59-9	Acifluorfen (Blazer)	0.062	U	0.062	0.053
25057-89-0	Bentazon	0.062	U	0.062	0.006
1689-84-5	Bromoxynil	0.062	U	0.062	0.006
1702-17-6	Clopyralid	0.062	UJ L	0.062	0.008
1861-32-1	Dacthal (DCPA)	0.062	U	0.062	0.005
1918-00-9	Dicamba I	0.062	U	0.062	0.007
120-36-5	Dichlorprop	0.062	U	0.062	0.008
51338-27-3	Diclofop-Methyl	0.062	U	0.062	0.017
88-85-7	Dinoseb	0.062	U	0.062	0.040
1689-83-4	Ioxynil	0.062	U	0.062	0.016
94-74-6	**MCPA**	**0.11**	**NJ** T	0.062	0.008
93-65-2	MCPP (Mecoprop)	0.062	U	0.062	0.008
87-86-5	Pentachlorophenol	0.062	U	0.062	0.007
1918-02-1	Picloram	0.062	UJ L	0.062	0.018
55335-06-3	Trichlopyr	0.062	U	0.062	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.965	0.99	98	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.827	0.99	84	40-130

Authorized by: ______________ Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Everett**

Work Order: 0902008	Lab ID #: 0902008-04	Batch ID: B09B148
Project Officer: Maroncelli, Jim	Collected: 2/12/2009	Prepared: 2/17/2009
Initial Vol: 1015 mL	Prep Method: SW3535	Analyzed: 3/3/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.062	U	0.062	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.062	U	0.062	0.007
93-76-5	2,4,5-T	0.062	U	0.062	0.009
93-72-1	2,4,5-TP (Silvex)	0.062	U	0.062	0.010
95-95-4	2,4,5-Trichlorophenol	0.062	U	0.062	0.008
88-06-2	2,4,6-Trichlorophenol	0.062	U	0.062	0.011
94-75-7	2,4-D	0.062	U	0.062	0.012
94-82-6	2,4-DB	0.062	U	0.062	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.062	U	0.062	0.007
100-02-7	4-Nitrophenol	0.062	U	0.062	0.021
62476-59-9	Acifluorfen (Blazer)	0.062	U	0.062	0.053
25057-89-0	Bentazon	0.062	U	0.062	0.006
1689-84-5	Bromoxynil	0.062	U	0.062	0.006
1702-17-6	Clopyralid	0.062	UJ ✓	0.062	0.008
1861-32-1	Dacthal (DCPA)	0.062	U	0.062	0.005
1918-00-9	Dicamba I	0.062	U	0.062	0.007
120-36-5	Dichlorprop	0.062	U	0.062	0.008
51338-27-3	Diclofop-Methyl	0.062	U	0.062	0.017
88-85-7	Dinoseb	0.062	U	0.062	0.040
1689-83-4	Ioxynil	0.062	U	0.062	0.016
94-74-6	MCPA	0.062	U	0.062	0.008
93-65-2	MCPP (Mecoprop)	0.062	U	0.062	0.008
87-86-5	Pentachlorophenol	0.062	U	0.062	0.007
1918-02-1	Picloram	0.062	UJ ✓	0.062	0.017
55335-06-3	Trichlopyr	0.062	U	0.062	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	1.08	0.985	110	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.788	0.985	80	40-130

Authorized by: ______________ Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Bellingham**

Work Order: 0902008	Lab ID #: 0902008-10	Batch ID: B09B148
Project Officer: Maroncelli, Jim	Collected: 2/12/2009	Prepared: 2/17/2009
Initial Vol: 1010 mL	Prep Method: SW3535	Analyzed: 3/3/2009
Final Vol: 0.5 mL	Analysis Method: SW 8270	Matrix: Water
		Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.062	U	0.062	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.062	U	0.062	0.007
93-76-5	2,4,5-T	0.062	U	0.062	0.009
93-72-1	2,4,5-TP (Silvex)	0.062	U	0.062	0.010
95-95-4	2,4,5-Trichlorophenol	0.062	U	0.062	0.008
88-06-2	**2,4,6-Trichlorophenol**	**0.049**	JT	0.062	0.011
94-75-7	2,4-D	0.062	U	0.062	0.012
94-82-6	2,4-DB	0.062	U	0.062	0.008
51-36-5	3,5-Dichlorobenzoic Acid	0.062	U	0.062	0.007
100-02-7	4-Nitrophenol	0.062	U	0.062	0.021
62476-59-9	Acifluorfen (Blazer)	0.062	U	0.062	0.053
25057-89-0	Bentazon	0.062	U	0.062	0.006
1689-84-5	Bromoxynil	0.062	U	0.062	0.006
1702-17-6	Clopyralid	0.062	UJL	0.062	0.008
1861-32-1	Dacthal (DCPA)	0.062	U	0.062	0.005
1918-00-9	Dicamba I	0.062	U	0.062	0.007
120-36-5	Dichlorprop	0.062	U	0.062	0.008
51338-27-3	Diclofop-Methyl	0.062	U	0.062	0.017
88-85-7	Dinoseb	0.062	U	0.062	0.040
1689-83-4	Ioxynil	0.062	U	0.062	0.016
94-74-6	MCPA	0.062	U	0.062	0.008
93-65-2	MCPP (Mecoprop)	0.062	U	0.062	0.008
87-86-5	**Pentachlorophenol**	**0.076**	NJT	0.062	0.007
1918-02-1	Picloram	0.062	UJL	0.062	0.018
55335-06-3	Trichlopyr	0.062	U	0.062	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.985	0.99	100	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.718	0.99	72	40-130

Authorized by:

Release Date: 3-16-09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Chlorophenoxy Herbicides

Project: Phase 3: Priority Pollutant Scans of Ten **Field ID: Field Blank**

Work Order: 0902008
Project Officer: Maroncelli, Jim
Initial Vol: 970 mL
Final Vol: 0.5 mL

Lab ID #: 0902008-11
Collected: 2/12/2009
Prep Method: SW3535
Analysis Method: SW 8270

Batch ID: B09B148
Prepared: 2/17/2009
Analyzed: 3/3/2009
Matrix: Water
Units: ug/L

CAS#	Analyte	Result	Qualifier	RL	MDL
4901-51-3	2,3,4,5-Tetrachlorophenol	0.064	U	0.064	0.004
58-90-2	2,3,4,6-Tetrachlorophenol	0.064	U	0.064	0.007
93-76-5	2,4,5-T	0.064	U	0.064	0.009
93-72-1	2,4,5-TP (Silvex)	0.064	U	0.064	0.010
95-95-4	2,4,5-Trichlorophenol	0.064	U	0.064	0.009
88-06-2	2,4,6-Trichlorophenol	0.064	U	0.064	0.011
94-75-7	2,4-D	0.064	U	0.064	0.013
94-82-6	2,4-DB	0.064	U	0.064	0.009
51-36-5	3,5-Dichlorobenzoic Acid	0.064	U	0.064	0.007
100-02-7	4-Nitrophenol	0.064	U	0.064	0.022
62476-59-9	Acifluorfen (Blazer)	0.064	U	0.064	0.055
25057-89-0	Bentazon	0.064	U	0.064	0.007
1689-84-5	Bromoxynil	0.064	U	0.064	0.006
1702-17-6	Clopyralid	0.064	UJ	0.064	0.009
1861-32-1	Dacthal (DCPA)	0.064	U	0.064	0.006
1918-00-9	Dicamba I	0.064	U	0.064	0.007
120-36-5	Dichlorprop	0.064	U	0.064	0.009
51338-27-3	Diclofop-Methyl	0.064	U	0.064	0.017
88-85-7	Dinoseb	0.064	U	0.064	0.042
1689-83-4	Ioxynil	0.064	U	0.064	0.016
94-74-6	MCPA	0.064	U	0.064	0.008
93-65-2	MCPP (Mecoprop)	0.064	U	0.064	0.008
87-86-5	Pentachlorophenol	0.064	U	0.064	0.007
1918-02-1	Picloram	0.064	UJ	0.064	0.018
55335-06-3	Trichlopyr	0.064	U	0.064	0.007

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Surrogate Recovery:

CAS#	Analyte	Result	Spike Level	% Recovery	%Rec.Limits
118-79-6	2,4,6-Tribromophenol	0.938	1.03	91	40-130
19719-28-9	2,4-Dichlorophenylacetic acid	0.732	1.03	71	40-130

Authorized by: Release Date: 3-16-09

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: August 26, 2009	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0907021	Gig Harbor	0907021-01	07/14/2009		
0907021	Bremerton	0907021-02	07/14/2009		
0907021	West Point	0907021-04	07/14/2009	MS/MSD	
0907021	Burlington	0907021-05	07/14/2009		
0907021	Tacoma	0907021-06	07/16/2009		
0907021	Chambers Creek	0907021-07	07/16/2009		
0907021	Sumner	0907021-08	07/17/2009		
0907021	Bellingham	0907021-09	07/16/2009		
0907021	Everett	0907021-10	07/20/2009		
0907021	Rinsate	0907021-12	07/10/2009		
0907021	Shelton	0907021-13	07/20/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0907021	Water	EPA 535/8270	Chlorinated Herbicides by solid phase extraction and GC/MS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, implied in the data review memoranda by Bob Carrell.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, implied in the data review memoranda by Bob Carrell.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	No.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- Internal Standards Outside Limits (Table 4);
- Surrogates Outside Limits (Table 5);
- LCS Outside Limits (Table 6);
- MS/MSD Outside Limits (Table 7); and
- Re-analysis Results (Table 8).

The chlorinated herbicides analyses data was originally reviewed by Bob Carrell, Manchester Environmental Laboratory (MEL) on July 29, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Chlorinated Pesticides by GC/ECD	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 3)?	No.
For samples, if results are <10 times the blank then "UJ" flag data.	Not applicable.
Laboratory QC frequency of one method blank and LCS with each batch per 20 samples?	Yes
Internal standards and clean-up standards percent recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	Yes.
Internal standards and clean-up standards recovery values for samples and MS/MSD within laboratory QC limits (see Table 4)?	Yes.
Surrogate recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	Yes.
Surrogate recovery values for samples and MS/MSD within laboratory QC limits (see Table 5)?	Yes.
LCS percent recovery values within Laboratory QC criteria (see Table 6)?	No, picloram was outside QC limits, associated sample results were qualified as estimated (UJG).
MS/MSD percent recovery values within laboratory QC criteria (see Table 7)?	No, several compounds were outside Laboratory QC limits, West Point results were qualified as estimated (UJG or JG), except for picloram. The Picloram quantitation limit was qualified as rejected (REJ).
MS/MSD relative percent difference values within laboratory QC criteria (see Table 7)?	Yes.
Is initial calibration for target compounds <20 % RSD or curve fit?	Yes.
Is continuing calibration for target compounds < 20%?	No, 2,4,6-trichlorophenol and 3,5-dichlorobenzoic acid were outside calibration QC limits. Associated sample results were qualified as estimated (UJK, JTK, or JK).
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	Yes.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns

The picloram was outside LCS QC limits, associated sample results were qualified as estimated (UJG). Several compounds were outside Laboratory MS/MSD QC limits, West Point results were qualified as estimated (UJG or JG), except for picloram. The Picloram quantitation limit was qualified as rejected (REJ). 2,4,6-Trichlorophenol and 3,5-dichlorobenzoic acid were outside calibration QC limits. Associated sample results were qualified as estimated (UJK, JTK, or JK). Sample results greater than MDL and less than PQL are flagged estimated (JT). Sample results that are outside laboratory QC criteria, the results are flagged tentative identification (NK or NJK).

Table 3 – List of Positive Results for Blank Samples
None.

Table 3A - List of Samples Qualified for Method Blank Contamination
None.

Table 4 - List Internal Standard Recovery Values outside Control Limits
None.

Table 5 – Surrogate Precent Recovery Values outside Control Limits
None.

Table 6 – LCS Precent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
EPA 8270	B09G181-BS1	Picloram	38	NA	40 – 130	None
EPA 8270	B09G181-BSD1	Picloram	NA	50	40	None

Table 7 – MS/MSD Precent Recovery Values outside Control Limits

Method	Sample ID	Analyte	MS Recovery	MSD Recovery	QC Limit	Sample Qualification
EPA 8270	West Point	2,4,5-T	33	39	40 – 130	UJG
EPA 8270	West Point	2,4-D	28	34	40 – 130	JG
EPA 8270	West Point	4-Nitrophenol	15	19	40 – 130	UJG
EPA 8270	West Point	Bentazon	30	38	40 – 130	UJG
EPA 8270	West Point	Clopyralid	30	34	40 – 130	UJG
EPA 8270	West Point	Picloram	6	7	40 – 130	REJ

Table 8 - Samples that were Reanalyzed
None.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a “tentative identification”.
NJ	The analysis indicates the presence of an analyte that has been “tentatively identified” and the associated numerical value represents its approximate concentration.

REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
T	Sample results are greater than MDL and less than PQL
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: June 19, 2009	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0902008	Sumner	0902008-01	02/12/2009		
0902008	Gig Harbor	0902008-02	02/10/2009		
0902008	Shelton	0902008-03	02/10/2009		
0902008	Everett	0902008-04	02/12/2009		
0902008	Burlington	0902008-05	02/10/2009		
0902008	Bremerton	0902008-06	02/10/2009		
0902008	Tacoma	0902008-07	02/19/2009	MS/MSD	
0902008	Chambers Creek	0902008-08	02/19/2009		
0902008	Metro West Point	0902008-09	02/10/2009		
0902008	Bellingham	0902008-10	02/12/2009		
0902008	Field Blank	0902008-11	02/12/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0902008	Water	EPA 8081	Chlorinated Pesticide Compounds by GC/ECD	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes.
Did coolers arrive at lab less than 6^{o}C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, according to the data review memoranda by M. Mandjikov.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	No.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7)

The Chlorinated pesticides analyses (BNAs) data was originally reviewed by M. Mandjikov, Manchester Environmental Laboratory (MEL) on May 21, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Chlorinated Pesticides by GC/ECD	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 2)?	Yes.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data. Qualification also applies to TICs.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes
Surrogate recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	No. No action was taken for the outliers.
Surrogate recovery values for samples and MS/MSD within laboratory QC limits (see Table 4)?	No.
MS/MSD percent recovery values within laboratory QC criteria (see Table 4)?	No – Several compounds were outside QC limits. The analytes were not qualified in the parent sample.
MS/MSD relative percent difference values within QC criteria (see Table 5) of <35%?	No – Several compounds were outside QC limits. No action was taken.
LCS percent recovery values within Laboratory QC criteria (see Table 6)?	No – Several compounds were outside QC limits in B09B101-BSD1, according to the memoranda by M. Madjikov, the laboratory lost part of the sample extract. No action was taken for this LCSD, since the associated LCS was within QC limits.
Confirmation column quantitation results are with QC limits of less than 40 percent?	Several compounds were quantitatively confirmed on the confirmation sample. Sample results that exceeded a relative percent difference of 40% were qualified as estimated bias unknown (JK or JTK).
Is initial calibration for target compounds <20 % RSD or curve fit?	Yes.
Is continuing calibration for target compounds < 20%?	Yes
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	No

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Analytes were detected in the method blanks. The associated samples results were not changed and flagged U. Several MS/MSD compound percent recovery values were outside QC limits. Sample results greater than MDL and less than PQL are flagged estimated (JT).

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
SW846 8081	B09B101-BLK1	MBLK	Lindane	0.004	J	µg/L	0.25
SW846 8081	B09B117-BLK1	MBLK	Lindane	0.003	J	µg/L	0.25
SW846 8081	B09B135-BLK1	MBLK	Lindane	0.004	J	µg/L	0.25

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	Sample ID	Analyte	Result	Qual
SW846 8081	Sumner	Lindane	0.0045	U
SW846 8081	Gig Harbor	Lindane	0.0049	U
SW846 8081	Shelton	Lindane	0.0043	U
SW846 8081	Everett	Lindane	0.0025	U
SW846 8081	Burlington	Lindane	0.0049	U
SW846 8081	Bremerton	Lindane	0.0037	U
SW846 8081	Tacoma	Lindane	0.0039	U
SW846 8081	Chambers Creek	Lindane	0.0048	U
SW846 8081	Metro West Point	Lindane	0.0029	U
SW846 8081	Bellingham	Lindane	0.0040	U

Table 4 - List of Samples with Surrogates outside Control Limits

Method	Sample ID	TMX Recovery	DBOB Recovery	DBC Recovery	DCB Recovery	QC Limit	Sample Qualification
SW846 8081	Sumner	52	63	55	74	50 – 150	None
SW846 8081	Gig Harbor	54	56	29	50	50 – 150	UJG or JG
SW846 8081	Shelton	62	73	53	76	50 – 150	None
SW846 8081	Everett	47	56	28	55	50 – 150	UJG
SW846 8081	Burlington	60	72	51	81	50 – 150	None
SW846 8081	Bremerton	60	71	51	73	50 – 150	None
SW846 8081	Tacoma	58	65	39	68	50 – 150	UJG
SW846 8081	Chambers Creek	54	65	38	71	50 – 150	UJG
SW846 8081	Metro West Point	49	56	33	48	50 – 150	UJG
SW846 8081	Bellingham	40	56	38	56	50 – 150	UJG

TMX = Tetrachloro-m-xylene.
DBOB = Dibromooctafluorobiphenyl.
DBC = Dibutylchlrendate.
DCB = Decachlorobiphenyl.

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	Tacoma MS	Aldrin	49	NA	50 – 150	None
SW846 8270	Tacoma MSD	Aldrin	48	NA	50 – 150	None
SW846 8270	Tacoma MS	4,4’-DDE	41	NA	50 – 150	None
SW846 8270	Tacoma MSD	4,4’-DDE	39	NA	50 – 150	None
SW846 8270	Tacoma MS	4,4’-DDT	46	NA	50 – 150	None
SW846 8270	Tacoma MSD	4,4’-DDT	42	NA	50 – 150	None
SW846 8270	Tacoma MSD	cis-Nonachlor	49	NA	50 – 150	None

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8270	Tacoma MSD	trans-Nonachlor	49	NA	50 – 150	None

Table 6 - List LCS Percent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8081	B09B117-BS1	Endrin aldehyde	49	NA	50 – 150	None

Table 7 –Samples that were Reanalyzed
None

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: September 9, 2009	**Completed by: Mark Woodke**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0907021	Gig Harbor	0907021-01	07/14/2009		
0907021	Bremerton	0907021-02	07/14/2009		
0907021	West Point	0907021-04	07/14/2009	MS/MSD	
0907021	Burlington	0907021-05	07/14/2009		
0907021	Tacoma	0907021-06	07/16/2009		
0907021	Chambers Creek	0907021-07	07/16/2009		
0907021	Sumner	0907021-08	07/17/2009		
0907021	Bellingham	0907021-09	07/16/2009		
0907021	Everett	0907021-10	07/16/2009		
0907021	Rinsate	0907021-12	07/10/2009		
0907021	Shelton	0907021-13	07/15/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0907021	Water	EPA 8081	Chlorinated Pesticides Compounds by GC/ECD	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, implied in the data review memorandum by M. Mandjikov.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, implied in the data review memorandum by M. Mandjikov.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes.
Case narrative present and complete?	Yes.
Any holding time violations?	No.

The following tables are presented at the end of this QA1 Review Memorandum and provide summaries of results outside QC criteria.

- Method Blank Results (Table 3);
- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7).

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: September 9, 2009	Completed by: Mark Woodke

The chlorinated pesticides analyses data was originally reviewed by M. Mandjikov, Manchester Environmental Laboratory (MEL) on August 19, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Chlorinated Pesticides by GC/ECD	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 3)?	Yes.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data. Qualification also applies to TICs.	Sample results below the PQL are reported at the PQL and flagged U. Sample results greater than the PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes.
Surrogate recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	No. No action was taken for the outliers.
Surrogate recovery values for samples and MS/MSD within laboratory QC limits (see Table 4)?	No.
LCS percent recovery values within Laboratory QC criteria (see Table 6)?	Yes.
MS/MSD percent recovery values within laboratory QC criteria (see Table 5)?	No, several compounds were outside Laboratory QC limits. The analytes were not qualified in the parent sample.
MS/MSD relative percent difference values within laboratory QC criteria of < 35% (see Table 5)?	Yes.
Confirmation column quantitation results are within QC limits of less than 40 percent?	Several compounds were quantitatively confirmed on the confirmation sample. Sample results that exceeded a relative percent difference of 40 % were qualified as estimated with an unknown bias (JK or JTK).
Is initial calibration for target compounds <20 % RSD or curve fit?	Yes.
Is continuing calibration for target compounds < 20%?	Yes.
Were any samples re-analyzed or diluted (see Table 7)? For any sample re-analysis and dilutions is only one reportable result by flagged?	No.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Analytes were detected in the method blanks. The associated sample results were not changed and were flagged U. Several MS/MSD compound percent recovery values were outside QC limits. Sample results greater than the MDL and less than the PQL are flagged as estimated quantities (JT).

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
SW846 8081	B09G116-BLK1	MBLK	Lindane	0.005	J	µg/L	0.0025
SW846 8081	B09G178-BLK1	MBLK	Lindane	0.002	J	µg/L	0.0025

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	Sample ID	Analyte	Result	Qual
SW846 8081	Sumner	Lindane	0.0027	UJ
SW846 8081	Gig Harbor	Lindane	0.010	UJ
SW846 8081	Shelton	Lindane	0.0027	UJ
SW846 8081	Everett	Lindane	0.0051	UJ
SW846 8081	Burlington	Lindane	0.0066	UJ
SW846 8081	Bremerton	Lindane	0.0036	UJ
SW846 8081	Tacoma	Lindane	0.0032	UJ
SW846 8081	Metro West Point	Lindane	0.0047	UJ
SW846 8081	Bellingham	Lindane	0.0053	UJ

Table 4 - List of Samples with Surrogates Outside Control Limits

Method	Sample ID	TMX Recovery	DBOB Recovery	DBC Recovery	DCB Recovery	QC Limit	Sample Qualification
SW846 8081	Gig Harbor	64	57	49	59	50 - 150	JG or UJG
SW846 8081	Everett	33	37	40	69	50 - 150	JG or UJG
SW846 8081	Metro West Point	56	57	48	64	50 - 150	JG or UJG

TMX = Tetrachloro-m-xylene.
DBOB = Dibromooctafluorobiphenyl.
DBC = Dibutylchlorendate.
DCB = Decachlorobiphenyl.

Table 5 – List of MS/MSD Percent Recovery Values and RPDs outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
SW846 8081	Metro West Point MS	2,4'-DDT	39	NA	50 – 150	None
SW846 8081	Metro West Point MS	4,4'-DDE	37	NA	50 – 150	None
SW846 8081	Metro West Point MS	4,4'-DDT	42	NA	50 – 150	None
SW846 8081	Metro West Point MS	Aldrin	45	NA	50 – 150	None
SW846 8081	Metro West Point MS	Cis-Nonachlor	39	NA	50 – 150	None
SW846 8081	Metro West Point MS	Mirex	29	NA	50 – 150	None
SW846 8081	Metro West Point MS	Trans-Nonachlor	46	NA	50 – 150	None
SW846 8081	Metro West Point MSD	2,4'-DDT	38	NA	50 – 150	None
SW846 8081	Metro West Point MSD	4,4'-DDE	38	NA	50 – 150	None
SW846 8081	Metro West Point MSD	4,4'-DDT	42	NA	50 – 150	None
SW846 8081	Metro West Point MSD	Aldrin	47	NA	50 – 150	None
SW846 8081	Metro West Point MSD	Cis-Nonachlor	42	NA	50 – 150	None
SW846 8081	Metro West Point MSD	Mirex	28	NA	50 – 150	None

Table 6 – List of LCS Percent Recovery Values Outside Control Limits
None.

Table 7 - Samples that were Reanalyzed

None.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a “tentative identification”.
NJ	The analysis indicates the presence of an analyte that has been “tentatively identified” and the associated numerical value represents its approximate concentration.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
T	Sample results are greater than MDL and less than PQL
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: May 29, 2009	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
PR90268	Summer	PR90276	02/12/2009		Sumner
PR90268	Gig Harbor	PR90277	02/10/2009		
PR90268	Shelton	PR90278	02/10/2009		
PR90268	Everett	PR90269	02/12/2009		
PR90268	Burlington	PR90280	02/10/2009		
PR90268	Bremerton	PR90270	02/10/2009		
PR90268	Tacoma	PR90271	02/19/2009		
PR90268	Chambers Creek	PR90273	02/19/2009		
PR90268	Metro West Point	PR90274	02/10/2009	Dup	
PR90268	Bellingham	PR90286	02/12/2009		
PR90268	Herrera	PR90287	02/12/2009		Field Blank

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
PR90268	Water	EPA 1614	Brominated Diphenyl Ethers in Water, Soil, Sediment, and Tissue by HRGC/HRMS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, according to the data review memoranda by Karin Feddersen.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, according to the data review memoranda by Karin Feddersen.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	No, according to the data review memoranda by Karin Feddersen.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- OPR outside QC limits (Table 4);
- Sample Reanalysis (Table 5).

The Polybrominated Diphenyl Ethers (PBDEs) data were originally reviewed by Karin Feddersen, Manchester Environmental Laboratory (MEL) on May 11, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

PFOAs by LCMS-MS	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks?	Yes, according to the data review memoranda by Karin Feddersen.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and ongoing precision and recovery (OPR) with each batch?	Yes, according to the data review memoranda by Feddersen.
Initial precision and recovery (IPR) values are within QC limits?	Yes, according to the data review memoranda by Karin Feddersen.
OPR recovery values are within laboratory QC limits?	Yes, according to the data review memoranda by Karin Feddersen.
C-13 labeled isotope dilution internal standard recovery values for samples within QC limits?	Yes, according to the data review memoranda by Karin Feddersen.
Is initial calibration within Method QC limits?	Yes, according to the data review memoranda by Karin Feddersen.
Is continuing calibration within Method QC limits?	Yes, according to the data review memoranda by Karin Feddersen.
Were any samples re-analyzed or diluted? For any sample re-analysis and dilutions is only one reportable result by flagged?	No.
Did compound ion abundances meet method QC requirements for compound identification?	No, according to the data review memoranda by Karin Feddersen. Data was qualified as estimated tentatively identified, bias unknown (NJK or NK).
Laboratory Duplicate Sample analyzed?	Yes, all relative percent difference values were within QC limits.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Several compound ion abundances did not meet method QC requirements for compound identification. Data was qualified as estimated tentatively identified (NJK or NK). No Form Is were received by the secondary reviewer. Several qualifiers were changed by the secondary reviewer, and the spreadsheet that accompanied the data review was updated.

Table 3 – List of Positive Results for Blank Samples
None

Table 4 - OPR outside QC limits
None

Table 5 - List of Reanalyzed Samples
None

Data Validation Qualifiers:

Code	**Description**
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a “tentative identification”.
NJ	The analysis indicates the presence of an analyte that has been “tentatively identified” and the associated numerical value represents its approximate concentration.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: October 14, 2009	**Completed by: Mark Woodke**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
PR90775	Gig Harbor	PR90775	07/16/2009		
PR90775	Bremerton	PR90776	07/16/2009		
PR90775	West Point	PR90777	07/16/2009		
PR90775	Burlington	PR90778	07/16/2009		
PR90775	Tacoma	PR90802	07/24/2009		
PR90775	Chambers Creek	PR90803	07/24/2009		
PR90775	Sumner	PR90804	07/24/2009		
PR90775	Bellingham	PR90805	07/24/2009		
PR90775	Everett	PR90806	07/24/2009	Dup	
PR90775	Shelton	PR90808	07/24/2009		
PR90775	X	PR90779	07/16/2009		Rinsate Blank

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
PR90775	Water	EPA 1614	Brominated Diphenyl Ethers in Water, Soil, Sediment, and Tissue by HRGC/HRMS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, implied in the data review memoranda by Karin Feddersen.
Did coolers arrive at lab less than 6^{o}C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, according to the data review memoranda by Karin Feddersen.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes.
Case narrative present and complete?	Yes.
Any holding time violations?	No, according to the data review memoranda by Karin Feddersen.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blank Results (Table 3);
- OPR outside QC limits (Table 4);
- Sample Reanalysis (Table 5).

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: October 14, 2009	**Completed by: Mark Woodke**

The Polybrominated Diphenyl Ethers (PBDEs) data were originally reviewed by Karin Feddersen, Manchester Environmental Laboratory (MEL) on October 9, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

PBDEs by HRGC/HRMS	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks?	Yes, according to the data review memoranda by Karin Feddersen.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged UJ.
Laboratory QC frequency of one method blank and ongoing precision and recovery (OPR) with each batch?	Yes, according to the data review memoranda by Karin Feddersen.
Initial precision and recovery (IPR) values are within QC limits?	Not discussed in the data review memorandum.
OPR recovery values are within laboratory QC limits?	Yes, according to the data review memoranda by Karin Feddersen.
C-13 labeled isotope dilution internal standard recovery values for samples within QC limits?	No, associated results were qualified UJ.
Is initial calibration within Method QC limits?	No, associated results were qualified JH.
Is continuing calibration within Method QC limits?	No, no qualifiers were applied based on these outliers.
Were any samples re-analyzed or diluted? For any sample re-analysis and dilutions is only one reportable result by flagged?	Yes.
Did compound ion abundances meet method QC requirements for compound identification?	No, according to the data review memoranda by Karin Feddersen. Data was qualified as estimated tentatively identified, bias unknown (NJK or NK).
Laboratory Duplicate Sample analyzed?	Yes, but was not discussed in the data review memorandum.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Several compound ion abundances did not meet method QC requirements for compound identification. Data was qualified as estimated tentatively identified (NJK). Sample results less than 10 times the associated method blank results were qualified UJ. Positive calibration outliers were qualified as estimated quantities (JH). Internal standard quantitation limit outliers were qualified as estimated (UJG). No Form Is were received by the secondary reviewer. Several qualifiers were changed by the secondary reviewer, and the spreadsheet that accompanied the data review was updated.

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
1614	BDE09323B	MBLK	BDE-047	26		pg/L	25
1614	BDE09323B	MBLK	BDE-099	15	J	pg/L	25

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	Sample ID	Analyte	Result	Qualifier
1614	Rinsate	BDE-047	151	UJ

Table 4 - OPR outside QC limits

None

Table 5 - List of Reanalyzed Samples

Sample ID	Reason for Reanalysis
BDE09323B	Sample was reanalyzed to get appropriate detection limits.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
K	Bias could not be determined.
L	The result is low biased.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a “tentative identification”.
NJ	The analysis indicates the presence of an analyte that has been “tentatively identified” and the associated numerical value represents its approximate concentration.
T	The associated positive result is less than the quantitation limit.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: August 10, 2009	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0902008	Shelton	0902008-03	02/10/2009		
0902008	Everett	0902008-04	02/12/2009		
0902008	Bremerton	0902008-06	02/10/2009		
0902008	Tacoma	0902008-07	02/19/2009	MS/MSD	
0902008	Chambers Creek	0902008-08	02/19/2009		
0902008	Metro West Point	0902008-09	02/10/2009		
0902008	Field Blank	0902008-11	02/12/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0902008	Water	EPA 1668	Chlorinated Biphenyl Congeners by HRGC/HRMS	7

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, according to the data review memoranda by Karin Feddersen.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	No.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- Internal and Clean-up Standards Outside Limits (Table 4);
- LCS Outside Limits (Table 5); and
- Re-analysis Results (Table 6)

The chlorinated biphenyl congeners analyses data was originally reviewed by Karin Feddersen, Manchester Environmental Laboratory (MEL) on August 9, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Chlorinated Pesticides by GC/ECD	
Description	**Notes and Qualifiers**

Chlorinated Pesticides by GC/ECD	
Description	**Notes and Qualifiers**
Any compounds present in method, trip, and field blanks (see Table 2)?	Yes.
For samples, if results are <10 times the blank then "UJ" flag data. Qualification also applies to Total Homolog data.	Samples results are flagged UJ. Associated Total Homolog results are not changed and flagged J.
Laboratory QC frequency of one method blank and LCS (OPR) with each batch per 20 samples?	Yes
Internal standards and clean-up standards percent recovery values for method blanks and LCS/LCSD samples within laboratory QC limits?	Yes.
Internal standards and clean-up standards recovery values for samples and MS/MSD within laboratory QC limits (see Table 4)?	No. No action was taken.
MS/MSD percent recovery values within laboratory QC criteria?	Not required.
MS/MSD relative percent difference values within QC criteria of <35%?	Not required.
LCS percent recovery values within Laboratory QC criteria (see Table 5)?	Yes
Is initial calibration for target compounds <20 % RSD or curve fit?	Yes.
Is continuing calibration for target compounds < 20%?	Yes
Were any samples re-analyzed or diluted (see Table 6)? For any sample re-analysis and dilutions is only one reportable result by flagged?	Yes.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
Analytes were detected in the method blanks. The associated samples results were not changed and flagged UJ. Associated total homolog results were not corrected and were qualified as estimated (J). For sample results with peak ratios outside of acceptable criteria, the results are flagged tentative identification (N or NJ).

Table 3 – List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Units	PQL
EPA 1668	PC09100B	MBLK	PCB-005/008	10.5		pg/L	10
EPA 1668	PC09100B	MBLK	PCB-011	43.3		pg/L	10
EPA 1668	PC09100B	MBLK	PCB-052/069	11.6		pg/L	10
EPA 1668	PC09100B	MBLK	PCB-101	11		pg/L	10
EPA 1668	PC09100B	MBLK	Dichlorobiphenyls	53.8		pg/L	10
EPA 1668	PC09100B	MBLK	Tetrachlorobiphenyls	11.6		pg/L	10
EPA 1668	PC09100B	MBLK	Pentachlorobiphenyls	11		pg/L	10
EPA 1668	PC09100B	MBLK	Total PCB	76.4		pg/L	10

Table 3A - List of Samples Qualified for Method Blank Contamination

Method	Sample ID	Analyte	Result	Qual

Method	Sample ID	Analyte	Result	Qual
EPA 1668	Everett	PCB-005/008	77	UJ
EPA 1668	Everett	PCB-011	283	UJ
EPA 1668	Bremerton	PCB-005/008	12.1	UJ
EPA 1668	Bremerton	PCB-011	42.9	UJ
EPA 1668	Bremerton	PCB-052/069	19.8	UJ
EPA 1668	Chambers Creek	PCB-005/008	37.5	UJ
EPA 1668	Chambers Creek	PCB-011	94	UJ
EPA 1668	Chambers Creek	PCB-052/069	43.6	UJ
EPA 1668	Metro West Point	PCB-005/008	64.9	UJ
EPA 1668	Metro West Point	PCB-011	68.5	UJ
EPA 1668	Metro West Point	PCB-052/069	89.9	UJ
EPA 1668	Shelton	PCB-011	28.5	UJ
EPA 1668	Shelton	PCB-052/069	27.7	UJ
EPA 1668	Tacoma	PCB-011	95.1	UJ
EPA 1668	Herrera	PCB-011	42.1	UJ
EPA 1668	Herrera	PCB-052/069	32	UJ

Table 4 - List Internal Standard Percent Recovery Values outside Control Limits

Method	Sample ID	Analyte	Percent Recovery	RPD	QC Limit	Sample Qualification
EPA 1668	Shelton	PCB-178L	173	NA	60 – 130	None
EPA 1668	Everett	PCB-178L	160	NA	60 – 130	None
EPA 1668	Bremerton	PCB-178L	190	NA	60 – 130	None

Table 5 – LCS Precent Recovery Values outside Control Limits
None.

Table 6 - Samples that were Reanalyzed

Method	Sample	Reason
EPA 1668	Bremerton	Retention time shifting and peak area suppression. Report original sample.

Data Validation Qualifiers:

Code	Description
G	Value is likely greater than the reported result. Reported result may be biased low.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a “tentative identification”.
NJ	The analysis indicates the presence of an analyte that has been “tentatively identified” and the associated numerical value represents its approximate concentration.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: May 12, 2009	Completed by: David Ikeda

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
L12354	Field Blank	L12354-01	02/12/2009		
L12354	Summer	L12354-02	02/12/2009		Sumner
L12354	Gig Harbor	L12354-03	02/10/2009		
L12354	Shelton	L12354-04	02/10/2009		
L12354	Everett	L12354-05	02/12/2009		
L12354	Burlington	L12354-06	02/10/2009		
L12354	Bremerton	L12354-07	02/10/2009		
L12354	Tacoma	L12354-08	02/19/2009		
L12354	Chambers Creek	L12354-09	02/19/2009		
L12354	Metro West Point	L12354-10	02/10/2009	Dup	
L12354	Bellingham	L12354-12	02/12/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
L12354	Water	MLA-060	Analytical Procedure for the Analysis of Perfluorinated Organic Compounds in Aqueous Samples by LC-MS/MS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, according to the data review memoranda by Jim Maroncelli.
Did coolers arrive at lab less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, according to the data review memoranda by Jim Maroncelli.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes
Case narrative present and complete?	Yes.
Any holding time violations?	No, according to the data review memoranda by Jim Maroncelli.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);
- OPR outside QC limits (Table 4);
- Sample Reanalysis (Table 5).

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: May 12, 2009	Completed by: David Ikeda

The perfluorinated organic analyses (PFOAs) data was originally reviewed by Jim Maroncelli, Manchester Environmental Laboratory (MEL) on May 5, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

PFOAs by LCMS-MS	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks?	No.
For samples, if results are <5 times the blank or < 10 times blank for common laboratory contaminants then "U" flag data.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one method blank and ongoing precision and recovery (OPR) with each batch?	Yes.
Initial precision and recovery (IPR) values are within QC limits?	Yes.
OPR recovery values are within laboratory QC limits?	Yes.
C-13 labeled isotope dilution internal standard recovery values for samples within QC limits?	Yes.
Is initial calibration within Method QC limits?	Yes, according to the data review memoranda by Jim Maroncelli.
Is continuing calibration within Method QC limits?	Yes, according to the data review memoranda by Jim Maroncelli.
Were any samples re-analyzed or diluted? For any sample re-analysis and dilutions is only one reportable result by flagged?	No.
Laboratory Duplicate Sample analyzed?	Yes, all relative percent difference values were within QC limits.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
None

Table 3 – List of Positive Results for Blank Samples
None

Table 4 - OPR outside QC limits
None

Table 5 - List of Reanalyzed Samples
None

Data Validation Qualifiers:

Code	Description
U	Analyte was not detected at or above the reported result.

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AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
Field Blank
Sample Collection:
N/A

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V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-1
Matrix:	AQUEOUS	**Sample Size:**	0.504 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 01:12:50	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 13**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG[1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		0.993	
PFPeA	U		0.993	
PFHxA	U		0.993	
PFHpA	U		0.993	
PFOA	U		0.993	
PFNA	U		0.993	
PFDA	U		0.993	
PFUnA	U		0.993	
PFDoA	U		0.993	
PFBS	U		1.99	
PFHxS	U		1.99	
PFOS	U		1.99	
PFOSA	U		0.993	

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12 MAY 2009

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CLIENT SAMPLE NO.
~~Summer~~ SOMNER
Sample Collection:
N/A

6/12/09

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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-2
Matrix:	AQUEOUS	**Sample Size:**	0.510 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 01:31:33	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 14**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		2.95	0.981	5:23
PFPeA		13.3	0.981	6:05
PFHxA		52.1	0.981	6:28
PFHpA		4.29	0.981	6:51
PFOA		69.8	0.981	7:17
PFNA		6.27	0.981	7:41
PFDA		7.85	0.981	8:11
PFUnA	U		0.981	
PFDoA	U		0.981	
PFBS	U		1.96	
PFHxS	U		1.96	
PFOS		2.57	1.96	8:31
PFOSA		1.08	0.981	10:08

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These pages are part of a larger report that may contain information necessary for full data evaluation. Results reported relate only to the sample tested. Results are compliant with NELAP where specific accreditation is held.

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CLIENT SAMPLE NO.
Gig Harbor
Sample Collection:
N/A

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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-3
Matrix:	AQUEOUS	**Sample Size:**	0.505 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 01:50:14	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 15**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		0.991	
PFPeA		15.9	1.05	6:05
PFHxA		34.1	0.991	6:29
PFHpA		4.65	0.991	6:51
PFOA		48.6	0.991	7:17
PFNA		12.3	0.991	7:41
PFDA		5.66	0.991	8:15
PFUnA	U		0.991	
PFDoA	U		0.991	
PFBS	U		1.98	
PFHxS	U		1.98	
PFOS		5.60	1.98	8:31
PFOSA	U		0.991	

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12MAY2009

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CLIENT SAMPLE NO.
Shelton
Sample Collection:
N/A

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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-4
Matrix:	AQUEOUS	**Sample Size:**	0.504 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 02:08:05	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 16**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG 1	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		0.991	
PFPeA		8.47	1.65	6:05
PFHxA		25.5	1.03	6:28
PFHpA		2.80	1.10	6:51
PFOA		33.1	1.05	7:14
PFNA		1.39	0.991	7:41
PFDA		5.78	0.991	8:11
PFUnA	U		0.991	
PFDoA	U		0.991	
PFBS	U		1.98	
PFHxS	U		1.98	
PFOS	U		1.98	
PFOSA	U		0.991	

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AXYS METHOD MLA-060 Rev 07		**CLIENT SAMPLE NO.**	**Everett**
		Sample Collection:	**N/A**

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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-5
Matrix:	AQUEOUS	**Sample Size:**	0.480 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 02:26:47	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 17**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		1.04	
PFPeA	U		1.50	
PFHxA		11.9	1.04	6:28
PFHpA		10.3	1.04	6:51
PFOA		24.3	1.04	7:14
PFNA		134	1.04	7:41
PFDA		1.91	1.04	8:11
PFUnA		1.18	1.04	8:49
PFDoA	U		1.04	
PFBS	U		2.08	
PFHxS		2.57	2.08	7:26
PFOS		7.57	2.08	8:15
PFOSA	U		1.04	

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CLIENT SAMPLE NO.
Burlington
Sample Collection:
N/A

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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-6
Matrix:	AQUEOUS	**Sample Size:**	0.505 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 02:45:31	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 18**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		0.991	
PFPeA		5.80	1.58	6:05
PFHxA		24.9	1.24	6:29
PFHpA		4.06	1.31	6:51
PFOA		30.5	0.991	7:17
PFNA		13.1	0.991	7:41
PFDA		4.27	0.991	8:11
PFUnA	U		0.991	
PFDoA	U		0.991	
PFBS	U		1.98	
PFHxS		3.17	1.98	7:26
PFOS		5.89	1.98	8:31
PFOSA		1.95	0.991	10:07

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CLIENT SAMPLE NO.
Bremerton
Sample Collection:
N/A

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AXYS ANALYTICAL SERVICES
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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-7
Matrix:	AQUEOUS	**Sample Size:**	0.516 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 03:04:13	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 19**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		1.40	1.36	5:23
PFPeA		1.16	0.968	6:05
PFHxA		10.8	0.968	6:28
PFHpA		2.08	0.968	6:51
PFOA		11.3	0.968	7:14
PFNA		2.36	0.968	7:41
PFDA		1.74	0.968	8:02
PFUnA	U		0.968	
PFDoA	U		0.968	
PFBS	U		1.94	
PFHxS	U		1.94	
PFOS		4.50	1.94	8:31
PFOSA	U		0.968	

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①

12 May 2009

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AXYS METHOD MLA-060 Rev 07		**CLIENT SAMPLE NO.**	**Tacoma**
		Sample Collection:	**N/A**

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		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-8
Matrix:	AQUEOUS	**Sample Size:**	0.509 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 03:22:55	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 20**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	**LAB FLAG** [1]	**CONC. FOUND**	**DETECTION LIMIT**	**RETENTION TIME**
PFBA		1.38	0.982	5:22
PFPeA		3.77	2.25	6:05
PFHxA		10.9	1.83	6:27
PFHpA		5.64	0.982	6:51
PFOA		27.0	0.982	7:14
PFNA		4.47	0.982	7:41
PFDA		2.62	0.982	8:11
PFUnA	U		0.982	
PFDoA	U		0.982	
PFBS	U		1.96	
PFHxS		4.42	2.75	7:26
PFOS		9.71	1.96	8:27
PFOSA	U		0.982	

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Report Filename: PFC_FC_LC_PFOA_L12354-8_Form1A_FC9G_069S20_SJ990261.html; Workgroup: WG28032; Design ID: 1058]

12 May 2009

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AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
Chambers Creek
Sample Collection:
N/A

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V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-9
Matrix:	AQUEOUS	**Sample Size:**	0.509 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 03:41:37	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 21**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		3.60	0.983	5:23
PFPeA		2.02	1.11	6:02
PFHxA		12.1	1.17	6:28
PFHpA		3.98	1.09	6:51
PFOA		10.9	0.983	7:14
PFNA		2.76	0.983	7:41
PFDA		5.54	0.983	7:59
PFUnA	U		0.983	
PFDoA	U		0.983	
PFBS	U		1.97	
PFHxS		6.87	1.97	7:26
PFOS		6.56	1.97	8:27
PFOSA	U		0.983	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

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[illegible]Mar2009

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AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
Metro West Point (GP)
Sample Collection:
N/A

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V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-10
Matrix:	AQUEOUS	**Sample Size:**	0.501 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 04:00:19	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 22**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		1.31	0.997	5:20
PFPeA		1.84	1.46	6:03
PFHxA		13.2	0.997	6:28
PFHpA		2.75	0.997	6:51
PFOA		12.5	0.997	7:14
PFNA		3.73	0.997	7:41
PFDA		2.82	0.997	8:11
PFUnA	U		0.997	
PFDoA	U		0.997	
PFBS	U		1.99	
PFHxS		3.12	1.99	7:26
PFOS		19.5	1.99	8:31
PFOSA	U		0.997	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: ________Matthew Ou________ QA/QC Chemist

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12Mar 2009

Contact: analytical@axys.com

AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
Bellingham
Sample Collection:
N/A

Form 1A
PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L12354-12
Matrix:	AQUEOUS	**Sample Size:**	0.499 L
Sample Receipt Date:	24-Feb-2009	**Initial Calibration Date:**	25-Feb-2009
Extraction Date:	26-Feb-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	27-Feb-2009 **Time:** 04:37:43	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_069 S: 24**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_069 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_069 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		1.86	1.00	5:22
PFPeA		1.90	1.00	6:05
PFHxA		15.4	1.00	6:28
PFHpA		3.53	1.00	6:51
PFOA		11.6	1.00	7:17
PFNA		3.52	1.00	7:41
PFDA		1.37	1.00	8:11
PFUnA	U		1.00	
PFDoA	U		1.00	
PFBS	U		2.00	
PFHxS		3.31	2.00	7:26
PFOS		6.02	2.28	8:27
PFOSA	U		1.00	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: Matthew Ou QA/QC Chemist

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① 12MAY2009

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: October 7, 2009	**Completed by: Mark Woodke**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
L13114	Field Blank	L12114-1	07/14/2009		
L13114	0907021-01	L12114-2	07/14/2009		
L13114	0907021-02	L12114-3	07/14/2009		
L13114	0907021-03	L12114-4	07/14/2009		
L13114	0907021-04	L12114-5(A)	07/14/2009	DUP	
L13114	0907021-05	L12114-7	07/14/2009		
L13114	0907021-06	L12114-8	07/16/2009		
L13114	0907021-07	L12114-9	07/16/2009		
L13114	0907021-08	L12114-10	07/16/2009		
L13114	0907021-09	L12114-11	07/16/2009		
L13114	0907021-10	L12114-12	07/16/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
L13114	Water	MLA-060	Analytical Procedure for the Analysis of Perfluorinated Organic Compounds in Aqueous Samples by LC-MS/MS	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, implied in the data review memorandum by Karin Feddersen.
Did coolers arrive at lab at less than 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, implied in the data review memorandum by Karin Feddersen.
Frequency of Field QC Samples Correct? Field Duplicate – Not required.	Yes.
Case narrative present and complete?	Yes.
Any holding time violations?	No, according to the data review memorandum by Karin Feddersen.

The following tables are presented at the end of this QA1 Review Memorandum and provide summaries of results outside QC criteria.

- Method Blank Results (Table 3);
- OPR Outside Limits (Table 4); and
- Sample Reanalysis (Table 5).

Quality Assurance Review Level 1 Report	Project: Ecology – POTW Pollution Scans
Date Completed: October 7, 2009	Completed by: Mark Woodke

The Perfluorinated organic analyses (PFOAs) data was originally reviewed by Karin Feddersen, Manchester Environmental Laboratory, on October 5, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided with the deliverable.

Metals by GC/ECD	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks?	No.
For samples, if results are <5 times the blank or <10 times the blank for common laboratory contaminants then "U" flag data.	Not applicable.
Laboratory QC frequency of one method blank and ongoing precision and recovery (OPR) with each batch?	Yes.
Initial precision and recovery (IPR) values are within QC limits?	Not provided.
OPR recovery values are within laboratory QC limits?	Yes.
C-13 labeled isotope dilution internal standard recovery values for samples within QC limits?	Yes.
Is initial calibration within method QC limits?	Yes according to the data review memorandum by Karin Feddersen.
Is continuing calibration within method QC limits?	Yes according to the data review memorandum by Karin Feddersen.
Were any samples re-analyzed or diluted? For any sample re-analysis and dilutions, is only one reportable result flagged?	No.
Laboratory duplicate sample analyzed?	Yes, all relative percent difference values were within QC limits.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
None.

Table 3 – List of Positive Results for Blank Samples

None

Table 4 – OPR outside QC Limits

None

Table 5 – List of Reanalyzed Samples

None.

Data Validation Qualifiers:

Code	Description
U	Analyte was not detected at or above the reported result.

AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
Field Blank
Sample Collection:
N/A

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AXYS ANALYTICAL SERVICES
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V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-1
Matrix:	AQUEOUS	**Sample Size:**	0.496 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 14:55:09	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 13**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		1.01	
PFPeA	U		1.01	
PFHxA	U		1.01	
PFHpA	U		1.01	
PFOA	U		1.01	
PFNA	U		1.01	
PFDA	U		1.01	
PFUnA	U		1.01	
PFDoA	U		1.01	
PFBS	U		2.01	
PFHxS	U		2.01	
PFOS	U		2.01	
PFOSA	U		2.52	

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Approved by: __________Bryan Alonzo_________ QA/QC Chemist

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These pages are part of a larger report that may contain information necessary for full data evaluation.
Results reported relate only to the sample tested.
Results are compliant with NELAP where specific accreditation is held.

JMW
10-7-09

AXYS METHOD MLA-060 Rev 07		**CLIENT SAMPLE NO.**	**0907021-01** **Sample Collection:** **14-Jul-2009 12:15**

Form 1A
PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-2
Matrix:	AQUEOUS	**Sample Size:**	0.492 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 15:14:36	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 14**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		1.38	1.02	5:23
PFPeA		12.6	1.02	6:06
PFHxA		41.3	1.02	6:28
PFHpA		5.27	1.02	6:51
PFOA		52.5	1.02	7:17
PFNA		23.2	1.02	7:41
PFDA		7.31	1.02	8:15
PFUnA	U		1.02	
PFDoA	U		1.02	
PFBS	U		2.03	
PFHxS	U		2.03	
PFOS		2.24	2.03	8:21
PFOSA	U		2.54	

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Approved by: __________Bryan Alonzo__________ QA/QC Chemist

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Report Filename: PFC_FC_LC_PFOA_L13114-2_Form1A_FC9G_347S14_SJ1043103.html; Workgroup: WG29556; Design ID: 1058]

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10-7-09

AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-02
Sample Collection:
14-Jul-2009 09:45

Form 1A

PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-3
Matrix:	AQUEOUS	**Sample Size:**	0.499 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 15:34:03	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 15**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		1.83	1.00	5:20
PFPeA	U		1.00	
PFHxA		14.3	1.00	6:29
PFHpA		3.44	1.00	6:51
PFOA		11.1	1.00	7:17
PFNA		10.8	1.00	7:41
PFDA		2.77	1.00	8:15
PFUnA	U		1.00	
PFDoA	U		1.00	
PFBS		17.7	2.01	6:26
PFHxS		7.79	2.01	7:30
PFOS		55.0	2.01	8:31
PFOSA	U		2.51	

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Approved by: Bryan Alonzo QA/QC Chemist

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AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-03
Sample Collection:
14-Jul-2009 07:30

Form 1A
PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-4
Matrix:	AQUEOUS	**Sample Size:**	0.489 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 Time: 15:52:42	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 16**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		2.99	1.02	5:20
PFPeA		16.5	1.02	6:05
PFHxA		44.3	1.02	6:28
PFHpA		3.74	1.02	6:47
PFOA		38.9	1.02	7:14
PFNA		3.29	1.02	7:41
PFDA		6.30	1.02	8:15
PFUnA	U		1.02	
PFDoA	U		1.02	
PFBS	U		2.04	
PFHxS	U		2.04	
PFOS		4.37	2.04	8:31
PFOSA	U		2.56	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

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AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-04
Sample Collection:
14-Jul-2009 07:17

Form 1A
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V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-5 (A)
Matrix:	AQUEOUS	**Sample Size:**	0.506 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 16:11:20	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 17**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		2.47	1.52	5:20
PFPeA	U		1.38	
PFHxA		16.1	0.987	6:27
PFHpA		6.00	1.04	6:51
PFOA		22.6	0.987	7:14
PFNA		5.83	0.987	7:38
PFDA		4.28	0.987	8:11
PFUnA	U		0.987	
PFDoA	U		0.987	
PFBS		13.8	1.97	6:28
PFHxS		2.65	1.97	7:26
PFOS		21.2	1.97	8:27
PFOSA	U		2.47	

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Mw
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AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-05
Sample Collection:
14-Jul-2009 17:00

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AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-7
Matrix:	AQUEOUS	**Sample Size:**	0.508 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 16:48:37	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 19**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		1.27	
PFPeA		1.94	0.984	6:03
PFHxA		9.62	0.984	6:28
PFHpA		4.73	0.984	6:51
PFOA		16.5	0.984	7:14
PFNA		4.11	0.984	7:41
PFDA		3.57	0.984	8:11
PFUnA	U		0.984	
PFDoA	U		0.984	
PFBS	U		1.97	
PFHxS		2.34	1.97	7:26
PFOS		3.51	1.97	8:31
PFOSA	U		2.46	

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Form 1A

PERFLUORINATED ORGANICS ANALYSIS REPORT

CLIENT SAMPLE NO.
0907021-06
Sample Collection:
16-Jul-2009 14:40

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	4499	**Project No.**	PRIORITY POLLUTANTS IN 10 POTWS
		Lab Sample I.D.:	L13114-8
Matrix:	AQUEOUS	**Sample Size:**	0.506 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 Time: 17:08:12	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 20**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		1.53	
PFPeA		6.79	0.988	6:05
PFHxA		22.8	0.988	6:28
PFHpA		9.69	0.988	6:51
PFOA		30.2	0.988	7:14
PFNA		7.02	0.988	7:41
PFDA		1.54	0.988	8:08
PFUnA	U		0.988	
PFDoA	U		0.988	
PFBS	U		1.98	
PFHxS		7.01	1.98	7:26
PFOS		4.23	1.98	8:21
PFOSA	U		2.47	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: ________Bryan Alonzo________ QA/QC Chemist

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Results reported relate only to the sample tested.
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Contact: analytical@axys.com

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CLIENT SAMPLE NO.
0907021-07
Sample Collection:
16-Jul-2009 16:14

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AXYS ANALYTICAL SERVICES
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V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	4499	**Project No.**	PRIORITY POLLUTANTS IN 10 POTWS
		Lab Sample I.D.:	L13114-9
Matrix:	AQUEOUS	**Sample Size:**	0.504 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 17:27:39	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 21**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		4.87	1.46	5:22
PFPeA		1.98	0.993	6:03
PFHxA		18.5	0.993	6:28
PFHpA		6.49	0.993	6:51
PFOA		13.2	0.993	7:14
PFNA		5.76	1.02	7:41
PFDA		3.66	0.993	8:05
PFUnA	U		0.993	
PFDoA	U		0.993	
PFBS		14.7	1.99	6:32
PFHxS		8.27	1.99	7:26
PFOS		8.78	1.99	8:27
PFOSA	U		2.48	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: __________Bryan Alonzo__________ QA/QC Chemist

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MW
10-7-09

AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-08
Sample Collection:
16-Jul-2009 11:05

Form 1A

PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	PRIORITY POLLUTANTS IN 10 POTWS
Contract No.:	4499	**Lab Sample I.D.:**	L13114-10
Matrix:	AQUEOUS	**Sample Size:**	0.508 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 Time: 17:47:06	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 22**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG 1	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		0.985	
PFPeA		18.2	0.985	6:06
PFHxA		30.9	0.985	6:29
PFHpA		6.96	0.985	6:51
PFOA		46.5	0.985	7:17
PFNA		9.16	0.985	7:41
PFDA		10.4	0.985	8:15
PFUnA	U		0.985	
PFDoA	U		0.985	
PFBS	U		1.97	
PFHxS	U		1.97	
PFOS		10.7	1.97	8:31
PFOSA	U		2.46	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: __________Bryan Alonzo__________ QA/QC Chemist

For Axys Internal Use Only [XSL Template: FC-Form1A.xsl; Created: 01-Sep-2009 10:13:54; Application: XMLTransformer-1.10.4; Report Filename: PFC_FC_LC_PFOA_L13114-10_Form1A_FC9G_347S22_SJ1043111.html; Workgroup: WG29556; Design ID: 1058]

MW
10-7-09

Contact: analytical@axys.com

AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-09
Sample Collection:
16-Jul-2009 09:24

Form 1A
PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	4499	**Project No.**	PRIORITY POLLUTANTS IN 10 POTWS
		Lab Sample I.D.:	L13114-11
Matrix:	AQUEOUS	**Sample Size:**	0.505 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 **Time:** 18:05:44	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 23**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA	U		1.46	
PFPeA		2.05	0.991	6:03
PFHxA		17.2	0.991	6:28
PFHpA		5.10	0.991	6:51
PFOA		17.4	0.991	7:14
PFNA		22.0	0.991	7:38
PFDA		2.82	0.991	8:08
PFUnA	U		0.991	
PFDoA	U		0.991	
PFBS	U		1.98	
PFHxS		2.41	1.98	7:26
PFOS	U		1.98	
PFOSA	U		2.48	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: __________Bryan Alonzo__________ QA/QC Chemist

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MW 10-7-09

AXYS METHOD MLA-060 Rev 07

CLIENT SAMPLE NO.
0907021-10
Sample Collection:
16-Jul-2009 12:37

Form 1A
PERFLUORINATED ORGANICS ANALYSIS REPORT

AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	4499	**Project No.**	PRIORITY POLLUTANTS IN 10 POTWS
		Lab Sample I.D.:	L13114-12
Matrix:	AQUEOUS	**Sample Size:**	0.500 L
Sample Receipt Date:	22-Jul-2009	**Initial Calibration Date:**	06-Aug-2009
Extraction Date:	23-Jul-2009	**Instrument ID:**	LC MS/MS
Analysis Date:	08-Aug-2009 Time: 18:24:23	**Column ID:**	C18
Extract Volume (uL):	4000	**Sample Data Filename:**	**FC9G_347 S: 24**
Injection Volume (uL):	15	**Blank Data Filename:**	FC9G_347 S: 11
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	FC9G_347 S: 4
Concentration Units:	ng/L		

COMPOUND	LAB FLAG [1]	CONC. FOUND	DETECTION LIMIT	RETENTION TIME
PFBA		3.24	1.00	5:24
PFPeA		3.18	1.41	6:03
PFHxA		16.1	1.04	6:27
PFHpA		7.83	1.33	6:51
PFOA		16.8	1.00	7:14
PFNA		28.7	1.47	7:41
PFDA		2.55	1.00	8:11
PFUnA	U		1.00	
PFDoA	U		1.00	
PFBS	U		2.00	
PFHxS		3.36	2.00	7:23
PFOS		10.0	2.00	8:31
PFOSA	U		2.50	

(1) Where applicable, custom lab flags have been used on this report; U = not detected.

Approved by: __________Bryan Alonzo__________ QA/QC Chemist

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These pages are part of a larger report that may contain information necessary for full data evaluation.
Results reported relate only to the sample tested.
Results are compliant with NELAP where specific accreditation is held.

MW 10-7-09

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: March 31, 2008	**Completed by: David Ikeda**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance level 1 review (QA1) (PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Matrix	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0902008	Water	Sumner	0902008-01	02/12/2009		None
0902008	Water	Gig Harbor	0902008-02	02/10/2009	MS/MSD	None
0902008	Water	Shelton	0902008-03	02/10/2009		None
0902008	Water	Everett	0902008-04	02/12/2009		None
0902008	Water	Burlington	0902008-05	02/10/2009		None
0902008	Water	Bremerton	0902008-06	02/10/2009		None
0902008	Water	Tacoma	0902008-07	02/19/2009		None
0902008	Water	Chambers Creek	0902008-08	02/19/2009		None
0902008	Water	Metro West Point	0902008-09	02/10/2009	Duplicate	None
0902008	Water	Bellingham	0902008-10	02/12/2009		None
0902008	Water	Field Blank	0902008-11	02/12/2009		None

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Orders	Matrix	Test Method	Method Name	Number of Samples
0902008	Water	EPA 200.8	Inductively Coupled Plasma - Mass Spectrometry	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes
Did coolers arrive at lab between 0 °C and 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes
Frequency of Field QC Samples Correct? Field Duplicate – Not required. Field Blank – 1/20 samples. MS/MSD samples – 1/20 samples.	Yes
Case narrative present and complete?	Yes
Any holding time violations?	No - All samples were prepared and analyzed within holding times.

The following tables are presented at the end of this QA1 Review Memorandum and provided summaries of results outside QC criteria.

- Method Blanks Results (Table 3);

- Surrogates Outside Limits (Table 4);
- MS/MSD Outside Limits (Table 5);
- LCS Outside Limits (Table 6); and
- Re-analysis Results (Table 7).

The inorganic data was originally reviewed Dean Momohara, Manchester Environmental Laboratory (MEL) on March 4, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided by the laboratory.

Metals by ICPMS	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks as noted on Table 2?	Yes – Copper was detected in the Field Blank.
For samples, if results are <3 times the blank then "U" flag data.	Samples results below the PQL are reported at the PQL and flagged U. Sample results greater than PQL are not changed and flagged U.
Laboratory QC frequency of one blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes
MS/MSD percent recovery values within QC criteria (see Table 4) of 75-125%? QC limits are not applicable to sample results greater than 4 times spike amount.	Yes
Sample and duplicate relative percent difference values within QC criteria (see Table 4) of <20%? Apply criteria only when both results are >PQL.	Yes
LCS percent recovery values within QC criteria (see Table 5) of 85-115%? If the value is high with no positive values in the associated data; then no data qualification is required.	Yes
Is there one serial dilution per 20 samples? Are percent difference values within laboratory QC criteria?	Information not provided by the laboratory.
Spot check ICS recoveries 80-120%. Contact lab.	Information not provided by the laboratory.
Correlation Coefficient > 0.995.	Yes
ICV and CCV recovery between 90-110%. Contact lab.	Yes
Internal Standard recovery values for samples and MS/MSD within laboratory QC limits?	Yes.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
None

Table 3 - List of Positive Results for Blank Samples

Method	Sample ID	Samp Type	Analyte	Result	Qual	Anal Type	Units	PQL	MDL
EPA 200.8	0902008-11	FBLK	Copper	0.71		A	µg/L	0.10	0.02

Table 3A - List of Samples Qualified for Method Blank Contamination

None

Table 4 - List of Samples with Surrogates outside Control Limits

None

Table 5 - List MS/MSD Percent Recovery Values and RPDs outside Control Limits
None

Table 6 - List LCS Percent Recovery Values outside Control Limits
None

Table 7 –Samples that were Reanalyzed
None

Key:
A = Analyte
NC = Not Calculated
ND = Not Detected
PQL = Practical Quantitation Limit
RPD = Relative Percent Difference

Data Validation Qualifiers:

Code	Description
B	Analyte detected in sample and method blank. Reported result is sample concentration without blank correction or associated quantitation limit.
JG	Analyte was positively identified. Value may be greater than the reported estimate.
JK	Analyte was positively identified. Reported result is an estimate with unknown bias.
JL	Analyte was positively identified. Value may be less than the reported estimate.
JT	Analyte was positively identified. Reported result is an estimate below the associated quantitation limit but above the MDL.
JTG	Analyte was positively identified. Value may be greater than the reported result, which is an estimate below the associated quantitation limit but above the MDL.
JTK	Analyte was positively identified. Reported result is an estimate with unknown bias, below the associated quantitation limit but above the MDL.
JTL	Analyte was positively identified. Value may be less than the reported result which is an estimate below associated quantitation limit but above MDL.
NJ	There is evidence that the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate.
NJT	There is evidence the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate below the associated quantitation limit but above the MDL.
NU	There is evidence the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported result.
NUJ	There is evidence the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported estimate.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJG	Analyte was not detected at or above the reported estimate with likely low bias.
UJK	Analyte was not detected at or above the reported estimate with unknown bias.
UJL	Analyte was not detected at or above the reported estimate with likely high bias.

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Copper

Project Name: Phase 3: Priority Pollutant Scans of Ten
Work Order: 0902008
Project Officer: Maroncelli, Jim

Analyte: Copper
Method: EPA200.8
Matrix: Water
Units: ug/L

Sample #	Sample ID	Result	Qualifier	RL	MDL	Collected	Analyzed	Batch ID
0902008-01	**Sumner**	**13.2**		0.10	0.02	02/12/09	03/02/09	B09B136
0902008-02	**Gig Harbor**	**9.28**		0.10	0.02	02/10/09	03/02/09	B09B136
0902008-03	**Shelton**	**7.31**		0.10	0.02	02/10/09	03/02/09	B09B136
0902008-04	**Everett**	**11.8**		0.10	0.02	02/12/09	03/02/09	B09B136
0902008-05	**Burlington**	**2.56**		0.10	0.02	02/10/09	03/02/09	B09B136
0902008-06	**Bremerton**	**3.52**		0.10	0.02	02/10/09	03/02/09	B09B136
0902008-07	**Tacoma**	**9.65**		0.10	0.02	02/19/09	03/02/09	B09B136
0902008-08	**Chambers Creek**	**11.9**		0.10	0.02	02/19/09	03/02/09	B09B136
0902008-09	**Metro West Point**	**11.7**		0.10	0.02	02/10/09	03/02/09	B09B136
0902008-10	**Bellingham**	**6.21**		0.10	0.02	02/12/09	03/02/09	B09B136
0902008-11	**Field Blank**	**0.71**		0.10	0.02	02/12/09	03/02/09	B09B136

10 Mar 2009

QC Results for Batch ID: B09B136

Method Blank	Sample ID	Result	Qualifer	RL	Analyzed
B09B136-BLK1	Blank	0.10	U	0.10	03/02/09

Sample #	QC Sample	Result	Spike Level	Source Sample	Source Result	%Rec	%Rec Limits	RPD	RPD Limit
B09B136-BS1	LCS	20.8	20			104	85-115		
B09B136-DUP1	Duplicate	11.6		0902008-09	11.7			0.4	20
B09B136-MS1	Matrix Spike	28.8	20	0902008-02	9.28	98	75-125		
B09B136-MSD1	Matrix Spike Dup	28.8	20	0902008-02	9.28	97	75-125	0.07	20

Authorized by: DM

Release Date: 3/4/09

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for
Lead

Project Name: Phase 3: Priority Pollutant Scans of Ten	Analyte: Lead
Work Order: 0902008	Method: EPA200.8
Project Officer: Maroncelli, Jim	Matrix: Water
	Units: ug/L

Sample #	Sample ID	Result	Qualifier	RL	MDL	Collected	Analyzed	Batch ID
0902008-01	**Sumner**	**0.18**		0.10	0.007	02/12/09	03/02/09	B09B136
0902008-02	**Gig Harbor**	**0.68**		0.10	0.007	02/10/09	03/02/09	B09B136
0902008-03	**Shelton**	**0.40**		0.10	0.007	02/10/09	03/02/09	B09B136
0902008-04	**Everett**	**1.17**		0.10	0.007	02/12/09	03/02/09	B09B136
0902008-05	**Burlington**	**0.31**		0.10	0.007	02/10/09	03/02/09	B09B136
0902008-06	**Bremerton**	**0.28**		0.10	0.007	02/10/09	03/02/09	B09B136
0902008-07	**Tacoma**	**0.72**		0.10	0.007	02/19/09	03/02/09	B09B136
0902008-08	**Chambers Creek**	**0.29**		0.10	0.007	02/19/09	03/02/09	B09B136
0902008-09	**Metro West Point**	**0.38**		0.10	0.007	02/10/09	03/02/09	B09B136
0902008-10	**Bellingham**	**0.44**		0.10	0.007	02/12/09	03/02/09	B09B136
0902008-11	Field Blank	0.10	U	0.10	0.007	02/12/09	03/02/09	B09B136

QC Results for Batch ID: B09B136

Method Blank	Sample ID	Result	Qualifer	RL	Analyzed
B09B136-BLK1	Blank	0.10	U	0.10	03/02/09

Sample #	QC Sample	Result	Spike Level	Source Sample	Source Result	%Rec	%Rec Limits	RPD	RPD Limit
B09B136-BS1	LCS	20.9	20			105	85-115		
B09B136-DUP1	Duplicate	0.376		0902008-09	0.38			2	20
B09B136-MS1	Matrix Spike	20.3	20	0902008-02	0.680	98	75-125		
B09B136-MSD1	Matrix Spike Dup	20.3	20	0902008-02	0.680	98	75-125	0.1	20

10 APRIL 2009

Authorized by: DM

Release Date: 3/4/9

Washington State Department of Ecology
Manchester Environmental Laboratory
Final Analysis Report for:
Zinc

Project Name: Phase 3: Priority Pollutant Scans of Ten
Work Order: 0902008
Project Officer: Maroncelli, Jim

Analyte: Zinc
Method: EPA200.8
Matrix: Water
Units: ug/L

Sample #	Sample ID	Result	Qualifier	RL	MDL	Collected	Analyzed	Batch ID
0902008-01	Sumner	**49.9**		5.0	0.5	02/12/09	03/02/09	B09B136
0902008-02	Gig Harbor	**76.2**		5.0	0.5	02/10/09	03/02/09	B09B136
0902008-03	Shelton	**44.5**		5.0	0.5	02/10/09	03/02/09	B09B136
0902008-04	Everett	**29.6**		5.0	0.5	02/12/09	03/02/09	B09B136
0902008-05	Burlington	**41.1**		5.0	0.5	02/10/09	03/02/09	B09B136
0902008-06	Bremerton	**21.7**		5.0	0.5	02/10/09	03/02/09	B09B136
0902008-07	Tacoma	**44.5**		5.0	0.5	02/19/09	03/02/09	B09B136
0902008-08	Chambers Creek	**34.5**		5.0	0.5	02/19/09	03/02/09	B09B136
0902008-09	Metro West Point	**33.0**		5.0	0.5	02/10/09	03/02/09	B09B136
0902008-10	Bellingham	**39.7**		5.0	0.5	02/12/09	03/02/09	B09B136
0902008-11	Field Blank	5.0	U	5.0	0.5	02/12/09	03/02/09	B09B136

QC Results for Batch ID: B09B136

Method Blank	Sample ID	Result	Qualifer	RL	Analyzed
B09B136-BLK1	Blank	5.0	U	5.0	03/02/09

10 April 2009

Sample #	QC Sample	Result	Spike Level	Source Sample	Source Result	%Rec	%Rec Limits	RPD	RPD Limit
B09B136-BS1	LCS	21.9	20			109	85-115		
B09B136-DUP1	Duplicate	33.0		0902008-09	33.0			0.06	20
B09B136-MS1	Matrix Spike	95.1	20	0902008-02	76.2	94	75-125		
B09B136-MSD1	Matrix Spike Dup	95.4	20	0902008-02	76.2	96	75-125	0.3	20

Authorized by: DM

Release Date: 3/4/9

Quality Assurance Review Level 1 Report	**Project: Ecology – POTW Pollution Scans**
Date Completed: September 15, 2009	**Completed by: Mark Woodke**

The analytical data provided by the laboratory were reviewed for precision, accuracy, and completeness per Washington Department of Ecology (Ecology) Quality Assurance Review Guidance for the quality assurance review level 1 review (QA1, PTI, 1989). Specific criteria for QC limits were obtained from the project QAPP. Compliance with the project QA program is indicated on the in the checklist and tables. Any major or minor concern affecting data usability is summarized below. The checklist and tables also indicate whether data qualification is required and/or the type of qualifier assigned.

Reference:

Table 1 Sample Summary Tables from Electronic Data Deliverable

Work Order	Sample ID	Lab ID	Sample Date	Lab QC	ID Corrections
0907021	Gig Harbor	0907021-01	07/14/2009		
0907021	Bremerton	0907021-02	07/14/2009	MS/MSD	
0907021	Shelton	0907021-03	07/14/2009		
0907021	West Point	0907021-04	07/14/2009		
0907021	Burlington	0907021-05	07/16/2009		
0907021	Tacoma	0907021-06	07/16/2009		
0907021	Chambers Creek	0907021-07	07/16/2009		
0907021	Sumner	0907021-08	07/17/2009		
0907021	Bellingham	0907021-09	07/16/2009		
0907021	Everett	0907021-10	07/16/2009		
0907021	Rinsate	0907021-11	07/14/2009		

Table 2 Work Orders, Tests and Number of Samples included in this DUSR

Work Order	Matrix	Test Method	Method Name	Number of Samples
0907021	Water	EPA 200.8	Inductively Coupled Plasma – Mass Spectrometry	11

General Sample Information	
Do Samples and Analyses on COC check against Lab Sample Tracking Form?	Yes, implied in the data review memorandum by Dean Momohara.
Did coolers arrive at lab between 0°C and 6°C and in good condition as indicated on COC and Cooler Receipt Form?	Yes, implied in the data review memorandum by Dean Momohara.
Frequency of Field QC Samples Correct? Field Duplicate – Not required. Field Blank – Not required. MS/MSD samples – 1/20 samples.	Yes.
Case narrative present and complete?	Yes.
Any holding time violations?	No.

The following tables are presented at the end of this QA1 Review Memorandum and provide summaries of results outside QC criteria.

- Method Blank Results (Table 3);
- MS/MSD Outside Limits (Table 4);
- LCS Outside Limits (Table 5); and
- Re-analysis Results (Table 6).

The inorganic data was originally reviewed by Dean Momohara, Manchester Environmental Laboratory (MEL) on August 3, 2009. The laboratory provided analytical summaries for samples, including QC samples. No raw data was provided by the laboratory.

Metals by GC/ECD	
Description	**Notes and Qualifiers**
Any compounds present in method and field blanks as noted on Table 3?	No.
For samples, if results are <3 times the blank then "U" flag data.	Not applicable.
Laboratory QC frequency of one blank and LCS with each batch and one set of MS/MSD per 20 samples?	Yes.
MS/MSD percent recovery values within QC criteria (see Table 4) of 75 – 125%? QC limits are not applicable to sample results greater than 4 times spike amount.	Yes.
Sample and duplicate relative percent difference values within QC criteria (see Table 4) of < 20%? Apply criteria only when both results are >PQL.	Yes.
LCS percent recovery values within QC criteria (see Table 5) of 85-115%? If the value is high with no positive values in the associated data, then no qualification is required.	Yes.
Is there one serial dilution per 20 samples? Are percent difference values within laboratory QC criteria?	Information not provided by the laboratory.
Spot check ICS recoveries 80-120. Contact lab.	Information not provided by the laboratory.
Correlation coefficient > 0.995?	Yes.
ICV and CCV recovery between 90-110%. Contact lab.	Yes.
Internal standard recovery values for samples and MS/MSD within laboratory QC limits?	Yes.

Summary of Potential Impacts on Data Usability
Major Concerns
None
Minor Concerns
None

Table 3 – List of Positive Results for Blank Samples
None

Table 3A - List of Samples Qualified for Method Blank Contamination
None

Table 4 – List of MS/MSD Percent Recovery Values and RPDs outside Control Limits
None

Table 5 – List of LCS Percent Recovery Values Outside Control Limits
None.

Table 6 - Samples that were Reanalyzed
None.

Key:
A = Analyte
NC = Not Calculated
ND = Not Detected
PQL = Practical Quantitation Limit
RPD = Relative Percent Difference

Data Validation Qualifiers:

Code	Description
B	Analyte detected in sample and method blank. Reported result is sample concentration without blank correction or associated quantitation limit.
JG	Analyte was positively identified. Value may be greater than the reported estimate.
JK	Analyte was positively identified. Reported result is an estimate with an unknown bias.
JL	Analyte was positively identified. Value may be less than the reported estimate.
JT	Analyte was positively identified. Reported result is an estimate below the associated quantitation limit but above the MDL.
JTG	Analyte was positively identified. Value may be greater than the reported result, which is an estimate below the associated quantitation limit but above the MDL.
JTK	Analyte was positively identified. Reported result is an estimate with unknown bias, below the associated quantitation limit but above the MDL.
JTL	Analyte was positively identified. Value may be less than the reported result which is an estimate below associated quantitation limit but above the MDL.
NJ	There is evidence that the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate.
NJT	There is evidence that the analyte is present in the sample. Reported result for the tentatively identified analyte is an estimate below the associated quantitation limit but above the MDL.
NU	There is evidence that the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported result.
NUJ	There is evidence that the analyte is present in the sample. Tentatively identified analyte was not detected at or above the reported estimate.
REJ	Data are unusable for all purposes. Sample results rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Analyte was not detected at or above the reported result.
UJG	Analyte was not detected at or above the reported estimate with likely low bias.
UJK	Analyte was not detected at or above the reported estimate with unknown bias.
UJL	Analyte was not detected at or above the reported estimate with likely high bias.

Appendix C.

Summary of Analytical Results

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Polycyclic Aromatic Hydrocarbons (PAHs)																							
Low Molecular Weight PAHs (LPAHs)																							
Acenaphthene		83-32-9	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	8.20E-02	JG	6.00E-03	U	6.30E-03	UJG	1.10E-02		5.80E-03	UJG	6.60E-03	U	6.00E-03	UJG
Acenaphthylene		208-96-8	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	5.20E-02		6.00E-03	U	6.30E-03	UJG	5.80E-03	JT	5.80E-03	UJG	6.60E-03	U	6.00E-03	UJG
Anthracene		120-12-7	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	8.20E-03		6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	6.00E-03	U
Fluorene		86-73-7	ug/L	1.10E-02		5.70E-03	U	6.90E-03		1.70E-01		1.10E-02		6.30E-03	UJG	2.20E-02		5.80E-03	U	6.60E-03	U	6.00E-03	U
Naphthalene		91-20-3	ug/L	3.70E-02	UFB	5.70E-03	UJG	4.00E-02	UFB	3.40E-01	JG	2.70E-02	UFB	6.30E-03	JTG	3.60E-02	UFB	1.20E-02	UJG	1.80E-02	UFB	1.20E-02	UJG
Phenanthrene		85-01-8	ug/L	1.10E-02		3.90E-03	JT	5.40E-03	JT	6.60E-02		6.00E-03	U	6.30E-03	UJG	8.00E-03		5.80E-03	U	6.60E-03	U	6.00E-03	U
Number of Detects =				2		1		2		6		1		1		4		0		0		0	
Sum of Detects =			ug/L	2.20E-02		3.90E-03	J	1.23E-02	J	7.18E-01	J	1.10E-02		6.30E-03	J	4.68E-02	J	1.20E-02	U	1.80E-02	U	1.20E-02	U
High Molecular Weight PAHs (HPAHs)																							
Benzo(a)anthracene		56-55-3	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	5.50E-03	JT
Benzo(a)pyrene		50-32-8	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	1.20E-02	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	1.20E-02	U
Benzo(b)fluoranthene		205-99-2	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	2.10E-02	JL
Benzo(g,h,i)perylene		191-24-2	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	UJG	5.90E-03	JT	1.20E-02	UJG
Benzo(k)fluoranthene		207-08-9	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	6.00E-03	U
Chrysene		218-01-9	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	8.20E-03	
Dibenzo(a,h)anthracene		53-70-3	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	UJG	6.60E-03	U	1.20E-02	UJG
Fluoranthene		206-44-0	ug/L	8.40E-03		4.00E-03	JT	3.70E-03	JT	4.80E-03	JT	3.70E-03	JT	2.00E-03	JTG	1.50E-02		5.80E-03	U	8.70E-03		9.80E-03	
Indeno(1,2,3-cd)pyrene		193-39-5	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	UJG	1.60E-02		1.20E-02	UJG
Pyrene		129-00-0	ug/L	7.80E-03		6.60E-03		6.00E-03	JT	5.60E-03	JT	4.50E-03	JT	5.00E-03	JTG	1.80E-02		5.20E-03	JT	1.60E-02		3.10E-02	
Number of Detects =				2		2		2		2		2		2		2		1		4		5	
Sum of Detects =			ug/L	1.62E-02		1.06E-02	J	9.70E-03	J	1.04E-02	J	8.20E-03	J	7.00E-03	J	3.30E-02		5.20E-03	J	4.66E-02	J	7.55E-02	J
Carcinogenic PAHs (cPAHs)																							
Benzo(a)anthracene		56-55-3	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	5.50E-03	JT
Benzo(a)pyrene		50-32-8	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	1.20E-02	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	1.20E-02	U
Benzo(b)fluoranthene		205-99-2	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	2.10E-02	JL
Benzo(k)fluoranthene		207-08-9	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	6.00E-03	U
Chrysene		218-01-9	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	8.20E-03	
Dibenzo(a,h)anthracene		53-70-3	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	UJG	6.60E-03	U	1.20E-02	UJG
Indeno(1,2,3-cd)pyrene		193-39-5	ug/L	6.10E-03	U	5.70E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	UJG	1.60E-02		1.20E-02	UJG
Number of Detects =				0		0		0		0		0		0		0		0		1		3	
Sum of Detects =			ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	1.20E-02	U	6.00E-03	U	6.30E-03	U	7.40E-03	U	5.80E-03	U	1.60E-02		3.47E-02	J
Total PAHs (LPAHs+HPAHs)																							
Number of Detects =				4		3		4		8		3		3		6		1		4		5	
Sum of Detects =			ug/L	3.82E-02		1.45E-02	J	2.20E-02	J	7.28E-01	J	1.92E-02	J	1.33E-02	J	7.98E-02	J	5.20E-03	J	4.66E-02	J	7.55E-02	J
Phthalates																							
bis(2-Ethylhexyl) phthalate		117-81-7	ug/L	5.90E-01	UJL	4.70E-01		2.40E+00		4.30E-01		5.30E-01		8.40E-01		2.80E+00		2.30E+00		3.40E+00		5.30E+00	
Butylbenzyl phthalate		85-68-7	ug/L	6.00E-01	U	6.00E-01	U	1.00E-01	JT	5.90E-01	U	4.60E-01		6.40E-01	U	1.90E-01	JT	5.90E-01	U	6.50E-01	UJK	6.00E-01	U
Di-N-butyl phthalate		84-74-2	ug/L	4.90E-01		2.60E-01	UJL	3.60E-01	UJL	1.90E-01	UJL	2.40E-01	UJL	3.90E-01	UJL	2.80E-01	UJG	2.40E-01	UJL	1.60E-01	U	2.50E-01	UJL
Di-N-octyl phthalate		117-84-0	ug/L	3.00E-01	UJG	3.00E-01	U	2.90E-01	U	3.00E-01	U	2.80E-01	U	3.20E-01	U	3.60E-01	U	2.90E-01	U	3.20E-01	UJG	3.00E-01	U
Diethyl phthalate		84-66-2	ug/L	3.00E-01	U	2.70E-01	UFB	2.90E-01	U	3.00E-01	U	3.40E-01		3.20E-01	U	1.40E-01	JT	2.90E-01	U	3.20E-01	UJK	3.00E-01	U
Dimethyl phthalate		131-11-3	ug/L	3.00E-01	UFB	3.00E-01	U	2.90E-01	U	3.00E-01	U	2.80E-01	U	3.20E-01	U	3.60E-01	U	2.90E-01	U	3.20E-01	UJK	3.00E-01	U
Number of Detects =				1		1		2		1		3		1		3		1		1		1	
Sum of Detects =			ug/L	4.90E-01		4.70E-01		2.50E+00		4.30E-01		1.33E+00		8.40E-01		3.13E+00	J	2.30E+00		3.40E+00		5.30E+00	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Polycyclic Aromatic Hydrocarbons (PAHs)																							
Low Molecular Weight PAHs (LPAHs)																							
Acenaphthene		83-32-9	ug/L	6.70E-03	U	8.90E-02	JG	1.20E-02		6.00E-03	UJG	1.40E-02		6.10E-03	UJG	6.30E-03	U	6.20E-03	UJG	5.50E-03	JT	1.50E-02	JG
Acenaphthylene		208-96-8	ug/L	6.70E-03	U	5.50E-02	JG	5.10E-03	JT	6.00E-03	UJK	6.50E-03	U	6.10E-03	UJG	6.30E-03	U	6.20E-03	UJG	3.20E-03	JT	2.30E-02	JG
Anthracene		120-12-7	ug/L	6.70E-03	U	8.40E-03	JG	3.90E-03	JT	6.00E-03	UJK	6.50E-03	U	6.61E-02	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	7.00E-03	
Fluorene		86-73-7	ug/L	6.70E-03	U	2.00E-01	JG	2.50E-02		6.00E-03	UJK	1.80E-02		1.10E-02		5.70E-03	JT	6.20E-03	U	9.00E-03		1.20E-01	
Naphthalene		91-20-3	ug/L	1.30E-01		3.70E-01	JG	4.40E-02	UFB	6.00E-03	UJG	6.30E-02		1.20E-02	UJG	2.50E-02	UFB	1.20E-02	UJG	3.00E-02	UFB	2.20E-02	JG
Phenanthrene		85-01-8	ug/L	6.10E-03	JT	7.10E-02	JG	1.60E-02		4.50E-03	JTK	1.60E-02		1.40E-02		5.10E-03	JT	6.20E-03	U	6.00E-03	JT	5.40E-02	
Number of Detects =				2		6		5		1		4		2		2		0		4		6	
Sum of Detects =			ug/L	1.36E-01		7.93E-01	J	6.20E-02	J	4.50E-03	J	1.11E-01		2.50E-02		1.08E-02	J	1.20E-02	U	2.37E-02	J	2.41E-01	J
High Molecular Weight PAHs (HPAHs)																							
Benzo(a)anthracene		56-55-3	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.61E-02	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Benzo(a)pyrene		50-32-8	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	1.20E-02	U	6.30E-03	U	1.20E-02	U	6.20E-03	U	1.20E-02	U
Benzo(b)fluoranthene		205-99-2	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Benzo(g,h,i)perylene		191-24-2	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.30E-03	U	1.20E-02	UJG	6.20E-03	U	1.20E-02	UJG
Benzo(k)fluoranthene		207-08-9	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Chrysene		218-01-9	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Dibenzo(a,h)anthracene		53-70-3	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.30E-03	U	1.20E-02	UJG	6.20E-03	U	1.20E-02	UJG
Fluoranthene		206-44-0	ug/L	6.70E-03	U	4.70E-03	JTG	7.50E-03		4.40E-03	JT	8.50E-03		9.50E-03		6.30E-03	U	6.20E-03	U	4.90E-03	JT	4.80E-03	JT
Indeno(1,2,3-cd)pyrene		193-39-5	ug/L	6.70E-03	U	1.30E-02	UJG	4.70E-03	JT	6.00E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.30E-03	U	1.20E-02	UJG	6.20E-03	U	1.20E-02	UJG
Pyrene		129-00-0	ug/L	4.30E-03	JT	1.10E-02	JG	1.40E-02		7.70E-03		6.80E-03		6.30E-03		6.30E-03	U	6.20E-03	U	4.30E-03	JT	3.20E-03	JT
Number of Detects =				1		2		3		2		2		2		0		0		2		2	
Sum of Detects =			ug/L	4.30E-03	J	1.57E-02	J	2.62E-02	J	1.21E-02	J	1.53E-02		1.58E-02		6.30E-03	U	1.20E-02	U	9.20E-03	J	8.00E-03	J
Carcinogenic PAHs (cPAHs)																							
Benzo(a)anthracene		56-55-3	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.61E-02	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Benzo(a)pyrene		50-32-8	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	1.20E-02	U	6.30E-03	U	1.20E-02	U	6.20E-03	U	1.20E-02	U
Benzo(b)fluoranthene		205-99-2	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Benzo(k)fluoranthene		207-08-9	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Chrysene		218-01-9	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Dibenzo(a,h)anthracene		53-70-3	ug/L	6.70E-03	U	1.30E-02	UJG	5.90E-03	U	6.00E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.30E-03	U	1.20E-02	UJG	6.20E-03	U	1.20E-02	UJG
Indeno(1,2,3-cd)pyrene		193-39-5	ug/L	6.70E-03	U	1.30E-02	UJG	4.70E-03	JT	6.00E-03	UJG	6.50E-03	U	1.20E-02	UJG	6.30E-03	U	1.20E-02	UJG	6.20E-03	U	1.20E-02	UJG
Number of Detects =				0		0		1		0		0		0		0		0		0		0	
Sum of Detects =			ug/L	6.70E-03	U	1.30E-02	U	4.70E-03	J	6.00E-03	U	6.50E-03	U	1.20E-02	U	6.30E-03	U	1.20E-02	U	6.20E-03	U	1.20E-02	U
Total PAHs (LPAHs+HPAHs)																							
Number of Detects =				3		8		8		3		6		4		2		0		6		8	
Sum of Detects =			ug/L	1.40E-01		8.09E-01	J	8.82E-02	J	1.66E-02	J	1.26E-01		4.08E-02		1.08E-02	J	1.20E-02	U	3.29E-02	J	2.49E-01	J
Phthalates																							
bis(2-Ethylhexyl) phthalate		117-81-7	ug/L	1.40E+00		1.80E+00		1.40E+00		8.70E-01		1.20E+00		4.10E-01		1.00E+00		2.40E-01	JT	1.10E+00	UJL	1.90E-01	JT
Butylbenzyl phthalate		85-68-7	ug/L	8.00E-02	JT	6.30E-01	U	1.90E-01	JT	5.70E-01	U	6.80E-01	U	5.90E-01	U	6.30E-01	U	5.90E-01	U	6.20E-01	UJK	6.00E-01	U
Di-N-butyl phthalate		84-74-2	ug/L	2.20E-01	UJL	3.20E-01	UJL	3.80E-01	UJL	2.10E-01	UJL	1.50E-01	JT	3.30E-01	UJL	4.30E-01	UJL	2.20E-01	UJL	1.50E-01	U	2.40E-01	UJL
Di-N-octyl phthalate		117-84-0	ug/L	3.20E-01	U	3.20E-01	U	2.90E-01	U	2.90E-01	U	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.90E-01	U	3.10E-01	UJK	3.00E-01	U
Diethyl phthalate		84-66-2	ug/L	3.30E-01		5.40E-01	UFB	2.90E-01	U	2.90E-01	U	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.90E-01	U	3.10E-01	JT	3.00E-01	U
Dimethyl phthalate		131-11-3	ug/L	3.20E-01	U	3.20E-01	U	2.90E-01	U	2.90E-01	U	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.90E-01	U	3.10E-01	UJK	3.00E-01	U
Number of Detects =				3		1		2		1		2		1		1		1		1		1	
Sum of Detects =			ug/L	1.81E+00		1.80E+00		1.59E+00	J	8.70E-01		1.35E+00	J	4.10E-01		1.00E+00		2.40E-01	J	3.10E-01	J	1.90E-01	J

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Other Base/Neutral/Acid Extractables																							
1,2,4-Trichlorobenzene		120-82-1	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U	1.80E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U
1,2-Dichlorobenzene		95-50-1	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U	1.80E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U
1,3-Dichlorobenzene		541-73-1	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U	1.80E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U
1,4-Dichlorobenzene		106-46-7	ug/L	2.40E-01		2.10E-01		1.60E-01		2.00E-01		8.60E-01		4.70E-01		5.10E-01		6.30E-01		9.00E-02	JT	1.50E-01	U
1-Methylnaphthalene		90-12-0	ug/L	9.90E-03	UJL	5.70E-03	UJG	1.20E-02	UJL	1.10E-01	JG	9.70E-03	UJL	6.30E-03	UJG	1.50E-02	UJL	1.20E-02	UJG	6.60E-03	U	1.20E-02	UJG
2,3,4,5-Tetrachlorophenol		4901-51-3	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
2,3,4,6-Tetrachlorophenol		58-90-2	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	UJL	6.40E-02	U	6.10E-02	UJL	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
2,4,5-Trichlorophenol		95-95-4	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
2,4,6-Trichlorophenol		88-06-2	ug/L	4.90E-02	JT	5.90E-02	JTG	3.30E-02	JT	1.50E-01	JG	2.90E-02	JT	9.80E-02	JG	1.20E-01		1.00E-01	JG	6.20E-02	U	6.60E-02	NJG
2,4-Dichlorophenol		120-83-2	ug/L	2.10E-01	JT	1.50E+00	U	2.50E-01	JT	1.50E+00	U	1.80E-01	JT	1.60E+00	U	2.90E-01	JT	1.50E+00	U	1.40E-01	JT	1.50E+00	U
2,4-Dimethylphenol		105-67-9	ug/L	1.50E+00	UJK	1.00E-01	JT		REJ	1.50E+00	U	2.20E-01	JTK	1.60E+00	U	1.80E+00	UJK	1.50E+00	U	1.60E+00	UJG	1.50E+00	U
2,4-Dinitrophenol		51-28-5	ug/L	1.50E+00	U	1.50E+00	U	1.50E+00	UJK	1.50E+00	U	2.20E-01	JTK	1.60E+00	U	1.80E+00	UJK	1.50E+00	UJG	1.60E+00	UJK	1.50E+00	UJG
2,4-Dinitrotoluene		121-14-2	ug/L	6.00E-01	U	6.00E-01	U	5.80E-01	U	5.90E-01	U	5.60E-01	U	6.40E-01	U	7.20E-01	U	5.90E-01	U	6.50E-01	UJK	6.00E-01	U
2,6-Dinitrotoluene		606-20-2	ug/L	6.00E-01	U	6.00E-01	U	5.80E-01	U	5.90E-01	U	5.60E-01	U	6.40E-01	U	7.20E-01	U	5.90E-01	U	6.50E-01	UJK	6.00E-01	U
2-Chloroethanol phosphate (3:1)		115-96-8	ug/L	na		7.00E-02	JT	na		2.70E-01		na		1.50E-01	JT	na		3.10E-01		na		4.30E-01	
2-Chloronaphthalene		91-58-7	ug/L	8.60E-03		5.70E-03	UJG	6.50E-03	U	6.20E-03	UJG	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	UJG	6.60E-03	U	6.00E-03	UJG
2-Chlorophenol		95-57-8	ug/L	6.00E-01	U	6.00E-01	U	5.80E-01	U	5.90E-01	U	5.60E-01	U	6.40E-01	U	7.20E-01	U	5.90E-01	U	6.50E-01	U	6.00E-01	U
2-Methylnaphthalene		91-57-6	ug/L	1.00E-02	UJL	5.70E-03	UJG	1.10E-02	UJL	1.70E-01	JG	8.20E-03	UJL	6.30E-03	UJG	8.20E-03	UJL	1.20E-02	UJG	6.60E-03	U	1.20E-02	UJG
2-Methylphenol	o-Cresol	95-48-7	ug/L	1.50E+00	U	1.50E+00	U	1.50E+00	U	1.50E+00	U	1.40E+00	U	1.20E-01	JT	1.80E+00	U	7.00E-02	JT	1.60E+00	U	1.50E+00	U
2-Nitroaniline	o-Nitroaniline	88-74-4	ug/L		REJ	3.00E+00	U	2.90E+00	UJK	3.00E+00	U	2.80E+00	UJK	3.20E+00	U		REJ	2.90E+00	U		REJ	3.00E+00	U
2-Nitrophenol		88-75-5	ug/L	3.00E-01	U	3.00E-01	U	1.70E-01	JT	3.00E-01	U	2.80E-01	U	3.20E-01	U	2.30E-01	JT	2.90E-01	U	3.20E-01	U	3.00E-01	U
3,3'-Dichlorobenzidine		91-94-1	ug/L		REJ	3.00E-01	UJK		REJ	3.00E-01	UJK		REJ	3.20E-01	UJK		REJ	2.90E-01	UJG		REJ	3.00E-01	UJG
3B-Coprostanol		360-68-9	ug/L	na		9.40E+00	JG	na		1.50E+00	UJG	na		1.50E+01	JG	na		1.40E+01	JG	na		1.50E+01	JG
3-Nitroaniline	m-Nitroaniline	99-09-2	ug/L		REJ	6.00E-01	U	5.80E-01	UJK	5.90E-01	U	5.60E-01	UJK	6.40E-01	U		REJ	5.90E-01	U		REJ	6.00E-01	U
4,6-Dinitro-2-methylphenol		534-52-1	ug/L	6.00E-01	U	6.00E-01	UJG	5.80E-01	U	5.90E-01	UJG	5.60E-01	U	6.40E-01	UJG	7.20E-01	U	5.90E-01	UJG	6.50E-01	U	6.00E-01	UJG
4-Bromophenylphenyl ether		101-55-3	ug/L	3.00E-01	U	3.00E-01	U	2.90E-01	U	3.00E-01	U	2.80E-01	U	3.20E-01	U	3.60E-01	U	2.90E-01	U	6.30E-01	U	3.00E-01	U
4-Chloro-3-methylphenol	p-Chloro-m-cresol	59-50-7	ug/L	1.50E+00	UJK	1.50E+00	U	1.50E+00	UJK	1.50E+00	U	1.40E+00	UJK	1.60E+00	U	1.80E+00	UJG	1.50E+00	U	1.60E+00	UJG	1.50E+00	U
4-Chloroaniline		106-47-8	ug/L		REJ		REJ		REJ		REJ		REJ		REJ		REJ		REJ		REJ		REJ
4-Chlorophenylphenyl ether		7005-72-3	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U	1.80E-01	U	1.50E-01	U	1.60E-01	UJK	1.50E-01	U
4-Methylphenol	p-Cresol	106-44-5	ug/L	4.90E-01	JTK	2.80E+00		2.60E-01	JTK	1.00E+00	JT	1.40E+00	UJK	1.60E+00	U	2.60E-01	JTG	1.50E+00	U	1.60E+00	UJG	1.50E+00	U
4-Nitroaniline	p-Nitroaniline	100-01-6	ug/L		REJ	6.00E-01	UJK		REJ	5.90E-01	UJK		REJ	6.40E-01	UJK		REJ	5.90E-01	U		REJ	6.00E-01	UJL
4-Nitrophenol		100-02-7	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	UJL	6.40E-02	U	6.10E-02	UJL	6.40E-02	U	6.20E-02	UJL	6.10E-02	U	6.20E-02	U	6.30E-02	U
4-Nonylphenol		104-40-5	ug/L	6.00E-01	UJG	6.00E-01	U		REJ	5.90E-01	U	5.60E-01	U	6.40E-01	U	1.00E+00	JG	5.90E-01	U	6.50E-01	UFB	6.00E-01	U
Benzoic acid		65-85-0	ug/L	na		1.80E+00	UFB	na		1.50E+00	UFB	na		1.60E+00	UJG	na		1.50E+00	UJG	na		1.50E+00	UJG
Benzyl alcohol		100-51-6	ug/L	na		1.40E+00	JG	na		1.50E+00	UJG	na		1.60E+00	UJG	na		1.50E+00	UJG	na		1.50E+00	UJG
bis(2-Chloroethoxy) methane		111-91-1	ug/L		REJ	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U		REJ	1.50E-01	U		REJ	1.50E-01	U
bis(2-Chloroethyl) ether		111-44-4	ug/L	3.00E-01	U	3.00E-01	U	2.90E-01	U	3.00E-01	U	2.80E-01	U	3.20E-01	U	3.60E-01	U	2.90E-01	U	3.20E-01	U	3.00E-01	U
Bisphenol A		80-05-7	ug/L		REJ	6.70E-01	JK	5.80E-01	UJK	8.40E-01		2.00E-01	JT	6.40E-01	U		REJ	1.20E+00	JK		REJ	6.00E-01	U
Caffeine		58-08-2	ug/L		REJ	3.00E-01	U	2.80E+00		1.00E-01	JT	1.20E+01		3.20E-01	U	5.30E-01	JTG	2.90E-01	U		REJ	3.00E-01	U
Carbazole		86-74-8	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	6.00E-03	U
Cholesterol		57-88-5	ug/L	na		1.30E+01	JG	na		8.40E+00	JG	na		1.70E+01	JG	na		2.30E+01	JG	na		1.70E+01	JG
Dibenzofuran		132-64-9	ug/L	1.10E-02		5.70E-03	UJG	6.20E-03	JT	1.90E-01		6.10E-03		6.30E-03	UJG	1.90E-02		5.80E-03	UJG	6.60E-03	U	6.90E-03	JG
Hexachlorobutadiene		87-68-3	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	UJG	1.60E-01	U	1.80E-01	UJG	1.50E-01	U	1.60E-01	U	1.50E-01	U
Hexachlorocyclopentadiene		77-47-4	ug/L	6.00E-01	U	6.00E-01	UJG	5.80E-01	UJG	5.90E-01	UJG	5.60E-01	U	6.40E-01	UJG	7.20E-01	U	5.90E-01	UJG	6.50E-01	UJK	6.00E-01	UJG
Hexachloroethane		67-72-1	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U	1.80E-01	UJG	1.50E-01	U	1.60E-01	U	1.50E-01	U
Isophorone		78-59-1	ug/L	3.00E-01	U	6.00E-02	JT	2.90E-01	U	3.00E-01	U	2.80E-01	U	3.20E-01	U	3.60E-01	U	1.40E-01	JT	3.20E-01	U	3.00E-01	U
Nitrobenzene		98-95-3	ug/L	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U	1.40E-01	U	1.60E-01	U	1.80E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U
N-Nitrosodimethylamine		62-75-9	ug/L	6.00E-01	U	na		5.80E-01	U	na		5.60E-01	U	na		6.50E-01	JTG	na		6.50E-01	U	na	
N-Nitrosodi-n-propylamine		621-64-7	ug/L	1.80E-01	U	1.80E-01	U	1.70E-01	U	1.80E-01	U	1.70E-01	U	1.90E-01	U	2.20E-01	U	1.80E-01	U	1.90E-01	U	1.80E-01	U
N-Nitrosodiphenylamine		86-30-6	ug/L	3.00E-01	UJG	3.00E-01	U	2.90E-01	UJK	3.00E-01	U	2.80E-01	UJK	3.20E-01	U	3.60E-01	UJK	2.90E-01	U	3.20E-01	UJG	3.00E-01	U

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Other Base/Neutral/Acid Extractables																							
1,2,4-Trichlorobenzene		120-82-1	ug/L	1.60E-01	U	1.60E-01	U	1.50E-01	U	1.40E-01	U	1.70E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U
1,2-Dichlorobenzene		95-50-1	ug/L	1.60E-01	UFB	1.60E-01	U	1.50E-01	U	1.40E-01	U	1.70E-01	U	7.00E-02	JTG	1.60E-01	UFB	1.50E-01	U	1.50E-01	UFB	1.50E-01	U
1,3-Dichlorobenzene		541-73-1	ug/L	1.60E-01	UFB	1.60E-01	U	1.50E-01	U	1.40E-01	U	1.70E-01	U	1.50E-01	U	1.60E-01	UFB	1.50E-01	U	1.50E-01	U	1.50E-01	U
1,4-Dichlorobenzene		106-46-7	ug/L	2.90E-01		1.10E-01	JTG	2.20E+00		7.60E-01		2.20E-01		2.80E-01		7.00E-02	JT	7.00E-02	JT	1.40E-01	JT	1.90E-01	
1-Methylnaphthalene		90-12-0	ug/L	1.20E-02	UJL	1.20E-01	JG	2.00E-02		6.00E-03	UJG	2.50E-02		1.20E-02	UJG	8.40E-03	UJL	1.20E-02	UJK	1.20E-02	UJL	8.00E-03	JG
2,3,4,5-Tetrachlorophenol		4901-51-3	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
2,3,4,6-Tetrachlorophenol		58-90-2	ug/L	6.30E-02	UJL	6.40E-02	U	6.20E-02	UJL	6.60E-02	U	6.40E-02	U	6.30E-02	U	1.50E-01	JL	6.20E-02	U	6.20E-02	U	6.40E-02	U
2,4,5-Trichlorophenol		95-95-4	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
2,4,6-Trichlorophenol		88-06-2	ug/L	1.60E-01		1.70E-01	JG	4.60E-02	JT	2.30E-01	JG	9.20E-02		1.20E-01	JG	3.00E-01		2.70E-01	JG	5.70E-02	JT	2.20E-02	JTG
2,4-Dichlorophenol		120-83-2	ug/L	2.70E-01	JT	1.60E+00	U	2.10E-01	JT	1.40E+00	U	2.70E-01	JT	1.50E+00	U	1.60E+00	U	1.50E+00	U	1.50E-01	JTK	1.50E+00	U
2,4-Dimethylphenol		105-67-9	ug/L	3.40E-01	JTK	5.00E-02	JT	2.40E-01	JTK	1.40E+00	U	3.10E-01	JTK	3.50E-01	JT		REJ	1.50E+00	U	1.50E+00	U	1.50E+00	U
2,4-Dinitrophenol		51-28-5	ug/L	3.40E-01	JTK	1.60E+00	UJG	2.40E-01	JTK	1.40E+00	U	1.70E+00	UJK	1.50E+00	U	1.60E+00	UJK	1.50E+00	UJG	1.20E-01	JT	1.50E+00	U
2,4-Dinitrotoluene		121-14-2	ug/L	6.30E-01	U	6.30E-01	U	5.90E-01	U	5.70E-01	U	6.80E-01	U	5.90E-01	U	6.30E-01	UJK	5.90E-01	U	6.20E-01	UJK	6.00E-01	U
2,6-Dinitrotoluene		606-20-2	ug/L	6.30E-01	U	6.30E-01	U	5.90E-01	U	5.70E-01	U	6.80E-01	U	5.90E-01	U	6.30E-01	U	5.90E-01	U	6.20E-01	UJK	6.00E-01	U
2-Chloroethanol phosphate (3:1)		115-96-8	ug/L	na		9.00E-02	JT	na		2.90E-01		na		4.10E-01		na		1.90E-01		na		1.90E-01	
2-Chloronaphthalene		91-58-7	ug/L	6.70E-03	U	6.60E-03	UJG	5.90E-03	U	6.00E-03	UJG	6.50E-03	U	6.10E-03	UJG	4.70E-03	JT	6.20E-03	UJG	6.20E-03	U	6.20E-03	UJG
2-Chlorophenol		95-57-8	ug/L	6.30E-01	U	6.30E-01	U	5.90E-01	U	5.70E-01	U	6.80E-01	U	5.90E-01	U	6.30E-01	U	5.90E-01	U	6.20E-01	U	6.00E-01	U
2-Methylnaphthalene		91-57-6	ug/L	9.40E-03	UJL	1.80E-01	JG	2.20E-02		6.00E-03	UJG	1.40E-02	UJL	1.20E-02	UJG	9.00E-03	UJL	1.20E-02	UJK	9.00E-03	UJL	1.30E-02	JG
2-Methylphenol	o-Cresol	95-48-7	ug/L	2.00E-01	JT	1.60E+00	U	1.90E-01	JT	1.40E+00	U	1.70E+00	U	1.50E+00	U	1.50E-01	JT	1.50E+00	U	1.90E-01	JT	1.50E+00	U
2-Nitroaniline	o-Nitroaniline	88-74-4	ug/L	3.20E+00	UJK	3.20E+00	U	2.90E+00	UJK	2.90E+00	U		REJ	2.90E+00	U	3.20E+00	UJK	2.90E+00	U		REJ	3.00E+00	U
2-Nitrophenol		88-75-5	ug/L	1.50E-01	JT	3.20E-01	U	2.90E-01	U	2.90E-01	U	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.90E-01	U	3.10E-01	U	3.00E-01	U
3,3'-Dichlorobenzidine		91-94-1	ug/L		REJ	3.20E-01	UJG		REJ		REJ		REJ	2.90E-01	UJK		REJ	2.90E-01	UJG		REJ	3.00E-01	UJK
3B-Coprostanol		360-68-9	ug/L	na		2.00E+01	JG	na		8.70E+00	JG	na		7.70E+00	JG	na		6.10E+00	JG	na		4.30E+00	JG
3-Nitroaniline	m-Nitroaniline	99-09-2	ug/L	6.30E-01	UJK	6.30E-01	U	5.90E-01	UJK	5.70E-01	U		REJ	5.90E-01	U	6.30E-01	UJK	5.90E-01	U		REJ	6.00E-01	U
4,6-Dinitro-2-methylphenol		534-52-1	ug/L	6.30E-01	U	6.30E-01	UJG	5.90E-01	U	5.70E-01	UJG	6.80E-01	U	5.90E-01	UJG	6.30E-01	U	5.90E-01	UJG	6.20E-01	U	6.00E-01	UJG
4-Bromophenylphenyl ether		101-55-3	ug/L	3.20E-01	U	3.20E-01	U	2.90E-01	U	2.90E-01	U	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.90E-01	U	3.10E-01	UJK	3.00E-01	U
4-Chloro-3-methylphenol	p-Chloro-m-cresol	59-50-7	ug/L	1.60E+00	UJK	1.60E+00	U	1.50E+00	UJK	1.40E+00	U	1.70E+00	UJK	1.50E+00	U	1.60E+00	UJK	1.50E+00	U	1.50E+00	UJK	1.50E+00	U
4-Chloroaniline		106-47-8	ug/L		REJ		REJ		REJ		REJ		REJ		REJ		REJ		REJ		REJ		REJ
4-Chlorophenylphenyl ether		7005-72-3	ug/L	1.60E-01	U	1.60E-01	U	1.50E-01	U	1.40E-01	U	1.70E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U	1.50E-01	UJK	1.50E-01	U
4-Methylphenol	p-Cresol	106-44-5	ug/L	1.70E+00	UJK	8.10E+00		4.60E-01	JTK	4.80E-01	JT	2.30E-01	JTK	1.10E-01	JT	2.10E-01	JTK	1.20E-01	JT	2.10E-01	JT	1.50E+00	U
4-Nitroaniline	p-Nitroaniline	100-01-6	ug/L		REJ	6.30E-01	UJK		REJ	5.70E-01	UJG		REJ	5.90E-01	UJK		REJ	5.90E-01	U		REJ	6.00E-01	UJK
4-Nitrophenol		100-02-7	ug/L	6.30E-02	UJL	6.40E-02	U	6.20E-02	UJL	6.60E-02	UJG	6.40E-02	U	6.30E-02	U	6.30E-02	UJL	6.20E-02	U	6.20E-02	U	6.40E-02	U
4-Nonylphenol		104-40-5	ug/L		REJ	6.30E-01	U		REJ	5.70E-01	U	6.80E-01	UFB	5.90E-01	U		REJ	5.90E-01	U	8.40E-01	UFB	6.00E-01	U
Benzoic acid		65-85-0	ug/L	na		1.70E+00	UFB	na		1.40E+00	UFB	na		1.50E+00	UFB	na		1.50E+00	UJG	na		1.50E+00	UJG
Benzyl alcohol		100-51-6	ug/L	na		1.50E-01	JG	na		1.40E+00	UJG	na		9.00E-02	JG	na		1.50E+00	UJG	na		1.50E+00	UJG
bis(2-Chloroethoxy) methane		111-91-1	ug/L	1.60E-01	U	1.60E-01	U	1.50E-01	U	5.00E-02	JT		REJ	1.50E-01	U	1.60E-01	U	1.50E-01	U		REJ	1.50E-01	U
bis(2-Chloroethyl) ether		111-44-4	ug/L	3.20E-01	U	3.20E-01	U	2.90E-01	U	2.90E-01	U	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.90E-01	U	3.10E-01	U	3.00E-01	U
Bisphenol A		80-05-7	ug/L	2.60E-01	JTK	6.30E-01	U	5.90E-01	UJK	1.10E+00	JL		REJ	1.60E+00	JK	2.80E-01	JTK	5.90E-01	U		REJ	6.00E-01	U
Caffeine		58-08-2	ug/L	4.20E+01		4.00E-01		7.00E-01		2.90E-01	U	5.90E-01	JTG	8.60E-01		8.00E-02	JT	2.90E-01	U		REJ	3.00E-01	U
Carbazole		86-74-8	ug/L	6.70E-03	U	3.60E-02	UJG	5.90E-03	U	6.00E-03	U	6.50E-03	U	6.10E-03	U	6.30E-03	U	6.20E-03	U	6.20E-03	U	6.20E-03	U
Cholesterol		57-88-5	ug/L	na		3.20E+01	JG	na		1.20E+01	JG	na		7.90E+00	JG	na		8.50E+00	JG	na		4.90E+00	JG
Dibenzofuran		132-64-9	ug/L	6.70E-03	U	1.90E-01	JG	2.10E-02		6.00E-03	UJK	1.60E-02		6.10E-03	UJG	5.60E-03	JT	6.20E-03	UJG	8.10E-03		9.50E-02	JG
Hexachlorobutadiene		87-68-3	ug/L	1.60E-01	U	1.60E-01	U	1.50E-01	U	1.40E-01	U	1.70E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U
Hexachlorocyclopentadiene		77-47-4	ug/L	6.30E-01	UJG	6.30E-01	UJG	5.90E-01	UJG	5.70E-01	UJG	6.80E-01	U	5.90E-01	UJG	6.30E-01	UJG	5.90E-01	UJG	6.20E-01	UJK	6.00E-01	UJG
Hexachloroethane		67-72-1	ug/L	1.60E-01	U	1.60E-01	U	1.50E-01	U	1.40E-01	UJG	1.70E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U
Isophorone		78-59-1	ug/L	3.20E-01	U	3.20E-01	U	2.90E-01	U	4.00E-02	JT	3.40E-01	U	2.90E-01	U	3.20E-01	U	2.00E-02	JT	3.10E-01	U	3.00E-01	U
Nitrobenzene		98-95-3	ug/L	1.60E-01	U	1.60E-01	U	1.50E-01	U	1.40E-01	U	1.70E-01	U	1.50E-01	U	1.60E-01	U	1.50E-01	U	1.50E-01	U	1.50E-01	U
N-Nitrosodimethylamine		62-75-9	ug/L	6.30E-01	U	na		5.90E-01	U	na		6.80E-01	U	na		6.30E-01	U	na		6.20E-01	U	na	
N-Nitrosodi-n-propylamine		621-64-7	ug/L	1.90E-01	U	1.90E-01	U	1.80E-01	U	1.70E-01	U	2.10E-01	U	1.80E-01	U	1.90E-01	U	1.80E-01	U	1.90E-01	U	1.80E-01	U
N-Nitrosodiphenylamine		86-30-6	ug/L	3.20E-01	UJK	3.20E-01	U	2.90E-01	UJK	2.90E-01	U	3.40E-01	UJK	2.90E-01	U	3.20E-01	UJK	2.90E-01	U	1.20E-01	JTG	3.00E-01	U

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Pentachlorophenol		87-86-5	ug/L	7.60E-02	NJT	5.60E-02	JT	4.40E-02	NJT	6.40E-02	U	3.70E-02	NJT	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Phenol		108-95-2	ug/L	9.60E-01	JT	1.10E+00		8.60E-01	JG	1.40E+00		5.60E-01	UFB	1.10E-01	UFB	7.20E-01	UFB	5.90E-01	UFB	7.80E-01		6.00E-01	UFB
Retene		483-65-8	ug/L	6.10E-03	U	5.70E-03	U	6.50E-03	U	6.20E-03	U	6.00E-03	U	6.30E-03	UJG	7.40E-03	U	5.80E-03	U	6.60E-03	U	6.00E-03	U
Triclosan		3380-34-5	ug/L	2.90E-01		7.30E-01		5.50E-01		5.30E-01		1.80E-01	NJG	5.70E-01		8.80E-01	JG	1.30E+00		1.60E-01	UJG	8.50E-01	
Triethyl citrate		77-93-0	ug/L	5.10E-01	JT	1.40E+00		9.10E-01		7.10E-01		8.30E-01		3.50E+00		1.10E+00		1.20E+00		9.00E-02	JK	5.80E-01	JT
Number of Detects =				10		14		11		13		11		8		11		10		4		7	
Sum of Detects =			ug/L	2.84E+00	J	3.11E+01	J	6.04E+00	J	1.41E+01	J	1.48E+01		3.69E+01	J	5.59E+00	J	4.20E+01	J	1.10E+00	J	3.39E+01	J
Pesticides																							
2,4'-DDD		53-19-0	ug/L	na		2.60E-03	U	na		2.80E-03	U	na		2.60E-03	U	na		2.50E-03	U	na		2.60E-03	UJG
2,4'-DDE		3424-82-6	ug/L	na		2.60E-03	U	na		2.80E-03	U	na		2.60E-03	U	na		2.50E-03	U	na		2.60E-03	UJG
2,4'-DDT		789-02-6	ug/L	na		2.60E-03	U	na		2.80E-03	U	na		2.60E-03	U	na		2.50E-03	U	na		2.60E-03	UJG
4,4'-DDD		72-54-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
4,4'-DDE		72-55-9	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
4,4'-DDT		50-29-3	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Aldrin		309-00-2	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
alpha-BHC		319-84-6	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
beta-BHC		319-85-7	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.60E-03	UJK	2.50E-03	UJG	2.60E-03	UJG
delta-BHC		319-86-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	3.00E-03	UJK	2.50E-03	UJG	2.60E-03	UJG
gamma-BHC	Lindane	58-89-9	ug/L	4.00E-03	UJK	5.30E-03	UJL	3.70E-03	UJL	3.60E-03	UJL	4.90E-03	UJL	6.60E-03	UJL	3.90E-03	UJK	3.20E-03	UJL	2.50E-03	UJG	5.10E-03	UJK
cis-Chlordane		5103-71-9	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
trans-Chlordane		5103-74-2	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Chlordane, technical		12789-03-6	ug/L	na		2.60E-02	U	na		2.80E-02	U	na		2.60E-02	U	na		2.50E-02	U	na		2.60E-02	UJG
Chlorpyriphos		2921-88-2	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	1.20E-02	JG
Dacthal	DCPA	1861-32-1	ug/L	6.20E-02	U	2.60E-03	U	6.30E-02	U	2.80E-03	U	6.10E-02	U	2.60E-03	U	6.20E-02	U	2.50E-03	U	6.20E-02	U	2.60E-03	UJG
DDMU		1022-22-6	ug/L	na		2.60E-03	U	na		4.80E-03	UJK	na		2.60E-03	U	na		2.50E-03	U	na		2.60E-03	UJG
Dieldrin		60-57-1	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	6.80E-03	UJK	2.50E-03	UJG	2.60E-03	UJG
Endosulfan I		959-98-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.60E-03		2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Endosulfan II		33213-65-9	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Endosulfan sulfate		1031-07-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Endrin		72-20-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Endrin aldehyde		7421-93-4	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Endrin ketone		53494-70-5	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Heptachlor		76-44-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Heptachlor epoxide		1024-57-3	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Hexachlorobenzene		118-74-1	ug/L	2.50E-03	UJG	2.60E-03	U	3.10E-03	JK	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Methoxychlor		72-43-5	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Mirex		2385-85-5	ug/L	na		2.60E-03	U	na		2.80E-03	U	na		2.60E-03	U	na		2.50E-03	U	na		2.60E-03	UJG
cis-Nonachlor		5103-73-1	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
trans-Nonachlor		39765-80-5	ug/L	2.50E-03	UJG	2.60E-03	U	2.40E-03	U	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Oxychlordane		27304-13-8	ug/L	2.50E-03	UJG	2.60E-03	U	2.50E-03	UJK	2.80E-03	U	2.50E-03	U	2.60E-03	U	2.50E-03	UJG	2.50E-03	U	2.50E-03	UJG	2.60E-03	UJG
Pentachloroanisole		1825-21-4	ug/L	na		2.60E-03	U	na		2.80E-03	U	na		4.30E-03		na		2.50E-03	U	na		2.50E-03	JGT
Toxaphene		8001-35-2	ug/L	2.50E-02	UJG	1.00E-01	UJK	2.40E-02	U	1.50E-01	UJK	2.50E-02	U	1.10E-01	UJK	2.50E-02	UJG	1.60E-01	JK	2.50E-02	UJG	1.00E-01	UJG
Number of Detects =				0		0		1		0		1		1		0		1		0		2	
Sum of Detects =			ug/L	6.20E-02	U	1.00E-01	U	3.10E-03	J	1.50E-01	U	2.60E-03		4.30E-03		6.20E-02	U	1.60E-01	J	6.20E-02	U	1.45E-02	J

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Pentachlorophenol		87-86-5	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Phenol		108-95-2	ug/L	1.00E+00	JT	1.10E+00		9.40E-01		2.80E+00	JG	6.80E-01	UFB	6.90E-01		6.30E-01	UFB	1.50E+00		6.20E-01	UFB	6.00E-01	UFB
Retene		483-65-8	ug/L	6.70E-03	U	6.60E-03	UJG	5.90E-03	U	6.00E-03	UJK	6.50E-03	U	6.10E-03	U	6.30E-03	U	1.60E-03	JT	6.20E-03	U	6.20E-03	U
Triclosan		3380-34-5	ug/L	5.50E-01	JG	9.30E-01		4.60E-01	JG	8.60E-01		4.70E-01	JG	1.00E+00		1.80E-01		3.60E-01		8.40E-01	UJG	3.00E-01	
Triethyl citrate		77-93-0	ug/L	1.10E+00		1.00E+00		6.00E-01		8.20E-01		1.10E+00		1.20E+00		3.70E-01	JT	1.90E-01	JT	1.30E-01	JK	4.60E-01	JT
Number of Detects =				12		15		14		12		10		14		11		11		9		10	
Sum of Detects =			ug/L	4.67E+01		6.46E+01	J	6.35E+00	J	2.81E+01	J	3.32E+00	J	2.24E+01	J	1.80E+00	J	1.73E+01	J	1.13E+00	J	1.05E+01	J
Pesticides																							
2,4'-DDD		53-19-0	ug/L	na		2.50E-03	UJG	na		2.70E-03	UJG	na		3.40E-03	UJK	na		2.50E-03	U	na		4.50E-03	UJK
2,4'-DDE		3424-82-6	ug/L	na		2.50E-03	UJG	na		2.70E-03	UJG	na		2.50E-03	U	na		2.50E-03	U	na		2.50E-03	U
2,4'-DDT		789-02-6	ug/L	na		2.50E-03	UJG	na		2.70E-03	UJG	na		2.50E-03	U	na		2.50E-03	U	na		2.50E-03	U
4,4'-DDD		72-54-8	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
4,4'-DDE		72-55-9	ug/L	2.50E-03	U	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
4,4'-DDT		50-29-3	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Aldrin		309-00-2	ug/L	2.50E-03	U	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
alpha-BHC		319-84-6	ug/L	3.50E-03	JG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
beta-BHC		319-85-7	ug/L	2.50E-03	UJG	4.20E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	3.60E-03	UJK	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
delta-BHC		319-86-8	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.60E-03	UJK	2.50E-03	U	2.50E-03	U
gamma-BHC	Lindane	58-89-9	ug/L	4.90E-03	UJK	1.00E-02	UJK	2.90E-03	UJK	4.70E-03	UJK	4.80E-03	UJK	2.50E-03	U	4.30E-03	UJL	2.70E-03	UJL	4.50E-03	UJL	2.70E-03	UJL
cis-Chlordane		5103-71-9	ug/L	2.50E-03	U	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
trans-Chlordane		5103-74-2	ug/L	5.10E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	4.00E-03	UJK	2.50E-03	U	2.50E-03	U	2.50E-03	U
Chlordane, technical		12789-03-6	ug/L	na		5.10E-02	UJG	na		5.30E-02	UJG	na		2.50E-02	U	na		2.50E-02	U	na		2.50E-02	U
Chlorpyriphos		2921-88-2	ug/L	2.50E-03	UJG	7.20E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	3.30E-03	UJK	2.50E-03	U	3.50E-03	UJK	2.50E-03	U	2.50E-03	U
Dacthal	DCPA	1861-32-1	ug/L	6.30E-02	U	2.50E-03	UJG	6.20E-02	U	2.70E-03	UJG	6.40E-02	U	2.50E-03	U	6.30E-02	U	2.50E-03	U	6.20E-02	U	2.50E-03	U
DDMU		1022-22-6	ug/L	na		8.20E-03	UJG	na		2.70E-03	UJG	na		2.50E-03	U	na		2.50E-03	U	na		2.50E-03	U
Dieldrin		60-57-1	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	5.30E-03	UJK	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Endosulfan I		959-98-8	ug/L	7.70E-03	JG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	1.20E-02		2.50E-03	U	5.30E-03		2.50E-03	U
Endosulfan II		33213-65-9	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Endosulfan sulfate		1031-07-8	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Endrin		72-20-8	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Endrin aldehyde		7421-93-4	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Endrin ketone		53494-70-5	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Heptachlor		76-44-8	ug/L	2.50E-03	U	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Heptachlor epoxide		1024-57-3	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Hexachlorobenzene		118-74-1	ug/L	2.50E-03	U	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	3.70E-03	JK	2.50E-03	U	2.50E-03	U
Methoxychlor		72-43-5	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Mirex		2385-85-5	ug/L	na		2.50E-03	UJG	na		2.70E-03	UJG	na		2.50E-03	U	na		2.50E-03	U	na		2.50E-03	U
cis-Nonachlor		5103-73-1	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
trans-Nonachlor		39765-80-5	ug/L	2.50E-03	U	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Oxychlordane		27304-13-8	ug/L	2.50E-03	UJG	2.50E-03	UJG	2.50E-03	UJG	2.70E-03	UJG	2.50E-03	UJG	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U	2.50E-03	U
Pentachloroanisole		1825-21-4	ug/L	na		2.50E-03	UJG	na		2.70E-03	UJG	na		2.50E-03	U	na		2.50E-03	U	na		3.00E-03	
Toxaphene		8001-35-2	ug/L	2.50E-02	UJG	1.00E-01	JG	2.50E-02	UJG	1.50E-01	UJG	2.50E-02	UJG	5.10E-02	UJK	2.50E-02	U	5.10E-02	UJK	2.50E-02	U	1.00E-01	UJK
Number of Detects =				2		1		0		0		0		0		1		1		1		1	
Sum of Detects =			ug/L	1.12E-02	J	1.00E-01	J	6.20E-02	U	1.50E-01	U	6.40E-02	U	5.10E-02	U	1.20E-02		3.70E-03	J	5.30E-03		3.00E-03	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Herbicides																							
2,4,5-T		93-76-5	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
2,4,5-TP	Silvex	93-72-1	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
2,4-D		94-75-7	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	1.80E-01		6.10E-02	U	6.70E-02	NJK	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
2,4-DB	2,4-D butyric acid	94-82-6	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U		REJ	6.10E-02	U	6.20E-02	U	6.30E-02	U
3,5-Dichlorobenzoic acid		51-36-5	ug/L	6.20E-02	U	6.40E-02	UJK	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	UJK	6.20E-02	U	6.30E-02	UJK
Acifluorfen	Blazer	62476-59-9	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U		REJ	6.10E-02	U	6.20E-02	U	6.30E-02	U
Bentazon		25057-89-0	ug/L	6.10E-03	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Bromoxynil		1689-84-5	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Clopyralid		1702-17-6	ug/L	6.20E-02	UJG	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	UJG	6.10E-02	U	6.20E-02	UJG	6.30E-02	U
Dicamba I		1918-00-9	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	2.90E-02	NJTK	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Dichlorprop		120-36-5	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Diclofop-Methyl		51338-27-3	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Dinoseb		88-85-7	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U		REJ	6.10E-02	U	6.20E-02	U	6.30E-02	U
Ioxynil		1689-83-4	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
MCPA		94-74-6	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
MCPP	Mecoprop	93-65-2	ug/L	6.20E-02	U	5.90E-02	NJTK	6.30E-02	U	7.10E-02	NJK	6.10E-02	U	6.40E-02	U	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Picloram		1918-02-01	ug/L	6.20E-02	UJG	6.40E-02	UJG	6.30E-02	UJG	6.40E-02	U	6.10E-02	UJG	6.40E-02	U		REJ	6.10E-02	UJG	6.20E-02	UJG	6.30E-02	UJG
Triclopyr		55335-06-3	ug/L	6.20E-02	U	6.40E-02	U	6.30E-02	U	6.40E-02	U	6.10E-02	U	6.30E-02	NJTK	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Number of Detects =				0		1		0		3		0		2		0		0		0		0	
Sum of Detects =			ug/L	6.20E-02	U	5.90E-02	NJ	6.30E-02	U	2.80E-01	NJ	6.10E-02	U	1.30E-01	NJ	6.20E-02	U	6.10E-02	U	6.20E-02	U	6.30E-02	U
Polybrominated Diphenyl Ethers (Congeners)																							
2,4-DiBDE	BDE-007		pg/L	5.00E+00	U	5.00E+00	UJK	6.80E+00	JT	1.13E+01	JT	9.70E+00	JT	5.00E+00	UJK	5.00E+00	U	5.00E+00	UJK	1.45E+01	JT	2.30E+01	JT
2,6-DiBDE	BDE-010		pg/L	5.00E+00	U	5.00E+00	UJK	5.00E+00	U	2.50E+01	UJK	5.00E+00	U	5.00E+00	UJK	5.00E+00	U	5.00E+00	UJK	5.00E+00	U	5.00E+00	UJK
4,4'-DiBDE	BDE-015	2050-47-7	pg/L	6.70E+00	JT	9.40E+00	JT	8.20E+00	JT	2.50E+01	UJK	4.33E+01		5.64E+01		1.62E+01	JT	1.26E+01	JT	1.30E+02		4.53E+02	
2,2',4-TrBDE	BDE-017	147217-75-2	pg/L	3.63E+01		2.66E+01		4.70E+01		2.50E+01	UJK	1.59E+02		4.96E+02		7.76E+01		7.87E+01		3.13E+02		4.59E+02	
2,4,4'-TrBDE	BDE-028	41318-75-6	pg/L	9.58E+01		7.51E+01		9.67E+01		5.13E+01	JT	4.18E+02		1.19E+03		2.29E+02		2.14E+02		5.86E+02		1.06E+03	
2,4,6-TrBDE	BDE-030		pg/L	1.24E+01	JT	5.00E+00	UJK	1.08E+01	NJK	2.50E+01	UJK	5.00E+00	U	5.00E+00	UJK	3.12E+01	NJK	5.00E+00	UJK	2.84E+01	NJK	1.26E+01	JT
2,2',4,4'-TeBDE	BDE-047	5436-43-1	pg/L	5.26E+03		3.91E+03		5.35E+03		5.38E+03		2.97E+03		7.11E+03		1.41E+04		1.53E+04		3.19E+04		4.10E+04	
2,2',4,5'-TeBDE	BDE-049	243982-82-3	pg/L	co-elute		1.79E+01	JT	co-elute		5.00E+01	UJK	co-elute		1.00E+01	UJK	co-elute		3.52E+02		co-elute		1.26E+03	
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071		pg/L	1.93E+02		co-elute		1.88E+02		co-elute		3.95E+02		co-elute		5.15E+02		co-elute		1.38E+03		co-elute	
2,3',4,4'-TeBDE	BDE-066	189084-61-5	pg/L	1.00E+01	U	1.55E+02		1.00E+01	U	4.77E+02		2.00E+02		5.00E+01	NJK	5.45E+02		1.00E+01	UJK	9.87E+02		2.53E+03	
2,3',4',6-TeBDE	BDE-071	189084-62-6	pg/L	co-elute		1.00E+01	UJK	co-elute		7.97E+01	JT	co-elute		5.37E+02		co-elute		5.14E+01		co-elute		1.55E+02	
3,3',4,4'-TeBDE	BDE-077	93703-48-1	pg/L	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
2,2',3,4,4'-PeBDE	BDE-085	182346-21-0	pg/L	1.47E+02		1.13E+02		1.88E+02		3.80E+02		1.00E+01	U	2.02E+02		3.74E+02		2.68E+02		1.23E+03		1.31E+03	
2,2',4,4',5-PeBDE	BDE-099	60348-60-9	pg/L	4.54E+03		2.99E+03		5.05E+03		4.58E+03		2.25E+03		6.30E+03		1.37E+04		1.48E+04		3.24E+04		3.77E+04	
2,2',4,4',6-PeBDE	BDE-100	189084-64-8	pg/L	9.52E+02		6.09E+02		1.09E+03		1.07E+03		5.52E+02		1.41E+03		2.88E+03		2.78E+03		6.65E+03		6.91E+03	
2,3',4,4',6-PeBDE	BDE-119	189084-66-0	pg/L	7.27E+01		1.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	5.83E+01		7.89E+01		1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
3,3',4,4',5-PeBDE	BDE-126	366791-32-4	pg/L	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
2,2',3,4,4',5'-HxBDE	BDE-138	182677-30-1	pg/L	1.00E+01	U	4.56E+01	JT	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.74E+02		2.91E+02		5.18E+02	
2,2',3,4,4',6-HxBDE	BDE-139		pg/L	1.00E+01	U	2.99E+01	JG	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	7.96E+01		2.27E+02	JG	2.93E+02		3.86E+02	
2,2',3,4,4',6'-HxBDE	BDE-140	243982-83-4	pg/L	1.00E+01	U	2.37E+01	JT	1.00E+01	U	4.42E+01	JT	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	8.65E+01		9.08E+01		1.74E+02	
2,2',4,4',5,5'-HxBDE	BDE-153	68631-49-2	pg/L	3.62E+02		2.97E+02		4.45E+02		8.26E+02		2.08E+02		5.13E+02		1.32E+03		1.23E+03		3.27E+03		4.79E+03	
2,2',4,4',5,6'-HxBDE	BDE-154	207122-15-4	pg/L	2.92E+02		1.55E+02		4.02E+02		3.77E+02		1.44E+02		4.06E+02		9.48E+02		8.23E+02		2.32E+03		2.31E+03	
2,3,3',4,4',5/3,3',4,4',5,5'-HxBDE	BDE-156/169		pg/L	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	7.46E+01	JT
2,2',3,3',4,4',6-HpBDE	BDE-171		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	5.54E+01	JT
2,2',3,4,4',5,5'-HpBDE	BDE-180		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	9.26E+01	JT
2,2',3,4,4',5',6-HpBDE	BDE-183	207122-16-5	pg/L	4.41E+01	JT	1.20E+01	NJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	1.37E+02		1.31E+02		4.91E+02		5.98E+02	
2,2',3,4,4',6,6'-HpBDE	BDE-184		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	6.22E+01	JT
2,3,3',4,4',5',6-HpBDE	BDE-191		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.81E+01	JT

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Herbicides																							
2,4,5-T		93-76-5	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	UJG	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
2,4,5-TP	Silvex	93-72-1	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
2,4-D		94-75-7	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	1.30E-01	JG	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
2,4-DB	2,4-D butyric acid	94-82-6	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
3,5-Dichlorobenzoic acid		51-36-5	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	UJK	6.30E-02	U	6.20E-02	UJK	6.20E-02	U	6.40E-02	UJK
Acifluorfen	Blazer	62476-59-9	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Bentazon		25057-89-0	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	UJG	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Bromoxynil		1689-84-5	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Clopyralid		1702-17-6	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	UJG	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	UJG	6.40E-02	U
Dicamba I		1918-00-9	ug/L	6.30E-02	U	6.40E-02	U	3.10E-02	NJT	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	2.90E-02	JT
Dichlorprop		120-36-5	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Diclofop-Methyl		51338-27-3	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Dinoseb		88-85-7	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	UJG	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
Ioxynil		1689-83-4	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	6.20E-02	U	6.40E-02	U
MCPA		94-74-6	ug/L	6.30E-02	U	6.40E-02	U	1.60E-01	NJT	6.60E-02	U	6.40E-02	U	6.30E-02	U	6.30E-02	U	6.20E-02	U	1.10E-01	NJT	7.80E-02	NJK
MCPP	Mecoprop	93-65-2	ug/L	6.30E-02	U	6.40E-02	U	6.20E-02	U	6.60E-02	U	2.30E-01		2.50E-01		6.30E-02	U	6.20E-02	U	6.20E-02	U	3.10E-02	JT
Picloram		1918-02-01	ug/L	6.30E-02	UJG	6.40E-02	U	6.20E-02	UJG		REJ	6.40E-02	U	6.30E-02	UJG	6.30E-02	UJG	6.20E-02	UJG	6.20E-02	UJG	6.40E-02	UJG
Triclopyr		55335-06-3	ug/L	6.30E-02	U	6.40E-02	U	5.10E-02	NJT	6.60E-02	U	6.40E-02	U	6.30E-02	U	5.40E-02	NJT	1.10E-01		6.20E-02	U	3.00E-02	JT
Number of Detects =				0		0		3		1		1		1		1		1		1		4	
Sum of Detects =			ug/L	6.30E-02	U	6.40E-02	U	2.42E-01	NJ	1.30E-01	J	2.30E-01		2.50E-01		5.40E-02	NJ	1.10E-01		1.10E-01	NJ	1.68E-01	J
Polybrominated Diphenyl Ethers (Congeners)																							
2,4-DiBDE	BDE-007		pg/L	5.00E+00	U	4.88E+01	JT	5.00E+00	U	2.50E+01	UJK	1.11E+01	JT	2.13E+01	JT	5.00E+00	U	5.00E+00	UJK	5.00E+00	U	1.84E+01	JT
2,6-DiBDE	BDE-010		pg/L	5.00E+00	U	2.50E+01	UJK	5.00E+00	U	2.50E+01	UJK	5.00E+00	U	5.00E+00	UJK	5.00E+00	U	5.00E+00	UJK	5.00E+00	U	5.00E+00	UJK
4,4'-DiBDE	BDE-015	2050-47-7	pg/L	6.30E+00	NJK	1.08E+01	JT	1.18E+01	JT	9.00E+00	JT	6.46E+01		8.20E+01		5.00E+00	U	5.00E+00	UJK	3.26E+01		1.65E+01	JT
2,2',4-TrBDE	BDE-017	147217-75-2	pg/L	3.65E+01		1.09E+02		4.70E+01		3.70E+01	JT	2.91E+02		3.71E+02		7.64E+01		9.18E+01		1.54E+02		2.71E+02	
2,4,4'-TrBDE	BDE-028	41318-75-6	pg/L	9.01E+01		1.43E+02		1.12E+02		8.94E+01		8.04E+02		7.55E+02		1.75E+02		1.26E+02		2.85E+02		2.22E+02	
2,4,6-TrBDE	BDE-030		pg/L	5.00E+00	U	2.50E+01	UJK	7.30E+00	NJK	2.50E+01	UJK	5.00E+00	U	5.00E+00	UJK	2.30E+01	NJK	5.00E+00	UJK	5.00E+00	U	5.00E+00	UJK
2,2',4,4'-TeBDE	BDE-047	5436-43-1	pg/L	4.80E+03		9.38E+03		6.03E+03		6.90E+03		7.62E+03		6.44E+03		1.45E+04		6.31E+03		3.34E+03		6.63E+03	
2,2',4,5'-TeBDE	BDE-049	243982-82-3	pg/L	co-elute		2.07E+02		co-elute		1.75E+02		co-elute		5.55E+02		co-elute		2.27E+02		co-elute		2.38E+02	
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071		pg/L	1.60E+02		co-elute		2.34E+02		co-elute		8.06E+02		co-elute		5.72E+02		co-elute		2.97E+02		co-elute	
2,3',4,4'-TeBDE	BDE-066	189084-61-5	pg/L	1.00E+01	U	3.52E+02		1.36E+02		1.08E+02	JT	3.81E+02		1.00E+01	UJK	1.00E+01	U	1.68E+02		1.49E+02		5.15E+02	
2,3',4',6-TeBDE	BDE-071	189084-62-6	pg/L	co-elute		4.06E+01	JT	co-elute		2.40E+01	JT	co-elute		2.07E+02		co-elute		3.57E+01	JT	co-elute		3.98E+01	JT
3,3',4,4'-TeBDE	BDE-077	93703-48-1	pg/L	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
2,2',3,4,4'-PeBDE	BDE-085	182346-21-0	pg/L	1.80E+02		7.16E+02		2.14E+02		3.04E+02		2.64E+02		2.48E+02		6.82E+02		2.18E+02		1.00E+01	U	8.96E+02	
2,2',4,4',5-PeBDE	BDE-099	60348-60-9	pg/L	3.96E+03		8.55E+03		5.72E+03		6.30E+03		6.76E+03		4.79E+03		1.85E+04		6.62E+03		2.20E+03		1.50E+04	
2,2',4,4',6-PeBDE	BDE-100	189084-64-8	pg/L	8.58E+02		1.61E+03		1.16E+03		1.22E+03		1.49E+03		1.02E+03		3.95E+03		1.34E+03		5.32E+02		2.42E+03	
2,3',4,4',6-PeBDE	BDE-119	189084-66-0	pg/L	1.85E+01		5.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.09E+02		1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
3,3',4,4',5-PeBDE	BDE-126	366791-32-4	pg/L	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
2,2',3,4,4',5'-HxBDE	BDE-138	182677-30-1	pg/L	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	4.39E+01	JT	1.00E+01	U	1.94E+02	
2,2',3,4,4',6-HxBDE	BDE-139		pg/L	1.00E+01	U	5.00E+01	UJK	3.26E+01	JT	5.70E+01	JG	5.53E+01		1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	3.44E+02	JG
2,2',3,4,4',6'-HxBDE	BDE-140	243982-83-4	pg/L	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	3.00E+01	NJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	9.64E+01	
2,2',4,4',5,5'-HxBDE	BDE-153	68631-49-2	pg/L	3.43E+02		1.54E+03		4.82E+02		5.22E+02		5.64E+02		2.77E+02		1.73E+03		8.00E+02		1.78E+02		2.30E+03	
2,2',4,4',5,6'-HxBDE	BDE-154	207122-15-4	pg/L	2.44E+02		5.52E+02		3.62E+02		3.78E+02		4.68E+02		3.19E+02		1.37E+03		4.90E+02		1.48E+02		1.12E+03	
2,3,3',4,4',5/3,3',4,4',5,5'-HxBDE	BDE-156/169		pg/L	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	5.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK	1.00E+01	U	1.00E+01	UJK
2,2',3,3',4,4',6-HpBDE	BDE-171		pg/L	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK
2,2',3,4,4',5,5'-HpBDE	BDE-180		pg/L	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK
2,2',3,4,4',5',6-HpBDE	BDE-183	207122-16-5	pg/L	2.00E+01	U	1.00E+02	UJK	4.67E+01	JT	1.00E+02	UJK	7.10E+01	JT	2.00E+01	UJK	1.39E+02		7.05E+01	JT	2.00E+01	U	1.02E+02	
2,2',3,4,4',6,6'-HpBDE	BDE-184		pg/L	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.06E+01	JT	2.00E+01	U	2.00E+01	UJK
2,3,3',4,4',5',6-HpBDE	BDE-191		pg/L	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,2',3,3',4,4',5,6'-OcBDE	BDE-196		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	7.17E+01	JT	5.14E+01	JT	3.81E+02		5.86E+02	
2,2',3,3',4,4',6,6'/ 2,2',3,4,4',5,6,6'-OcBDE	BDE-197/204		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	8.32E+01	JT	8.27E+01	JT	3.12E+02		3.87E+02	
2,2',3,3',4,5',6,6'-OcBDE	BDE-201		pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	3.19E+01	JT	2.00E+01	UJK	1.98E+02		4.34E+02	
2,2',3,4,4',5,5',6-OcBDE	BDE-203	337513-72-1	pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	4.33E+01	JT	3.30E+01	NJK	3.40E+02		6.48E+02	
2,3,3',4,4',5,5',6-OcBDE	BDE-205	446255-56-7	pg/L	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	63387-28-0	pg/L	1.57E+02	JT	5.00E+01	UJK	3.00E+02		2.50E+02	UJK	1.56E+02	JT	5.00E+01	UJK	6.45E+02		6.84E+02		2.59E+03		2.31E+03	
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	437701-79-6	pg/L	1.25E+02	JT	1.38E+02	JT	1.91E+02	JT	2.50E+02	UJK	2.30E+02	JT	5.00E+01	UJK	5.54E+02		3.44E+02		2.23E+03		2.91E+03	
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208		pg/L	9.96E+01	JT	5.00E+01	UJK	1.15E+02	JT	2.50E+02	UJK	1.21E+02	JT	5.00E+01	UJK	3.11E+02		4.77E+02		1.49E+03		3.50E+03	
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	1163-19-5	pg/L	2.00E+03		1.39E+03	UFB	3.34E+03		7.50E+02	UJK	3.06E+03		4.46E+03		6.83E+03		8.87E+03		3.55E+04		2.20E+04	
Number of Detects =				17		16		16		11		16		13		22		22		25		31	
Sum of Detects =			pg/L	1.44E+04		8.61E+03		1.68E+04		1.33E+04		1.10E+04		2.28E+04		4.35E+04		4.71E+04		1.25E+05		1.35E+05	
Polybrominated Diphenyl Ethers (Homologs)																							
Decabromodiphenyl ether			pg/L	2.00E+03		1.39E+03	U	3.34E+03		7.50E+02	UJ	3.06E+03		4.46E+03		6.83E+03		8.87E+03		3.55E+04		2.20E+04	
Dibromodiphenyl ethers			pg/L	6.70E+00	J	9.40E+00	J	1.50E+01	J	1.13E+01	J	5.30E+01	J	5.64E+01		1.62E+01	J	1.26E+01	J	1.45E+02		4.76E+02	
Heptabromodiphenyl ethers			pg/L	4.41E+01	J	1.20E+01	NJ	2.00E+01	U	1.00E+02	UJ	2.00E+01	U	2.00E+01	UJ	1.37E+02		1.31E+02		4.91E+02		8.36E+02	J
Hexabromodiphenyl ethers			pg/L	6.54E+02		5.51E+02	J	8.47E+02		1.25E+03		3.52E+02		9.19E+02		2.35E+03		2.54E+03		6.26E+03		8.18E+03	
Nonabromodiphenyl ethers			pg/L	3.82E+02	J	1.38E+02	J	6.06E+02	J	2.50E+02	UJ	5.07E+02	J	5.00E+01	UJ	1.51E+03		1.51E+03		6.31E+03		8.72E+03	
Octabromodiphenyl ethers			pg/L	2.00E+01	U	2.00E+01	UJ	2.00E+01	U	1.00E+02	UJ	2.00E+01	U	2.00E+01	UJ	2.30E+02	J	1.67E+02	J	1.23E+03		2.06E+03	
Pentabromodiphenyl ethers			pg/L	5.71E+03		3.71E+03		6.33E+03		6.03E+03		2.86E+03		7.99E+03		1.70E+04		1.78E+04		4.03E+04		4.59E+04	
Tetrabromodiphenyl ethers			pg/L	5.45E+03		4.08E+03		5.54E+03		5.94E+03		3.57E+03		7.70E+03		1.52E+04		1.57E+04		3.43E+04		4.49E+04	
Tribromodiphenyl ethers			pg/L	1.45E+02		1.02E+02		1.55E+02		5.13E+01	J	5.77E+02		1.69E+03		3.38E+02		2.93E+02		9.27E+02		1.53E+03	
Number of Detects =				8		7		7		5		7		6		9		9		9		9	
Perfluorinated Compounds																							
Perfluorobutane sulfonate	PFBS	45187-15-3	ng/L	2.00E+00	U	1.98E+00	U	1.94E+00	U	1.77E+01		1.98E+00	U	1.97E+00	U	1.96E+00	U	1.98E+00	U	2.08E+00	U	2.00E+00	U
Perfluorobutanoate	PFBA	375-22-4	ng/L	1.86E+00		1.46E+00	U	1.40E+00		1.83E+00		9.91E-01	U	1.27E+00	U	1.38E+00		1.53E+00	U	1.04E+00	U	3.24E+00	
Perfluorodecanoate	PFDA	335-76-2	ng/L	1.37E+00		2.82E+00		1.74E+00		2.77E+00		4.27E+00		3.57E+00		2.62E+00		1.54E+00		1.91E+00		2.55E+00	
Perfluorododecanoate	PFDoA	307-55-1	ng/L	1.00E+00	U	9.91E-01	U	9.68E-01	U	1.00E+00	U	9.91E-01	U	9.84E-01	U	9.82E-01	U	9.88E-01	U	1.04E+00	U	1.00E+00	U
Perfluoroheptanoate	PFHpA	375-85-9	ng/L	3.53E+00		5.10E+00		2.08E+00		3.44E+00		4.06E+00		4.73E+00		5.64E+00		9.69E+00		1.03E+01		7.83E+00	
Perfluorohexane sulfonate	PFHxS	108427-53-8	ng/L	3.31E+00		2.41E+00		1.94E+00	U	7.79E+00		3.17E+00		2.34E+00		4.42E+00		7.01E+00		2.57E+00		3.36E+00	
Perfluorohexanoate	PFHxA	307-24-4	ng/L	1.54E+01		1.72E+01		1.08E+01		1.43E+01		2.49E+01		9.62E+00		1.09E+01		2.28E+01		1.19E+01		1.61E+01	
Perfluorononanoate	PFNA	375-95-1	ng/L	3.52E+00		2.20E+01		2.36E+00		1.08E+01		1.31E+01		4.11E+00		4.47E+00		7.02E+00		1.34E+02		2.87E+01	
Perfluorooctane sulfonamide	PFOSA	754-91-6	ng/L	1.00E+00	U	2.48E+00	U	9.68E-01	U	2.51E+00	U	1.95E+00		2.46E+00	U	9.82E-01	U	2.47E+00	U	1.04E+00	U	2.50E+00	U
Perfluorooctane sulfonate	PFOS	45298-90-6	ng/L	6.02E+00		1.98E+00	U	4.50E+00		5.50E+01		5.89E+00		3.51E+00		9.71E+00		4.23E+00		7.57E+00		1.00E+01	
Perfluorooctanoate	PFOA	335-67-1	ng/L	1.16E+01		1.74E+01		1.13E+01		1.11E+01		3.05E+01		1.65E+01		2.70E+01		3.02E+01		2.43E+01		1.68E+01	
Perfluoropentanoate	PFPeA	2706-90-3	ng/L	1.90E+00		2.05E+00		1.16E+00		1.00E+00	U	5.80E+00		1.94E+00		3.77E+00		6.79E+00		1.50E+00	U	3.18E+00	
Perfluoroundecanoate	PFUnA	2058-94-8	ng/L	1.00E+00	U	9.91E-01	U	9.68E-01	U	1.00E+00	U	9.91E-01	U	9.84E-01	U	9.82E-01	U	9.88E-01	U	1.18E+00		1.00E+00	U
Number of Detects =				9		7		8		9		9		8		9		8		8		9	
Sum of Detects =			ng/L	4.85E+01		6.90E+01		3.53E+01		1.25E+02		9.36E+01		4.63E+01		6.99E+01		8.93E+01		1.94E+02		9.18E+01	
Polychlorinated Biphenyls (Congeners)																							
2-MoCB	PCB-001	2051-60-7	pg/L	na		na		1.00E+01	U	na		na		na		4.14E+01		na		5.08E+01		na	
3-MoCB	PCB-002	2051-61-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
4-MoCB	PCB-003	2051-62-9	pg/L	na		na		1.00E+01	U	na		na		na		2.91E+01		na		1.00E+01	U	na	
2,2'-DiCB	PCB-004	13029-08-8	pg/L	na		na		1.00E+01	U	na		na		na		8.48E+01		na		1.04E+03		na	
2,3/2,4'-DiCB	PCB-005/008		pg/L	na		na		1.21E+01	UJL	na		na		na		1.30E+02		na		7.70E+01	UJL	na	
2,3'-DiCB	PCB-006	25569-80-6	pg/L	na		na		1.00E+01	U	na		na		na		2.23E+01		na		3.06E+01		na	
2,4-DiCB	PCB-007	33284-50-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.39E+01		na	
2,5-DiCB	PCB-009	34883-39-1	pg/L	na		na		1.00E+01	U	na		na		na		1.11E+01		na		1.00E+01	U	na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,2',3,3',4,4',5,6'-OcBDE	BDE-196		pg/L	2.00E+01	U	1.00E+02	UJK	2.36E+01	JT	1.00E+02	UJK	4.44E+01	JT	2.00E+01	UJK	2.00E+01	U	9.78E+01	JT	2.00E+01	U	2.00E+01	UJK
2,2',3,3',4,4',6,6'/ 2,2',3,4,4',5,6,6'-OcBDE	BDE-197/204		pg/L	2.00E+01	U	1.00E+02	UJK	3.23E+01	JT	1.00E+02	UJK	7.15E+01	JT	2.00E+01	UJK	6.84E+01	JT	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK
2,2',3,3',4,5',6,6'-OcBDE	BDE-201		pg/L	2.00E+01	U	1.00E+02	UJK	2.54E+01	JT	1.00E+02	UJK	5.63E+01	JT	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK
2,2',3,4,4',5,5',6-OcBDE	BDE-203	337513-72-1	pg/L	2.00E+01	U	1.00E+02	UJK	3.11E+01	JT	1.00E+02	UJK	1.23E+02		2.00E+01	UJK	2.00E+01	U	1.38E+02		2.00E+01	U	2.00E+01	UJK
2,3,3',4,4',5,5',6-OcBDE	BDE-205	446255-56-7	pg/L	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	1.00E+02	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK	2.00E+01	U	2.00E+01	UJK
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	63387-28-0	pg/L	3.34E+02		1.13E+03		2.46E+02	JT	2.50E+02	UJK	2.84E+02		5.00E+01	UJK	8.84E+02		6.10E+02		5.00E+01	U	5.00E+01	UJK
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	437701-79-6	pg/L	3.02E+02		1.39E+03		2.75E+02		2.50E+02	UJK	3.77E+02		5.00E+01	UJK	7.14E+02		6.78E+02		5.00E+01	U	5.00E+01	UJK
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208		pg/L	2.40E+02	JT	1.22E+03		1.25E+02	JT	2.50E+02	UJK	2.53E+02		5.00E+01	UJK	4.09E+02		7.83E+02		5.00E+01	U	5.00E+01	UJK
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	1163-19-5	pg/L	1.07E+04		1.88E+04		2.54E+03		2.15E+03		2.87E+03		2.50E+02	U	1.06E+04		5.61E+03		1.78E+03		2.50E+02	UJK
Number of Detects =				15		17		22		14		23		13		16		20		11		17	
Sum of Detects =			pg/L	2.23E+04		4.58E+04		1.79E+04		1.83E+04		2.38E+04		1.51E+04		5.44E+04		2.45E+04	J	9.10E+03		3.04E+04	
Polybrominated Diphenyl Ethers (Homologs)																							
Decabromodiphenyl ether			pg/L	1.07E+04		1.88E+04		2.54E+03		2.15E+03		2.87E+03		2.50E+02	U	1.06E+04		5.61E+03		1.78E+03		2.50E+02	UJ
Dibromodiphenyl ethers			pg/L	6.30E+00	NJ	5.96E+01	J	1.18E+01	J	9.00E+00	J	7.57E+01	J	1.03E+02	J	5.00E+00	U	5.00E+00	U	3.26E+01		3.49E+01	J
Heptabromodiphenyl ethers			pg/L	2.00E+01	U	1.00E+02	UJ	4.67E+01	J	1.00E+02	UJ	7.10E+01	J	2.00E+01	UJ	1.39E+02		9.11E+01	J	2.00E+01	U	1.02E+02	
Hexabromodiphenyl ethers			pg/L	5.87E+02		2.09E+03		8.77E+02		9.57E+02		1.09E+03		6.26E+02		3.10E+03		1.33E+03		3.26E+02		4.05E+03	
Nonabromodiphenyl ethers			pg/L	8.76E+02	J	3.74E+03		6.46E+02	J	2.50E+02	UJ	9.14E+02		5.00E+01	UJ	2.01E+03		2.07E+03		5.00E+01	U	5.00E+01	UJ
Octabromodiphenyl ethers			pg/L	2.00E+01	U	1.00E+02	UJ	1.12E+02	J	1.00E+02	UJ	2.95E+02	J	2.00E+01	UJ	6.84E+01	J	2.36E+02	J	2.00E+01	U	2.00E+01	UJ
Pentabromodiphenyl ethers			pg/L	5.02E+03		1.09E+04		7.09E+03		7.82E+03		8.62E+03		6.06E+03		2.31E+04		8.18E+03		2.73E+03		1.83E+04	
Tetrabromodiphenyl ethers			pg/L	4.96E+03		9.98E+03		6.40E+03		7.21E+03		8.81E+03		7.20E+03		1.51E+04		6.74E+03		3.79E+03		7.42E+03	
Tribromodiphenyl ethers			pg/L	1.27E+02		2.52E+02		1.66E+02		1.26E+02	J	1.10E+03		1.13E+03		2.74E+02		2.18E+02		4.39E+02		4.93E+02	
Number of Detects =				7		7		9		6		9		5		8		8		6		6	
Perfluorinated Compounds																							
Perfluorobutane sulfonate	PFBS	45187-15-3	ng/L	1.98E+00	U	2.03E+00	U	1.99E+00	U	1.38E+01		1.97E+00	U	1.47E+01		1.98E+00	U	2.04E+00	U	1.96E+00	U	1.97E+00	U
Perfluorobutanoate	PFBA	375-22-4	ng/L	9.91E-01	U	1.38E+00		1.31E+00		2.47E+00		3.60E+00		4.87E+00		9.91E-01	U	2.99E+00		2.95E+00		9.85E-01	U
Perfluorodecanoate	PFDA	335-76-2	ng/L	5.66E+00		7.31E+00		2.82E+00		4.28E+00		5.54E+00		3.66E+00		5.78E+00		6.30E+00		7.85E+00		1.04E+01	
Perfluorododecanoate	PFDoA	307-55-1	ng/L	9.91E-01	U	1.02E+00	U	9.97E-01	U	9.87E-01	U	9.83E-01	U	9.93E-01	U	9.91E-01	U	1.02E+00	U	9.81E-01	U	9.85E-01	U
Perfluoroheptanoate	PFHpA	375-85-9	ng/L	4.65E+00		5.27E+00		2.75E+00		6.00E+00		3.98E+00		6.49E+00		2.80E+00		3.74E+00		4.29E+00		6.96E+00	
Perfluorohexane sulfonate	PFHxS	108427-53-8	ng/L	1.98E+00	U	2.03E+00	U	3.12E+00		2.65E+00		6.87E+00		8.27E+00		1.98E+00	U	2.04E+00	U	1.96E+00	U	1.97E+00	U
Perfluorohexanoate	PFHxA	307-24-4	ng/L	3.41E+01		4.13E+01		1.32E+01		1.61E+01		1.21E+01		1.85E+01		2.55E+01		4.43E+01		5.21E+01		3.09E+01	
Perfluorononanoate	PFNA	375-95-1	ng/L	1.23E+01		2.32E+01		3.73E+00		5.83E+00		2.76E+00		5.76E+00		1.39E+00		3.29E+00		6.27E+00		9.16E+00	
Perfluorooctane sulfonamide	PFOSA	754-91-6	ng/L	9.91E-01	U	2.54E+00	U	9.97E-01	U	2.47E+00	U	9.83E-01	U	2.48E+00	U	9.91E-01	U	2.56E+00	U	1.08E+00		2.46E+00	U
Perfluorooctane sulfonate	PFOS	45298-90-6	ng/L	5.60E+00		2.24E+00		1.95E+01		2.12E+01		6.56E+00		8.78E+00		1.98E+00	U	4.37E+00		2.57E+00		1.07E+01	
Perfluorooctanoate	PFOA	335-67-1	ng/L	4.86E+01		5.25E+01		1.25E+01		2.26E+01		1.09E+01		1.32E+01		3.31E+01		3.89E+01		6.98E+01		4.65E+01	
Perfluoropentanoate	PFPeA	2706-90-3	ng/L	1.59E+01		1.26E+01		1.84E+00		1.38E+00	U	2.02E+00		1.98E+00		8.47E+00		1.65E+01		1.33E+01		1.82E+01	
Perfluoroundecanoate	PFUnA	2058-94-8	ng/L	9.91E-01	U	1.02E+00	U	9.97E-01	U	9.87E-01	U	9.83E-01	U	9.93E-01	U	9.91E-01	U	1.02E+00	U	9.81E-01	U	9.85E-01	U
Number of Detects =				7		8		9		9		9		10		6		8		9		7	
Sum of Detects =			ng/L	1.27E+02		1.46E+02		6.08E+01		9.49E+01		5.43E+01		8.62E+01		7.70E+01		1.20E+02		1.60E+02		1.33E+02	
Polychlorinated Biphenyls (Congeners)																							
2-MoCB	PCB-001	2051-60-7	pg/L	na		na		1.91E+01		na		1.01E+01		na		1.00E+01	U	na		na		na	
3-MoCB	PCB-002	2051-61-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
4-MoCB	PCB-003	2051-62-9	pg/L	na		na		1.35E+01		na		1.30E+01		na		1.00E+01	U	na		na		na	
2,2'-DiCB	PCB-004	13029-08-8	pg/L	na		na		4.69E+01		na		2.90E+01		na		1.00E+01	U	na		na		na	
2,3/2,4'-DiCB	PCB-005/008		pg/L	na		na		6.49E+01	UJL	na		3.75E+01	UJL	na		1.00E+01	U	na		na		na	
2,3'-DiCB	PCB-006	25569-80-6	pg/L	na		na		1.46E+01		na		1.68E+01		na		1.00E+01	U	na		na		na	
2,4-DiCB	PCB-007	33284-50-3	pg/L	na		na		1.23E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,5-DiCB	PCB-009	34883-39-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,6-DiCB	PCB-010	33146-45-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,3'-DiCB	PCB-011	2050-67-1	pg/L	na		na		4.29E+01	UJL	na		na		na		9.51E+01	UJL	na		2.83E+02	UJL	na	
3,4/3,4'-DiCB	PCB-012/013		pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.42E+01		na	
3,5-DiCB	PCB-014	34883-41-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
4,4'-DiCB	PCB-015	2050-68-2	pg/L	na		na		1.00E+01	UFB	na		na		na		3.62E+01		na		1.29E+02		na	
2,2',3-TrCB	PCB-016	38444-78-9	pg/L	na		na		1.43E+01		na		na		na		4.86E+01		na		8.82E+01		na	
2,2',4-TrCB	PCB-017	37680-66-3	pg/L	na		na		1.00E+01	U	na		na		na		4.75E+01		na		1.66E+02		na	
2,2',5-TrCB	PCB-018	37680-65-2	pg/L	na		na		1.59E+01	UFB	na		na		na		1.36E+02		na		2.65E+02		na	
2,2',6-TrCB	PCB-019	38444-73-4	pg/L	na		na		1.00E+01	U	na		na		na		1.84E+01		na		1.65E+02		na	
2,3,3'/2,3',4'-TriCB	PCB-020/033		pg/L	na		na		1.37E+01		na		na		na		9.46E+01		na		9.66E+01		na	
2,3,4-TrCB	PCB-021	55702-46-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4'-TrCB	PCB-022	38444-85-8	pg/L	na		na		1.00E+01	U	na		na		na		5.42E+01		na		1.26E+02		na	
2,3,5-TrCB	PCB-023	55720-44-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,6-TrCB	PCB-024	55702-45-9	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3',4-TrCB	PCB-025	55712-37-3	pg/L	na		na		1.00E+01	U	na		na		na		1.07E+01		na		3.21E+01		na	
2,3',5-TrCB	PCB-026	38444-81-4	pg/L	na		na		1.00E+01	U	na		na		na		2.13E+01		na		5.46E+01		na	
2,3',6-TrCB	PCB-027	38444-76-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		3.84E+01		na	
2,4,4'-TrCB	PCB-028	7012-37-5	pg/L	na		na		1.46E+01		na		na		na		1.16E+02		na		2.84E+02		na	
2,4,5-TrCB	PCB-029	15862-07-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,4,6-TrCB	PCB-030	35693-92-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,4',5-TrCB	PCB-031	16606-02-3	pg/L	na		na		1.63E+01		na		na		na		1.23E+02		na		2.89E+02		na	
2,4',6-TrCB	PCB-032	38444-77-8	pg/L	na		na		1.00E+01	U	na		na		na		4.07E+01		na		1.33E+02		na	
2,3',5'-TrCB	PCB-034	37680-68-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,3',4-TrCB	PCB-035	37680-69-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.47E+01		na	
3,3',5-TrCB	PCB-036	38444-87-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.16E+01		na	
3,4,4'-TrCB	PCB-037	38444-90-5	pg/L	na		na		1.00E+01	U	na		na		na		3.58E+01		na		1.11E+02		na	
3,4,5-TrCB	PCB-038	53555-66-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,4',5-TrCB	PCB-039	38444-88-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3'-TeCB	PCB-040	38444-93-8	pg/L	na		na		1.00E+01	U	na		na		na		2.35E+01		na		4.38E+01		na	
2,3,4',6-TeCB	PCB-041	52663-59-9	pg/L	na		na		1.00E+01	U	na		na		na		1.14E+01		na		2.40E+01		na	
2,2',3,4'-TeCB	PCB-042	36559-22-5	pg/L	na		na		1.00E+01	U	na		na		na		2.91E+01		na		7.51E+01		na	
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049		pg/L	na		na		1.00E+01	U	na		na		na		9.47E+01		na		2.45E+02		na	
2,2',3,5'-TeCB	PCB-044	41464-39-5	pg/L	na		na		1.39E+01	UFB	na		na		na		1.27E+02		na		3.35E+02		na	
2,2',3,6-TeCB	PCB-045	70362-45-7	pg/L	na		na		1.00E+01	U	na		na		na		1.65E+01		na		3.44E+01		na	
2,2',3,6'-TeCB	PCB-046	41464-47-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.96E+01		na	
2,2',4,4'/2,2',4,5-TeCB	PCB-047/048		pg/L	na		na		1.00E+01	U	na		na		na		2.84E+01		na		8.16E+01		na	
2,2',4,6-TeCB	PCB-050	62796-65-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',4,6'-TeCB	PCB-051	68194-04-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		3.93E+01		na	
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069		pg/L	na		na		1.98E+01	UJL	na		na		na		1.50E+02		na		4.69E+02		na	
2,2',5,6'-TeCB	PCB-053	41464-41-9	pg/L	na		na		1.00E+01	U	na		na		na		1.62E+01		na		6.07E+01	N	na	
2,2',6,6'-TeCB	PCB-054	15968-05-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4-TeCB	PCB-055	74338-24-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4'-TeCB	PCB-056	41464-43-1	pg/L	na		na		1.00E+01	U	na		na		na		5.03E+01		na		1.15E+02		na	
2,3,3',5-TeCB	PCB-057	70424-67-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',5'-TeCB	PCB-058	41464-49-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',6-TeCB	PCB-059	74472-33-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4,4'-TeCB	PCB-060	33025-41-1	pg/L	na		na		1.00E+01	U	na		na		na		1.73E+01		na		5.83E+01		na	
2,3,4,5-TeCB	PCB-061	33284-53-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4,6-TeCB	PCB-062	54230-22-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4',5-TeCB	PCB-063	74472-34-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4',6/2,3',5,5'-TeCB	PCB-064/072		pg/L	na		na		1.00E+01	U	na		na		na		5.48E+01		na		1.23E+02		na	
2,3,5,6/2,4,4',6-TeCB	PCB-065/075		pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,6-DiCB	PCB-010	33146-45-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3'-DiCB	PCB-011	2050-67-1	pg/L	na		na		6.85E+01	UJL	na		9.40E+01	UJL	na		2.85E+01	UJL	na		na		na	
3,4/3,4'-DiCB	PCB-012/013		pg/L	na		na		1.00E+01	U	na		2.66E+01		na		1.00E+01	U	na		na		na	
3,5-DiCB	PCB-014	34883-41-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
4,4'-DiCB	PCB-015	2050-68-2	pg/L	na		na		2.03E+01	UFB	na		2.35E+01	UFB	na		1.00E+01	UFB	na		na		na	
2,2',3-TrCB	PCB-016	38444-78-9	pg/L	na		na		3.58E+01		na		1.78E+01		na		1.00E+01	U	na		na		na	
2,2',4-TrCB	PCB-017	37680-66-3	pg/L	na		na		2.15E+01		na		1.33E+01		na		1.00E+01	U	na		na		na	
2,2',5-TrCB	PCB-018	37680-65-2	pg/L	na		na		7.06E+01		na		4.01E+01		na		1.85E+01	UFB	na		na		na	
2,2',6-TrCB	PCB-019	38444-73-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3'/2,3',4'-TriCB	PCB-020/033		pg/L	na		na		3.33E+01		na		1.76E+01		na		1.00E+01	U	na		na		na	
2,3,4-TrCB	PCB-021	55702-46-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4'-TrCB	PCB-022	38444-85-8	pg/L	na		na		2.00E+01		na		1.25E+01		na		1.00E+01	U	na		na		na	
2,3,5-TrCB	PCB-023	55720-44-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,6-TrCB	PCB-024	55702-45-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4-TrCB	PCB-025	55712-37-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',5-TrCB	PCB-026	38444-81-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',6-TrCB	PCB-027	38444-76-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,4,4'-TrCB	PCB-028	7012-37-5	pg/L	na		na		4.18E+01		na		2.17E+01		na		1.56E+01		na		na		na	
2,4,5-TrCB	PCB-029	15862-07-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,4,6-TrCB	PCB-030	35693-92-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,4',5-TrCB	PCB-031	16606-02-3	pg/L	na		na		4.93E+01		na		3.03E+01		na		1.53E+01		na		na		na	
2,4',6-TrCB	PCB-032	38444-77-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',5'-TrCB	PCB-034	37680-68-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',4-TrCB	PCB-035	37680-69-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',5-TrCB	PCB-036	38444-87-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,4,4'-TrCB	PCB-037	38444-90-5	pg/L	na		na		1.51E+01		na		2.11E+01		na		1.00E+01	U	na		na		na	
3,4,5-TrCB	PCB-038	53555-66-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,4',5-TrCB	PCB-039	38444-88-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3'-TeCB	PCB-040	38444-93-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4',6-TeCB	PCB-041	52663-59-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4'-TeCB	PCB-042	36559-22-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049		pg/L	na		na		3.65E+01		na		2.08E+01		na		1.43E+01		na		na		na	
2,2',3,5'-TeCB	PCB-044	41464-39-5	pg/L	na		na		6.02E+01	UFB	na		3.19E+01	UFB	na		2.01E+01	UFB	na		na		na	
2,2',3,6-TeCB	PCB-045	70362-45-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,6'-TeCB	PCB-046	41464-47-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,4'/2,2',4,5-TeCB	PCB-047/048		pg/L	na		na		1.08E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,6-TeCB	PCB-050	62796-65-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,6'-TeCB	PCB-051	68194-04-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069		pg/L	na		na		8.99E+01		na		4.36E+01		na		2.77E+01	UJL	na		na		na	
2,2',5,6'-TeCB	PCB-053	41464-41-9	pg/L	na		na		1.20E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',6,6'-TeCB	PCB-054	15968-05-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4-TeCB	PCB-055	74338-24-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4'-TeCB	PCB-056	41464-43-1	pg/L	na		na		2.09E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',5-TeCB	PCB-057	70424-67-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',5'-TeCB	PCB-058	41464-49-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',6-TeCB	PCB-059	74472-33-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4,4'-TeCB	PCB-060	33025-41-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4,5-TeCB	PCB-061	33284-53-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4,6-TeCB	PCB-062	54230-22-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4',5-TeCB	PCB-063	74472-34-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4',6/2,3',5,5'-TeCB	PCB-064/072		pg/L	na		na		1.76E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,5,6/2,4,4',6-TeCB	PCB-065/075		pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,3',4,4'-TeCB	PCB-066	32598-10-0	pg/L	na		na		1.05E+01		na		na		na		9.22E+01		na		2.45E+02		na	
2,3',4,5-TeCB	PCB-067	73575-53-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.06E+01		na	
2,2',3,4-TeCB	PCB-068	73575-52-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3',4',5-TeCB	PCB-070	32598-11-1	pg/L	na		na		1.52E+01	UFB	na		na		na		1.34E+02		na		4.37E+02		na	
2,3',4',6-TeCB	PCB-071	41464-46-4	pg/L	na		na		1.00E+01	U	na		na		na		2.94E+01		na		6.86E+01		na	
2,2',5,5'-TeCB	PCB-073	74338-23-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,4,4',5-TeCB	PCB-074	32690-93-0	pg/L	na		na		1.00E+01	U	na		na		na		5.62E+01		na		1.54E+02		na	
2,3',4',5'-TeCB	PCB-076	70362-48-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,3',4,4'-TeCB	PCB-077	32598-13-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		3.91E+01		na	
3,3',4,5-TeCB	PCB-078	70362-49-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,3',4,5'-TeCB	PCB-079	41464-48-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,3',5,5'-TeCB	PCB-080	33284-52-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,4,4',5-TeCB	PCB-081	70362-50-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4-PeCB	PCB-082	52663-62-4	pg/L	na		na		1.00E+01	U	na		na		na		1.66E+01	N	na		9.24E+01		na	
2,2',3,3',5-PeCB	PCB-083	60145-20-2	pg/L	na		na		1.00E+01	U	na		na		na		1.22E+01		na		2.57E+01		na	
2,2',3,3',6-PeCB	PCB-084	52663-60-2	pg/L	na		na		1.00E+01	U	na		na		na		3.20E+01		na		1.22E+02		na	
2,2',3,4,4'-PeCB	PCB-085	65510-45-4	pg/L	na		na		1.00E+01	U	na		na		na		2.67E+01		na		1.21E+02		na	
2,2',3,4,5/2,2',3,4',5'/2,3,4',5,6-PeCB	PCB-086/097/117		pg/L	na		na		1.00E+01	U	na		na		na		5.17E+01		na		2.32E+02		na	
2,2',3,4,5'/2,3,4,4',6-PeCB	PCB-087/115		pg/L	na		na		1.11E+01	UFB	na		na		na		7.05E+01		na		3.09E+02		na	
2,2',3,4,6-PeCB	PCB-088	55215-17-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4,6'-PeCB	PCB-089	73575-57-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4',5-PeCB	PCB-090	68194-07-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4',6-PeCB	PCB-091	68194-05-8	pg/L	na		na		1.00E+01	U	na		na		na		2.40E+01		na		7.28E+01		na	
2,2',3,5,5'-PeCB	PCB-092	52663-61-3	pg/L	na		na		1.00E+01	U	na		na		na		4.51E+01		na		1.82E+02		na	
2,2',3,5,6/2,2',3,5',6/2,2',3,4',6'/2,2',4,5,6'-PeCB	PCB-093/095/098/102		pg/L	na		na		2.00E+01	UFB	na		na		na		1.60E+02		na		6.01E+02		na	
2,2',3,5,6'-PeCB	PCB-094	73575-55-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,6,6'-PeCB	PCB-096	73575-54-9	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',4,4',5-PeCB	PCB-099	38380-01-7	pg/L	na		na		1.00E+01	U	na		na		na		7.65E+01		na		2.97E+02		na	
2,2',4,4',6-PeCB	PCB-100	39485-83-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',4,5,5'-PeCB	PCB-101	37680-73-2	pg/L	na		na		2.28E+01	UFB	na		na		na		2.06E+02		na		7.77E+02		na	
2,2',4,5',6-PeCB	PCB-103	60145-21-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',4,6,6'-PeCB	PCB-104	56558-16-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,4'-PeCB	PCB-105	32598-14-4	pg/L	na		na		1.00E+01	U	na		na		na		5.65E+01		na		2.69E+02		na	
2,3,3',4,5-PeCB	PCB-106	70424-69-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4',5/2,3,3',4,5'-PeCB	PCB-107/108		pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		4.89E+01		na	
2,3,3',4,6-PeCB	PCB-109	74472-35-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4',6-PeCB	PCB-110	38380-03-9	pg/L	na		na		2.48E+01	UFB	na		na		na		1.95E+02		na		7.56E+02		na	
2,3,3',5,5'-PeCB	PCB-111	39635-32-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',5,6/2,3',4,4',6-PeCB	PCB-112/119		pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',5',6-PeCB	PCB-113	68194-10-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4,4',5-PeCB	PCB-114	74472-37-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.44E+01		na	
2,3,4,5,6/2,3',4',5',6-PeCB	PCB-116/125		pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3',4,4',5-PeCB	PCB-118	31508-00-6	pg/L	na		na		1.96E+01	UFB	na		na		na		1.35E+02		na		6.48E+02		na	
2,3',4,5,5'-PeCB	PCB-120	68194-12-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3',4,5',6-PeCB	PCB-121	56558-18-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4',5'-PeCB	PCB-122	76842-07-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3',4,4',5'-PeCB	PCB-123	65510-44-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.92E+01	N	na	
2,3',4',5,5'-PeCB	PCB-124	70424-70-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.68E+01		na	
3,3',4,4',5-PeCB	PCB-126	57465-28-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.33E+01		na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,3',4,4'-TeCB	PCB-066	32598-10-0	pg/L	na		na		3.02E+01		na		1.00E+01	U	na		1.14E+01		na		na		na	
2,3',4,5-TeCB	PCB-067	73575-53-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4-TeCB	PCB-068	73575-52-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4',5-TeCB	PCB-070	32598-11-1	pg/L	na		na		5.65E+01	UFB	na		3.59E+01	UFB	na		2.19E+01	UFB	na		na		na	
2,3',4',6-TeCB	PCB-071	41464-46-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',5,5'-TeCB	PCB-073	74338-23-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,4,4',5-TeCB	PCB-074	32690-93-0	pg/L	na		na		1.96E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4',5'-TeCB	PCB-076	70362-48-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',4,4'-TeCB	PCB-077	32598-13-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',4,5-TeCB	PCB-078	70362-49-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',4,5'-TeCB	PCB-079	41464-48-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',5,5'-TeCB	PCB-080	33284-52-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,4,4',5-TeCB	PCB-081	70362-50-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4-PeCB	PCB-082	52663-62-4	pg/L	na		na		1.07E+01	N	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',5-PeCB	PCB-083	60145-20-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',6-PeCB	PCB-084	52663-60-2	pg/L	na		na		1.61E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4'-PeCB	PCB-085	65510-45-4	pg/L	na		na		1.13E+01	N	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5/2,2',3,4',5'/2,3,4',5,6-PeCB	PCB-086/097/117		pg/L	na		na		3.08E+01	UFB	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5'/2,3,4,4',6-PeCB	PCB-087/115		pg/L	na		na		4.11E+01	UFB	na		1.85E+01	UFB	na		1.66E+01	UFB	na		na		na	
2,2',3,4,6-PeCB	PCB-088	55215-17-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,6'-PeCB	PCB-089	73575-57-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',5-PeCB	PCB-090	68194-07-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',6-PeCB	PCB-091	68194-05-8	pg/L	na		na		1.19E+01		na		1.12E+01	N	na		1.00E+01	U	na		na		na	
2,2',3,5,5'-PeCB	PCB-092	52663-61-3	pg/L	na		na		2.60E+01		na		1.49E+01	N	na		1.08E+01		na		na		na	
2,2',3,5,6/2,2',3,5',6/2,2',3,4',6'/2,2',4,5,6'-PeCB	PCB-093/095/098/102		pg/L	na		na		9.50E+01	UFB	na		4.34E+01	UFB	na		3.10E+01	UFB	na		na		na	
2,2',3,5,6'-PeCB	PCB-094	73575-55-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,6,6'-PeCB	PCB-096	73575-54-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,4',5-PeCB	PCB-099	38380-01-7	pg/L	na		na		3.83E+01		na		2.08E+01	UFB	na		1.90E+01	UFB	na		na		na	
2,2',4,4',6-PeCB	PCB-100	39485-83-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,5,5'-PeCB	PCB-101	37680-73-2	pg/L	na		na		1.09E+02	UFB	na		5.25E+01	UFB	na		3.87E+01	UFB	na		na		na	
2,2',4,5',6-PeCB	PCB-103	60145-21-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,6,6'-PeCB	PCB-104	56558-16-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4'-PeCB	PCB-105	32598-14-4	pg/L	na		na		2.97E+01		na		1.00E+01	U	na		1.33E+01		na		na		na	
2,3,3',4,5-PeCB	PCB-106	70424-69-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4',5/2,3,3',4,5'-PeCB	PCB-107/108		pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,6-PeCB	PCB-109	74472-35-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4',6-PeCB	PCB-110	38380-03-9	pg/L	na		na		9.69E+01	UFB	na		4.64E+01	UFB	na		4.10E+01	UFB	na		na		na	
2,3,3',5,5'-PeCB	PCB-111	39635-32-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',5,6/2,3',4,4',6-PeCB	PCB-112/119		pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',5',6-PeCB	PCB-113	68194-10-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4,4',5-PeCB	PCB-114	74472-37-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4,5,6/2,3',4',5',6-PeCB	PCB-116/125		pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4,4',5-PeCB	PCB-118	31508-00-6	pg/L	na		na		7.19E+01		na		3.17E+01	UFB	na		3.16E+01	UFB	na		na		na	
2,3',4,5,5'-PeCB	PCB-120	68194-12-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4,5',6-PeCB	PCB-121	56558-18-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4',5'-PeCB	PCB-122	76842-07-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4,4',5'-PeCB	PCB-123	65510-44-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4',5,5'-PeCB	PCB-124	70424-70-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',4,4',5-PeCB	PCB-126	57465-28-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
3,3',4,5,5'-PeCB	PCB-127	39635-33-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,4'-HxCB	PCB-128	38380-07-3	pg/L	na		na		1.00E+01	U	na		na		na		3.50E+01		na		1.62E+02		na	
2,2',3,3',4,5-HxCB	PCB-129	55215-18-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.96E+01		na	
2,2',3,3',4,5'-HxCB	PCB-130	52663-66-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		4.42E+01		na	
2,2',3,3',4,6-HxCB	PCB-131	61798-70-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,6'-HxCB	PCB-132	38380-05-1	pg/L	na		na		1.21E+01	UFB	na		na		na		7.93E+01		na		2.91E+02		na	
2,2',3,3',5,5'-HxCB	PCB-133	35694-04-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.08E+01		na	
2,2',3,3',5,6-HxCB	PCB-134	52704-70-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		3.77E+01		na	
2,2',3,3',5,6'-HxCB	PCB-135	52744-13-5	pg/L	na		na		1.00E+01	U	na		na		na		2.43E+01		na		7.70E+01		na	
2,2',3,3',6,6'-HxCB	PCB-136	38411-22-2	pg/L	na		na		1.00E+01	U	na		na		na		3.79E+01		na		9.15E+01		na	
2,2',3,4,4',5-HxCB	PCB-137	35694-06-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		3.08E+01		na	
2,2',3,4,4',5'-HxCB	PCB-138	35065-28-2	pg/L	na		na		1.64E+01	UFB	na		na		na		1.68E+02		na		7.15E+02		na	
2,2',3,4,4',6/2,2',3,4',5',6-HxCB	PCB-139/149		pg/L	na		na		1.84E+01	UFB	na		na		na		1.78E+02		na		5.77E+02		na	
2,2',3,4,4',6'-HxCB	PCB-140	59291-64-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4,5,5'-HxCB	PCB-141	52712-04-6	pg/L	na		na		1.00E+01	U	na		na		na		3.34E+01		na		9.08E+01		na	
2,2',3,4,5,6-HxCB	PCB-142	41411-61-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4,5,6'-HxCB	PCB-143	68194-15-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4,5',6-HxCB	PCB-144	68194-14-9	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.95E+01		na	
2,2',3,4,6,6'-HxCB	PCB-145	74472-40-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4',5,5'-HxCB	PCB-146	51908-16-8	pg/L	na		na		1.00E+01	U	na		na		na		3.60E+01		na		9.96E+01		na	
2,2',3,4',5,6-HxCB	PCB-147	68194-13-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4',5,6'-HxCB	PCB-148	74472-41-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4',6,6'-HxCB	PCB-150	68194-08-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,5,5',6-HxCB	PCB-151	52663-63-5	pg/L	na		na		1.00E+01	U	na		na		na		5.46E+01		na		1.43E+02		na	
2,2',3,5,6,6'-HxCB	PCB-152	68194-09-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',4,4',5,5'-HxCB	PCB-153	35065-27-1	pg/L	na		na		2.13E+01	UFB	na		na		na		1.92E+02		na		6.66E+02		na	
2,2',4,4',5,6'-HxCB	PCB-154	60145-22-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',4,4',6,6'-HxCB	PCB-155	33979-03-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,4',5-HxCB	PCB-156	38380-08-4	pg/L	na		na		1.00E+01	U	na		na		na		2.02E+01		na		8.69E+01		na	
2,3,3',4,4',5'-HxCB	PCB-157	69782-90-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.75E+01		na	
2,3,3',4,4',6-HxCB	PCB-158	74472-42-7	pg/L	na		na		1.00E+01	U	na		na		na		1.84E+01		na		8.23E+01		na	
2,3,3',4,5,5'-HxCB	PCB-159	39635-35-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,5,6-HxCB	PCB-160	41411-62-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,5',6-HxCB	PCB-161	74472-43-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4',5,5'-HxCB	PCB-162	39635-34-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164		pg/L	na		na		1.00E+01	U	na		na		na		6.18E+01		na		2.06E+02		na	
2,3,3',5,5',6-HxCB	PCB-165	74472-46-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,4,4',5,6-HxCB	PCB-166	41411-63-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3',4,4',5,5'-HxCB	PCB-167	52663-72-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		3.28E+01		na	
2,3',4,4',5',6-HxCB	PCB-168	59291-65-5	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
3,3',4,4',5,5'-HxCB	PCB-169	32774-16-6	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,4',5-HpCB	PCB-170	35065-30-6	pg/L	na		na		1.00E+01	U	na		na		na		4.23E+01		na		8.58E+01		na	
2,2',3,3',4,4',6-HpCB	PCB-171	52663-71-5	pg/L	na		na		1.00E+01	U	na		na		na		1.73E+01		na		3.00E+01		na	
2,2',3,3',4,5,5'-HpCB	PCB-172	52663-74-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.23E+01	NJ	na	
2,2',3,3',4,5,6-HpCB	PCB-173	68194-16-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,5,6'-HpCB	PCB-174	38411-25-5	pg/L	na		na		1.00E+01	U	na		na		na		6.61E+01		na		1.30E+02		na	
2,2',3,3',4,5',6-HpCB	PCB-175	40186-70-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,6,6'-HpCB	PCB-176	52663-65-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.64E+01		na	
2,2',3,3',4,5',6'-HpCB	PCB-177	52663-70-4	pg/L	na		na		1.00E+01	U	na		na		na		2.85E+01		na		7.63E+01		na	
2,2',3,3',5,5',6-HpCB	PCB-178	52663-67-9	pg/L	na		na		1.00E+01	U	na		na		na		1.24E+01		na		2.89E+01		na	
2,2',3,3',5,6,6'-HpCB	PCB-179	52663-64-6	pg/L	na		na		1.00E+01	U	na		na		na		2.91E+01		na		5.54E+01		na	
2,2',3,4,4',5,5'-HpCB	PCB-180	35065-29-3	pg/L	na		na		1.00E+01	U	na		na		na		1.42E+02		na		2.67E+02		na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
3,3',4,5,5'-PeCB	PCB-127	39635-33-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4'-HxCB	PCB-128	38380-07-3	pg/L	na		na		1.38E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5-HxCB	PCB-129	55215-18-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5'-HxCB	PCB-130	52663-66-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,6-HxCB	PCB-131	61798-70-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,6'-HxCB	PCB-132	38380-05-1	pg/L	na		na		3.88E+01	UFB	na		1.78E+01	UFB	na		1.88E+01	UFB	na		na		na	
2,2',3,3',5,5'-HxCB	PCB-133	35694-04-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',5,6-HxCB	PCB-134	52704-70-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',5,6'-HxCB	PCB-135	52744-13-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',6,6'-HxCB	PCB-136	38411-22-2	pg/L	na		na		1.45E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4',5-HxCB	PCB-137	35694-06-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4',5'-HxCB	PCB-138	35065-28-2	pg/L	na		na		6.83E+01		na		3.16E+01	UFB	na		4.60E+01	UFB	na		na		na	
2,2',3,4,4',6/2,2',3,4',5',6-HxCB	PCB-139/149		pg/L	na		na		6.63E+01	UFB	na		3.09E+01	UFB	na		4.09E+01	UFB	na		na		na	
2,2',3,4,4',6'-HxCB	PCB-140	59291-64-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5,5'-HxCB	PCB-141	52712-04-6	pg/L	na		na		1.15E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5,6-HxCB	PCB-142	41411-61-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5,6'-HxCB	PCB-143	68194-15-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5',6-HxCB	PCB-144	68194-14-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,6,6'-HxCB	PCB-145	74472-40-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',5,5'-HxCB	PCB-146	51908-16-8	pg/L	na		na		1.00E+01		na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',5,6-HxCB	PCB-147	68194-13-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',5,6'-HxCB	PCB-148	74472-41-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',6,6'-HxCB	PCB-150	68194-08-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,5,5',6-HxCB	PCB-151	52663-63-5	pg/L	na		na		2.01E+01		na		1.00E+01	U	na		1.38E+01		na		na		na	
2,2',3,5,6,6'-HxCB	PCB-152	68194-09-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,4',5,5'-HxCB	PCB-153	35065-27-1	pg/L	na		na		7.08E+01	UFB	na		2.98E+01	UFB	na		5.27E+01	UFB	na		na		na	
2,2',4,4',5,6'-HxCB	PCB-154	60145-22-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',4,4',6,6'-HxCB	PCB-155	33979-03-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',5-HxCB	PCB-156	38380-08-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',5'-HxCB	PCB-157	69782-90-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',6-HxCB	PCB-158	74472-42-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,5,5'-HxCB	PCB-159	39635-35-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,5,6-HxCB	PCB-160	41411-62-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,5',6-HxCB	PCB-161	74472-43-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4',5,5'-HxCB	PCB-162	39635-34-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164		pg/L	na		na		2.16E+01		na		1.12E+01		na		1.15E+01	N	na		na		na	
2,3,3',5,5',6-HxCB	PCB-165	74472-46-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,4,4',5,6-HxCB	PCB-166	41411-63-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4,4',5,5'-HxCB	PCB-167	52663-72-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3',4,4',5',6-HxCB	PCB-168	59291-65-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
3,3',4,4',5,5'-HxCB	PCB-169	32774-16-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',5-HpCB	PCB-170	35065-30-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',6-HpCB	PCB-171	52663-71-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5,5'-HpCB	PCB-172	52663-74-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5,6-HpCB	PCB-173	68194-16-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5,6'-HpCB	PCB-174	38411-25-5	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.55E+01	N	na		na		na	
2,2',3,3',4,5',6-HpCB	PCB-175	40186-70-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,6,6'-HpCB	PCB-176	52663-65-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5',6'-HpCB	PCB-177	52663-70-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',5,5',6-HpCB	PCB-178	52663-67-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',5,6,6'-HpCB	PCB-179	52663-64-6	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4',5,5'-HpCB	PCB-180	35065-29-3	pg/L	na		na		3.53E+01		na		1.59E+01		na		3.39E+01		na		na		na	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,2',3,4,4',5,6-HpCB	PCB-181	74472-47-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4,4',5,6'/ 2,2',3,4',5,5',6-HpCB	PCB-182/187		pg/L	na		na		1.00E+01	U	na		na		na		7.48E+01		na		1.85E+02		na	
2,2',3,4,4',5',6-HpCB	PCB-183	52663-69-1	pg/L	na		na		1.00E+01	U	na		na		na		3.39E+01		na		8.68E+01		na	
2,2',3,4,4',6,6'-HpCB	PCB-184	74472-48-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4,5,5',6-HpCB	PCB-185	52712-05-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.58E+01		na	
2,2',3,4,5,6,6'-HpCB	PCB-186	74472-49-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,4',5,6,6'-HpCB	PCB-188	74487-85-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,4',5,5'-HpCB	PCB-189	39635-31-9	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.01E+01	NJ	na	
2,3,3',4,4',5,6-HpCB	PCB-190	41411-64-7	pg/L	na		na		1.00E+01	U	na		na		na		1.11E+01		na		2.30E+01		na	
2,3,3',4,4',5',6-HpCB	PCB-191	74472-50-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,5,5',6-HpCB	PCB-192	74472-51-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4',5,5',6-HpCB	PCB-193	69782-91-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,4',5,5'-OcCB	PCB-194	35694-08-7	pg/L	na		na		1.00E+01	U	na		na		na		2.13E+01		na		5.09E+01	NJ	na	
2,2',3,3',4,4',5,6-OcCB	PCB-195	52663-78-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.07E+01		na	
2,2',3,3',4,4',5,6'-OcCB	PCB-196	42740-50-1	pg/L	na		na		1.00E+01	U	na		na		na		1.57E+01		na		3.28E+01		na	
2,2',3,3',4,4',6,6'-OcCB	PCB-197	33091-17-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,5,5',6-OcCB	PCB-198	68194-17-2	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,5,5',6'-OcCB	PCB-199	52663-75-9	pg/L	na		na		1.00E+01	U	na		na		na		3.88E+01		na		8.81E+01		na	
2,2',3,3',4,5,6,6'-OcCB	PCB-200	52663-73-7	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,5',6,6'-OcCB	PCB-201	40186-71-8	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.29E+01	NJ	na	
2,2',3,3',5,5',6,6'-OcCB	PCB-202	2136-99-4	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.84E+01		na	
2,2',3,4,4',5,5',6-OcCB	PCB-203	52663-76-0	pg/L	na		na		1.00E+01	U	na		na		na		2.28E+01		na		5.63E+01		na	
2,2',3,4,4',5,6,6'-OcCB	PCB-204	74472-52-9	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,3,3',4,4',5,5',6-OcCB	PCB-205	74472-53-0	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,4',5,5',6-NoCB	PCB-206	40186-72-9	pg/L	na		na		1.00E+01	U	na		na		na		1.47E+01		na		5.06E+01		na	
2,2',3,3',4,4',5,6,6'-NoCB	PCB-207	52663-79-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.00E+01	U	na	
2,2',3,3',4,5,5',6,6'-NoCB	PCB-208	52663-77-1	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		1.76E+01		na	
2,2',3,3',4,4',5,5',6,6'-DeCB	PCB-209	2051-24-3	pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.31E+01	UFB	na	
Number of Detects =				nc		nc		5		nc		nc		nc		77		nc		105		nc	
Sum of Detects =			pg/L	nc		nc		6.94E+01		nc		nc		nc		4.65E+03		nc		1.54E+04		nc	
Polychlorinated Biphenyls (Homologs)																							
Decachlorobiphenyl			pg/L	na		na		1.00E+01	U	na		na		na		1.00E+01	U	na		2.31E+01		na	
Dichlorobiphenyls			pg/L	na		na		5.50E+01	UFB	na		na		na		3.80E+02		na		1.60E+03	JL	na	
Heptachlorobiphenyls			pg/L	na		na		1.00E+01	U	na		na		na		4.58E+02		na		1.00E+03		na	
Hexachlorobiphenyls			pg/L	na		na		5.61E+01	UFB	na		na		na		9.39E+02		na		3.51E+03		na	
Monochlorobiphenyls			pg/L	na		na		1.00E+01	U	na		na		na		7.05E+01		na		5.08E+01		na	
Nonachlorobiphenyls			pg/L	na		na		1.00E+01	U	na		na		na		1.47E+01		na		6.82E+01		na	
Octachlorobiphenyls			pg/L	na		na		1.00E+01	U	na		na		na		9.86E+01		na		2.16E+02		na	
Pentachlorobiphenyls			pg/L	na		na		8.72E+01	UFB	na		na		na		1.09E+03		na		4.62E+03		na	
Tetrachlorobiphenyls			pg/L	na		na		5.94E+01	UFB	na		na		na		9.31E+02		na		2.62E+03		na	
Trichlorobiphenyls			pg/L	na		na		7.48E+01		na		na		na		7.47E+02		na		1.90E+03		na	
Number of Detects =				nc		nc		1		nc		nc		nc		9		nc		10		nc	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
2,2',3,4,4',5,6-HpCB	PCB-181	74472-47-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4',5,6'/ 2,2',3,4',5,5',6-HpCB	PCB-182/187		pg/L	na		na		1.68E+01		na		1.11E+01	N	na		2.59E+01		na		na		na	
2,2',3,4,4',5',6-HpCB	PCB-183	52663-69-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4',6,6'-HpCB	PCB-184	74472-48-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5,5',6-HpCB	PCB-185	52712-05-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,5,6,6'-HpCB	PCB-186	74472-49-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4',5,6,6'-HpCB	PCB-188	74487-85-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',5,5'-HpCB	PCB-189	39635-31-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',5,6-HpCB	PCB-190	41411-64-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',5',6-HpCB	PCB-191	74472-50-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,5,5',6-HpCB	PCB-192	74472-51-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4',5,5',6-HpCB	PCB-193	69782-91-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',5,5'-OcCB	PCB-194	35694-08-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',5,6-OcCB	PCB-195	52663-78-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',5,6'-OcCB	PCB-196	42740-50-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.03E+01	N	na		na		na	
2,2',3,3',4,4',6,6'-OcCB	PCB-197	33091-17-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5,5',6-OcCB	PCB-198	68194-17-2	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5,5',6'-OcCB	PCB-199	52663-75-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.27E+01		na		na		na	
2,2',3,3',4,5,6,6'-OcCB	PCB-200	52663-73-7	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5',6,6'-OcCB	PCB-201	40186-71-8	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',5,5',6,6'-OcCB	PCB-202	2136-99-4	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,4,4',5,5',6-OcCB	PCB-203	52663-76-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.09E+01	N	na		na		na	
2,2',3,4,4',5,6,6'-OcCB	PCB-204	74472-52-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,3,3',4,4',5,5',6-OcCB	PCB-205	74472-53-0	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',5,5',6-NoCB	PCB-206	40186-72-9	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.10E+01	N	na		na		na	
2,2',3,3',4,4',5,6,6'-NoCB	PCB-207	52663-79-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,5,5',6,6'-NoCB	PCB-208	52663-77-1	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
2,2',3,3',4,4',5,5',6,6'-DeCB	PCB-209	2051-24-3	pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
Number of Detects =				nc		nc		38		nc		20		nc		15		nc		nc		nc	
Sum of Detects =			pg/L	nc		nc		1.06E+03		nc		3.99E+02		nc		2.26E+02	NJ	nc		nc		nc	
Polychlorinated Biphenyls (Homologs)																							
Decachlorobiphenyl			pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
Dichlorobiphenyls			pg/L	na		na		2.28E+02	JL	na		2.27E+02	JL	na		2.85E+01	UFB	na		na		na	
Heptachlorobiphenyls			pg/L	na		na		5.21E+01		na		1.59E+01		na		5.98E+01		na		na		na	
Hexachlorobiphenyls			pg/L	na		na		3.36E+02		na		1.21E+02	UFB	na		1.72E+02	UFB	na		na		na	
Monochlorobiphenyls			pg/L	na		na		3.26E+01		na		2.31E+01		na		1.00E+01	U	na		na		na	
Nonachlorobiphenyls			pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.00E+01	U	na		na		na	
Octachlorobiphenyls			pg/L	na		na		1.00E+01	U	na		1.00E+01	U	na		1.27E+01		na		na		na	
Pentachlorobiphenyls			pg/L	na		na		5.67E+02		na		2.13E+02	UFB	na		1.83E+02	UFB	na		na		na	
Tetrachlorobiphenyls			pg/L	na		na		3.54E+02	JL	na		1.32E+02		na		7.53E+01		na		na		na	
Trichlorobiphenyls			pg/L	na		na		2.87E+02		na		1.74E+02		na		4.94E+01		na		na		na	
Number of Detects =				nc		nc		7		nc		5		nc		4		nc		nc		nc	

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Bellingham STP				Bremerton STP				Burlington WWTP				City of Tacoma (Central No. 1)				Everett STP (Outfall 100)			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Metals																							
Copper		7440-50-8	ug/L	6.21E+00		2.69E+00		3.52E+00		3.96E+00		2.56E+00		5.27E+00		9.65E+00		9.16E+00		1.18E+01		5.34E+00	
Lead		7439-92-1	ug/L	4.40E-01		4.60E-01		2.80E-01		1.90E-01		3.10E-01		4.50E-01		7.20E-01		6.00E-01		1.17E+00		5.20E-01	
Zinc		7440-66-6	ug/L	3.97E+01		4.47E+01		2.17E+01		1.32E+01		4.11E+01		6.37E+01		4.45E+01		3.75E+01		2.96E+01		1.79E+01	

Key:

See User Study ID **ToxLPh3F** in the Ecology Environmental Information Management (EIM) System for more details.

The precision of the data in this table is only two significant figures.

Winter = A 24-hour composite from February 2009.
Summer = A 24-hour composite from July 2009.
co-elute = BDE049 and BDE071 coeluted in the analyses of the winter samples.
nc = Not calculated.
na = Not analyzed.
ng/L = Nanograms per liter.
pg/L = Picograms per liter.
ug/L = Micrograms per liter.

Data Qualifiers:

G = Value is likely greater than the reported result. Reported result may be biased low.
J = Analyte was positively identified. Value is the approximate concentration.
K = Bias could not be determined.
L = Value is likely less than the reported result. Reported result may be biased high.
NJ = Analyte was "tentatively identified." Value is its approximate concentration.
REJ = Datum is unusable for all purposes due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence of absence of the analyte cannot be verified.
T = The positive result is less than the quantitation limit.
U = Analyte was not detected at or above the reported result.
UFB = Result was less than three times the respective result in the field blank. In the EIM System, this qualifier was substituted with a "U" plus a note in the Result Value Comment field.
UJ = Analyte was not detected above the reported quantitation limit, which is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Appendix C. Summary of Analytical Results

Chemical of Concern	Alternate Name	CAS Number	Units	Gig Harbor STP				King County West Point				Pierce County Chambers Creek STP				Shelton STP				Sumner STP			
				Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter		Summer	
				Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Metals																							
Copper		7440-50-8	ug/L	9.28E+00		1.14E+01		1.17E+01		1.39E+01		1.19E+01		1.11E+01		7.31E+00		8.29E+00		1.32E+01		1.72E+01	
Lead		7439-92-1	ug/L	6.80E-01		6.00E-01		3.80E-01		3.90E-01		2.90E-01		3.00E-01		4.00E-01		3.50E-01		1.80E-01		1.50E-01	
Zinc		7440-66-6	ug/L	7.62E+01		9.51E+01		3.30E+01		3.86E+01		3.45E+01		3.55E+01		4.45E+01		5.31E+01		4.99E+01		5.29E+01	

Key:

See User Study ID **ToxLPh3F** in the Ecology Environmental Information Management (EIM) System for more details.

The precision of the data in this table is only two significant figures.

Winter = A 24-hour composite from February 2009.
Summer = A 24-hour composite from July 2009.
co-elute = BDE049 and BDE071 coeluted in the analyses of the winter samples.
nc = Not calculated.
na = Not analyzed.
ng/L = Nanograms per liter.
pg/L = Picograms per liter.
ug/L = Micrograms per liter.

Data Qualifiers:

G = Value is likely greater than the reported result. Reported result may be biased low.
J = Analyte was positively identified. Value is the approximate concentration.
K = Bias could not be determined.
L = Value is likely less than the reported result. Reported result may be biased high.
NJ = Analyte was "tentatively identified." Value is its approximate concentration.
REJ = Datum is unusable for all purposes due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence of absence of the analyte cannot be verified.
T = The positive result is less than the quantitation limit.
U = Analyte was not detected at or above the reported result.
UFB = Result was less than three times the respective result in the field blank. In the EIM System, this qualifier was substituted with a "U" plus a note in the Result Value Comment field.
UJ = Analyte was not detected above the reported quantitation limit, which is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Appendix D.

Percent Detection for Individual Chemicals

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
Polycyclic Aromatic Hydrocarbons (PAHs)					
Low Molecular Weight PAHs (LPAHs)					
Phenanthrene		20	6	0	**70.0**
Fluorene		20	8	0	**60.0**
Acenaphthene		20	13	0	**35.0**
Acenaphthylene		20	14	0	**30.0**
Naphthalene		20	6	8	**30.0**
Anthracene		20	16	0	**20.0**
High Molecular Weight PAHs (HPAHs)					
Pyrene		20	2	0	**90.0**
Fluoranthene		20	4	0	**80.0**
Indeno(1,2,3-cd)pyrene		20	18	0	**10.0**
Benzo(a)anthracene		20	19	0	**5.0**
Benzo(b)fluoranthene		20	19	0	**5.0**
Benzo(g,h,i)perylene		20	19	0	**5.0**
Chrysene		20	19	0	**5.0**
Benzo(a)pyrene		20	20	0	**0.0**
Benzo(k)fluoranthene		20	20	0	**0.0**
Dibenzo(a,h)anthracene		20	20	0	**0.0**
Carcinogenic PAHs (cPAHs)					
Indeno(1,2,3-cd)pyrene		20	18	0	**10.0**
Benzo(a)anthracene		20	19	0	**5.0**
Benzo(b)fluoranthene		20	19	0	**5.0**
Chrysene		20	19	0	**5.0**
Benzo(a)pyrene		20	20	0	**0.0**
Benzo(k)fluoranthene		20	20	0	**0.0**
Dibenzo(a,h)anthracene		20	20	0	**0.0**
Total PAHs (LPAHs+HPAHs)		20	1	0	**95.0**
Phthalates					
bis(2-Ethylhexyl) phthalate		20	2	0	**90.0**
Butylbenzyl phthalate		20	15	0	**25.0**
Diethyl phthalate		20	14	2	**20.0**
Di-N-butyl phthalate		20	18	0	**10.0**
Di-N-octyl phthalate		20	20	0	**0.0**
Dimethyl phthalate		20	19	1	**0.0**
Other Base/Neutral/Acid Extractables					
2-Chloroethanol phosphate (3:1)		10	0	0	**100.0**
Cholesterol		10	0	0	**100.0**
Triethyl citrate		20	0	0	**100.0**
1,4-Dichlorobenzene		20	1	0	**95.0**
2,4,6-Trichlorophenol		20	1	0	**95.0**
3B-Coprostanol		10	1	0	**90.0**
Triclosan		20	2	0	**90.0**
4-Methylphenol	p-Cresol	20	7	0	**65.0**
Dibenzofuran		20	8	0	**60.0**
Caffeine		17	7	0	**58.8**
Phenol		20	0	9	**55.0**
Bisphenol A		15	7	0	**53.3**
2,4-Dichlorophenol		20	11	0	**45.0**
2,4-Dimethylphenol		18	11	0	**38.9**
2-Methylphenol	o-Cresol	20	14	0	**30.0**
Benzyl alcohol		10	7	0	**30.0**
1-Methylnaphthalene		20	15	0	**25.0**
2,4-Dinitrophenol		20	16	0	**20.0**
2-Methylnaphthalene		20	16	0	**20.0**
Isophorone		20	16	0	**20.0**
Pentachlorophenol		20	16	0	**20.0**
2-Nitrophenol		20	17	0	**15.0**
2-Chloronaphthalene		20	18	0	**10.0**
N-Nitrosodimethylamine		10	9	0	**10.0**
bis(2-Chloroethoxy) methane		15	14	0	**6.7**
4-Nonylphenol		16	12	3	**6.3**
1,2-Dichlorobenzene		20	16	3	**5.0**
2,3,4,6-Tetrachlorophenol		20	19	0	**5.0**
N-Nitrosodiphenylamine		20	19	0	**5.0**

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
Retene		20	19	0	**5.0**
1,2,4-Trichlorobenzene		20	20	0	**0.0**
1,3-Dichlorobenzene		20	18	2	**0.0**
2,3,4,5-Tetrachlorophenol		20	20	0	**0.0**
2,4,5-Trichlorophenol		20	20	0	**0.0**
2,4-Dinitrotoluene		20	20	0	**0.0**
2,6-Dinitrotoluene		20	20	0	**0.0**
2-Chlorophenol		20	20	0	**0.0**
2-Nitroaniline	o-Nitroaniline	15	15	0	**0.0**
3,3'-Dichlorobenzidine		9	9	0	**0.0**
3-Nitroaniline	m-Nitroaniline	15	15	0	**0.0**
4,6-Dinitro-2-methylphenol		20	20	0	**0.0**
4-Bromophenylphenyl ether		20	20	0	**0.0**
4-Chloro-3-methylphenol	p-Chloro-m-cresol	20	20	0	**0.0**
4-Chlorophenylphenyl ether		20	20	0	**0.0**
4-Nitroaniline	p-Nitroaniline	10	10	0	**0.0**
4-Nitrophenol		20	20	0	**0.0**
Benzoic acid		10	5	5	**0.0**
bis(2-Chloroethyl) ether		20	20	0	**0.0**
Carbazole		20	20	0	**0.0**
Hexachlorobutadiene		20	20	0	**0.0**
Hexachlorocyclopentadiene		20	20	0	**0.0**
Hexachloroethane		20	20	0	**0.0**
Nitrobenzene		20	20	0	**0.0**
N-Nitrosodi-n-propylamine		20	20	0	**0.0**
4-Chloroaniline		0	0	0	**no data**
Pesticides					
Pentachloroanisole		10	7	0	**30.0**
Endosulfan I		20	16	0	**20.0**
Hexachlorobenzene		20	18	0	**10.0**
Toxaphene		20	18	0	**10.0**
alpha-BHC		20	19	0	**5.0**
Chlorpyriphos		20	19	0	**5.0**
2,4'-DDD		10	10	0	**0.0**
2,4'-DDE		10	10	0	**0.0**
2,4'-DDT		10	10	0	**0.0**
4,4'-DDD		20	20	0	**0.0**
4,4'-DDE		20	20	0	**0.0**
4,4'-DDT		20	20	0	**0.0**
Aldrin		20	20	0	**0.0**
beta-BHC		20	20	0	**0.0**
delta-BHC		20	20	0	**0.0**
gamma-BHC	Lindane	20	20	0	**0.0**
cis-Chlordane		20	20	0	**0.0**
trans-Chlordane		20	20	0	**0.0**
Chlordane, technical		10	10	0	**0.0**
Dacthal	DCPA	20	20	0	**0.0**
DDMU		10	10	0	**0.0**
Dieldrin		20	20	0	**0.0**
Endosulfan II		20	20	0	**0.0**
Endosulfan sulfate		20	20	0	**0.0**
Endrin		20	20	0	**0.0**
Endrin aldehyde		20	20	0	**0.0**
Endrin ketone		20	20	0	**0.0**
Heptachlor		20	20	0	**0.0**
Heptachlor epoxide		20	20	0	**0.0**
Methoxychlor		20	20	0	**0.0**
Mirex		10	10	0	**0.0**
cis-Nonachlor		20	20	0	**0.0**
trans-Nonachlor		20	20	0	**0.0**
Oxychlordane		20	20	0	**0.0**
Herbicides					
MCPP	Mecoprop	20	15	0	**25.0**
Triclopyr		20	15	0	**25.0**
2,4-D		20	17	0	**15.0**
Dicamba I		20	17	0	**15.0**
MCPA		20	17	0	**15.0**
2,4,5-T		20	20	0	**0.0**

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
2,4,5-TP	Silvex	20	20	0	**0.0**
2,4-DB	2,4-D butyric acid	19	19	0	**0.0**
3,5-Dichlorobenzoic acid		20	20	0	**0.0**
Acifluorfen	Blazer	19	19	0	**0.0**
Bentazon		20	20	0	**0.0**
Bromoxynil		20	20	0	**0.0**
Clopyralid		20	20	0	**0.0**
Dichlorprop		20	20	0	**0.0**
Diclofop-Methyl		20	20	0	**0.0**
Dinoseb		19	19	0	**0.0**
Ioxynil		20	20	0	**0.0**
Picloram		18	18	0	**0.0**
Polybrominated Diphenyl Ethers (Congeners)					
2,4,4'-TrBDE	BDE-028	20	0	0	**100.0**
2,2',4,4'-TeBDE	BDE-047	20	0	0	**100.0**
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071	10	0	0	**100.0**
2,2',4,4',5-PeBDE	BDE-099	20	0	0	**100.0**
2,2',4,4',6-PeBDE	BDE-100	20	0	0	**100.0**
2,2',4,4',5,5'-HxBDE	BDE-153	20	0	0	**100.0**
2,2',4,4',5,6'-HxBDE	BDE-154	20	0	0	**100.0**
2,2',4-TrBDE	BDE-017	20	1	0	**95.0**
2,3',4',6-TeBDE	BDE-071	10	1	0	**90.0**
2,2',3,4,4'-PeBDE	BDE-085	20	2	0	**90.0**
4,4'-DiBDE	BDE-015	20	3	0	**85.0**
2,2',4,5'-TeBDE	BDE-049	10	2	0	**80.0**
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	20	3	1	**80.0**
2,3',4,4'-TeBDE	BDE-066	20	6	0	**70.0**
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	20	6	0	**70.0**
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	20	7	0	**65.0**
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	20	7	0	**65.0**
2,2',3,4,4',5',6-HpBDE	BDE-183	20	9	0	**55.0**
2,4-DiBDE	BDE-007	20	11	0	**45.0**
2,2',3,4,4',6-HxBDE	BDE-139	20	11	0	**45.0**
2,4,6-TrBDE	BDE-030	20	13	0	**35.0**
2,2',3,4,4',6'-HxBDE	BDE-140	20	13	0	**35.0**
2,2',3,3',4,4',5,6'-OcBDE	BDE-196	20	13	0	**35.0**
2,2',3,3',4,4',6,6'/ 2,2',3,4,4',5,6,6'-OcBDE	BDE-197/204	20	13	0	**35.0**
2,2',3,4,4',5,5',6-OcBDE	BDE-203	20	13	0	**35.0**
2,2',3,4,4',5'-HxBDE	BDE-138	20	14	0	**30.0**
2,3',4,4',6-PeBDE	BDE-119	20	15	0	**25.0**
2,2',3,3',4,5',6,6'-OcBDE	BDE-201	20	15	0	**25.0**
2,2',3,4,4',6,6'-HpBDE	BDE-184	20	18	0	**10.0**
2,3,3',4,4',5/3,3',4,4',5,5'-HxBDE	BDE-156/169	20	19	0	**5.0**
2,2',3,3',4,4',6-HpBDE	BDE-171	20	19	0	**5.0**
2,2',3,4,4',5,5'-HpBDE	BDE-180	20	19	0	**5.0**
2,3,3',4,4',5',6-HpBDE	BDE-191	20	19	0	**5.0**
2,6-DiBDE	BDE-010	20	20	0	**0.0**
3,3',4,4'-TeBDE	BDE-077	20	20	0	**0.0**
3,3',4,4',5-PeBDE	BDE-126	20	20	0	**0.0**
2,3,3',4,4',5,5',6-OcBDE	BDE-205	20	20	0	**0.0**
Polybrominated Diphenyl Ethers (Homologs)					
Hexabromodiphenyl ethers		20	0	0	**100.0**
Pentabromodiphenyl ethers		20	0	0	**100.0**
Tetrabromodiphenyl ethers		20	0	0	**100.0**
Tribromodiphenyl ethers		20	0	0	**100.0**
Dibromodiphenyl ethers		20	2	0	**90.0**
Decabromodiphenyl ether		20	4	0	**80.0**
Nonabromodiphenyl ethers		20	6	0	**70.0**
Heptabromodiphenyl ethers		20	9	0	**55.0**
Octabromodiphenyl ethers		20	12	0	**40.0**

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
Perfluorinated Compounds					
Perfluorodecanoate	PFDA	20	0	0	**100.0**
Perfluoroheptanoate	PFHpA	20	0	0	**100.0**
Perfluorohexanoate	PFHxA	20	0	0	**100.0**
Perfluorononanoate	PFNA	20	0	0	**100.0**
Perfluorooctanoate	PFOA	20	0	0	**100.0**
Perfluorooctane sulfonate	PFOS	20	2	0	**90.0**
Perfluoropentanoate	PFPeA	20	3	0	**85.0**
Perfluorohexane sulfonate	PFHxS	20	7	0	**65.0**
Perfluorobutanoate	PFBA	20	8	0	**60.0**
Perfluorobutane sulfonate	PFBS	20	17	0	**15.0**
Perfluorooctane sulfonamide	PFOSA	20	18	0	**10.0**
Perfluoroundecanoate	PFUnA	20	19	0	**5.0**
Perfluorododecanoate	PFDoA	20	20	0	**0.0**
Polychlorinated Biphenyls (Congeners)					
2,4,4'-TrCB	PCB-028	6	0	0	**100.0**
2,4',5-TrCB	PCB-031	6	0	0	**100.0**
2,2',3-TrCB	PCB-016	6	1	0	**83.3**
2,3,3'/2,3',4'-TriCB	PCB-020/033	6	1	0	**83.3**
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	6	1	0	**83.3**
2,3',4,4'-TeCB	PCB-066	6	1	0	**83.3**
2,2',3,5,5'-PeCB	PCB-092	6	1	0	**83.3**
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	6	1	0	**83.3**
2,2',3,4,4',5,5'-HpCB	PCB-180	6	1	0	**83.3**
2,2',3,4,4',5,6'/ 2,2',3,4',5,5',6-HpCB	PCB-182/187	6	1	0	**83.3**
2-MoCB	PCB-001	6	2	0	**66.7**
2,2'-DiCB	PCB-004	6	2	0	**66.7**
2,3'-DiCB	PCB-006	6	2	0	**66.7**
2,2',4-TrCB	PCB-017	6	2	0	**66.7**
2,2',5-TrCB	PCB-018	6	0	2	**66.7**
2,3,4'-TrCB	PCB-022	6	2	0	**66.7**
3,4,4'-TrCB	PCB-037	6	2	0	**66.7**
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	6	2	0	**66.7**
2,2',3,4',6-PeCB	PCB-091	6	2	0	**66.7**
2,3,3',4,4'-PeCB	PCB-105	6	2	0	**66.7**
2,2',3,5,5',6-HxCB	PCB-151	6	2	0	**66.7**
4-MoCB	PCB-003	6	3	0	**50.0**
2,2',4,4'/2,2',4,5-TeCB	PCB-047/048	6	3	0	**50.0**
2,2',5,6'-TeCB	PCB-053	6	3	0	**50.0**
2,3,3',4'-TeCB	PCB-056	6	3	0	**50.0**
2,3,4',6/2,3',5,5'-TeCB	PCB-064/072	6	3	0	**50.0**
2,4,4',5-TeCB	PCB-074	6	3	0	**50.0**
2,2',3,3',4-PeCB	PCB-082	6	3	0	**50.0**
2,2',3,3',6-PeCB	PCB-084	6	3	0	**50.0**
2,2',3,4,4'-PeCB	PCB-085	6	3	0	**50.0**
2,2',4,4',5-PeCB	PCB-099	6	1	2	**50.0**
2,3',4,4',5-PeCB	PCB-118	6	0	3	**50.0**
2,2',3,3',4,4'-HxCB	PCB-128	6	3	0	**50.0**
2,2',3,3',6,6'-HxCB	PCB-136	6	3	0	**50.0**
2,2',3,4,4',5'-HxCB	PCB-138	6	0	3	**50.0**
2,2',3,4,5,5'-HxCB	PCB-141	6	3	0	**50.0**
2,2',3,4',5,5'-HxCB	PCB-146	6	3	0	**50.0**
2,2',3,3',4,5,6'-HpCB	PCB-174	6	3	0	**50.0**
2,2',3,3',4,4',5,6'-OcCB	PCB-196	6	3	0	**50.0**
2,2',3,3',4,5,5',6'-OcCB	PCB-199	6	3	0	**50.0**
2,2',3,4,4',5,5',6-OcCB	PCB-203	6	3	0	**50.0**
2,2',3,3',4,4',5,5',6-NoCB	PCB-206	6	3	0	**50.0**
2,4-DiCB	PCB-007	6	4	0	**33.3**
3,4/3,4'-DiCB	PCB-012/013	6	4	0	**33.3**
4,4'-DiCB	PCB-015	6	0	4	**33.3**
2,2',6-TrCB	PCB-019	6	4	0	**33.3**
2,3',4-TrCB	PCB-025	6	4	0	**33.3**
2,3',5-TrCB	PCB-026	6	4	0	**33.3**
2,4',6-TrCB	PCB-032	6	4	0	**33.3**

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
2,2',3,3'-TeCB	PCB-040	6	4	0	**33.3**
2,3,4',6-TeCB	PCB-041	6	4	0	**33.3**
2,2',3,4'-TeCB	PCB-042	6	4	0	**33.3**
2,2',3,5'-TeCB	PCB-044	6	0	4	**33.3**
2,2',3,6-TeCB	PCB-045	6	4	0	**33.3**
2,3,4,4'-TeCB	PCB-060	6	4	0	**33.3**
2,3',4',5-TeCB	PCB-070	6	0	4	**33.3**
2,3',4',6-TeCB	PCB-071	6	4	0	**33.3**
2,2',3,3',5-PeCB	PCB-083	6	4	0	**33.3**
2,2',3,4,5/2,2',3,4',5'/ 2,3,4',5,6-PeCB	PCB-086/097/117	6	3	1	**33.3**
2,2',3,4,5'/2,3,4,4',6-PeCB	PCB-087/115	6	0	4	**33.3**
2,2',3,5,6/2,2',3,5',6/2,2',3,4',6'/ 2,2',4,5,6'-PeCB	PCB-093/095/098/102	6	0	4	**33.3**
2,2',4,5,5'-PeCB	PCB-101	6	0	4	**33.3**
2,3,3',4',6-PeCB	PCB-110	6	0	4	**33.3**
2,2',3,3',4,6'-HxCB	PCB-132	6	0	4	**33.3**
2,2',3,3',5,6'-HxCB	PCB-135	6	4	0	**33.3**
2,2',3,4,4',6/2,2',3,4',5',6-HxCB	PCB-139/149	6	0	4	**33.3**
2,2',4,4',5,5'-HxCB	PCB-153	6	0	4	**33.3**
2,3,3',4,4',5-HxCB	PCB-156	6	4	0	**33.3**
2,3,3',4,4',6-HxCB	PCB-158	6	4	0	**33.3**
2,2',3,3',4,4',5-HpCB	PCB-170	6	4	0	**33.3**
2,2',3,3',4,4',6-HpCB	PCB-171	6	4	0	**33.3**
2,2',3,3',4,5',6'-HpCB	PCB-177	6	4	0	**33.3**
2,2',3,3',5,5',6-HpCB	PCB-178	6	4	0	**33.3**
2,2',3,3',5,6,6'-HpCB	PCB-179	6	4	0	**33.3**
2,2',3,4,4',5',6-HpCB	PCB-183	6	4	0	**33.3**
2,3,3',4,4',5,6-HpCB	PCB-190	6	4	0	**33.3**
2,2',3,3',4,4',5,5'-OcCB	PCB-194	6	4	0	**33.3**
2,3/2,4'-DiCB	PCB-005/008	6	5	0	**16.7**
2,5-DiCB	PCB-009	6	5	0	**16.7**
2,3',6-TrCB	PCB-027	6	5	0	**16.7**
3,3',4-TrCB	PCB-035	6	5	0	**16.7**
3,3',5-TrCB	PCB-036	6	5	0	**16.7**
2,2',3,6'-TeCB	PCB-046	6	5	0	**16.7**
2,2',4,6'-TeCB	PCB-051	6	5	0	**16.7**
2,3',4,5-TeCB	PCB-067	6	5	0	**16.7**
3,3',4,4'-TeCB	PCB-077	6	5	0	**16.7**
2,3,3',4',5/2,3,3',4,5'-PeCB	PCB-107/108	6	5	0	**16.7**
2,3,4,4',5-PeCB	PCB-114	6	5	0	**16.7**
2,3',4,4',5'-PeCB	PCB-123	6	5	0	**16.7**
2,3',4',5,5'-PeCB	PCB-124	6	5	0	**16.7**
3,3',4,4',5-PeCB	PCB-126	6	5	0	**16.7**
2,2',3,3',4,5-HxCB	PCB-129	6	5	0	**16.7**
2,2',3,3',4,5'-HxCB	PCB-130	6	5	0	**16.7**
2,2',3,3',5,5'-HxCB	PCB-133	6	5	0	**16.7**
2,2',3,3',5,6-HxCB	PCB-134	6	5	0	**16.7**
2,2',3,4,4',5-HxCB	PCB-137	6	5	0	**16.7**
2,2',3,4,5',6-HxCB	PCB-144	6	5	0	**16.7**
2,3,3',4,4',5'-HxCB	PCB-157	6	5	0	**16.7**
2,3',4,4',5,5'-HxCB	PCB-167	6	5	0	**16.7**
2,2',3,3',4,5,5'-HpCB	PCB-172	6	5	0	**16.7**
2,2',3,3',4,6,6'-HpCB	PCB-176	6	5	0	**16.7**
2,2',3,4,5,5',6-HpCB	PCB-185	6	5	0	**16.7**
2,3,3',4,4',5,5'-HpCB	PCB-189	6	5	0	**16.7**
2,2',3,3',4,4',5,6-OcCB	PCB-195	6	5	0	**16.7**
2,2',3,3',4,5',6,6'-OcCB	PCB-201	6	5	0	**16.7**
2,2',3,3',5,5',6,6'-OcCB	PCB-202	6	5	0	**16.7**
2,2',3,3',4,5,5',6,6'-NoCB	PCB-208	6	5	0	**16.7**
3-MoCB	PCB-002	6	6	0	**0.0**
2,6-DiCB	PCB-010	6	6	0	**0.0**
3,3'-DiCB	PCB-011	6	6	0	**0.0**
3,5-DiCB	PCB-014	6	6	0	**0.0**
2,3,4-TrCB	PCB-021	6	6	0	**0.0**

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
2,3,5-TrCB	PCB-023	6	6	0	**0.0**
2,3,6-TrCB	PCB-024	6	6	0	**0.0**
2,4,5-TrCB	PCB-029	6	6	0	**0.0**
2,4,6-TrCB	PCB-030	6	6	0	**0.0**
2,3',5'-TrCB	PCB-034	6	6	0	**0.0**
3,4,5-TrCB	PCB-038	6	6	0	**0.0**
3,4',5-TrCB	PCB-039	6	6	0	**0.0**
2,2',4,6-TeCB	PCB-050	6	6	0	**0.0**
2,2',6,6'-TeCB	PCB-054	6	6	0	**0.0**
2,3,3',4-TeCB	PCB-055	6	6	0	**0.0**
2,3,3',5-TeCB	PCB-057	6	6	0	**0.0**
2,3,3',5'-TeCB	PCB-058	6	6	0	**0.0**
2,3,3',6-TeCB	PCB-059	6	6	0	**0.0**
2,3,4,5-TeCB	PCB-061	6	6	0	**0.0**
2,3,4,6-TeCB	PCB-062	6	6	0	**0.0**
2,3,4',5-TeCB	PCB-063	6	6	0	**0.0**
2,3,5,6/2,4,4',6-TeCB	PCB-065/075	6	6	0	**0.0**
2,2',3,4-TeCB	PCB-068	6	6	0	**0.0**
2,2',5,5'-TeCB	PCB-073	6	6	0	**0.0**
2,3',4',5'-TeCB	PCB-076	6	6	0	**0.0**
3,3',4,5-TeCB	PCB-078	6	6	0	**0.0**
3,3',4,5'-TeCB	PCB-079	6	6	0	**0.0**
3,3',5,5'-TeCB	PCB-080	6	6	0	**0.0**
3,4,4',5-TeCB	PCB-081	6	6	0	**0.0**
2,2',3,4,6-PeCB	PCB-088	6	6	0	**0.0**
2,2',3,4,6'-PeCB	PCB-089	6	6	0	**0.0**
2,2',3,4',5-PeCB	PCB-090	6	6	0	**0.0**
2,2',3,5,6'-PeCB	PCB-094	6	6	0	**0.0**
2,2',3,6,6'-PeCB	PCB-096	6	6	0	**0.0**
2,2',4,4',6-PeCB	PCB-100	6	6	0	**0.0**
2,2',4,5',6-PeCB	PCB-103	6	6	0	**0.0**
2,2',4,6,6'-PeCB	PCB-104	6	6	0	**0.0**
2,3,3',4,5-PeCB	PCB-106	6	6	0	**0.0**
2,3,3',4,6-PeCB	PCB-109	6	6	0	**0.0**
2,3,3',5,5'-PeCB	PCB-111	6	6	0	**0.0**
2,3,3',5,6/2,3',4,4',6-PeCB	PCB-112/119	6	6	0	**0.0**
2,3,3',5',6-PeCB	PCB-113	6	6	0	**0.0**
2,3,4,5,6/2,3',4',5',6-PeCB	PCB-116/125	6	6	0	**0.0**
2,3',4,5,5'-PeCB	PCB-120	6	6	0	**0.0**
2,3',4,5',6-PeCB	PCB-121	6	6	0	**0.0**
2,3,3',4',5'-PeCB	PCB-122	6	6	0	**0.0**
3,3',4,5,5'-PeCB	PCB-127	6	6	0	**0.0**
2,2',3,3',4,6-HxCB	PCB-131	6	6	0	**0.0**
2,2',3,4,4',6'-HxCB	PCB-140	6	6	0	**0.0**
2,2',3,4,5,6-HxCB	PCB-142	6	6	0	**0.0**
2,2',3,4,5,6'-HxCB	PCB-143	6	6	0	**0.0**
2,2',3,4,6,6'-HxCB	PCB-145	6	6	0	**0.0**
2,2',3,4',5,6-HxCB	PCB-147	6	6	0	**0.0**
2,2',3,4',5,6'-HxCB	PCB-148	6	6	0	**0.0**
2,2',3,4',6,6'-HxCB	PCB-150	6	6	0	**0.0**
2,2',3,5,6,6'-HxCB	PCB-152	6	6	0	**0.0**
2,2',4,4',5,6'-HxCB	PCB-154	6	6	0	**0.0**
2,2',4,4',6,6'-HxCB	PCB-155	6	6	0	**0.0**
2,3,3',4,5,5'-HxCB	PCB-159	6	6	0	**0.0**
2,3,3',4,5,6-HxCB	PCB-160	6	6	0	**0.0**
2,3,3',4,5',6-HxCB	PCB-161	6	6	0	**0.0**
2,3,3',4',5,5'-HxCB	PCB-162	6	6	0	**0.0**
2,3,3',5,5',6-HxCB	PCB-165	6	6	0	**0.0**
2,3,4,4',5,6-HxCB	PCB-166	6	6	0	**0.0**
2,3',4,4',5',6-HxCB	PCB-168	6	6	0	**0.0**
3,3',4,4',5,5'-HxCB	PCB-169	6	6	0	**0.0**
2,2',3,3',4,5,6-HpCB	PCB-173	6	6	0	**0.0**
2,2',3,3',4,5',6-HpCB	PCB-175	6	6	0	**0.0**
2,2',3,4,4',5,6-HpCB	PCB-181	6	6	0	**0.0**
2,2',3,4,4',6,6'-HpCB	PCB-184	6	6	0	**0.0**

Appendix D. Percent Detection for Individual Chemicals

Chemical of Concern	Alternate Name	Number of Valid Results	Number of Laboratory Non-Detects (a)	Number of Field/Rinseate Non-Detects (b)	Percent Detection (c)
2,2',3,4,5,6,6'-HpCB	PCB-186	6	6	0	**0.0**
2,2',3,4',5,6,6'-HpCB	PCB-188	6	6	0	**0.0**
2,3,3',4,4',5',6-HpCB	PCB-191	6	6	0	**0.0**
2,3,3',4,5,5',6-HpCB	PCB-192	6	6	0	**0.0**
2,3,3',4',5,5',6-HpCB	PCB-193	6	6	0	**0.0**
2,2',3,3',4,4',6,6'-OcCB	PCB-197	6	6	0	**0.0**
2,2',3,3',4,5,5',6-OcCB	PCB-198	6	6	0	**0.0**
2,2',3,3',4,5,6,6'-OcCB	PCB-200	6	6	0	**0.0**
2,2',3,4,4',5,6,6'-OcCB	PCB-204	6	6	0	**0.0**
2,3,3',4,4',5,5',6-OcCB	PCB-205	6	6	0	**0.0**
2,2',3,3',4,4',5,6,6'-NoCB	PCB-207	6	6	0	**0.0**
2,2',3,3',4,4',5,5',6,6'-DeCB	PCB-209	6	5	1	**0.0**
Polychlorinated Biphenyls (Homologs)					
Trichlorobiphenyls		6	0	0	**100.0**
Heptachlorobiphenyls		6	1	0	**83.3**
Tetrachlorobiphenyls		6	0	1	**83.3**
Dichlorobiphenyls		6	0	2	**66.7**
Monochlorobiphenyls		6	2	0	**66.7**
Hexachlorobiphenyls		6	0	3	**50.0**
Octachlorobiphenyls		6	3	0	**50.0**
Pentachlorobiphenyls		6	0	3	**50.0**
Nonachlorobiphenyls		6	4	0	**33.3**
Decachlorobiphenyl		6	5	0	**16.7**
Metals					
Copper		20	0	0	**100.0**
Lead		20	0	0	**100.0**
Zinc		20	0	0	**100.0**

Key:

The number of valid results varies for each chemical because some results were rejected for quality assurance reasons, and not all chemicals were sampled and analyzed the same number of times for each event.

(a) = Results qualified with a "U" because the analyte was not detected at or above the reported quantitation limit.

(b) = Results qualified with a "UFB" because the result was not at least 3 times the concentration in the respective field or rinseate blank.

(c) = ((Valid Results - Laboratory Non-Detects - Field/Rinseate Non-Detects) / Valid Results) x 100%

Appendix E.

Summary Statistics

Appendix E. Summary Statistics

Chemical of Concern	Alternate Name	Units	Sample Size	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
Polycyclic Aromatic Hydrocarbons (PAHs)								
Low Molecular Weight PAHs (LPAHs)								
Fluorene		ug/L	20	8.04E-04	1.43E-03	7.95E-03	1.90E-02	1.72E-01
Phenanthrene		ug/L	20	3.85E-03	4.89E-03	5.70E-03	1.45E-02	6.63E-02
Entire Chemical Class:		ug/L	20	3.84E-03	6.97E-03	1.72E-02	7.43E-02	7.22E-01
High Molecular Weight PAHs (HPAHs)								
Fluoranthene		ug/L	20	3.62E-03	4.23E-03	4.75E-03	8.43E-03	1.01E-02
Pyrene		ug/L	20	4.25E-03	4.68E-03	6.15E-03	8.60E-03	1.87E-02
Entire Chemical Class:		ug/L	20	4.29E-03	7.90E-03	1.05E-02	1.59E-02	4.80E-02
Total PAHs (LPAHs+HPAHs)		ug/L	20	5.19E-03	1.61E-02	3.95E-02	9.77E-02	7.32E-01
Phthalates								
bis(2-Ethylhexyl) phthalate		ug/L	20	2.38E-01	4.60E-01	9.35E-01	1.93E+00	3.50E+00
Entire Chemical Class:		ug/L	20	2.38E-01	4.60E-01	1.17E+00	1.93E+00	3.50E+00
Other Base/Neutral/Acid Extractables								
1,4-Dichlorobenzene		ug/L	20	7.00E-02	1.33E-01	2.15E-01	4.80E-01	9.27E-01
2,4,6-Trichlorophenol		ug/L	20	2.87E-02	4.83E-02	9.50E-02	1.53E-01	2.72E-01
2-Chloroethanol phosphate (3:1)		ug/L	10	7.90E-02	1.60E-01	2.30E-01	3.05E-01	4.21E-01
3B-Coprostanol		ug/L	10	3.58E+00	6.50E+00	9.05E+00	1.48E+01	1.78E+01
4-Methylphenol	p-Cresol	ug/L	20	1.20E-01	2.10E-01	3.27E-01	4.97E-01	3.07E+00
Bisphenol A		ug/L	15	2.00E-01	2.65E-01	2.80E-01	7.55E-01	1.32E+00
Caffeine		ug/L	17	1.88E-02	6.17E-02	1.51E-01	7.00E-01	1.80E+01
Cholesterol		ug/L	10	6.25E+00	8.43E+00	1.25E+01	1.70E+01	2.80E+01
Dibenzofuran		ug/L	20	1.82E-03	2.53E-03	6.15E-03	1.68E-02	1.90E-01
Phenol		ug/L	20	4.09E-01	4.13E-01	7.35E-01	1.03E+00	1.57E+00
Triclosan		ug/L	20	1.78E-01	3.45E-01	5.40E-01	8.53E-01	1.02E+00
Triethyl citrate		ug/L	20	1.28E-01	4.98E-01	8.25E-01	1.10E+00	1.51E+00
Polybrominated Diphenyl Ethers (Congeners)								
4,4'-DiBDE	BDE-015	pg/L	20	1.96E+00	8.71E+00	1.22E+01	4.66E+01	1.46E+02
2,2',4-TrBDE	BDE-017	pg/L	20	2.58E+01	4.45E+01	8.53E+01	2.76E+02	4.61E+02
2,4,4'-TrBDE	BDE-028	pg/L	20	7.39E+01	9.65E+01	1.95E+02	4.60E+02	1.07E+03
2,2',4,4'-TeBDE	BDE-047	pg/L	20	3.32E+03	5.33E+03	6.54E+03	1.06E+04	3.24E+04
2,2',4,5'-TeBDE	BDE-049	pg/L	10	1.52E+01	6.28E+01	2.17E+02	3.24E+02	9.43E+02
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071	pg/L	10	1.73E+02	2.03E+02	3.46E+02	5.58E+02	1.12E+03
2,3',4,4'-TeBDE	BDE-066	pg/L	20	1.52E+01	4.62E+01	1.52E+02	4.05E+02	1.06E+03

Appendix E. Summary Statistics

Chemical of Concern	Alternate Name	Units	Sample Size	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
2,3',4',6-TeBDE	BDE-071	pg/L	10	1.44E+01	3.67E+01	4.60E+01	1.36E+02	3.89E+02
2,2',3,4,4'-PeBDE	BDE-085	pg/L	20	6.98E+01	1.86E+02	2.56E+02	4.56E+02	1.23E+03
2,2',4,4',5-PeBDE	BDE-099	pg/L	20	2.25E+03	4.57E+03	6.30E+03	1.40E+04	3.27E+04
2,2',4,4',6-PeBDE	BDE-100	pg/L	20	5.51E+02	1.00E+03	1.28E+03	2.51E+03	6.66E+03
2,2',4,4',5,5'-HxBDE	BDE-153	pg/L	20	2.07E+02	3.57E+02	5.43E+02	1.38E+03	3.35E+03
2,2',4,4',5,6'-HxBDE	BDE-154	pg/L	20	1.48E+02	3.12E+02	4.04E+02	8.54E+02	2.31E+03
2,2',3,4,4',5',6-HpBDE	BDE-183	pg/L	20	6.82E+00	1.39E+01	4.39E+01	1.09E+02	4.96E+02
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	pg/L	20	3.84E+01	9.12E+01	2.65E+02	6.55E+02	2.32E+03
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	pg/L	20	3.63E+01	1.11E+02	2.53E+02	5.85E+02	2.26E+03
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	pg/L	20	1.68E+01	4.59E+01	1.23E+02	4.26E+02	1.59E+03
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	pg/L	20	6.61E+02	1.95E+03	3.20E+03	9.30E+03	2.27E+04
Entire Chemical Class:		pg/L	20	9.07E+03	1.49E+04	2.25E+04	4.41E+04	1.26E+05
Polybrominated Diphenyl Ethers (Homologs)								
Decabromodiphenyl ether		pg/L	20	6.61E+02	1.95E+03	3.20E+03	9.30E+03	2.27E+04
Dibromodiphenyl ethers		pg/L	20	2.13E+00	9.30E+00	1.56E+01	5.72E+01	1.62E+02
Heptabromodiphenyl ethers		pg/L	20	6.42E+00	1.36E+01	4.43E+01	1.09E+02	5.08E+02
Hexabromodiphenyl ethers		pg/L	20	3.51E+02	6.47E+02	1.02E+03	2.40E+03	6.36E+03
Nonabromodiphenyl ethers		pg/L	20	6.22E+01	1.41E+02	6.26E+02	1.64E+03	6.43E+03
Pentabromodiphenyl ethers		pg/L	20	2.85E+03	5.95E+03	7.91E+03	1.72E+04	4.06E+04
Tetrabromodiphenyl ethers		pg/L	20	3.78E+03	5.52E+03	7.21E+03	1.13E+04	3.48E+04
Tribromodiphenyl ethers		pg/L	20	9.95E+01	1.53E+02	2.84E+02	6.65E+02	1.54E+03
Perfluorinated Compounds								
Perfluorobutanoate	PFBA	ng/L	20	7.33E-01	8.80E-01	1.38E+00	2.59E+00	3.66E+00
Perfluorodecanoate	PFDA	ng/L	20	1.53E+00	2.60E+00	3.62E+00	5.69E+00	7.98E+00
Perfluoroheptanoate	PFHpA	ng/L	20	2.72E+00	3.69E+00	4.69E+00	6.12E+00	9.72E+00
Perfluorohexane sulfonate	PFHxS	ng/L	20	1.26E+00	1.27E+00	2.61E+00	3.63E+00	7.81E+00
Perfluorohexanoate	PFHxA	ng/L	20	1.07E+01	1.29E+01	1.67E+01	2.69E+01	4.47E+01
Perfluorononanoate	PFNA	ng/L	20	2.31E+00	3.68E+00	6.05E+00	1.25E+01	3.40E+01
Perfluorooctane sulfonate	PFOS	ng/L	20	1.35E+00	4.05E+00	5.96E+00	9.78E+00	2.29E+01
Perfluorooctanoate	PFOA	ng/L	20	1.11E+01	1.30E+01	2.35E+01	3.46E+01	5.34E+01
Perfluoropentanoate	PFPeA	ng/L	20	7.00E-01	1.89E+00	2.62E+00	9.50E+00	1.66E+01
Entire Chemical Class:		pg/L	20	4.58E+01	6.69E+01	9.05E+01	1.25E+02	1.62E+02
Polychlorinated Biphenyls (Congeners)								
2-MoCB	PCB-001	pg/L	6	5.00E+00	6.28E+00	1.46E+01	3.58E+01	4.85E+01
2,2'-DiCB	PCB-004	pg/L	6	5.00E+00	1.10E+01	3.80E+01	7.53E+01	8.01E+02
2,3'-DiCB	PCB-006	pg/L	6	5.00E+00	7.40E+00	1.57E+01	2.09E+01	2.85E+01

Appendix E. Summary Statistics

Chemical of Concern	Alternate Name	Units	Sample Size	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
2,2',3-TrCB	PCB-016	pg/L	6	7.33E+00	1.52E+01	2.68E+01	4.54E+01	7.83E+01
2,2',4-TrCB	PCB-017	pg/L	6	5.00E+00	7.08E+00	1.74E+01	4.10E+01	1.36E+02
2,2',5-TrCB	PCB-018	pg/L	6	8.28E+00	1.70E+01	5.54E+01	1.20E+02	2.33E+02
2,3,3'/2,3',4'-TriCB	PCB-020/033	pg/L	6	7.18E+00	1.47E+01	2.55E+01	7.93E+01	9.61E+01
2,3,4'-TrCB	PCB-022	pg/L	6	5.00E+00	6.88E+00	1.63E+01	4.57E+01	1.08E+02
2,4,4'-TrCB	PCB-028	pg/L	6	1.49E+01	1.71E+01	3.18E+01	9.75E+01	2.42E+02
2,4',5-TrCB	PCB-031	pg/L	6	1.56E+01	1.98E+01	3.98E+01	1.05E+02	2.48E+02
3,4,4'-TrCB	PCB-037	pg/L	6	5.00E+00	7.53E+00	1.81E+01	3.21E+01	9.22E+01
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	pg/L	6	7.33E+00	1.59E+01	2.87E+01	8.02E+01	2.07E+02
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	pg/L	6	1.09E+01	2.13E+01	6.68E+01	1.35E+02	3.89E+02
2,3',4,4'-TeCB	PCB-066	pg/L	6	6.38E+00	1.07E+01	2.08E+01	7.67E+01	2.07E+02
2,2',3,4',6-PeCB	PCB-091	pg/L	6	5.00E+00	6.55E+00	1.15E+01	2.10E+01	6.06E+01
2,2',3,5,5'-PeCB	PCB-092	pg/L	6	6.45E+00	1.18E+01	2.04E+01	4.03E+01	1.48E+02
2,3,3',4,4'-PeCB	PCB-105	pg/L	6	5.00E+00	7.08E+00	2.15E+01	4.98E+01	2.16E+02
2,2',3,5,5',6-HxCB	PCB-151	pg/L	6	5.00E+00	7.20E+00	1.70E+01	4.60E+01	1.21E+02
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	pg/L	6	6.55E+00	1.13E+01	1.65E+01	5.18E+01	1.70E+02
2,2',3,4,4',5,5'-HpCB	PCB-180	pg/L	6	7.73E+00	2.04E+01	3.46E+01	1.15E+02	2.36E+02
2,2',3,4,4',5,6'/2,2',3,4',5,5',6-HpCB	PCB-182/187	pg/L	6	6.52E+00	1.25E+01	2.14E+01	6.26E+01	1.57E+02
Entire Chemical Class:		pg/L	6	1.09E+02	2.69E+02	7.30E+02	3.73E+03	1.26E+04
Polychlorinated Biphenyls (Homologs)								
Dichlorobiphenyls		pg/L	6	1.76E+01	7.75E+01	2.27E+02	3.42E+02	1.29E+03
Heptachlorobiphenyls		pg/L	6	7.73E+00	2.50E+01	5.60E+01	3.58E+02	8.65E+02
Monochlorobiphenyls		pg/L	6	5.00E+00	9.53E+00	2.79E+01	4.63E+01	6.56E+01
Tetrachlorobiphenyls		pg/L	6	4.11E+01	8.95E+01	2.43E+02	7.87E+02	2.20E+03
Trichlorobiphenyls		pg/L	6	5.58E+01	9.97E+01	2.31E+02	6.32E+02	1.61E+03
Metals								
Copper		ug/L	20	2.68E+00	5.32E+00	9.22E+00	1.17E+01	1.41E+01
Lead		ug/L	20	1.79E-01	2.98E-01	3.95E-01	5.40E-01	7.43E-01
Zinc		ug/L	20	1.77E+01	3.41E+01	4.04E+01	5.07E+01	7.71E+01

Key:

The precision of the data in this table is only two significant figures.

Appendix F.

Comparision of Two Methods for Handling Non-Detect Values

Appendix F. Comparison of Two Methods for Handling Non-Detect Values (Regression on Order Statistics versus Substitution)

Chemical of Concern	Alternate Name	Relative Percent Differences Substitute Non-Detect Values with:		
		Zero	Half the Reporting Limit	Reporting Limit
Polycyclic Aromatic Hydrocarbons				
Low Molecular Weight PAHs (LPAHs)				
Fluorene		0.0%	0.0%	0.0%
Phenanthrene		0.0%	0.0%	**9.2%**
Entire Chemical Class =		0.0%	0.0%	**15.3%**
High Molecular Weight PAHs (HPAHs)				
Fluoranthene		0.0%	0.0%	**23.3%**
Pyrene		0.0%	0.0%	**2.4%**
Entire Chemical Class =		0.0%	0.0%	**7.3%**
Total PAHs (LPAHs+HPAHs)		0.0%	0.0%	0.0%
Phthalates				
bis(2-Ethylhexyl) phthalate		0.0%	0.0%	**11.6%**
Entire Chemical Class =		0.0%	0.0%	0.0%
Other Base/Neutral/Acid Extractables				
1,4-Dichlorobenzene		0.0%	0.0%	0.0%
2,4,6-Trichlorophenol		0.0%	0.0%	0.0%
3B-Coprostanol		0.0%	0.0%	0.0%
4-Methylphenol	p-Cresol	**43.5%**	**58.2%**	**78.0%**
Bisphenol A		**33.3%**	**6.9%**	**72.7%**
Caffeine		**40.9%**	**5.5%**	**71.5%**
Dibenzofuran		0.0%	0.0%	**7.8%**
Phenol		0.0%	0.0%	**2.0%**
Triclosan		0.0%	0.0%	**1.8%**
Polybrominated Diphenyl Ethers (Congeners)				
4,4'-DiBDE	BDE-015	0.0%	**2.8%**	**16.5%**
2,2',4-TrBDE	BDE-017	0.0%	0.0%	0.0%
2,2',4,5'-TeBDE	BDE-049	0.0%	0.0%	0.0%
2,3',4,4'-TeBDE	BDE-066	0.0%	0.0%	0.0%
2,3',4',6-TeBDE	BDE-071	0.0%	0.0%	0.0%
2,2',3,4,4'-PeBDE	BDE-085	0.0%	0.0%	0.0%
2,2',3,4,4',5',6-HpBDE	BDE-183	**44.1%**	**12.9%**	**46.8%**
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	0.0%	0.0%	**0.8%**
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	0.0%	0.0%	**3.9%**
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	0.0%	**1.6%**	**66.3%**
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	0.0%	0.0%	0.0%
Entire Chemical Class =		0.0%	0.0%	0.0%

Appendix F. Comparison of Two Methods for Handling Non-Detect Values (Regression on Order Statistics versus Substitution)

Chemical of Concern	Alternate Name	Relative Percent Differences Substitute Non-Detect Values with:		
		Zero	Half the Reporting Limit	Reporting Limit
Polybrominated Diphenyl Ethers (Homologs)				
Decabromodiphenyl ether		0.0%	0.0%	0.0%
Dibromodiphenyl ethers		0.0%	0.0%	0.0%
Heptabromodiphenyl ethers		**45.0%**	**12.0%**	**58.5%**
Nonabromodiphenyl ethers		0.0%	0.0%	0.0%
Perfluorinated Compounds				
Perfluorobutanoate	PFBA	0.0%	0.0%	**3.6%**
Perfluorohexane sulfonate	PFHxS	0.0%	0.0%	0.0%
Perfluorooctane sulfonate	PFOS	0.0%	0.0%	0.0%
Perfluoropentanoate	PFPeA	0.0%	0.0%	0.0%
	Entire Chemical Class =	0.0%	0.0%	0.0%
Polychlorinated Biphenyls (Congeners)				
2-MoCB	PCB-001	0.0%	0.0%	0.0%
2,2'-DiCB	PCB-004	0.0%	0.0%	0.0%
2,3'-DiCB	PCB-006	0.0%	0.0%	0.0%
2,2',3-TrCB	PCB-016	0.0%	0.0%	0.0%
2,2',4-TrCB	PCB-017	0.0%	0.0%	0.0%
2,2',5-TrCB	PCB-018	0.0%	0.0%	0.0%
2,3,3'/2,3',4'-TriCB	PCB-020/033	0.0%	0.0%	0.0%
2,3,4'-TrCB	PCB-022	0.0%	0.0%	0.0%
3,4,4'-TrCB	PCB-037	0.0%	0.0%	0.0%
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	0.0%	0.0%	0.0%
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	0.0%	0.0%	0.0%
2,3',4,4'-TeCB	PCB-066	0.0%	0.0%	0.0%
2,2',3,4',6-PeCB	PCB-091	0.0%	0.0%	0.0%
2,2',3,5,5'-PeCB	PCB-092	0.0%	0.0%	0.0%
2,3,3',4,4'-PeCB	PCB-105	0.0%	0.0%	0.0%
2,2',3,5,5',6-HxCB	PCB-151	0.0%	0.0%	0.0%
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	0.0%	0.0%	0.0%
2,2',3,4,4',5,5'-HpCB	PCB-180	0.0%	0.0%	0.0%
2,2',3,4,4',5,6'/2,2',3,4',5,5',6-HpCB	PCB-182/187	0.0%	0.0%	0.0%
	Entire Chemical Class =	0.0%	0.0%	0.0%
Polychlorinated Biphenyls (Homologs)				
Dichlorobiphenyls		0.0%	0.0%	0.0%
Heptachlorobiphenyls		0.0%	0.0%	0.0%
Monochlorobiphenyls		0.0%	0.0%	0.0%
Tetrachlorobiphenyls		0.0%	0.0%	0.0%

Key: Percent differences determined by:

$$\frac{(\text{Substituted Value - ROS Value}))}{((\text{Substituted Value + ROS Value}) / 2)}$$

Regression on Order Statistics (ROS) Values were from Appendix E.

Appendix G.

Loading Rates from Each of the Ten POTWs

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
Polycyclic Aromatic Hydrocarbons											
Low Molecular Weight PAHs (LPAHs)											
Acenaphthene		nd	2.53E-01	nd	1.91E-01	nd	5.16E-02	9.60E-01	2.11E-01	nd	2.85E-02
Acenaphthylene		nd	1.64E-01	nd	1.20E-01	nd	3.26E-02	5.18E-01	nd	nd	3.64E-02
Anthracene		nd	3.40E-02	nd	nd	nd	6.56E-03	4.41E-01	nd	nd	1.40E-02
Fluorene		1.18E-01	5.26E-01	1.60E-02	3.42E-01	nd	1.14E-01	1.79E+00	3.58E-01	1.21E-02	1.79E-01
Naphthalene		nd	1.07E+00	2.24E-02	nd	nd	2.79E-01	nd	8.53E-01	nd	5.14E-02
Phenanthrene		1.27E-01	2.12E-01	nd	1.50E-01	nd	4.30E-02	1.31E+00	3.71E-01	1.13E-02	8.34E-02
High Molecular Weight PAHs (HPAHs)											
Benzo(a)anthracene		nd	nd	nd	nd	6.45E-02	nd	nd	nd	nd	nd
Benzo(a)pyrene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo(b)fluoranthene		nd	nd	nd	nd	1.78E-01	nd	nd	nd	nd	nd
Benzo(g,h,i)perylene		nd	nd	nd	nd	8.72E-02	nd	nd	nd	nd	nd
Benzo(k)fluoranthene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chrysene		nd	nd	nd	nd	8.42E-02	nd	nd	nd	nd	nd
Dibenzo(a,h)anthracene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fluoranthene		1.05E-01	2.53E-02	6.46E-03	2.46E-01	1.36E-01	4.49E-03	7.61E-01	2.22E-01	nd	1.35E-02
Indeno(1,2,3-cd)pyrene		nd	nd	nd	nd	1.61E-01	nd	4.93E-01	nd	nd	nd
Pyrene		1.22E-01	3.45E-02	1.08E-02	3.19E-01	3.44E-01	8.54E-03	1.39E+00	1.62E-01	nd	1.04E-02
Carcinogenic PAHs (cPAHs)											
Benzo(a)anthracene		nd	nd	nd	nd	6.45E-02	nd	nd	nd	nd	nd
Benzo(a)pyrene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzo(b)fluoranthene		nd	nd	nd	nd	1.78E-01	nd	nd	nd	nd	nd
Benzo(k)fluoranthene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chrysene		nd	nd	nd	nd	8.42E-02	nd	nd	nd	nd	nd
Dibenzo(a,h)anthracene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Indeno(1,2,3-cd)pyrene		nd	nd	nd	nd	1.61E-01	nd	4.93E-01	nd	nd	nd
Total PAHs (LPAHs+HPAHs)		4.72E-01	2.32E+00	5.57E-02	1.37E+00	1.05E+00	5.40E-01	7.66E+00	2.18E+00	2.34E-02	4.17E-01
Phthalates											
bis(2-Ethylhexyl) phthalate		6.50E+00	8.41E+00	1.55E+00	7.01E+01	6.37E+01	1.79E+00	1.45E+02	1.99E+01	1.70E+00	1.03E+00
Butylbenzyl phthalate		nd	1.17E+00	8.84E-01	6.66E+00	nd	2.21E-01	3.04E+01	nd	nd	nd
Di-N-butyl phthalate		5.27E+00	nd	nd	nd	nd	nd	nd	3.89E+00	nd	nd
Di-N-octyl phthalate		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Diethyl phthalate		nd	nd	5.67E-01	3.92E+00	nd	3.35E-01	nd	nd	nd	6.39E-01
Dimethyl phthalate		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Other Base/Neutral/Acid Extractables											
1,2,4-Trichlorobenzene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2-Dichlorobenzene		nd	nd	nd	nd	nd	nd	nd	1.92E+00	nd	nd
1,3-Dichlorobenzene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,4-Dichlorobenzene		3.82E+00	1.07E+00	1.51E+00	1.57E+01	1.21E+00	2.23E-01	1.89E+02	6.18E+00	1.92E-01	4.58E-01
1-Methylnaphthalene		nd	3.45E-01	nd	nd	nd	7.04E-02	1.47E+00	3.83E-01	nd	1.94E-02
2,3,4,5-Tetrachlorophenol		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,3,4,6-Tetrachlorophenol		nd	nd	nd	nd	nd	nd	nd	nd	2.49E-01	nd

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
2,4,5-Trichlorophenol		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4,6-Trichlorophenol		9.18E-01	5.44E-01	1.44E-01	3.02E+00	7.11E-01	1.84E-01	1.77E+01	2.62E+00	7.83E-01	1.10E-01
2,4-Dichlorophenol		8.16E+00	2.97E+00	1.11E+00	1.43E+01	6.52E+00	5.97E-01	5.82E+01	1.26E+01	nd	1.25E+00
2,4-Dimethylphenol		7.22E+00	nd	1.16E+00	nd	nd	2.18E-01	6.01E+01	8.16E+00	nd	nd
2,4-Dinitrophenol		nd	nd	1.16E+00	nd	nd	6.37E-01	6.01E+01	nd	nd	1.21E+00
2,4-Dinitrotoluene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,6-Dinitrotoluene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-Chloroethanol phosphate (3:1)		1.19E+00	1.60E+00	3.40E-01	8.52E+00	6.30E+00	1.01E-01	3.71E+01	1.01E+01	5.22E-01	5.28E-01
2-Chloronaphthalene		9.73E-02	nd	nd	nd	nd	nd	nd	nd	1.07E-02	nd
2-Chlorophenol		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-Methylnaphthalene		nd	5.22E-01	nd	nd	nd	1.03E-01	1.60E+00	nd	nd	2.43E-02
2-Methylphenol	o-Cresol	nd	nd	9.30E-01	1.33E+01	nd	5.58E-01	5.69E+01	nd	1.24E+00	1.31E+00
2-Nitroaniline	o-Nitroaniline	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-Nitrophenol		nd	9.51E-01	nd	5.15E+00	nd	1.73E-01	nd	nd	nd	nd
3,3'-Dichlorobenzidine		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3B-Coprostanol		1.60E+02	nd	3.40E+01	3.85E+02	2.20E+02	2.23E+01	1.11E+03	1.90E+02	1.68E+01	1.19E+01
3-Nitroaniline	m-Nitroaniline	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4,6-Dinitro-2-methylphenol		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Bromophenylphenyl ether		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Chloro-3-methylphenol	p-Chloro-m-cresol	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Chloroaniline		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Chlorophenylphenyl ether		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Methylphenol	p-Cresol	2.80E+01	3.74E+00	nd	1.39E+01	nd	5.00E+00	6.01E+01	4.20E+00	4.53E-01	1.33E+00
4-Nitroaniline	p-Nitroaniline	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Nitrophenol		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Nonylphenol		nd	nd	nd	1.78E+01	nd	nd	nd	nd	nd	nd
Benzoic acid		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzyl alcohol		2.38E+01	nd	nd	nd	nd	1.68E-01	nd	2.22E+00	nd	nd
bis(2-Chloroethoxy) methane		nd	nd	nd	nd	nd	nd	8.00E+00	nd	nd	nd
bis(2-Chloroethyl) ether		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bisphenol A		1.14E+01	3.36E+00	5.90E-01	3.30E+01	nd	3.21E-01	8.92E+01	3.95E+01	7.90E-01	nd
Caffeine		nd	8.62E+00	1.38E+01	9.28E+00	nd	2.37E+01	5.41E+01	1.79E+01	3.09E-01	nd
Carbazole		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cholesterol		2.21E+02	4.99E+01	3.85E+01	6.32E+02	2.49E+02	3.57E+01	1.54E+03	1.95E+02	2.34E+01	1.36E+01
Dibenzofuran		1.18E-01	5.83E-01	1.05E-02	3.01E-01	7.47E-02	1.08E-01	1.54E+00	2.35E-01	1.20E-02	1.43E-01
Hexachlorobutadiene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachlorocyclopentadiene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachloroethane		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Isophorone		1.78E+00	nd	nd	4.40E+00	nd	nd	1.18E+01	nd	2.47E-01	nd
Nitrobenzene		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
N-Nitrosodimethylamine		nd	nd	nd	1.79E+01	nd	nd	nd	nd	nd	nd
N-Nitrosodi-n-propylamine		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
N-Nitrosodiphenylamine		nd	nd	nd	nd	nd	nd	nd	nd	nd	3.75E-01
Pentachlorophenol		1.12E+00	2.26E-01	7.82E-02	nd	nd	nd	nd	nd	nd	nd
Phenol		1.75E+01	6.72E+00	nd	nd	7.91E+00	1.17E+00	2.39E+02	1.27E+01	2.49E+00	nd
Retene		nd	nd	nd	nd	nd	nd	nd	nd	6.53E-03	nd
Triclosan		8.67E+00	3.21E+00	8.50E-01	3.00E+01	6.81E+00	8.26E-01	8.44E+01	1.82E+01	7.42E-01	1.00E+00
Triethyl citrate		1.62E+01	4.81E+00	4.91E+00	3.16E+01	4.91E+00	1.17E+00	9.08E+01	2.84E+01	7.69E-01	8.20E-01

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
Pesticides											
2,4'-DDD		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4'-DDE		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4'-DDT		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4,4'-DDD		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4,4'-DDE		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4,4'-DDT		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Aldrin		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
alpha-BHC		nd	nd	nd	nd	nd	2.65E-03	nd	nd	nd	nd
beta-BHC		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
delta-BHC		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
gamma-BHC	Lindane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
cis-Chlordane		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
trans-Chlordane		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chlordane, technical		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chlorpyriphos		nd	nd	nd	nd	9.71E-02	nd	nd	nd	nd	nd
Dacthal	DCPA	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DDMU		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dieldrin		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endosulfan I		nd	nd	4.42E-03	nd	nd	5.00E-03	nd	nd	1.82E-02	9.10E-03
Endosulfan II		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endosulfan sulfate		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endrin		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endrin aldehyde		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endrin ketone		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Heptachlor		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Heptachlor epoxide		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachlorobenzene		nd	1.34E-02	nd	nd	nd	nd	nd	nd	6.80E-03	nd
Methoxychlor		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mirex		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
cis-Nonachlor		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
trans-Nonachlor		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Oxychlordane		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pentachloroanisole		nd	nd	9.75E-03	nd	3.66E-02	nd	nd	nd	nd	8.34E-03
Toxaphene		nd	nd	nd	2.37E+00	nd	6.28E-02	nd	nd	nd	nd
Herbicides											
2,4,5-T		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4,5-TP	Silvex	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,4-D		nd	6.28E-01	1.11E-01	nd	nd	nd	1.03E+01	nd	nd	nd
2,4-DB	2,4-D butyric acid	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3,5-Dichlorobenzoic acid		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acifluorfen	Blazer	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bentazon		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bromoxynil		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Clopyralid		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dicamba I		nd	1.80E-01	nd	nd	nd	nd	4.09E+00	nd	nd	8.34E-02
Dichlorprop		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Diclofop-Methyl		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
Dinoseb		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ioxynil		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
MCPA		nd	nd	nd	nd	nd	nd	1.23E+01	nd	nd	2.61E-01
MCPP	Mecoprop	7.65E-01	3.05E-01	nd	nd	nd	nd	nd	5.93E+00	nd	8.61E-02
Picloram		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Triclopyr		nd	nd	1.06E-01	nd	nd	nd	5.37E+00	nd	2.25E-01	8.47E-02
Polybrominated Diphenyl Ethers (Congeners)											
2,4-DiBDE	BDE-007	nd	5.38E-05	1.38E-05	nd	2.75E-04	2.86E-05	nd	4.00E-04	nd	2.90E-05
2,6-DiBDE	BDE-010	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4,4'-DiBDE	BDE-015	1.37E-04	6.15E-05	1.13E-04	3.96E-04	4.27E-03	9.55E-06	1.33E-03	1.81E-03	nd	6.82E-05
2,2',4-TrBDE	BDE-017	5.35E-04	1.77E-04	7.43E-04	2.15E-03	5.65E-03	8.12E-05	5.37E-03	8.18E-03	2.31E-04	5.90E-04
2,4,4'-TrBDE	BDE-028	1.45E-03	4.40E-04	1.82E-03	6.09E-03	1.21E-02	1.30E-04	1.29E-02	1.93E-02	4.14E-04	7.04E-04
2,4,6-TrBDE	BDE-030	1.27E-04	6.92E-05	nd	4.63E-04	3.00E-04	nd	1.27E-03	nd	3.50E-05	nd
2,2',4,4'-TeBDE	BDE-047	7.79E-02	3.19E-02	1.14E-02	4.04E-01	5.34E-01	7.92E-03	8.27E-01	1.74E-01	2.86E-02	1.39E-02
2,2',4,5'-TeBDE	BDE-049	3.04E-06	nd	nd	9.67E-03	1.85E-02	2.31E-04	2.24E-02	1.37E-02	6.24E-04	6.61E-04
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071	3.28E-03	1.12E-03	8.96E-04	1.42E-02	2.02E-02	1.79E-04	2.99E-02	1.99E-02	1.57E-03	8.25E-04
2,3',4,4'-TeBDE	BDE-066	1.36E-03	1.43E-03	2.83E-04	7.56E-03	2.58E-02	1.99E-04	1.56E-02	4.77E-03	2.38E-04	9.22E-04
2,3',4',6-TeBDE	BDE-071	nd	4.74E-04	1.22E-03	1.41E-03	2.27E-03	4.53E-05	3.07E-03	5.12E-03	9.81E-05	1.11E-04
3,3',4,4'-TeBDE	BDE-077	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,2',3,4,4'-PeBDE	BDE-085	2.21E-03	1.69E-03	2.35E-04	8.82E-03	1.86E-02	5.00E-04	3.31E-02	6.33E-03	1.24E-03	1.25E-03
2,2',4,4',5-PeBDE	BDE-099	6.40E-02	2.86E-02	9.69E-03	3.92E-01	5.13E-01	6.98E-03	7.69E-01	1.43E-01	3.45E-02	2.39E-02
2,2',4,4',6-PeBDE	BDE-100	1.33E-02	6.42E-03	2.22E-03	7.78E-02	9.93E-02	1.38E-03	1.52E-01	3.10E-02	7.27E-03	4.10E-03
2,3',4,4',6-PeBDE	BDE-119	6.60E-04	nd	1.56E-04	nd	nd	2.43E-05	nd	1.41E-03	nd	nd
3,3',4,4',5-PeBDE	BDE-126	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,2',3,4,4',5'-HxBDE	BDE-138	4.30E-04	nd	nd	2.46E-03	5.93E-03	nd	nd	nd	6.72E-05	2.76E-04
2,2',3,4,4',6-HxBDE	BDE-139	2.97E-04	nd	nd	4.21E-03	4.97E-03	nd	5.73E-03	7.45E-04	nd	4.85E-04
2,2',3,4,4',6'-HxBDE	BDE-140	2.44E-04	1.46E-04	nd	1.26E-03	1.94E-03	nd	nd	4.33E-04	nd	1.41E-04
2,2',4,4',5,5'-HxBDE	BDE-153	5.60E-03	3.78E-03	8.17E-04	3.50E-02	5.90E-02	1.05E-03	6.42E-02	1.04E-02	3.48E-03	3.44E-03
2,2',4,4',5,6'-HxBDE	BDE-154	3.80E-03	2.31E-03	6.24E-04	2.43E-02	3.39E-02	4.44E-04	4.73E-02	9.73E-03	2.56E-03	1.76E-03
2,3,3',4,4',5/3,3',4,4',5,5'-HxBDE	BDE-156/169	nd	nd	nd	nd	5.83E-04	nd	nd	nd	nd	nd
2,2',3,3',4,4',6-HpBDE	BDE-171	nd	nd	nd	nd	4.79E-04	nd	nd	nd	nd	nd
2,2',3,4,4',5,5'-HpBDE	BDE-180	nd	nd	nd	nd	7.52E-04	nd	nd	nd	nd	nd
2,2',3,4,4',5',6-HpBDE	BDE-183	4.77E-04	nd	nd	3.68E-03	7.98E-03	nd	6.19E-03	1.00E-03	2.88E-04	1.56E-04
2,2',3,4,4',6,6'-HpBDE	BDE-184	nd	nd	nd	nd	5.29E-04	nd	nd	nd	4.20E-05	nd
2,3,3',4,4',5',6-HpBDE	BDE-191	nd	nd	nd	nd	2.79E-04	nd	nd	nd	nd	nd
2,2',3,3',4,4',5,6'-OcBDE	BDE-196	nd	nd	nd	1.69E-03	7.08E-03	nd	4.71E-03	6.72E-04	1.48E-04	nd
2,2',3,3',4,4',6,6'/ 2,2',3,4,4',5,6,6'-OcBDE	BDE-197/204	nd	nd	nd	2.28E-03	5.12E-03	nd	5.26E-03	1.01E-03	1.08E-04	nd
2,2',3,3',4,5',6,6'-OcBDE	BDE-201	nd	nd	nd	5.76E-04	4.63E-03	nd	4.82E-03	8.19E-04	nd	nd
2,2',3,4,4',5,5',6-OcBDE	BDE-203	nd	nd	nd	1.05E-03	7.24E-03	nd	5.19E-03	1.64E-03	2.03E-04	nd
2,3,3',4,4',5,5',6-OcBDE	BDE-205	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	1.55E-03	1.26E-03	2.05E-04	1.83E-02	3.59E-02	8.17E-04	2.37E-02	3.82E-03	2.05E-03	nd
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	2.24E-03	9.39E-04	2.89E-04	1.23E-02	3.76E-02	9.45E-04	2.56E-02	4.97E-03	1.91E-03	nd
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	1.06E-03	7.13E-04	1.66E-04	1.08E-02	3.66E-02	8.15E-04	1.60E-02	3.44E-03	1.64E-03	nd
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	2.29E-02	1.10E-02	8.53E-03	2.16E-01	4.21E-01	1.65E-02	3.00E-01	3.70E-02	2.23E-02	2.65E-03

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
Polybrominated Diphenyl Ethers (Homologs)											
Decabromodiphenyl ether		2.29E-02	1.10E-02	6.79E-03	2.16E-01	4.21E-01	1.65E-02	3.00E-01	3.70E-02	2.23E-02	2.65E-03
Dibromodiphenyl ethers		1.37E-04	7.82E-05	9.40E-05	3.96E-04	4.55E-03	3.68E-05	1.33E-03	2.21E-03	nd	9.38E-05
Heptabromodiphenyl ethers		4.77E-04	nd	nd	3.68E-03	9.72E-03	nd	6.19E-03	1.00E-03	3.16E-04	1.56E-04
Hexabromodiphenyl ethers		1.02E-02	6.23E-03	1.44E-03	6.72E-02	1.06E-01	1.49E-03	1.17E-01	2.12E-02	6.09E-03	6.08E-03
Nonabromodiphenyl ethers		4.42E-03	2.17E-03	6.03E-04	4.15E-02	1.10E-01	2.58E-03	4.93E-02	1.16E-02	5.61E-03	nd
Octabromodiphenyl ethers		nd	nd	nd	5.46E-03	2.41E-02	nd	1.04E-02	3.77E-03	4.18E-04	nd
Pentabromodiphenyl ethers		8.01E-02	3.67E-02	1.23E-02	4.78E-01	6.31E-01	8.89E-03	9.54E-01	1.81E-01	4.30E-02	2.92E-02
Tetrabromodiphenyl ethers		8.10E-02	3.41E-02	1.28E-02	4.25E-01	5.80E-01	8.34E-03	8.71E-01	1.98E-01	3.00E-02	1.56E-02
Tribromodiphenyl ethers		2.10E-03	6.13E-04	2.57E-03	8.67E-03	1.80E-02	2.12E-04	1.87E-02	2.76E-02	6.76E-04	1.29E-03
Perfluorinated Compounds											
Perfluorobutane sulfonate	PFBS	nd	5.55E-02	nd	nd	nd	nd	9.46E-01	1.94E-01	nd	nd
Perfluorobutanoate	PFBA	2.20E-02	9.60E-03	nd	2.95E-02	2.75E-02	1.05E-03	2.42E-01	1.05E-01	4.79E-03	4.78E-03
Perfluorodecanoate	PFDA	3.56E-02	1.34E-02	8.89E-03	5.72E-02	3.27E-02	7.24E-03	4.54E-01	1.14E-01	1.66E-02	2.54E-02
Perfluorododecanoate	PFDoA	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Perfluoroheptanoate	PFHpA	7.33E-02	1.64E-02	9.97E-03	2.11E-01	1.33E-01	5.54E-03	5.60E-01	1.29E-01	8.99E-03	1.56E-02
Perfluorohexane sulfonate	PFHxS	4.86E-02	2.60E-02	6.25E-03	1.57E-01	4.34E-02	nd	3.69E-01	1.87E-01	nd	nd
Perfluorohexanoate	PFHxA	2.77E-01	7.46E-02	3.91E-02	4.63E-01	2.05E-01	4.21E-02	1.87E+00	3.78E-01	9.59E-02	1.15E-01
Perfluorononanoate	PFNA	2.17E-01	3.91E-02	1.95E-02	1.58E-01	1.19E+00	1.98E-02	6.12E-01	1.05E-01	6.43E-03	2.14E-02
Perfluorooctane sulfonamide	PFOSA	nd	nd	3.61E-03	nd	nd	nd	nd	nd	nd	3.21E-03
Perfluorooctane sulfonate	PFOS	5.96E-02	1.77E-01	1.07E-02	1.92E-01	1.29E-01	4.38E-03	2.60E+00	1.90E-01	7.37E-03	1.84E-02
Perfluorooctanoate	PFOA	2.46E-01	6.66E-02	5.33E-02	7.86E-01	3.01E-01	5.64E-02	2.25E+00	2.98E-01	9.89E-02	1.62E-01
Perfluoropentanoate	PFPeA	3.36E-02	4.93E-03	8.78E-03	1.45E-01	2.88E-02	1.59E-02	1.62E-01	4.94E-02	3.43E-02	4.38E-02
Perfluoroundecanoate	PFUnA	nd	nd	nd	nd	1.23E-02	nd	nd	nd	nd	nd
Polychlorinated Biphenyls (Congeners)											
2-MoCB	PCB-001	na	nd	na	1.14E-03	7.44E-04	na	2.44E-03	2.50E-04	nd	na
3-MoCB	PCB-002	na	nd	na	nd	nd	na	nd	nd	nd	na
4-MoCB	PCB-003	na	nd	na	8.00E-04	nd	na	1.73E-03	3.21E-04	nd	na
2,2'-DiCB	PCB-004	na	nd	na	2.33E-03	1.52E-02	na	6.00E-03	7.17E-04	nd	na
2,3/2,4'-DiCB	PCB-005/008	na	nd	na	3.57E-03	nd	na	nd	nd	nd	na
2,3'-DiCB	PCB-006	na	nd	na	6.13E-04	4.48E-04	na	1.87E-03	4.15E-04	nd	na
2,4-DiCB	PCB-007	na	nd	na	nd	2.04E-04	na	1.57E-03	nd	nd	na
2,5-DiCB	PCB-009	na	nd	na	3.05E-04	nd	na	nd	nd	nd	na
2,6-DiCB	PCB-010	na	nd	na	nd	nd	na	nd	nd	nd	na
3,3'-DiCB	PCB-011	na	nd	na	nd	nd	na	nd	nd	nd	na
3,4/3,4'-DiCB	PCB-012/013	na	nd	na	nd	3.55E-04	na	nd	6.58E-04	nd	na
3,5-DiCB	PCB-014	na	nd	na	nd	nd	na	nd	nd	nd	na
4,4'-DiCB	PCB-015	na	nd	na	9.95E-04	1.89E-03	na	nd	nd	nd	na
2,2',3-TrCB	PCB-016	na	8.50E-05	na	1.34E-03	1.29E-03	na	4.58E-03	4.40E-04	nd	na
2,2',4-TrCB	PCB-017	na	nd	na	1.31E-03	2.43E-03	na	2.75E-03	3.29E-04	nd	na
2,2',5-TrCB	PCB-018	na	nd	na	3.74E-03	3.88E-03	na	9.03E-03	9.91E-04	nd	na
2,2',6-TrCB	PCB-019	na	nd	na	5.06E-04	2.42E-03	na	nd	nd	nd	na
2,3,3'/2,3',4'-TriCB	PCB-020/033	na	8.14E-05	na	2.60E-03	1.42E-03	na	4.26E-03	4.35E-04	nd	na
2,3,4-TrCB	PCB-021	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4'-TrCB	PCB-022	na	nd	na	1.49E-03	1.85E-03	na	2.56E-03	3.09E-04	nd	na
2,3,5-TrCB	PCB-023	na	nd	na	nd	nd	na	nd	nd	nd	na

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
2,3,6-TrCB	PCB-024	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4-TrCB	PCB-025	na	nd	na	2.94E-04	4.70E-04	na	nd	nd	nd	na
2,3',5-TrCB	PCB-026	na	nd	na	5.85E-04	8.00E-04	na	nd	nd	nd	na
2,3',6-TrCB	PCB-027	na	nd	na	nd	5.63E-04	na	nd	nd	nd	na
2,4,4'-TrCB	PCB-028	na	8.68E-05	na	3.19E-03	4.16E-03	na	5.35E-03	5.36E-04	4.29E-05	na
2,4,5-TrCB	PCB-029	na	nd	na	nd	nd	na	nd	nd	nd	na
2,4,6-TrCB	PCB-030	na	nd	na	nd	nd	na	nd	nd	nd	na
2,4',5-TrCB	PCB-031	na	9.69E-05	na	3.38E-03	4.23E-03	na	6.31E-03	7.49E-04	4.20E-05	na
2,4',6-TrCB	PCB-032	na	nd	na	1.12E-03	1.95E-03	na	nd	nd	nd	na
2,3',5'-TrCB	PCB-034	na	nd	na	nd	nd	na	nd	nd	nd	na
3,3',4-TrCB	PCB-035	na	nd	na	nd	3.62E-04	na	nd	nd	nd	na
3,3',5-TrCB	PCB-036	na	nd	na	nd	3.16E-04	na	nd	nd	nd	na
3,4,4'-TrCB	PCB-037	na	nd	na	9.84E-04	1.63E-03	na	1.93E-03	5.22E-04	nd	na
3,4,5-TrCB	PCB-038	na	nd	na	nd	nd	na	nd	nd	nd	na
3,4',5-TrCB	PCB-039	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3'-TeCB	PCB-040	na	nd	na	6.46E-04	6.42E-04	na	nd	nd	nd	na
2,3,4',6-TeCB	PCB-041	na	nd	na	3.13E-04	3.52E-04	na	nd	nd	nd	na
2,2',3,4'-TeCB	PCB-042	na	nd	na	8.00E-04	1.10E-03	na	nd	nd	nd	na
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	na	nd	na	2.60E-03	3.59E-03	na	4.67E-03	5.14E-04	3.93E-05	na
2,2',3,5'-TeCB	PCB-044	na	nd	na	3.49E-03	4.91E-03	na	nd	nd	nd	na
2,2',3,6-TeCB	PCB-045	na	nd	na	4.53E-04	5.04E-04	na	nd	nd	nd	na
2,2',3,6'-TeCB	PCB-046	na	nd	na	nd	2.87E-04	na	nd	nd	nd	na
2,2',4,4'/2,2',4,5-TeCB	PCB-047/048	na	nd	na	7.80E-04	1.20E-03	na	1.38E-03	nd	nd	na
2,2',4,6-TeCB	PCB-050	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',4,6'-TeCB	PCB-051	na	nd	na	nd	5.76E-04	na	nd	nd	nd	na
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	na	nd	na	4.12E-03	6.87E-03	na	1.15E-02	1.08E-03	nd	na
2,2',5,6'-TeCB	PCB-053	na	nd	na	4.45E-04	8.90E-04	na	1.54E-03	nd	nd	na
2,2',6,6'-TeCB	PCB-054	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4-TeCB	PCB-055	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4'-TeCB	PCB-056	na	nd	na	1.38E-03	1.68E-03	na	2.67E-03	nd	nd	na
2,3,3',5-TeCB	PCB-057	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',5'-TeCB	PCB-058	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',6-TeCB	PCB-059	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4,4'-TeCB	PCB-060	na	nd	na	4.75E-04	8.54E-04	na	nd	nd	nd	na
2,3,4,5-TeCB	PCB-061	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4,6-TeCB	PCB-062	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4',5-TeCB	PCB-063	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4',6/2,3',5,5'-TeCB	PCB-064/072	na	nd	na	1.51E-03	1.80E-03	na	2.25E-03	nd	nd	na
2,3,5,6/2,4,4',6-TeCB	PCB-065/075	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4,4'-TeCB	PCB-066	na	6.24E-05	na	2.53E-03	3.59E-03	na	3.86E-03	nd	3.13E-05	na
2,3',4,5-TeCB	PCB-067	na	nd	na	nd	1.55E-04	na	nd	nd	nd	na
2,2',3,4-TeCB	PCB-068	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4',5-TeCB	PCB-070	na	nd	na	3.68E-03	6.40E-03	na	nd	nd	nd	na
2,3',4',6-TeCB	PCB-071	na	nd	na	8.08E-04	1.00E-03	na	nd	nd	nd	na
2,2',5,5'-TeCB	PCB-073	na	nd	na	nd	nd	na	nd	nd	nd	na
2,4,4',5-TeCB	PCB-074	na	nd	na	1.54E-03	2.26E-03	na	2.51E-03	nd	nd	na
2,3',4',5'-TeCB	PCB-076	na	nd	na	nd	nd	na	nd	nd	nd	na
3,3',4,4'-TeCB	PCB-077	na	nd	na	nd	5.73E-04	na	nd	nd	nd	na
3,3',4,5-TeCB	PCB-078	na	nd	na	nd	nd	na	nd	nd	nd	na

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
3,3',4,5'-TeCB	PCB-079	na	nd	na	nd	nd	na	nd	nd	nd	na
3,3',5,5'-TeCB	PCB-080	na	nd	na	nd	nd	na	nd	nd	nd	na
3,4,4',5-TeCB	PCB-081	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4-PeCB	PCB-082	na	nd	na	4.55E-04	1.35E-03	na	1.37E-03	nd	nd	na
2,2',3,3',5-PeCB	PCB-083	na	nd	na	3.35E-04	3.76E-04	na	nd	nd	nd	na
2,2',3,3',6-PeCB	PCB-084	na	nd	na	8.79E-04	1.79E-03	na	2.06E-03	nd	nd	na
2,2',3,4,4'-PeCB	PCB-085	na	nd	na	7.34E-04	1.77E-03	na	1.44E-03	nd	nd	na
2,2',3,4,5/2,2',3,4',5'/ 2,3,4',5,6-PeCB	PCB-086/097/117	na	nd	na	1.42E-03	3.40E-03	na	nd	nd	nd	na
2,2',3,4,5'/2,3,4,4',6-PeCB	PCB-087/115	na	nd	na	1.94E-03	4.53E-03	na	nd	nd	nd	na
2,2',3,4,6-PeCB	PCB-088	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4,6'-PeCB	PCB-089	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4',5-PeCB	PCB-090	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4',6-PeCB	PCB-091	na	nd	na	6.60E-04	1.07E-03	na	1.52E-03	2.77E-04	nd	na
2,2',3,5,5'-PeCB	PCB-092	na	nd	na	1.24E-03	2.67E-03	na	3.33E-03	3.67E-04	2.97E-05	na
2,2',3,5,6/2,2',3,5',6/2,2',3,4',6'/ 2,2',4,5,6'-PeCB	PCB-093/095/098/102	na	nd	na	4.40E-03	8.80E-03	na	nd	nd	nd	na
2,2',3,5,6'-PeCB	PCB-094	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,6,6'-PeCB	PCB-096	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',4,4',5-PeCB	PCB-099	na	nd	na	2.10E-03	4.35E-03	na	4.90E-03	nd	nd	na
2,2',4,4',6-PeCB	PCB-100	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',4,5,5'-PeCB	PCB-101	na	nd	na	5.66E-03	1.14E-02	na	nd	nd	nd	na
2,2',4,5',6-PeCB	PCB-103	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',4,6,6'-PeCB	PCB-104	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,4'-PeCB	PCB-105	na	nd	na	1.55E-03	3.94E-03	na	3.80E-03	nd	3.66E-05	na
2,3,3',4,5-PeCB	PCB-106	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4',5/2,3,3',4,5'-PeCB	PCB-107/108	na	nd	na	nd	7.16E-04	na	nd	nd	nd	na
2,3,3',4,6-PeCB	PCB-109	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4',6-PeCB	PCB-110	na	nd	na	5.36E-03	1.11E-02	na	nd	nd	nd	na
2,3,3',5,5'-PeCB	PCB-111	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',5,6/2,3',4,4',6-PeCB	PCB-112/119	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',5',6-PeCB	PCB-113	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4,4',5-PeCB	PCB-114	na	nd	na	nd	3.57E-04	na	nd	nd	nd	na
2,3,4,5,6/2,3',4',5',6-PeCB	PCB-116/125	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4,4',5-PeCB	PCB-118	na	nd	na	3.71E-03	9.49E-03	na	9.20E-03	nd	nd	na
2,3',4,5,5'-PeCB	PCB-120	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4,5',6-PeCB	PCB-121	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4',5'-PeCB	PCB-122	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4,4',5'-PeCB	PCB-123	na	nd	na	nd	2.81E-04	na	nd	nd	nd	na
2,3',4',5,5'-PeCB	PCB-124	na	nd	na	nd	3.93E-04	na	nd	nd	nd	na
3,3',4,4',5-PeCB	PCB-126	na	nd	na	nd	1.95E-04	na	nd	nd	nd	na
3,3',4,5,5'-PeCB	PCB-127	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,4'-HxCB	PCB-128	na	nd	na	9.62E-04	2.37E-03	na	1.77E-03	nd	nd	na
2,2',3,3',4,5-HxCB	PCB-129	na	nd	na	nd	4.34E-04	na	nd	nd	nd	na
2,2',3,3',4,5'-HxCB	PCB-130	na	nd	na	nd	6.48E-04	na	nd	nd	nd	na
2,2',3,3',4,6-HxCB	PCB-131	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,6'-HxCB	PCB-132	na	nd	na	2.18E-03	4.26E-03	na	nd	nd	nd	na
2,2',3,3',5,5'-HxCB	PCB-133	na	nd	na	nd	1.58E-04	na	nd	nd	nd	na
2,2',3,3',5,6-HxCB	PCB-134	na	nd	na	nd	5.52E-04	na	nd	nd	nd	na

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2,2',3,3',5,6'-HxCB	PCB-135	na	nd	na	6.68E-04	1.13E-03	na	nd	nd	nd	na
2,2',3,3',6,6'-HxCB	PCB-136	na	nd	na	1.04E-03	1.34E-03	na	1.86E-03	nd	nd	na
2,2',3,4,4',5-HxCB	PCB-137	na	nd	na	nd	4.51E-04	na	nd	nd	nd	na
2,2',3,4,4',5'-HxCB	PCB-138	na	nd	na	4.62E-03	1.05E-02	na	8.74E-03	nd	nd	na
2,2',3,4,4',6/2,2',3,4',5',6-HxCB	PCB-139/149	na	nd	na	4.89E-03	8.45E-03	na	nd	nd	nd	na
2,2',3,4,4',6'-HxCB	PCB-140	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4,5,5'-HxCB	PCB-141	na	nd	na	9.18E-04	1.33E-03	na	1.47E-03	nd	nd	na
2,2',3,4,5,6-HxCB	PCB-142	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4,5,6'-HxCB	PCB-143	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4,5',6-HxCB	PCB-144	na	nd	na	nd	2.86E-04	na	nd	nd	nd	na
2,2',3,4,6,6'-HxCB	PCB-145	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4',5,5'-HxCB	PCB-146	na	nd	na	9.89E-04	1.46E-03	na	1.28E-03	nd	nd	na
2,2',3,4',5,6-HxCB	PCB-147	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4',5,6'-HxCB	PCB-148	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4',6,6'-HxCB	PCB-150	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,5,5',6-HxCB	PCB-151	na	nd	na	1.50E-03	2.09E-03	na	2.57E-03	nd	3.79E-05	na
2,2',3,5,6,6'-HxCB	PCB-152	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',4,4',5,5'-HxCB	PCB-153	na	nd	na	5.28E-03	9.76E-03	na	nd	nd	nd	na
2,2',4,4',5,6'-HxCB	PCB-154	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',4,4',6,6'-HxCB	PCB-155	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,4',5-HxCB	PCB-156	na	nd	na	5.55E-04	1.27E-03	na	nd	nd	nd	na
2,3,3',4,4',5'-HxCB	PCB-157	na	nd	na	nd	2.56E-04	na	nd	nd	nd	na
2,3,3',4,4',6-HxCB	PCB-158	na	nd	na	5.06E-04	1.21E-03	na	nd	nd	nd	na
2,3,3',4,5,5'-HxCB	PCB-159	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,5,6-HxCB	PCB-160	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,5',6-HxCB	PCB-161	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4',5,5'-HxCB	PCB-162	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	na	nd	na	1.70E-03	3.02E-03	na	2.76E-03	2.77E-04	3.16E-05	na
2,3,3',5,5',6-HxCB	PCB-165	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,4,4',5,6-HxCB	PCB-166	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3',4,4',5,5'-HxCB	PCB-167	na	nd	na	nd	4.81E-04	na	nd	nd	nd	na
2,3',4,4',5',6-HxCB	PCB-168	na	nd	na	nd	nd	na	nd	nd	nd	na
3,3',4,4',5,5'-HxCB	PCB-169	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,4',5-HpCB	PCB-170	na	nd	na	1.16E-03	1.26E-03	na	nd	nd	nd	na
2,2',3,3',4,4',6-HpCB	PCB-171	na	nd	na	4.75E-04	4.39E-04	na	nd	nd	nd	na
2,2',3,3',4,5,5'-HpCB	PCB-172	na	nd	na	nd	3.26E-04	na	nd	nd	nd	na
2,2',3,3',4,5,6-HpCB	PCB-173	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,5,6'-HpCB	PCB-174	na	nd	na	1.82E-03	1.90E-03	na	nd	nd	4.27E-05	na
2,2',3,3',4,5',6-HpCB	PCB-175	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,6,6'-HpCB	PCB-176	na	nd	na	nd	2.40E-04	na	nd	nd	nd	na
2,2',3,3',4,5',6'-HpCB	PCB-177	na	nd	na	7.83E-04	1.12E-03	na	nd	nd	nd	na
2,2',3,3',5,5',6-HpCB	PCB-178	na	nd	na	3.41E-04	4.23E-04	na	nd	nd	nd	na
2,2',3,3',5,6,6'-HpCB	PCB-179	na	nd	na	8.00E-04	8.12E-04	na	nd	nd	nd	na
2,2',3,4,4',5,5'-HpCB	PCB-180	na	nd	na	3.90E-03	3.91E-03	na	4.52E-03	3.93E-04	9.32E-05	na
2,2',3,4,4',5,6-HpCB	PCB-181	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4,4',5,6'/ 2,2',3,4',5,5',6-HpCB	PCB-182/187	na	nd	na	2.06E-03	2.71E-03	na	2.15E-03	2.74E-04	7.12E-05	na
2,2',3,4,4',5',6-HpCB	PCB-183	na	nd	na	9.32E-04	1.27E-03	na	nd	nd	nd	na
2,2',3,4,4',6,6'-HpCB	PCB-184	na	nd	na	nd	nd	na	nd	nd	nd	na

Appendix G. Loading Rates for Each of the Ten POTWs

Chemical of Concern	Alternate Name	Bellingham STP (kg/year)	Bremerton STP (kg/year)	Burlington WWTP (kg/year)	City of Tacoma (Central No. 1) (kg/year)	Everett STP (Outfall 100) (kg/year)	Gig Harbor STP (kg/year)	King County West Point (kg/year)	Pierce County Chambers Creek STP (kg/year)	Shelton STP (kg/year)	Sumner STP (kg/year)
2,2',3,4,5,5',6-HpCB	PCB-185	na	nd	na	nd	2.31E-04	na	nd	nd	nd	na
2,2',3,4,5,6,6'-HpCB	PCB-186	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,4',5,6,6'-HpCB	PCB-188	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,4',5,5'-HpCB	PCB-189	na	nd	na	nd	1.47E-04	na	nd	nd	nd	na
2,3,3',4,4',5,6-HpCB	PCB-190	na	nd	na	3.05E-04	3.37E-04	na	nd	nd	nd	na
2,3,3',4,4',5',6-HpCB	PCB-191	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,5,5',6-HpCB	PCB-192	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4',5,5',6-HpCB	PCB-193	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,4',5,5'-OcCB	PCB-194	na	nd	na	5.85E-04	7.45E-04	na	nd	nd	nd	na
2,2',3,3',4,4',5,6-OcCB	PCB-195	na	nd	na	nd	3.03E-04	na	nd	nd	nd	na
2,2',3,3',4,4',5,6'-OcCB	PCB-196	na	nd	na	4.31E-04	4.81E-04	na	nd	nd	2.82E-05	na
2,2',3,3',4,4',6,6'-OcCB	PCB-197	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,5,5',6-OcCB	PCB-198	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,5,5',6'-OcCB	PCB-199	na	nd	na	1.07E-03	1.29E-03	na	nd	nd	3.49E-05	na
2,2',3,3',4,5,6,6'-OcCB	PCB-200	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,5',6,6'-OcCB	PCB-201	na	nd	na	nd	1.89E-04	na	nd	nd	nd	na
2,2',3,3',5,5',6,6'-OcCB	PCB-202	na	nd	na	nd	2.70E-04	na	nd	nd	nd	na
2,2',3,4,4',5,5',6-OcCB	PCB-203	na	nd	na	6.27E-04	8.25E-04	na	nd	nd	3.00E-05	na
2,2',3,4,4',5,6,6'-OcCB	PCB-204	na	nd	na	nd	nd	na	nd	nd	nd	na
2,3,3',4,4',5,5',6-OcCB	PCB-205	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,4',5,5',6-NoCB	PCB-206	na	nd	na	4.04E-04	7.41E-04	na	nd	nd	3.03E-05	na
2,2',3,3',4,4',5,6,6'-NoCB	PCB-207	na	nd	na	nd	nd	na	nd	nd	nd	na
2,2',3,3',4,5,5',6,6'-NoCB	PCB-208	na	nd	na	nd	2.58E-04	na	nd	nd	nd	na
2,2',3,3',4,4',5,5',6,6'-DeCB	PCB-209	na	nd	na	nd	nd	na	nd	nd	nd	na
<u>Polychlorinated Biphenyls (Homologs)</u>											
Decachlorobiphenyl		na	nd	na	nd	3.38E-04	na	nd	nd	nd	na
Dichlorobiphenyls		na	nd	na	1.04E-02	2.34E-02	na	2.91E-02	5.62E-03	nd	na
Heptachlorobiphenyls		na	nd	na	1.26E-02	1.47E-02	na	6.67E-03	3.93E-04	1.64E-04	na
Hexachlorobiphenyls		na	nd	na	2.58E-02	5.14E-02	na	4.30E-02	nd	nd	na
Monochlorobiphenyls		na	nd	na	1.94E-03	7.44E-04	na	4.17E-03	5.71E-04	nd	na
Nonachlorobiphenyls		na	nd	na	4.04E-04	9.99E-04	na	nd	nd	nd	na
Octachlorobiphenyls		na	nd	na	2.71E-03	3.17E-03	na	nd	nd	3.49E-05	na
Pentachlorobiphenyls		na	nd	na	3.00E-02	6.77E-02	na	7.25E-02	nd	nd	na
Tetrachlorobiphenyls		na	nd	na	2.56E-02	3.83E-02	na	4.53E-02	3.27E-03	2.07E-04	na
Trichlorobiphenyls		na	4.45E-04	na	2.05E-02	2.78E-02	na	3.68E-02	4.31E-03	1.36E-04	na
<u>Metals</u>											
Copper		7.56E+01	2.22E+01	8.88E+00	2.58E+02	1.26E+02	1.15E+01	1.64E+03	2.84E+02	2.14E+01	4.22E+01
Lead		7.65E+00	1.40E+00	8.62E-01	1.81E+01	1.24E+01	7.15E-01	4.93E+01	7.29E+00	1.03E+00	4.58E-01
Zinc		7.17E+02	1.04E+02	1.19E+02	1.13E+03	3.48E+02	9.56E+01	4.58E+03	8.65E+02	1.34E+02	1.43E+02

Key:

The precision of the data in this table is only two significant figures.

na = Chemical was not analyzed during either the winter or summer sampling event.

nd = Chemical was not detected during either the winter or summer sampling event.

kg/year = Kilograms per year.

Appendix H.

Estimated Loadings to Puget Sound

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Admiralty Inlet			Commencement Bay			Hood Canal (North)			Hood Canal (South)			Main Basin		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
Polycyclic Aromatic Hydrocarbons (kg/year)																
Low Molecular Weight PAHs (LPAHs)																
Fluorene		1.80E-03	9.99E-03	2.39E-02	6.58E-02	3.66E-01	8.75E-01	3.97E-04	2.21E-03	5.28E-03	3.18E-05	1.77E-04	4.22E-04	3.92E-01	2.18E+00	5.22E+00
Phenanthrene		6.14E-03	7.16E-03	1.82E-02	2.25E-01	2.63E-01	6.68E-01	1.36E-03	1.58E-03	4.03E-03	1.09E-04	1.27E-04	3.22E-04	1.34E+00	1.57E+00	3.98E+00
Entire Chemical Class:		8.76E-03	2.16E-02	9.33E-02	3.21E-01	7.90E-01	3.42E+00	1.94E-03	4.77E-03	2.06E-02	1.55E-04	3.81E-04	1.65E-03	1.91E+00	4.71E+00	2.04E+01
High Molecular Weight PAHs (HPAHs)																
Fluoranthene		5.31E-03	5.97E-03	1.06E-02	1.95E-01	2.19E-01	3.88E-01	1.17E-03	1.32E-03	2.34E-03	9.39E-05	1.06E-04	1.87E-04	1.16E+00	1.30E+00	2.31E+00
Pyrene		5.88E-03	7.73E-03	1.08E-02	2.16E-01	2.83E-01	3.96E-01	1.30E-03	1.71E-03	2.39E-03	1.04E-04	1.37E-04	1.91E-04	1.28E+00	1.69E+00	2.36E+00
Entire Chemical Class:		9.93E-03	1.32E-02	2.00E-02	3.64E-01	4.84E-01	7.32E-01	2.20E-03	2.92E-03	4.42E-03	1.76E-04	2.33E-04	3.53E-04	2.17E+00	2.88E+00	4.37E+00
Total PAHs (LPAHs+HPAHs)		2.02E-02	4.96E-02	1.23E-01	7.40E-01	1.82E+00	4.50E+00	4.47E-03	1.10E-02	2.71E-02	3.57E-04	8.78E-04	2.17E-03	4.41E+00	1.08E+01	2.68E+01
Phthalates (kg/year)																
bis(2-Ethylhexyl) phthalate		5.78E-01	1.18E+00	2.42E+00	2.12E+01	4.31E+01	8.87E+01	1.28E-01	2.60E-01	5.35E-01	1.02E-02	2.08E-02	4.28E-02	1.26E+02	2.57E+02	5.29E+02
Entire Chemical Class:		5.78E-01	1.46E+00	2.43E+00	2.12E+01	5.37E+01	8.90E+01	1.28E-01	3.24E-01	5.37E-01	1.02E-02	2.59E-02	4.29E-02	1.26E+02	3.20E+02	5.31E+02
Other Base/Neutral/Acid Extractables (kg/year)																
1,4-Dichlorobenzene		1.67E-01	2.70E-01	6.03E-01	6.10E+00	9.90E+00	2.21E+01	3.68E-02	5.97E-02	1.33E-01	2.94E-03	4.78E-03	1.07E-02	3.64E+01	5.90E+01	1.32E+02
2,4,6-Trichlorophenol		6.06E-02	1.19E-01	1.92E-01	2.22E+00	4.38E+00	7.02E+00	1.34E-02	2.64E-02	4.24E-02	1.07E-03	2.11E-03	3.39E-03	1.32E+01	2.61E+01	4.19E+01
2-Chloroethanol phosphate (3:1)		2.01E-01	2.89E-01	3.83E-01	7.37E+00	1.06E+01	1.40E+01	4.45E-02	6.39E-02	8.47E-02	3.56E-03	5.11E-03	6.78E-03	4.39E+01	6.32E+01	8.38E+01
3B-Coprostanol		8.17E+00	1.14E+01	1.85E+01	2.99E+02	4.17E+02	6.79E+02	1.81E+00	2.51E+00	4.10E+00	1.44E-01	2.01E-01	3.28E-01	1.78E+03	2.49E+03	4.05E+03
4-Methylphenol	p-Cresol	2.64E-01	4.11E-01	6.25E-01	9.67E+00	1.51E+01	2.29E+01	5.83E-02	9.08E-02	1.38E-01	4.67E-03	7.26E-03	1.10E-02	5.77E+01	8.98E+01	1.36E+02
Bisphenol A		3.33E-01	3.52E-01	9.49E-01	1.22E+01	1.29E+01	3.48E+01	7.35E-02	7.78E-02	2.10E-01	5.88E-03	6.22E-03	1.68E-02	7.27E+01	7.69E+01	2.07E+02
Caffeine		7.75E-02	1.90E-01	8.80E-01	2.84E+00	6.97E+00	3.22E+01	1.71E-02	4.21E-02	1.94E-01	1.37E-03	3.36E-03	1.56E-02	1.69E+01	4.16E+01	1.92E+02
Cholesterol		1.06E+01	1.57E+01	2.14E+01	3.88E+02	5.76E+02	7.83E+02	2.34E+00	3.47E+00	4.72E+00	1.87E-01	2.78E-01	3.78E-01	2.31E+03	3.43E+03	4.67E+03
Dibenzofuran		3.18E-03	7.73E-03	2.11E-02	1.16E-01	2.83E-01	7.72E-01	7.02E-04	1.71E-03	4.65E-03	5.62E-05	1.37E-04	3.72E-04	6.94E-01	1.69E+00	4.60E+00
Phenol		5.19E-01	9.24E-01	1.29E+00	1.90E+01	3.39E+01	4.72E+01	1.15E-01	2.04E-01	2.85E-01	9.18E-03	1.63E-02	2.28E-02	1.13E+02	2.02E+02	2.81E+02
Triclosan		4.34E-01	6.79E-01	1.07E+00	1.59E+01	2.49E+01	3.93E+01	9.59E-02	1.50E-01	2.37E-01	7.67E-03	1.20E-02	1.89E-02	9.47E+01	1.48E+02	2.34E+02
Triethyl citrate		6.25E-01	1.04E+00	1.38E+00	2.29E+01	3.80E+01	5.07E+01	1.38E-01	2.29E-01	3.06E-01	1.11E-02	1.83E-02	2.44E-02	1.37E+02	2.27E+02	3.02E+02
Polybrominated Diphenyl Ethers (Congeners) (kg/year)																
4,4'-DiBDE	BDE-015	1.09E-05	1.53E-05	5.85E-05	4.01E-04	5.62E-04	2.15E-03	2.42E-06	3.39E-06	1.29E-05	1.94E-07	2.71E-07	1.03E-06	2.39E-03	3.35E-03	1.28E-02
2,2',4-TrBDE	BDE-017	5.59E-05	1.07E-04	3.47E-04	2.05E-03	3.93E-03	1.27E-02	1.24E-05	2.37E-05	7.67E-05	9.89E-07	1.89E-06	6.13E-06	1.22E-02	2.34E-02	7.58E-02
2,4,4'-TrBDE	BDE-028	1.21E-04	2.44E-04	5.78E-04	4.44E-03	8.96E-03	2.12E-02	2.68E-05	5.40E-05	1.28E-04	2.14E-06	4.32E-06	1.02E-05	2.65E-02	5.34E-02	1.26E-01
2,2',4,4'-TeBDE	BDE-047	6.70E-03	8.21E-03	1.33E-02	2.45E-01	3.01E-01	4.86E-01	1.48E-03	1.82E-03	2.93E-03	1.18E-04	1.45E-04	2.35E-04	1.46E+00	1.79E+00	2.90E+00
2,2',4,5'-TeBDE	BDE-049	7.90E-05	2.73E-04	4.07E-04	2.89E-03	1.00E-02	1.49E-02	1.75E-05	6.03E-05	8.99E-05	1.40E-06	4.82E-06	7.19E-06	1.73E-02	5.96E-02	8.88E-02
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071	2.55E-04	4.35E-04	7.01E-04	9.36E-03	1.59E-02	2.57E-02	5.65E-05	9.61E-05	1.55E-04	4.52E-06	7.69E-06	1.24E-05	5.58E-02	9.50E-02	1.53E-01
2,3',4,4'-TeBDE	BDE-066	5.80E-05	1.91E-04	5.09E-04	2.13E-03	7.00E-03	1.87E-02	1.28E-05	4.22E-05	1.13E-04	1.03E-06	3.38E-06	9.00E-06	1.27E-02	4.17E-02	1.11E-01

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Port Gardner			San Juan Islands			Sinclair-Dyes Inlet			South Sound (East)			South Sound (West)		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
Polycyclic Aromatic Hydrocarbons (kg/year)																
Low Molecular Weight PAHs (LPAHs)																
Fluorene		6.35E-02	3.53E-01	8.44E-01	4.48E-03	2.49E-02	5.96E-02	1.96E-02	1.09E-01	2.61E-01	3.84E-02	2.14E-01	5.10E-01	2.56E-02	1.42E-01	3.40E-01
Phenanthrene		2.17E-01	2.53E-01	6.44E-01	1.53E-02	1.79E-02	4.54E-02	6.71E-02	7.82E-02	1.99E-01	1.31E-01	1.53E-01	3.90E-01	8.76E-02	1.02E-01	2.60E-01
Entire Chemical Class:		3.10E-01	7.62E-01	3.30E+00	2.18E-02	5.38E-02	2.33E-01	9.56E-02	2.35E-01	1.02E+00	1.87E-01	4.61E-01	1.99E+00	1.25E-01	3.07E-01	1.33E+00
High Molecular Weight PAHs (HPAHs)																
Fluoranthene		1.88E-01	2.11E-01	3.74E-01	1.32E-02	1.49E-02	2.64E-02	5.80E-02	6.52E-02	1.16E-01	1.14E-01	1.28E-01	2.26E-01	7.57E-02	8.51E-02	1.51E-01
Pyrene		2.08E-01	2.73E-01	3.82E-01	1.47E-02	1.93E-02	2.70E-02	6.42E-02	8.44E-02	1.18E-01	1.26E-01	1.65E-01	2.31E-01	8.38E-02	1.10E-01	1.54E-01
Entire Chemical Class:		3.51E-01	4.66E-01	7.06E-01	2.48E-02	3.29E-02	4.98E-02	1.08E-01	1.44E-01	2.18E-01	2.12E-01	2.82E-01	4.27E-01	1.42E-01	1.88E-01	2.85E-01
Total PAHs (LPAHs+HPAHs)		7.14E-01	1.75E+00	4.34E+00	5.04E-02	1.24E-01	3.06E-01	2.21E-01	5.42E-01	1.34E+00	4.32E-01	1.06E+00	2.62E+00	2.88E-01	7.07E-01	1.75E+00
Phthalates (kg/year)																
bis(2-Ethylhexyl) phthalate		2.04E+01	4.15E+01	8.55E+01	1.44E+00	2.93E+00	6.03E+00	6.31E+00	1.28E+01	2.64E+01	1.24E+01	2.51E+01	5.17E+01	8.24E+00	1.67E+01	3.45E+01
Entire Chemical Class:		2.04E+01	5.18E+01	8.59E+01	1.44E+00	3.65E+00	6.06E+00	6.31E+00	1.60E+01	2.65E+01	1.24E+01	3.13E+01	5.19E+01	8.24E+00	2.09E+01	3.46E+01
Other Base/Neutral/Acid Extractables (kg/year)																
1,4-Dichlorobenzene		5.89E+00	9.55E+00	2.13E+01	4.15E-01	6.74E-01	1.50E+00	1.82E+00	2.95E+00	6.58E+00	3.56E+00	5.78E+00	1.29E+01	2.37E+00	3.85E+00	8.60E+00
2,4,6-Trichlorophenol		2.14E+00	4.22E+00	6.77E+00	1.51E-01	2.98E-01	4.78E-01	6.62E-01	1.30E+00	2.09E+00	1.30E+00	2.55E+00	4.10E+00	8.64E-01	1.70E+00	2.73E+00
2-Chloroethanol phosphate (3:1)		7.11E+00	1.02E+01	1.35E+01	5.01E-01	7.21E-01	9.56E-01	2.19E+00	3.16E+00	4.18E+00	4.30E+00	6.18E+00	8.19E+00	2.87E+00	4.12E+00	5.46E+00
3B-Coprostanol		2.89E+02	4.02E+02	6.55E+02	2.04E+01	2.84E+01	4.62E+01	8.92E+01	1.24E+02	2.02E+02	1.75E+02	2.43E+02	3.96E+02	1.16E+02	1.62E+02	2.64E+02
4-Methylphenol	p-Cresol	9.33E+00	1.45E+01	2.21E+01	6.58E-01	1.02E+00	1.56E+00	2.88E+00	4.48E+00	6.82E+00	5.64E+00	8.78E+00	1.34E+01	3.76E+00	5.85E+00	8.90E+00
Bisphenol A		1.18E+01	1.24E+01	3.35E+01	8.29E-01	8.78E-01	2.37E+00	3.63E+00	3.84E+00	1.04E+01	7.11E+00	7.52E+00	2.03E+01	4.74E+00	5.01E+00	1.35E+01
Caffeine		2.74E+00	6.73E+00	3.11E+01	1.93E-01	4.74E-01	2.19E+00	8.46E-01	2.08E+00	9.60E+00	1.66E+00	4.07E+00	1.88E+01	1.10E+00	2.71E+00	1.25E+01
Cholesterol		3.74E+02	5.55E+02	7.55E+02	2.64E+01	3.92E+01	5.33E+01	1.16E+02	1.71E+02	2.33E+02	2.26E+02	3.36E+02	4.57E+02	1.51E+02	2.24E+02	3.04E+02
Dibenzofuran		1.12E-01	2.73E-01	7.44E-01	7.92E-03	1.93E-02	5.25E-02	3.47E-02	8.44E-02	2.30E-01	6.79E-02	1.65E-01	4.50E-01	4.53E-02	1.10E-01	3.00E-01
Phenol		1.83E+01	3.27E+01	4.55E+01	1.29E+00	2.30E+00	3.21E+00	5.67E+00	1.01E+01	1.41E+01	1.11E+01	1.97E+01	2.75E+01	7.40E+00	1.32E+01	1.84E+01
Triclosan		1.53E+01	2.40E+01	3.79E+01	1.08E+00	1.69E+00	2.67E+00	4.73E+00	7.41E+00	1.17E+01	9.27E+00	1.45E+01	2.29E+01	6.18E+00	9.67E+00	1.53E+01
Triethyl citrate		2.21E+01	3.67E+01	4.89E+01	1.56E+00	2.59E+00	3.45E+00	6.82E+00	1.13E+01	1.51E+01	1.34E+01	2.22E+01	2.96E+01	8.91E+00	1.48E+01	1.97E+01
Polybrominated Diphenyl Ethers (Congeners) (kg/year)																
4,4'-DiBDE	BDE-015	3.87E-04	5.42E-04	2.07E-03	2.73E-05	3.82E-05	1.46E-04	1.20E-04	1.67E-04	6.39E-04	2.34E-04	3.28E-04	1.25E-03	1.56E-04	2.18E-04	8.34E-04
2,2',4-TrBDE	BDE-017	1.98E-03	3.79E-03	1.23E-02	1.39E-04	2.67E-04	8.65E-04	6.10E-04	1.17E-03	3.79E-03	1.20E-03	2.29E-03	7.41E-03	7.97E-04	1.53E-03	4.94E-03
2,4,4'-TrBDE	BDE-028	4.29E-03	8.64E-03	2.04E-02	3.02E-04	6.10E-04	1.44E-03	1.32E-03	2.67E-03	6.31E-03	2.59E-03	5.23E-03	1.24E-02	1.73E-03	3.48E-03	8.24E-03
2,2',4,4'-TeBDE	BDE-047	2.37E-01	2.90E-01	4.69E-01	1.67E-02	2.05E-02	3.31E-02	7.31E-02	8.96E-02	1.45E-01	1.43E-01	1.76E-01	2.84E-01	9.54E-02	1.17E-01	1.89E-01
2,2',4,5'-TeBDE	BDE-049	2.79E-03	9.64E-03	1.44E-02	1.97E-04	6.80E-04	1.01E-03	8.62E-04	2.98E-03	4.44E-03	1.69E-03	5.83E-03	8.69E-03	1.13E-03	3.89E-03	5.79E-03
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071	9.03E-03	1.54E-02	2.48E-02	6.37E-04	1.08E-03	1.75E-03	2.79E-03	4.75E-03	7.65E-03	5.46E-03	9.30E-03	1.50E-02	3.64E-03	6.20E-03	9.99E-03
2,3',4,4'-TeBDE	BDE-066	2.05E-03	6.75E-03	1.80E-02	1.45E-04	4.76E-04	1.27E-03	6.34E-04	2.09E-03	5.56E-03	1.24E-03	4.08E-03	1.09E-02	8.27E-04	2.72E-03	7.25E-03

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Strait of Georgia			Strait of Juan de Fuca			Whidbey Basin			Total Puget Sound		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
Polycyclic Aromatic Hydrocarbons (kg/year)													
Low Molecular Weight PAHs (LPAHs)													
Fluorene		3.28E-02	1.83E-01	4.36E-01	6.00E-03	3.34E-02	7.98E-02	2.07E-02	1.15E-01	2.75E-01	6.72E-01	3.74E+00	8.93E+00
Phenanthrene		1.12E-01	1.31E-01	3.33E-01	2.05E-02	2.40E-02	6.09E-02	7.08E-02	8.25E-02	2.10E-01	2.30E+00	2.68E+00	6.81E+00
Entire Chemical Class:		1.60E-01	3.94E-01	1.71E+00	2.93E-02	7.21E-02	3.12E-01	1.01E-01	2.48E-01	1.08E+00	3.27E+00	8.06E+00	3.49E+01
High Molecular Weight PAHs (HPAHs)													
Fluoranthene		9.71E-02	1.09E-01	1.94E-01	1.78E-02	2.00E-02	3.54E-02	6.12E-02	6.88E-02	1.22E-01	1.99E+00	2.23E+00	3.96E+00
Pyrene		1.07E-01	1.41E-01	1.98E-01	1.97E-02	2.58E-02	3.61E-02	6.77E-02	8.90E-02	1.25E-01	2.20E+00	2.89E+00	4.04E+00
Entire Chemical Class:		1.82E-01	2.41E-01	3.65E-01	3.32E-02	4.41E-02	6.68E-02	1.14E-01	1.52E-01	2.30E-01	3.71E+00	4.93E+00	7.47E+00
Total PAHs (LPAHs+HPAHs)		3.69E-01	9.07E-01	2.24E+00	6.75E-02	1.66E-01	4.10E-01	2.33E-01	5.72E-01	1.41E+00	7.55E+00	1.86E+01	4.59E+01
Phthalates (kg/year)													
bis(2-Ethylhexyl) phthalate		1.06E+01	2.15E+01	4.42E+01	1.93E+00	3.93E+00	8.09E+00	6.66E+00	1.35E+01	2.79E+01	2.16E+02	4.39E+02	9.05E+02
Entire Chemical Class:		1.06E+01	2.68E+01	4.44E+01	1.93E+00	4.90E+00	8.12E+00	6.66E+00	1.69E+01	2.80E+01	2.16E+02	5.47E+02	9.08E+02
Other Base/Neutral/Acid Extractables (kg/year)													
1,4-Dichlorobenzene		3.04E+00	4.94E+00	1.10E+01	5.57E-01	9.03E-01	2.02E+00	1.92E+00	3.11E+00	6.95E+00	6.23E+01	1.01E+02	2.26E+02
2,4,6-Trichlorophenol		1.11E+00	2.18E+00	3.50E+00	2.03E-01	3.99E-01	6.41E-01	6.99E-01	1.38E+00	2.21E+00	2.27E+01	4.46E+01	7.17E+01
2-Chloroethanol phosphate (3:1)		3.68E+00	5.28E+00	7.01E+00	6.72E-01	9.66E-01	1.28E+00	2.32E+00	3.33E+00	4.42E+00	7.52E+01	1.08E+02	1.43E+02
3B-Coprostanol		1.49E+02	2.08E+02	3.39E+02	2.73E+01	3.80E+01	6.20E+01	9.41E+01	1.31E+02	2.14E+02	3.05E+03	4.25E+03	6.93E+03
4-Methylphenol	p-Cresol	4.82E+00	7.51E+00	1.14E+01	8.82E-01	1.37E+00	2.09E+00	3.04E+00	4.73E+00	7.20E+00	9.87E+01	1.54E+02	2.34E+02
Bisphenol A		6.08E+00	6.43E+00	1.73E+01	1.11E+00	1.18E+00	3.17E+00	3.83E+00	4.05E+00	1.09E+01	1.24E+02	1.32E+02	3.55E+02
Caffeine		1.42E+00	3.48E+00	1.61E+01	2.59E-01	6.36E-01	2.94E+00	8.93E-01	2.19E+00	1.01E+01	2.90E+01	7.11E+01	3.29E+02
Cholesterol		1.94E+02	2.87E+02	3.90E+02	3.54E+01	5.25E+01	7.14E+01	1.22E+02	1.81E+02	2.46E+02	3.96E+03	5.87E+03	7.99E+03
Dibenzofuran		5.81E-02	1.41E-01	3.85E-01	1.06E-02	2.58E-02	7.04E-02	3.66E-02	8.90E-02	2.43E-01	1.19E+00	2.89E+00	7.87E+00
Phenol		9.49E+00	1.69E+01	2.35E+01	1.74E+00	3.09E+00	4.31E+00	5.98E+00	1.06E+01	1.48E+01	1.94E+02	3.45E+02	4.82E+02
Triclosan		7.92E+00	1.24E+01	1.96E+01	1.45E+00	2.27E+00	3.58E+00	5.00E+00	7.82E+00	1.23E+01	1.62E+02	2.54E+02	4.01E+02
Triethyl citrate		1.14E+01	1.90E+01	2.53E+01	2.09E+00	3.47E+00	4.62E+00	7.20E+00	1.19E+01	1.59E+01	2.34E+02	3.88E+02	5.17E+02
Polybrominated Diphenyl Ethers (Congeners) (kg/year)													
4,4'-DiBDE	BDE-015	2.00E-04	2.80E-04	1.07E-03	3.66E-05	5.13E-05	1.96E-04	1.26E-04	1.77E-04	6.74E-04	4.09E-03	5.73E-03	2.19E-02
2,2',4-TrBDE	BDE-017	1.02E-03	1.96E-03	6.34E-03	1.87E-04	3.58E-04	1.16E-03	6.44E-04	1.23E-03	4.00E-03	2.09E-02	4.01E-02	1.30E-01
2,4,4'-TrBDE	BDE-028	2.22E-03	4.47E-03	1.06E-02	4.05E-04	8.17E-04	1.93E-03	1.40E-03	2.82E-03	6.66E-03	4.53E-02	9.14E-02	2.16E-01
2,2',4,4'-TeBDE	BDE-047	1.22E-01	1.50E-01	2.43E-01	2.24E-02	2.75E-02	4.44E-02	7.71E-02	9.46E-02	1.53E-01	2.50E+00	3.07E+00	4.96E+00
2,2',4,5'-TeBDE	BDE-049	1.44E-03	4.98E-03	7.43E-03	2.64E-04	9.12E-04	1.36E-03	9.10E-04	3.14E-03	4.68E-03	2.95E-02	1.02E-01	1.52E-01
2,2',4,5'/2,3',4',6-TeBDE	BDE-049/071	4.67E-03	7.95E-03	1.28E-02	8.54E-04	1.45E-03	2.34E-03	2.94E-03	5.01E-03	8.08E-03	9.55E-02	1.63E-01	2.62E-01
2,3',4,4'-TeBDE	BDE-066	1.06E-03	3.49E-03	9.30E-03	1.94E-04	6.39E-04	1.70E-03	6.69E-04	2.20E-03	5.86E-03	2.17E-02	7.14E-02	1.90E-01

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Admiralty Inlet			Commencement Bay			Hood Canal (North)			Hood Canal (South)			Main Basin		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
2,3',4',6-TeBDE	BDE-071	4.62E-05	5.78E-05	1.71E-04	1.69E-03	2.12E-03	6.27E-03	1.02E-05	1.28E-05	3.78E-05	8.16E-07	1.02E-06	3.03E-06	1.01E-02	1.26E-02	3.74E-02
2,2',3,4,4'-PeBDE	BDE-085	2.34E-04	3.22E-04	5.72E-04	8.57E-03	1.18E-02	2.10E-02	5.17E-05	7.11E-05	1.27E-04	4.13E-06	5.69E-06	1.01E-05	5.11E-02	7.03E-02	1.25E-01
2,2',4,4',5-PeBDE	BDE-099	5.74E-03	7.92E-03	1.76E-02	2.11E-01	2.90E-01	6.44E-01	1.27E-03	1.75E-03	3.88E-03	1.02E-04	1.40E-04	3.11E-04	1.25E+00	1.73E+00	3.84E+00
2,2',4,4',6-PeBDE	BDE-100	1.26E-03	1.61E-03	3.15E-03	4.62E-02	5.90E-02	1.16E-01	2.79E-04	3.56E-04	6.97E-04	2.23E-05	2.84E-05	5.58E-05	2.75E-01	3.51E-01	6.89E-01
2,2',4,4',5,5'-HxBDE	BDE-153	4.49E-04	6.82E-04	1.73E-03	1.65E-02	2.50E-02	6.33E-02	9.93E-05	1.51E-04	3.82E-04	7.94E-06	1.21E-05	3.06E-05	9.81E-02	1.49E-01	3.78E-01
2,2',4,4',5,6'-HxBDE	BDE-154	3.92E-04	5.08E-04	1.07E-03	1.44E-02	1.86E-02	3.94E-02	8.68E-05	1.12E-04	2.37E-04	6.94E-06	8.98E-06	1.90E-05	8.57E-02	1.11E-01	2.35E-01
2,2',3,4,4',5',6-HpBDE	BDE-183	1.74E-05	5.52E-05	1.37E-04	6.39E-04	2.02E-03	5.03E-03	3.85E-06	1.22E-05	3.04E-05	3.08E-07	9.76E-07	2.43E-06	3.81E-03	1.21E-02	3.00E-02
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	1.15E-04	3.33E-04	8.23E-04	4.20E-03	1.22E-02	3.02E-02	2.53E-05	7.36E-05	1.82E-04	2.03E-06	5.89E-06	1.45E-05	2.50E-02	7.28E-02	1.80E-01
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	1.40E-04	3.17E-04	7.35E-04	5.13E-03	1.16E-02	2.69E-02	3.09E-05	7.02E-05	1.63E-04	2.47E-06	5.61E-06	1.30E-05	3.06E-02	6.93E-02	1.61E-01
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	5.76E-05	1.55E-04	5.35E-04	2.11E-03	5.67E-03	1.96E-02	1.27E-05	3.42E-05	1.18E-04	1.02E-06	2.73E-06	9.47E-06	1.26E-02	3.38E-02	1.17E-01
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	2.44E-03	4.02E-03	1.17E-02	8.96E-02	1.47E-01	4.29E-01	5.40E-04	8.89E-04	2.58E-03	4.32E-05	7.11E-05	2.07E-04	5.34E-01	8.79E-01	2.55E+00
Entire Chemical Class:		1.88E-02	2.83E-02	5.54E-02	6.88E-01	1.04E+00	2.03E+00	4.15E-03	6.26E-03	1.23E-02	3.32E-04	5.01E-04	9.80E-04	4.10E+00	6.19E+00	1.21E+01
Polybrominated Diphenyl Ethers (Homologs) (kg/year)																
Decabromodiphenyl ether		2.44E-03	4.02E-03	1.17E-02	8.96E-02	1.47E-01	4.29E-01	5.40E-04	8.89E-04	2.58E-03	4.32E-05	7.11E-05	2.07E-04	5.34E-01	8.79E-01	2.55E+00
Dibromodiphenyl ethers		1.17E-05	1.96E-05	7.19E-05	4.28E-04	7.19E-04	2.63E-03	2.58E-06	4.33E-06	1.59E-05	2.07E-07	3.47E-07	1.27E-06	2.55E-03	4.28E-03	1.57E-02
Heptabromodiphenyl ethers		1.71E-05	5.57E-05	1.37E-04	6.25E-04	2.04E-03	5.03E-03	3.77E-06	1.23E-05	3.04E-05	3.02E-07	9.85E-07	2.43E-06	3.73E-03	1.22E-02	3.00E-02
Hexabromodiphenyl ethers		8.13E-04	1.29E-03	3.01E-03	2.98E-02	4.71E-02	1.10E-01	1.80E-04	2.84E-04	6.66E-04	1.44E-05	2.27E-05	5.33E-05	1.78E-01	2.81E-01	6.58E-01
Nonabromodiphenyl ethers		1.78E-04	7.87E-04	2.05E-03	6.52E-03	2.88E-02	7.53E-02	3.93E-05	1.74E-04	4.54E-04	3.14E-06	1.39E-05	3.63E-05	3.88E-02	1.72E-01	4.49E-01
Pentabromodiphenyl ethers		7.48E-03	9.93E-03	2.16E-02	2.74E-01	3.64E-01	7.92E-01	1.65E-03	2.20E-03	4.78E-03	1.32E-04	1.76E-04	3.82E-04	1.63E+00	2.17E+00	4.72E+00
Tetrabromodiphenyl ethers		6.93E-03	9.05E-03	1.42E-02	2.54E-01	3.32E-01	5.19E-01	1.53E-03	2.00E-03	3.13E-03	1.23E-04	1.60E-04	2.50E-04	1.52E+00	1.98E+00	3.09E+00
Tribromodiphenyl ethers		1.92E-04	3.56E-04	8.35E-04	7.02E-03	1.31E-02	3.06E-02	4.24E-05	7.88E-05	1.85E-04	3.39E-06	6.30E-06	1.48E-05	4.19E-02	7.79E-02	1.82E-01
Perfluorinated Compounds (kg/year)																
Perfluorobutanoate	PFBA	1.11E-03	1.73E-03	3.25E-03	4.05E-02	6.36E-02	1.19E-01	2.45E-04	3.83E-04	7.20E-04	1.96E-05	3.07E-05	5.76E-05	2.42E-01	3.79E-01	7.11E-01
Perfluorodecanoate	PFDA	3.27E-03	4.54E-03	7.15E-03	1.20E-01	1.67E-01	2.62E-01	7.23E-04	1.00E-03	1.58E-03	5.78E-05	8.03E-05	1.26E-04	7.15E-01	9.93E-01	1.56E+00
Perfluoroheptanoate	PFHpA	4.63E-03	5.89E-03	7.69E-03	1.70E-01	2.16E-01	2.82E-01	1.02E-03	1.30E-03	1.70E-03	8.19E-05	1.04E-04	1.36E-04	1.01E+00	1.29E+00	1.68E+00
Perfluorohexane sulfonate	PFHxS	1.60E-03	3.28E-03	4.56E-03	5.87E-02	1.20E-01	1.67E-01	3.54E-04	7.25E-04	1.01E-03	2.83E-05	5.80E-05	8.05E-05	3.50E-01	7.17E-01	9.95E-01
Perfluorohexanoate	PFHxA	1.62E-02	2.09E-02	3.37E-02	5.95E-01	7.67E-01	1.24E+00	3.59E-03	4.63E-03	7.46E-03	2.87E-04	3.70E-04	5.97E-04	3.55E+00	4.57E+00	7.37E+00
Perfluorononanoate	PFNA	4.62E-03	7.60E-03	1.57E-02	1.69E-01	2.79E-01	5.76E-01	1.02E-03	1.68E-03	3.47E-03	8.17E-05	1.34E-04	2.78E-04	1.01E+00	1.66E+00	3.43E+00
Perfluorooctane sulfonate	PFOS	5.09E-03	7.48E-03	1.23E-02	1.87E-01	2.74E-01	4.51E-01	1.13E-03	1.65E-03	2.72E-03	9.00E-05	1.32E-04	2.17E-04	1.11E+00	1.64E+00	2.69E+00
Perfluorooctanoate	PFOA	1.64E-02	2.95E-02	4.34E-02	6.00E-01	1.08E+00	1.59E+00	3.62E-03	6.52E-03	9.60E-03	2.89E-04	5.21E-04	7.68E-04	3.58E+00	6.44E+00	9.49E+00
Perfluoropentanoate	PFPeA	2.37E-03	3.29E-03	1.19E-02	8.68E-02	1.20E-01	4.38E-01	5.24E-04	7.27E-04	2.64E-03	4.19E-05	5.81E-05	2.11E-04	5.18E-01	7.18E-01	2.61E+00
Entire Chemical Class:		8.41E-02	1.14E-01	1.57E-01	3.08E+00	4.17E+00	5.77E+00	1.86E-02	2.52E-02	3.48E-02	1.49E-03	2.01E-03	2.78E-03	1.84E+01	2.49E+01	3.44E+01
Polychlorinated Biphenyls (Congeners) (kg/year)																
2-MoCB	PCB-001	7.89E-06	1.83E-05	4.50E-05	2.89E-04	6.73E-04	1.65E-03	1.74E-06	4.06E-06	9.95E-06	1.39E-07	3.24E-07	7.96E-07	1.72E-03	4.01E-03	9.84E-03
2,2'-DiCB	PCB-004	1.38E-05	4.77E-05	9.47E-05	5.07E-04	1.75E-03	3.47E-03	3.06E-06	1.05E-05	2.09E-05	2.44E-07	8.43E-07	1.67E-06	3.02E-03	1.04E-02	2.07E-02
2,3'-DiCB	PCB-006	9.30E-06	1.97E-05	2.63E-05	3.41E-04	7.23E-04	9.64E-04	2.06E-06	4.36E-06	5.81E-06	1.64E-07	3.49E-07	4.65E-07	2.03E-03	4.31E-03	5.75E-03
2,2',3-TrCB	PCB-016	1.91E-05	3.37E-05	5.71E-05	6.99E-04	1.23E-03	2.09E-03	4.22E-06	7.45E-06	1.26E-05	3.37E-07	5.96E-07	1.01E-06	4.17E-03	7.36E-03	1.25E-02

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Port Gardner			San Juan Islands			Sinclair-Dyes Inlet			South Sound (East)			South Sound (West)		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
2,3',4',6-TeBDE	BDE-071	1.63E-03	2.04E-03	6.05E-03	1.15E-04	1.44E-04	4.27E-04	5.04E-04	6.31E-04	1.87E-03	9.87E-04	1.24E-03	3.66E-03	6.58E-04	8.24E-04	2.44E-03
2,2',3,4,4'-PeBDE	BDE-085	8.26E-03	1.14E-02	2.02E-02	5.83E-04	8.02E-04	1.43E-03	2.55E-03	3.51E-03	6.25E-03	5.00E-03	6.88E-03	1.22E-02	3.33E-03	4.58E-03	8.16E-03
2,2',4,4',5-PeBDE	BDE-099	2.03E-01	2.80E-01	6.21E-01	1.43E-02	1.97E-02	4.38E-02	6.27E-02	8.64E-02	1.92E-01	1.23E-01	1.69E-01	3.75E-01	8.18E-02	1.13E-01	2.50E-01
2,2',4,4',6-PeBDE	BDE-100	4.46E-02	5.69E-02	1.12E-01	3.14E-03	4.01E-03	7.87E-03	1.38E-02	1.76E-02	3.44E-02	2.69E-02	3.44E-02	6.74E-02	1.80E-02	2.29E-02	4.50E-02
2,2',4,4',5,5'-HxBDE	BDE-153	1.59E-02	2.41E-02	6.11E-02	1.12E-03	1.70E-03	4.31E-03	4.90E-03	7.45E-03	1.89E-02	9.60E-03	1.46E-02	3.69E-02	6.40E-03	9.72E-03	2.46E-02
2,2',4,4',5,6'-HxBDE	BDE-154	1.39E-02	1.79E-02	3.80E-02	9.79E-04	1.27E-03	2.68E-03	4.28E-03	5.54E-03	1.17E-02	8.39E-03	1.09E-02	2.29E-02	5.59E-03	7.24E-03	1.53E-02
2,2',3,4,4',5',6-HpBDE	BDE-183	6.16E-04	1.95E-03	4.85E-03	4.35E-05	1.38E-04	3.42E-04	1.90E-04	6.03E-04	1.50E-03	3.73E-04	1.18E-03	2.93E-03	2.48E-04	7.87E-04	1.96E-03
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	4.05E-03	1.18E-02	2.91E-02	2.86E-04	8.31E-04	2.05E-03	1.25E-03	3.64E-03	8.98E-03	2.45E-03	7.12E-03	1.76E-02	1.63E-03	4.75E-03	1.17E-02
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	4.95E-03	1.12E-02	2.60E-02	3.49E-04	7.91E-04	1.83E-03	1.53E-03	3.46E-03	8.03E-03	2.99E-03	6.78E-03	1.57E-02	1.99E-03	4.52E-03	1.05E-02
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	2.04E-03	5.46E-03	1.89E-02	1.44E-04	3.86E-04	1.34E-03	6.29E-04	1.69E-03	5.84E-03	1.23E-03	3.30E-03	1.14E-02	8.21E-04	2.20E-03	7.63E-03
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	8.64E-02	1.42E-01	4.13E-01	6.10E-03	1.00E-02	2.92E-02	2.67E-02	4.39E-02	1.28E-01	5.23E-02	8.60E-02	2.50E-01	3.48E-02	5.73E-02	1.67E-01
Entire Chemical Class:		6.64E-01	1.00E+00	1.96E+00	4.68E-02	7.07E-02	1.38E-01	2.05E-01	3.09E-01	6.05E-01	4.01E-01	6.06E-01	1.18E+00	2.67E-01	4.04E-01	7.90E-01
Polybrominated Diphenyl Ethers (Homologs) (kg/year)																
Decabromodiphenyl ether		8.64E-02	1.42E-01	4.13E-01	6.10E-03	1.00E-02	2.92E-02	2.67E-02	4.39E-02	1.28E-01	5.23E-02	8.60E-02	2.50E-01	3.48E-02	5.73E-02	1.67E-01
Dibromodiphenyl ethers		4.13E-04	6.93E-04	2.54E-03	2.91E-05	4.89E-05	1.79E-04	1.28E-04	2.14E-04	7.85E-04	2.50E-04	4.19E-04	1.54E-03	1.67E-04	2.79E-04	1.02E-03
Heptabromodiphenyl ethers		6.03E-04	1.97E-03	4.85E-03	4.25E-05	1.39E-04	3.42E-04	1.86E-04	6.08E-04	1.50E-03	3.65E-04	1.19E-03	2.93E-03	2.43E-04	7.94E-04	1.96E-03
Hexabromodiphenyl ethers		2.87E-02	4.55E-02	1.07E-01	2.03E-03	3.21E-03	7.51E-03	8.88E-03	1.40E-02	3.29E-02	1.74E-02	2.75E-02	6.44E-02	1.16E-02	1.83E-02	4.29E-02
Nonabromodiphenyl ethers		6.28E-03	2.78E-02	7.26E-02	4.43E-04	1.96E-03	5.12E-03	1.94E-03	8.59E-03	2.24E-02	3.80E-03	1.68E-02	4.39E-02	2.53E-03	1.12E-02	2.93E-02
Pentabromodiphenyl ethers		2.64E-01	3.51E-01	7.64E-01	1.86E-02	2.48E-02	5.39E-02	8.16E-02	1.08E-01	2.36E-01	1.60E-01	2.12E-01	4.62E-01	1.07E-01	1.42E-01	3.08E-01
Tetrabromodiphenyl ethers		2.45E-01	3.20E-01	5.00E-01	1.73E-02	2.26E-02	3.53E-02	7.57E-02	9.88E-02	1.54E-01	1.48E-01	1.94E-01	3.02E-01	9.88E-02	1.29E-01	2.02E-01
Tribromodiphenyl ethers		6.77E-03	1.26E-02	2.95E-02	4.78E-04	8.89E-04	2.08E-03	2.09E-03	3.89E-03	9.12E-03	4.10E-03	7.62E-03	1.79E-02	2.73E-03	5.08E-03	1.19E-02
Perfluorinated Compounds (kg/year)																
Perfluorobutanoate	PFBA	3.91E-02	6.13E-02	1.15E-01	2.76E-03	4.33E-03	8.12E-03	1.21E-02	1.89E-02	3.55E-02	2.36E-02	3.71E-02	6.96E-02	1.58E-02	2.47E-02	4.64E-02
Perfluorodecanoate	PFDA	1.16E-01	1.61E-01	2.53E-01	8.16E-03	1.13E-02	1.78E-02	3.57E-02	4.96E-02	7.81E-02	6.99E-02	9.71E-02	1.53E-01	4.66E-02	6.47E-02	1.02E-01
Perfluoroheptanoate	PFHpA	1.64E-01	2.08E-01	2.72E-01	1.16E-02	1.47E-02	1.92E-02	5.06E-02	6.43E-02	8.40E-02	9.91E-02	1.26E-01	1.64E-01	6.60E-02	8.40E-02	1.10E-01
Perfluorohexane sulfonate	PFHxS	5.66E-02	1.16E-01	1.61E-01	3.99E-03	8.18E-03	1.14E-02	1.75E-02	3.58E-02	4.97E-02	3.42E-02	7.01E-02	9.74E-02	2.28E-02	4.67E-02	6.49E-02
Perfluorohexanoate	PFHxA	5.74E-01	7.40E-01	1.19E+00	4.05E-02	5.22E-02	8.42E-02	1.77E-01	2.28E-01	3.68E-01	3.47E-01	4.47E-01	7.21E-01	2.31E-01	2.98E-01	4.81E-01
Perfluorononanoate	PFNA	1.63E-01	2.69E-01	5.55E-01	1.15E-02	1.90E-02	3.92E-02	5.04E-02	8.30E-02	1.71E-01	9.88E-02	1.63E-01	3.36E-01	6.59E-02	1.08E-01	2.24E-01
Perfluorooctane sulfonate	PFOS	1.80E-01	2.65E-01	4.35E-01	1.27E-02	1.87E-02	3.07E-02	5.56E-02	8.17E-02	1.34E-01	1.09E-01	1.60E-01	2.63E-01	7.25E-02	1.07E-01	1.75E-01
Perfluorooctanoate	PFOA	5.79E-01	1.04E+00	1.53E+00	4.08E-02	7.35E-02	1.08E-01	1.79E-01	3.22E-01	4.74E-01	3.50E-01	6.30E-01	9.28E-01	2.33E-01	4.20E-01	6.19E-01
Perfluoropentanoate	PFPeA	8.37E-02	1.16E-01	4.22E-01	5.91E-03	8.20E-03	2.98E-02	2.59E-02	3.59E-02	1.30E-01	5.06E-02	7.03E-02	2.55E-01	3.38E-02	4.68E-02	1.70E-01
Entire Chemical Class:		2.97E+00	4.02E+00	5.56E+00	2.10E-01	2.84E-01	3.93E-01	9.18E-01	1.24E+00	1.72E+00	1.80E+00	2.43E+00	3.36E+00	1.20E+00	1.62E+00	2.24E+00
Polychlorinated Biphenyls (Congeners) (kg/year)																
2-MoCB	PCB-001	2.79E-04	6.49E-04	1.59E-03	1.97E-05	4.58E-05	1.12E-04	8.61E-05	2.00E-04	4.91E-04	1.69E-04	3.92E-04	9.62E-04	1.12E-04	2.61E-04	6.42E-04
2,2'-DiCB	PCB-004	4.89E-04	1.69E-03	3.35E-03	3.45E-05	1.19E-04	2.36E-04	1.51E-04	5.21E-04	1.03E-03	2.96E-04	1.02E-03	2.02E-03	1.97E-04	6.80E-04	1.35E-03
2,3'-DiCB	PCB-006	3.29E-04	6.97E-04	9.30E-04	2.32E-05	4.92E-05	6.56E-05	1.02E-04	2.15E-04	2.87E-04	1.99E-04	4.22E-04	5.62E-04	1.33E-04	2.81E-04	3.75E-04
2,2',3-TrCB	PCB-016	6.74E-04	1.19E-03	2.02E-03	4.76E-05	8.40E-05	1.42E-04	2.08E-04	3.68E-04	6.23E-04	4.08E-04	7.20E-04	1.22E-03	2.72E-04	4.80E-04	8.13E-04

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Strait of Georgia			Strait of Juan de Fuca			Whidbey Basin			Total Puget Sound		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
2,3',4',6-TeBDE	BDE-071	8.44E-04	1.06E-03	3.13E-03	1.54E-04	1.93E-04	5.72E-04	5.32E-04	6.66E-04	1.97E-03	1.73E-02	2.16E-02	6.40E-02
2,2',3,4,4'-PeBDE	BDE-085	4.27E-03	5.88E-03	1.05E-02	7.82E-04	1.08E-03	1.91E-03	2.69E-03	3.71E-03	6.60E-03	8.74E-02	1.20E-01	2.14E-01
2,2',4,4',5-PeBDE	BDE-099	1.05E-01	1.45E-01	3.21E-01	1.92E-02	2.65E-02	5.87E-02	6.62E-02	9.12E-02	2.02E-01	2.15E+00	2.96E+00	6.57E+00
2,2',4,4',6-PeBDE	BDE-100	2.30E-02	2.94E-02	5.77E-02	4.21E-03	5.38E-03	1.05E-02	1.45E-02	1.85E-02	3.63E-02	4.71E-01	6.02E-01	1.18E+00
2,2',4,4',5,5'-HxBDE	BDE-153	8.21E-03	1.25E-02	3.16E-02	1.50E-03	2.28E-03	5.78E-03	5.17E-03	7.86E-03	1.99E-02	1.68E-01	2.55E-01	6.46E-01
2,2',4,4',5,6'-HxBDE	BDE-154	7.17E-03	9.28E-03	1.96E-02	1.31E-03	1.70E-03	3.59E-03	4.52E-03	5.85E-03	1.24E-02	1.47E-01	1.90E-01	4.01E-01
2,2',3,4,4',5',6-HpBDE	BDE-183	3.19E-04	1.01E-03	2.51E-03	5.83E-05	1.85E-04	4.59E-04	2.01E-04	6.36E-04	1.58E-03	6.52E-03	2.06E-02	5.13E-02
2,2',3,3',4,4',5,5',6-NoBDE	BDE-206	2.09E-03	6.09E-03	1.50E-02	3.83E-04	1.11E-03	2.75E-03	1.32E-03	3.84E-03	9.48E-03	4.29E-02	1.25E-01	3.08E-01
2,2',3,3',4,4',5,6,6'-NoBDE	BDE-207	2.56E-03	5.80E-03	1.34E-02	4.68E-04	1.06E-03	2.46E-03	1.61E-03	3.66E-03	8.47E-03	5.23E-02	1.19E-01	2.75E-01
2,2',3,3',4,5,5',6,6'-NoBDE	BDE-208	1.05E-03	2.83E-03	9.79E-03	1.93E-04	5.17E-04	1.79E-03	6.64E-04	1.78E-03	6.17E-03	2.16E-02	5.78E-02	2.00E-01
2,2',3,3',4,4',5,5',6,6'-DeBDE	BDE-209	4.47E-02	7.35E-02	2.14E-01	8.17E-03	1.34E-02	3.91E-02	2.82E-02	4.63E-02	1.35E-01	9.14E-01	1.50E+00	4.37E+00
Entire Chemical Class:		3.43E-01	5.18E-01	1.01E+00	6.28E-02	9.47E-02	1.85E-01	2.16E-01	3.26E-01	6.38E-01	7.02E+00	1.06E+01	2.07E+01
Polybrominated Diphenyl Ethers (Homologs) (kg/year)													
Decabromodiphenyl ether		4.47E-02	7.35E-02	2.14E-01	8.17E-03	1.34E-02	3.91E-02	2.82E-02	4.63E-02	1.35E-01	9.14E-01	1.50E+00	4.37E+00
Dibromodiphenyl ethers		2.14E-04	3.58E-04	1.31E-03	3.91E-05	6.55E-05	2.40E-04	1.35E-04	2.26E-04	8.28E-04	4.37E-03	7.33E-03	2.69E-02
Heptabromodiphenyl ethers		3.12E-04	1.02E-03	2.51E-03	5.70E-05	1.86E-04	4.59E-04	1.97E-04	6.42E-04	1.58E-03	6.38E-03	2.08E-02	5.13E-02
Hexabromodiphenyl ethers		1.49E-02	2.35E-02	5.51E-02	2.72E-03	4.30E-03	1.01E-02	9.37E-03	1.48E-02	3.47E-02	3.04E-01	4.81E-01	1.13E+00
Nonabromodiphenyl ethers		3.25E-03	1.44E-02	3.76E-02	5.94E-04	2.63E-03	6.87E-03	2.05E-03	9.06E-03	2.37E-02	6.65E-02	2.94E-01	7.68E-01
Pentabromodiphenyl ethers		1.37E-01	1.82E-01	3.95E-01	2.50E-02	3.32E-02	7.23E-02	8.62E-02	1.14E-01	2.49E-01	2.80E+00	3.71E+00	8.08E+00
Tetrabromodiphenyl ethers		1.27E-01	1.65E-01	2.59E-01	2.32E-02	3.03E-02	4.73E-02	7.99E-02	1.04E-01	1.63E-01	2.59E+00	3.39E+00	5.29E+00
Tribromodiphenyl ethers		3.50E-03	6.51E-03	1.53E-02	6.41E-04	1.19E-03	2.79E-03	2.21E-03	4.10E-03	9.62E-03	7.17E-02	1.33E-01	3.12E-01
Perfluorinated Compounds (kg/year)													
Perfluorobutanoate	PFBA	2.02E-02	3.17E-02	5.95E-02	3.70E-03	5.80E-03	1.09E-02	1.27E-02	2.00E-02	3.75E-02	4.14E-01	6.49E-01	1.22E+00
Perfluorodecanoate	PFDA	5.98E-02	8.30E-02	1.31E-01	1.09E-02	1.52E-02	2.39E-02	3.77E-02	5.23E-02	8.24E-02	1.22E+00	1.70E+00	2.67E+00
Perfluoroheptanoate	PFHpA	8.47E-02	1.08E-01	1.41E-01	1.55E-02	1.97E-02	2.57E-02	5.34E-02	6.79E-02	8.86E-02	1.73E+00	2.20E+00	2.88E+00
Perfluorohexane sulfonate	PFHxS	2.93E-02	6.00E-02	8.33E-02	5.35E-03	1.10E-02	1.52E-02	1.84E-02	3.78E-02	5.25E-02	5.99E-01	1.23E+00	1.70E+00
Perfluorohexanoate	PFHxA	2.97E-01	3.82E-01	6.17E-01	5.43E-02	7.00E-02	1.13E-01	1.87E-01	2.41E-01	3.89E-01	6.07E+00	7.82E+00	1.26E+01
Perfluorononanoate	PFNA	8.45E-02	1.39E-01	2.87E-01	1.55E-02	2.54E-02	5.25E-02	5.32E-02	8.76E-02	1.81E-01	1.73E+00	2.84E+00	5.87E+00
Perfluorooctane sulfonate	PFOS	9.30E-02	1.37E-01	2.25E-01	1.70E-02	2.50E-02	4.11E-02	5.86E-02	8.62E-02	1.42E-01	1.90E+00	2.80E+00	4.60E+00
Perfluorooctanoate	PFOA	2.99E-01	5.39E-01	7.94E-01	5.47E-02	9.85E-02	1.45E-01	1.89E-01	3.40E-01	5.00E-01	6.12E+00	1.10E+01	1.62E+01
Perfluoropentanoate	PFPeA	4.33E-02	6.01E-02	2.18E-01	7.92E-03	1.10E-02	3.99E-02	2.73E-02	3.79E-02	1.38E-01	8.86E-01	1.23E+00	4.47E+00
Entire Chemical Class:		1.54E+00	2.08E+00	2.88E+00	2.81E-01	3.80E-01	5.26E-01	9.69E-01	1.31E+00	1.81E+00	3.15E+01	4.25E+01	5.89E+01
Polychlorinated Biphenyls (Congeners) (kg/year)													
2-MoCB	PCB-001	1.44E-04	3.35E-04	8.23E-04	2.64E-05	6.13E-05	1.51E-04	9.09E-05	2.11E-04	5.19E-04	2.95E-03	6.86E-03	1.68E-02
2,2'-DiCB	PCB-004	2.53E-04	8.72E-04	1.73E-03	4.62E-05	1.59E-04	3.17E-04	1.59E-04	5.49E-04	1.09E-03	5.17E-03	1.78E-02	3.54E-02
2,3'-DiCB	PCB-006	1.70E-04	3.61E-04	4.81E-04	3.11E-05	6.60E-05	8.79E-05	1.07E-04	2.27E-04	3.03E-04	3.48E-03	7.38E-03	9.83E-03
2,2',3-TrCB	PCB-016	3.49E-04	6.16E-04	1.04E-03	6.38E-05	1.13E-04	1.91E-04	2.20E-04	3.88E-04	6.57E-04	7.13E-03	1.26E-02	2.13E-02

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Admiralty Inlet			Commencement Bay			Hood Canal (North)			Hood Canal (South)			Main Basin		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
2,2',4-TrCB	PCB-017	8.89E-06	2.19E-05	5.15E-05	3.26E-04	8.02E-04	1.89E-03	1.97E-06	4.83E-06	1.14E-05	1.57E-07	3.87E-07	9.11E-07	1.94E-03	4.78E-03	1.13E-02
2,2',5-TrCB	PCB-018	2.13E-05	6.96E-05	1.50E-04	7.81E-04	2.55E-03	5.51E-03	4.71E-06	1.54E-05	3.32E-05	3.77E-07	1.23E-06	2.66E-06	4.66E-03	1.52E-02	3.29E-02
2,3,3'/2,3',4'-TriCB	PCB-020/033	1.84E-05	3.20E-05	9.96E-05	6.76E-04	1.17E-03	3.65E-03	4.08E-06	7.07E-06	2.20E-05	3.26E-07	5.66E-07	1.76E-06	4.03E-03	6.99E-03	2.18E-02
2,3,4'-TrCB	PCB-022	8.64E-06	2.04E-05	5.74E-05	3.17E-04	7.49E-04	2.10E-03	1.91E-06	4.52E-06	1.27E-05	1.53E-07	3.61E-07	1.01E-06	1.89E-03	4.46E-03	1.25E-02
2,4,4'-TrCB	PCB-028	2.15E-05	3.99E-05	1.22E-04	7.89E-04	1.46E-03	4.49E-03	4.76E-06	8.82E-06	2.71E-05	3.81E-07	7.05E-07	2.17E-06	4.70E-03	8.72E-03	2.68E-02
2,4',5-TrCB	PCB-031	2.49E-05	5.00E-05	1.31E-04	9.12E-04	1.83E-03	4.82E-03	5.50E-06	1.11E-05	2.91E-05	4.40E-07	8.84E-07	2.32E-06	5.44E-03	1.09E-02	2.87E-02
3,4,4'-TrCB	PCB-037	9.46E-06	2.27E-05	4.04E-05	3.47E-04	8.34E-04	1.48E-03	2.09E-06	5.03E-06	8.93E-06	1.67E-07	4.02E-07	7.14E-07	2.07E-03	4.97E-03	8.82E-03
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	2.00E-05	3.60E-05	1.01E-04	7.34E-04	1.32E-03	3.69E-03	4.42E-06	7.96E-06	2.23E-05	3.54E-07	6.37E-07	1.78E-06	4.37E-03	7.87E-03	2.20E-02
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	2.68E-05	8.39E-05	1.70E-04	9.81E-04	3.07E-03	6.22E-03	5.91E-06	1.85E-05	3.75E-05	4.73E-07	1.48E-06	3.00E-06	5.85E-03	1.83E-02	3.71E-02
2,3',4,4'-TeCB	PCB-066	1.35E-05	2.61E-05	9.64E-05	4.94E-04	9.58E-04	3.53E-03	2.98E-06	5.78E-06	2.13E-05	2.38E-07	4.62E-07	1.70E-06	2.95E-03	5.71E-03	2.11E-02
2,2',3,4',6-PeCB	PCB-091	8.23E-06	1.45E-05	2.64E-05	3.02E-04	5.32E-04	9.66E-04	1.82E-06	3.21E-06	5.83E-06	1.45E-07	2.57E-07	4.66E-07	1.80E-03	3.17E-03	5.76E-03
2,2',3,5,5'-PeCB	PCB-092	1.48E-05	2.57E-05	5.07E-05	5.44E-04	9.41E-04	1.86E-03	3.28E-06	5.68E-06	1.12E-05	2.63E-07	4.54E-07	8.96E-07	3.24E-03	5.61E-03	1.11E-02
2,3,3',4,4'-PeCB	PCB-105	8.89E-06	2.70E-05	6.26E-05	3.26E-04	9.90E-04	2.29E-03	1.97E-06	5.97E-06	1.38E-05	1.57E-07	4.78E-07	1.11E-06	1.94E-03	5.90E-03	1.37E-02
2,2',3,5,5',6-HxCB	PCB-151	9.05E-06	2.13E-05	5.78E-05	3.32E-04	7.81E-04	2.12E-03	2.00E-06	4.71E-06	1.28E-05	1.60E-07	3.77E-07	1.02E-06	1.98E-03	4.65E-03	1.26E-02
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	1.42E-05	2.08E-05	6.50E-05	5.19E-04	7.62E-04	2.38E-03	3.13E-06	4.60E-06	1.44E-05	2.50E-07	3.68E-07	1.15E-06	3.10E-03	4.54E-03	1.42E-02
2,2',3,4,4',5,5'-HpCB	PCB-180	2.56E-05	4.35E-05	1.45E-04	9.40E-04	1.59E-03	5.31E-03	5.67E-06	9.61E-06	3.20E-05	4.53E-07	7.69E-07	2.56E-06	5.60E-03	9.50E-03	3.17E-02
2,2',3,4,4',5,6'/2,2',3,4',5,5',6-HpCB	PCB-182/187	1.57E-05	2.68E-05	7.86E-05	5.76E-04	9.83E-04	2.88E-03	3.48E-06	5.93E-06	1.74E-05	2.78E-07	4.74E-07	1.39E-06	3.44E-03	5.86E-03	1.72E-02
Entire Chemical Class:		3.39E-04	9.17E-04	4.69E-03	1.24E-02	3.36E-02	1.72E-01	7.49E-05	2.03E-04	1.04E-03	5.99E-06	1.62E-05	8.29E-05	7.40E-02	2.00E-01	1.02E+00
Polychlorinated Biphenyls (Homologs) (kg/year)																
Dichlorobiphenyls		9.74E-05	2.86E-04	4.29E-04	3.57E-03	1.05E-02	1.57E-02	2.15E-05	6.32E-05	9.49E-05	1.72E-06	5.05E-06	7.59E-06	2.13E-02	6.25E-02	9.38E-02
Heptachlorobiphenyls		3.14E-05	7.03E-05	4.50E-04	1.15E-03	2.58E-03	1.65E-02	6.93E-06	1.55E-05	9.95E-05	5.54E-07	1.24E-06	7.96E-06	6.85E-03	1.54E-02	9.83E-02
Monochlorobiphenyls		1.20E-05	3.50E-05	5.81E-05	4.39E-04	1.28E-03	2.13E-03	2.65E-06	7.74E-06	1.29E-05	2.12E-07	6.19E-07	1.03E-06	2.62E-03	7.65E-03	1.27E-02
Tetrachlorobiphenyls		1.13E-04	3.06E-04	9.89E-04	4.12E-03	1.12E-02	3.62E-02	2.49E-05	6.76E-05	2.19E-04	1.99E-06	5.40E-06	1.75E-05	2.46E-02	6.68E-02	2.16E-01
Trichlorobiphenyls		1.25E-04	2.90E-04	7.94E-04	4.59E-03	1.06E-02	2.91E-02	2.77E-05	6.42E-05	1.76E-04	2.22E-06	5.13E-06	1.40E-05	2.74E-02	6.34E-02	1.74E-01
Metals (kg/year)																
Copper		6.69E+00	1.16E+01	1.47E+01	2.45E+02	4.25E+02	5.40E+02	1.48E+00	2.56E+00	3.26E+00	1.18E-01	2.05E-01	2.61E-01	1.46E+03	2.53E+03	3.22E+03
Lead		3.74E-01	4.96E-01	6.79E-01	1.37E+01	1.82E+01	2.49E+01	8.27E-02	1.10E-01	1.50E-01	6.61E-03	8.78E-03	1.20E-02	8.17E+01	1.08E+02	1.48E+02
Zinc		4.29E+01	5.08E+01	6.37E+01	1.57E+03	1.86E+03	2.33E+03	9.48E+00	1.12E+01	1.41E+01	7.58E-01	8.98E-01	1.13E+00	9.37E+03	1.11E+04	1.39E+04

Key:

The units of measure are kilograms per year (kg/year).

The precision of the data in this table is only two significant figures.

The loadings from POTWs to the Elliott Bay Study Area were zero because this area of Puget Sound had no POTWs discharging to it.

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Port Gardner			San Juan Islands			Sinclair-Dyes Inlet			South Sound (East)			South Sound (West)		
		25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile	25th Percentile	50th Percentile	75th Percentile
2,2',4-TrCB	PCB-017	3.14E-04	7.73E-04	1.82E-03	2.22E-05	5.45E-05	1.29E-04	9.71E-05	2.39E-04	5.62E-04	1.90E-04	4.67E-04	1.10E-03	1.27E-04	3.12E-04	7.34E-04
2,2',5-TrCB	PCB-018	7.54E-04	2.46E-03	5.32E-03	5.32E-05	1.73E-04	3.75E-04	2.33E-04	7.59E-04	1.64E-03	4.56E-04	1.49E-03	3.21E-03	3.04E-04	9.91E-04	2.14E-03
2,3,3'/2,3',4'-TriCB	PCB-020/033	6.52E-04	1.13E-03	3.52E-03	4.60E-05	7.98E-05	2.48E-04	2.01E-04	3.49E-04	1.09E-03	3.94E-04	6.84E-04	2.13E-03	2.63E-04	4.56E-04	1.42E-03
2,3,4'-TrCB	PCB-022	3.05E-04	7.22E-04	2.03E-03	2.15E-05	5.09E-05	1.43E-04	9.43E-05	2.23E-04	6.26E-04	1.85E-04	4.37E-04	1.23E-03	1.23E-04	2.91E-04	8.18E-04
2,4,4'-TrCB	PCB-028	7.61E-04	1.41E-03	4.33E-03	5.37E-05	9.95E-05	3.05E-04	2.35E-04	4.36E-04	1.34E-03	4.60E-04	8.53E-04	2.62E-03	3.07E-04	5.69E-04	1.75E-03
2,4',5-TrCB	PCB-031	8.80E-04	1.77E-03	4.65E-03	6.21E-05	1.25E-04	3.28E-04	2.72E-04	5.46E-04	1.43E-03	5.32E-04	1.07E-03	2.81E-03	3.55E-04	7.13E-04	1.87E-03
3,4,4'-TrCB	PCB-037	3.34E-04	8.04E-04	1.43E-03	2.36E-05	5.67E-05	1.01E-04	1.03E-04	2.48E-04	4.41E-04	2.02E-04	4.86E-04	8.63E-04	1.35E-04	3.24E-04	5.75E-04
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	7.07E-04	1.27E-03	3.56E-03	4.99E-05	8.98E-05	2.51E-04	2.18E-04	3.93E-04	1.10E-03	4.28E-04	7.70E-04	2.15E-03	2.85E-04	5.13E-04	1.44E-03
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	9.46E-04	2.97E-03	6.00E-03	6.67E-05	2.09E-04	4.23E-04	2.92E-04	9.16E-04	1.85E-03	5.72E-04	1.79E-03	3.63E-03	3.81E-04	1.20E-03	2.42E-03
2,3',4,4'-TeCB	PCB-066	4.76E-04	9.24E-04	3.41E-03	3.36E-05	6.52E-05	2.40E-04	1.47E-04	2.85E-04	1.05E-03	2.88E-04	5.59E-04	2.06E-03	1.92E-04	3.73E-04	1.37E-03
2,2',3,4',6-PeCB	PCB-091	2.91E-04	5.13E-04	9.32E-04	2.05E-05	3.62E-05	6.57E-05	8.98E-05	1.58E-04	2.88E-04	1.76E-04	3.10E-04	5.63E-04	1.17E-04	2.07E-04	3.76E-04
2,2',3,5,5'-PeCB	PCB-092	5.25E-04	9.08E-04	1.79E-03	3.70E-05	6.40E-05	1.26E-04	1.62E-04	2.80E-04	5.53E-04	3.17E-04	5.49E-04	1.08E-03	2.12E-04	3.66E-04	7.22E-04
2,3,3',4,4'-PeCB	PCB-105	3.14E-04	9.55E-04	2.21E-03	2.22E-05	6.74E-05	1.56E-04	9.71E-05	2.95E-04	6.83E-04	1.90E-04	5.78E-04	1.34E-03	1.27E-04	3.85E-04	8.92E-04
2,2',3,5,5',6-HxCB	PCB-151	3.20E-04	7.53E-04	2.04E-03	2.26E-05	5.31E-05	1.44E-04	9.88E-05	2.33E-04	6.31E-04	1.93E-04	4.55E-04	1.24E-03	1.29E-04	3.04E-04	8.23E-04
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	5.01E-04	7.35E-04	2.30E-03	3.53E-05	5.19E-05	1.62E-04	1.55E-04	2.27E-04	7.10E-04	3.03E-04	4.44E-04	1.39E-03	2.02E-04	2.96E-04	9.27E-04
2,2',3,4,4',5,5'-HpCB	PCB-180	9.06E-04	1.54E-03	5.12E-03	6.39E-05	1.08E-04	3.61E-04	2.80E-04	4.75E-04	1.58E-03	5.48E-04	9.30E-04	3.10E-03	3.65E-04	6.20E-04	2.07E-03
2,2',3,4,4',5,6'/2,2',3,4',5,5',6-HpCB	PCB-182/187	5.56E-04	9.48E-04	2.78E-03	3.92E-05	6.69E-05	1.96E-04	1.72E-04	2.93E-04	8.58E-04	3.36E-04	5.74E-04	1.68E-03	2.24E-04	3.82E-04	1.12E-03
Entire Chemical Class:		1.20E-02	3.24E-02	1.66E-01	8.44E-04	2.29E-03	1.17E-02	3.70E-03	1.00E-02	5.12E-02	7.24E-03	1.96E-02	1.00E-01	4.82E-03	1.31E-02	6.68E-02
Polychlorinated Biphenyls (Homologs) (kg/year)																
Dichlorobiphenyls		3.44E-03	1.01E-02	1.52E-02	2.43E-04	7.13E-04	1.07E-03	1.06E-03	3.12E-03	4.68E-03	2.08E-03	6.11E-03	9.17E-03	1.39E-03	4.07E-03	6.12E-03
Heptachlorobiphenyls		1.11E-03	2.49E-03	1.59E-02	7.82E-05	1.75E-04	1.12E-03	3.42E-04	7.68E-04	4.91E-03	6.70E-04	1.50E-03	9.62E-03	4.47E-04	1.00E-03	6.41E-03
Monochlorobiphenyls		4.23E-04	1.24E-03	2.05E-03	2.99E-05	8.73E-05	1.45E-04	1.31E-04	3.82E-04	6.34E-04	2.56E-04	7.48E-04	1.24E-03	1.71E-04	4.99E-04	8.28E-04
Tetrachlorobiphenyls		3.98E-03	1.08E-02	3.50E-02	2.81E-04	7.62E-04	2.47E-03	1.23E-03	3.34E-03	1.08E-02	2.41E-03	6.53E-03	2.11E-02	1.60E-03	4.36E-03	1.41E-02
Trichlorobiphenyls		4.43E-03	1.03E-02	2.81E-02	3.12E-04	7.24E-04	1.98E-03	1.37E-03	3.17E-03	8.67E-03	2.68E-03	6.20E-03	1.70E-02	1.79E-03	4.14E-03	1.13E-02
Metals (kg/year)																
Copper		2.36E+02	4.10E+02	5.21E+02	1.67E+01	2.89E+01	3.67E+01	7.30E+01	1.26E+02	1.61E+02	1.43E+02	2.48E+02	3.15E+02	9.53E+01	1.65E+02	2.10E+02
Lead		1.32E+01	1.75E+01	2.40E+01	9.32E-01	1.24E+00	1.69E+00	4.08E+00	5.42E+00	7.41E+00	7.99E+00	1.06E+01	1.45E+01	5.33E+00	7.07E+00	9.67E+00
Zinc		1.52E+03	1.79E+03	2.25E+03	1.07E+02	1.27E+02	1.59E+02	4.68E+02	5.54E+02	6.95E+02	9.17E+02	1.09E+03	1.36E+03	6.11E+02	7.24E+02	9.07E+02

Key:

The units of measure are kilograms per year (kg/year).

The precision of the data in this table is only two significant figures.

The loadings from POTWs to the Elliott Bay Study Area were zero because this area of Puget Sound had no POTWs discharging to it.

Appendix H. Estimated Loadings to Puget Sound

Chemical of Concern	Alternate Name	Strait of Georgia			Strait of Juan de Fuca			Whidbey Basin			Total Puget Sound		
		25th Percentile	**50th Percentile**	**75th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**
2,2',4-TrCB	PCB-017	1.63E-04	4.00E-04	9.42E-04	2.97E-05	7.31E-05	1.72E-04	1.02E-04	2.52E-04	5.94E-04	3.32E-03	8.18E-03	1.93E-02
2,2',5-TrCB	PCB-018	3.90E-04	1.27E-03	2.75E-03	7.13E-05	2.33E-04	5.03E-04	2.46E-04	8.01E-04	1.73E-03	7.97E-03	2.60E-02	5.62E-02
2,3,3'/2,3',4'-TriCB	PCB-020/033	3.37E-04	5.85E-04	1.82E-03	6.17E-05	1.07E-04	3.33E-04	2.12E-04	3.68E-04	1.15E-03	6.90E-03	1.20E-02	3.73E-02
2,3,4'-TrCB	PCB-022	1.58E-04	3.73E-04	1.05E-03	2.89E-05	6.83E-05	1.92E-04	9.95E-05	2.35E-04	6.61E-04	3.23E-03	7.64E-03	2.15E-02
2,4,4'-TrCB	PCB-028	3.93E-04	7.29E-04	2.24E-03	7.20E-05	1.33E-04	4.09E-04	2.48E-04	4.60E-04	1.41E-03	8.05E-03	1.49E-02	4.58E-02
2,4',5-TrCB	PCB-031	4.55E-04	9.14E-04	2.40E-03	8.32E-05	1.67E-04	4.39E-04	2.87E-04	5.76E-04	1.51E-03	9.30E-03	1.87E-02	4.91E-02
3,4,4'-TrCB	PCB-037	1.73E-04	4.16E-04	7.38E-04	3.16E-05	7.61E-05	1.35E-04	1.09E-04	2.62E-04	4.65E-04	3.54E-03	8.51E-03	1.51E-02
2,2',3,5/2,2',4,5'-TeCB	PCB-043/049	3.66E-04	6.58E-04	1.84E-03	6.69E-05	1.20E-04	3.37E-04	2.31E-04	4.15E-04	1.16E-03	7.48E-03	1.35E-02	3.77E-02
2,2',5,5'/2,3',4,6-TeCB	PCB-052/069	4.89E-04	1.53E-03	3.10E-03	8.94E-05	2.80E-04	5.67E-04	3.08E-04	9.66E-04	1.95E-03	1.00E-02	3.14E-02	6.34E-02
2,3',4,4'-TeCB	PCB-066	2.46E-04	4.78E-04	1.76E-03	4.51E-05	8.74E-05	3.22E-04	1.55E-04	3.01E-04	1.11E-03	5.04E-03	9.77E-03	3.60E-02
2,2',3,4',6-PeCB	PCB-091	1.50E-04	2.65E-04	4.82E-04	2.75E-05	4.85E-05	8.81E-05	9.48E-05	1.67E-04	3.04E-04	3.08E-03	5.43E-03	9.86E-03
2,2',3,5,5'-PeCB	PCB-092	2.71E-04	4.69E-04	9.26E-04	4.96E-05	8.58E-05	1.69E-04	1.71E-04	2.96E-04	5.84E-04	5.55E-03	9.60E-03	1.89E-02
2,3,3',4,4'-PeCB	PCB-105	1.63E-04	4.94E-04	1.14E-03	2.97E-05	9.03E-05	2.09E-04	1.02E-04	3.11E-04	7.21E-04	3.32E-03	1.01E-02	2.34E-02
2,2',3,5,5',6-HxCB	PCB-151	1.65E-04	3.89E-04	1.06E-03	3.03E-05	7.12E-05	1.93E-04	1.04E-04	2.45E-04	6.66E-04	3.38E-03	7.97E-03	2.16E-02
2,3,3',4',5,6/2,3,3',4',5',6-HxCB	PCB-163/164	2.59E-04	3.80E-04	1.19E-03	4.74E-05	6.95E-05	2.17E-04	1.63E-04	2.40E-04	7.49E-04	5.30E-03	7.77E-03	2.43E-02
2,2',3,4,4',5,5'-HpCB	PCB-180	4.69E-04	7.95E-04	2.65E-03	8.57E-05	1.45E-04	4.85E-04	2.95E-04	5.01E-04	1.67E-03	9.59E-03	1.63E-02	5.42E-02
2,2',3,4,4',5,6'/2,2',3,4',5,5',6-HpCB	PCB-182/187	2.87E-04	4.90E-04	1.44E-03	5.26E-05	8.97E-05	2.63E-04	1.81E-04	3.09E-04	9.06E-04	5.88E-03	1.00E-02	2.94E-02
Entire Chemical Class:		6.19E-03	1.68E-02	8.57E-02	1.13E-03	3.07E-03	1.57E-02	3.90E-03	1.06E-02	5.40E-02	1.27E-01	3.43E-01	1.75E+00
Polychlorinated Biphenyls (Homologs) (kg/year)													
Dichlorobiphenyls		1.78E-03	5.22E-03	7.84E-03	3.26E-04	9.56E-04	1.43E-03	1.12E-03	3.29E-03	4.94E-03	3.64E-02	1.07E-01	1.60E-01
Heptachlorobiphenyls		5.73E-04	1.29E-03	8.22E-03	1.05E-04	2.35E-04	1.50E-03	3.61E-04	8.10E-04	5.18E-03	1.17E-02	2.63E-02	1.68E-01
Monochlorobiphenyls		2.19E-04	6.40E-04	1.06E-03	4.00E-05	1.17E-04	1.94E-04	1.38E-04	4.03E-04	6.70E-04	4.48E-03	1.31E-02	2.17E-02
Tetrachlorobiphenyls		2.06E-03	5.59E-03	1.81E-02	3.76E-04	1.02E-03	3.31E-03	1.30E-03	3.52E-03	1.14E-02	4.21E-02	1.14E-01	3.70E-01
Trichlorobiphenyls		2.29E-03	5.30E-03	1.45E-02	4.19E-04	9.70E-04	2.66E-03	1.44E-03	3.34E-03	9.15E-03	4.69E-02	1.09E-01	2.97E-01
Metals (kg/year)													
Copper		1.22E+02	2.12E+02	2.69E+02	2.24E+01	3.87E+01	4.93E+01	7.71E+01	1.33E+02	1.70E+02	2.50E+03	4.33E+03	5.51E+03
Lead		6.83E+00	9.07E+00	1.24E+01	1.25E+00	1.66E+00	2.27E+00	4.31E+00	5.72E+00	7.82E+00	1.40E+02	1.86E+02	2.54E+02
Zinc		7.84E+02	9.28E+02	1.16E+03	1.43E+02	1.70E+02	2.13E+02	4.94E+02	5.85E+02	7.33E+02	1.60E+04	1.90E+04	2.38E+04

Key:

The units of measure are kilograms per year (kg/year).

The precision of the data in this table is only two significant figures.

The loadings from POTWs to the Elliott Bay Study Area were zero because this area of Puget Sound had no POTWs discharging to it.

Study_ID	Study_Specific_Location_ID	Field_Collection_Start_Date	Field_Collection_Reference_Point	Field_Collection_Upper_Depth	Field_Collection_Lower_Depth	Field_Collection_Depth_Units	Sample_ID	Result_Parameter_Name	Result_Value	Result_Value_Units	Result_Data_Qualifier
RCOO0010	Nooksack River	1/6/2010	Water surface	0	11.2	ft	0912035-01	PCB, Sum of Congeners	5.794	pg/L	J
RCOO0010	South Sound	1/11/2010	Water surface	90	90	m	1001013-14	PCB, Sum of Congeners	26.309	pg/L	J
RCOO0010	South Sound	1/11/2010	Water surface	10	10	m	1001013-13	PCB, Sum of Congeners	19.63	pg/L	J
RCOO0010	Main Basin	1/12/2010	Water surface	80	80	m	1001013-12	PCB, Sum of Congeners	38.98	pg/L	J
RCOO0010	Main Basin	1/12/2010	Water surface	20	20	m	1001013-11	PCB, Sum of Congeners	13.26	pg/L	J
RCOO0010	Hood Canal	1/13/2010	Water surface	100	100	m	1001013-02	PCB, Sum of Congeners	18.91	pg/L	J
RCOO0010	Hood Canal	1/13/2010	Water surface	25	25	m	1001013-01	PCB, Sum of Congeners	6.09	pg/L	J
RCOO0010	Whidbey Basin	1/26/2010	Water surface	95	95	m	1001013-10	PCB, Sum of Congeners	37.885	pg/L	J
RCOO0010	Whidbey Basin	1/26/2010	Water surface	15	15	m	1001013-09	PCB, Sum of Congeners	18.39	pg/L	J
RCOO0010	Whidbey Basin	1/26/2010	Water surface	20	20	m	1001013-17	PCB, Sum of Congeners	22.59	pg/L	J
RCOO0010	Haro Strait	2/1/2010	Water surface	95	95	m	1001013-08	PCB, Sum of Congeners	23.59	pg/L	J
RCOO0010	Haro Strait	2/1/2010	Water surface	15	15	m	1001013-07	PCB, Sum of Congeners	17.658	pg/L	J
RCOO0010	SJdF North	2/2/2010	Water surface	120	120	m	1001013-06	PCB, Sum of Congeners	26.408	pg/L	J
RCOO0010	SJdF North	2/2/2010	Water surface	15	15	m	1001013-05	PCB, Sum of Congeners	6.345	pg/L	J
RCOO0010	SJdF at Sill	2/2/2010	Water surface	120	120	m	1001013-04	PCB, Sum of Congeners	38.694	pg/L	J
RCOO0010	SJdF at Sill	2/2/2010	Water surface	15	15	m	1001013-03	PCB, Sum of Congeners	14.209	pg/L	J
RCOO0010	Hood Canal	7/7/2009	Water surface	40	40	m	0906045-02	PCB, Sum of Congeners	44.89	pg/L	J
RCOO0010	Hood Canal	7/7/2009	Water surface	5	5	m	0906045-01	PCB, Sum of Congeners	12.21	pg/L	J
RCOO0010	SJdF at Sill	7/7/2009	Water surface	45	45	m	0906045-04	PCB, Sum of Congeners	8.29	pg/L	J
RCOO0010	SJdF at Sill	7/7/2009	Water surface	10	10	m	0906045-03	PCB, Sum of Congeners	10.59	pg/L	J
RCOO0010	Haro Strait	7/8/2009	Water surface	115	115	m	0906045-08	PCB, Sum of Congeners	14.62	pg/L	
RCOO0010	Haro Strait	7/8/2009	Water surface	15	15	m	0906045-07	PCB, Sum of Congeners	13.485	pg/L	J
RCOO0010	SJdF North	7/8/2009	Water surface	110	110	m	0906045-06	PCB, Sum of Congeners	14.209	pg/L	J
RCOO0010	SJdF North	7/8/2009	Water surface	15	15	m	0906045-05	PCB, Sum of Congeners	15.409	pg/L	J
RCOO0010	Main Basin	7/9/2009	Water surface	95	95	m	0906045-12	PCB, Sum of Congeners	19.535	pg/L	J
RCOO0010	Main Basin	7/9/2009	Water surface	15	15	m	0906045-11	PCB, Sum of Congeners	24.49	pg/L	J
RCOO0010	South Sound	7/9/2009	Water surface	85	85	m	0906045-14	PCB, Sum of Congeners	43.48	pg/L	J
RCOO0010	South Sound	7/9/2009	Water surface	10	10	m	0906045-13	PCB, Sum of Congeners	26.55	pg/L	J
RCOO0010	Whidbey Basin	7/10/2009	Water surface	75	75	m	0906045-10	PCB, Sum of Congeners	43.92	pg/L	J
RCOO0010	Whidbey Basin	7/10/2009	Water surface	5	5	m	0906045-09	PCB, Sum of Congeners	8.73	pg/L	J
RCOO0010	Whidbey Basin	7/10/2009	Water surface	75	75	m	0906045-17	PCB, Sum of Congeners	31.12	pg/L	J
RCOO0010	Whidbey Basin	7/10/2009	Water surface	75	75	m	0906045-19	PCB, Sum of Congeners	30.31	pg/L	J
RCOO0010	Nooksack River	7/21/2009	Water surface	0	6.6	ft	0907026-01	PCB, Sum of Congeners	6.41	pg/L	J
RCOO0010	Skagit River	7/21/2009	Water surface	0	8.4	ft	0907026-02	PCB, Sum of Congeners	7.33	pg/L	J
RCOO0010	Stillaguamish River	7/22/2009	Water surface	0	11.7	ft	0907026-03	PCB, Sum of Congeners	19.27	pg/L	J
RCOO0010	Snohomish River	7/22/2009	Water surface	0	17.6	ft	0907026-04	PCB, Sum of Congeners	18.781	pg/L	J
RCOO0010	Puyallup River	7/23/2009	Water surface	0	7.5	ft	0907026-05	PCB, Sum of Congeners	2.61	pg/L	J
RCOO0010	Puyallup River	7/23/2009	Water surface	0	7.5	ft	0907026-06	PCB, Sum of Congeners	6.701	pg/L	J
RCOO0010	Whidbey Basin	9/28/2009	Water surface	45	45	m	0910041-10	PCB, Sum of Congeners	57.56	pg/L	J
RCOO0010	Whidbey Basin	9/28/2009	Water surface	5	5	m	0910041-09	PCB, Sum of Congeners	75.139	pg/L	J
RCOO0010	Main Basin	9/29/2009	Water surface	80	80	m	0910041-12	PCB, Sum of Congeners	52.23	pg/L	J
RCOO0010	Main Basin	9/29/2009	Water surface	20	20	m	0910041-11	PCB, Sum of Congeners	25.376	pg/L	J
RCOO0010	Hood Canal	9/30/2009	Water surface	80	80	m	0910041-02	PCB, Sum of Congeners	33.583	pg/L	J
RCOO0010	Hood Canal	9/30/2009	Water surface	80	80	m	0910041-17	PCB, Sum of Congeners	19.058	pg/L	J
RCOO0010	Hood Canal	9/30/2009	Water surface	2	2	m	0910041-01	PCB, Sum of Congeners	27.033	pg/L	J
RCOO0010	South Sound	10/1/2009	Water surface	80	80	m	0910041-14	PCB, Sum of Congeners	36.806	pg/L	J
RCOO0010	South Sound	10/1/2009	Water surface	10	10	m	0910041-13	PCB, Sum of Congeners	25.389	pg/L	J
RCOO0010	Haro Strait	10/7/2009	Water surface	95	95	m	0910041-08	PCB, Sum of Congeners	32.535	pg/L	J
RCOO0010	Haro Strait	10/7/2009	Water surface	15	15	m	0910041-07	PCB, Sum of Congeners	19.29	pg/L	J
RCOO0010	SJdF North	10/7/2009	Water surface	95	95	m	0910041-06	PCB, Sum of Congeners	35.418	pg/L	J
RCOO0010	SJdF North	10/7/2009	Water surface	15	15	m	0910041-05	PCB, Sum of Congeners	19.055	pg/L	J
RCOO0010	SJdF at Sill	10/7/2009	Water surface	95	95	m	0910041-04	PCB, Sum of Congeners	39.4	pg/L	J
RCOO0010	SJdF at Sill	10/7/2009	Water surface	15	15	m	0910041-03	PCB, Sum of Congeners	18.664	pg/L	J
RCOO0010	Nooksack River	10/12/2009	Water surface	0	5.4	ft	0910039-01	PCB, Sum of Congeners	17.18	pg/L	J
RCOO0010	Skagit River	10/13/2009	Water surface	0	6.3	ft	0910039-02	PCB, Sum of Congeners	9.961	pg/L	J
RCOO0010	Puyallup River	10/15/2009	Water surface	0	7	ft	0910039-05	PCB, Sum of Congeners	40.18	pg/L	J
RCOO0010	Puyallup River	10/15/2009	Water surface	0	7	ft	0910039-06	PCB, Sum of Congeners	33.35	pg/L	J
RCOO0010	Stillaguamish River	10/19/2009	Water surface	0	14.8	ft	0910039-03	PCB, Sum of Congeners	58.978	pg/L	J
RCOO0010	Snohomish River	10/20/2009	Water surface	0	26	ft	0910039-04	PCB, Sum of Congeners	4.93	pg/L	J
RCOO0010	Hood Canal sedtraps	10/22/2009	Water Surface	126	126	ft	1001017-01	PCB, Sum of Congeners	2966	ng/Kg	
RCOO0010	Stillaguamish River	12/8/2009	Water surface	0	13.2	ft	0912035-03	PCB, Sum of Congeners	4.991	pg/L	J
RCOO0010	Puyallup River	12/13/2009	Sediment surface	-2.8	-2.8	ft	1001014-05	PCB, Sum of Congeners	145.36	ng/Kg	
RCOO0010	Puyallup River	12/14/2009	Water surface	0	6.7	ft	0912035-05	PCB, Sum of Congeners	21.497	pg/L	J
RCOO0010	Puyallup River	12/14/2009	Water surface	0	6.5	ft	0912035-06	PCB, Sum of Congeners	23.509	pg/L	J
RCOO0010	Skagit River	12/17/2009	Water surface	0	9	ft	0912035-02	PCB, Sum of Congeners	16.981	pg/L	J
RCOO0010	Snohomish River	12/22/2009	Water surface	0	30.5	ft	0912035-04	PCB, Sum of Congeners	7.293	pg/L	J

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Presidential Documents

Title 3—

The President

Executive Order 13563 of January 18, 2011

Improving Regulation and Regulatory Review

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to improve regulation and regulatory review, it is hereby ordered as follows:

Section 1. *General Principles of Regulation.* (a) Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation. It must be based on the best available science. It must allow for public participation and an open exchange of ideas. It must promote predictability and reduce uncertainty. It must identify and use the best, most innovative, and least burdensome tools for achieving regulatory ends. It must take into account benefits and costs, both quantitative and qualitative. It must ensure that regulations are accessible, consistent, written in plain language, and easy to understand. It must measure, and seek to improve, the actual results of regulatory requirements.

(b) This order is supplemental to and reaffirms the principles, structures, and definitions governing contemporary regulatory review that were established in Executive Order 12866 of September 30, 1993. As stated in that Executive Order and to the extent permitted by law, each agency must, among other things: (1) propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify); (2) tailor its regulations to impose the least burden on society, consistent with obtaining regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations; (3) select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity); (4) to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt; and (5) identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public.

(c) In applying these principles, each agency is directed to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible. Where appropriate and permitted by law, each agency may consider (and discuss qualitatively) values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts.

Sec. 2. *Public Participation.* (a) Regulations shall be adopted through a process that involves public participation. To that end, regulations shall be based, to the extent feasible and consistent with law, on the open exchange of information and perspectives among State, local, and tribal officials, experts in relevant disciplines, affected stakeholders in the private sector, and the public as a whole.

(b) To promote that open exchange, each agency, consistent with Executive Order 12866 and other applicable legal requirements, shall endeavor to provide the public with an opportunity to participate in the regulatory process. To the extent feasible and permitted by law, each agency shall afford the public a meaningful opportunity to comment through the Internet on any proposed regulation, with a comment period that should generally be at least 60 days. To the extent feasible and permitted by law, each agency shall also provide, for both proposed and final rules, timely online access to the rulemaking docket on regulations.gov, including relevant scientific and technical findings, in an open format that can be easily searched and downloaded. For proposed rules, such access shall include, to the extent feasible and permitted by law, an opportunity for public comment on all pertinent parts of the rulemaking docket, including relevant scientific and technical findings.

(c) Before issuing a notice of proposed rulemaking, each agency, where feasible and appropriate, shall seek the views of those who are likely to be affected, including those who are likely to benefit from and those who are potentially subject to such rulemaking.

Sec. 3. *Integration and Innovation.* Some sectors and industries face a significant number of regulatory requirements, some of which may be redundant, inconsistent, or overlapping. Greater coordination across agencies could reduce these requirements, thus reducing costs and simplifying and harmonizing rules. In developing regulatory actions and identifying appropriate approaches, each agency shall attempt to promote such coordination, simplification, and harmonization. Each agency shall also seek to identify, as appropriate, means to achieve regulatory goals that are designed to promote innovation.

Sec. 4. *Flexible Approaches.* Where relevant, feasible, and consistent with regulatory objectives, and to the extent permitted by law, each agency shall identify and consider regulatory approaches that reduce burdens and maintain flexibility and freedom of choice for the public. These approaches include warnings, appropriate default rules, and disclosure requirements as well as provision of information to the public in a form that is clear and intelligible.

Sec. 5. *Science.* Consistent with the President's Memorandum for the Heads of Executive Departments and Agencies, "Scientific Integrity" (March 9, 2009), and its implementing guidance, each agency shall ensure the objectivity of any scientific and technological information and processes used to support the agency's regulatory actions.

Sec. 6. *Retrospective Analyses of Existing Rules.* (a) To facilitate the periodic review of existing significant regulations, agencies shall consider how best to promote retrospective analysis of rules that may be outmoded, ineffective, insufficient, or excessively burdensome, and to modify, streamline, expand, or repeal them in accordance with what has been learned. Such retrospective analyses, including supporting data, should be released online whenever possible.

(b) Within 120 days of the date of this order, each agency shall develop and submit to the Office of Information and Regulatory Affairs a preliminary plan, consistent with law and its resources and regulatory priorities, under which the agency will periodically review its existing significant regulations to determine whether any such regulations should be modified, streamlined, expanded, or repealed so as to make the agency's regulatory program more effective or less burdensome in achieving the regulatory objectives.

Sec. 7. *General Provisions.* (a) For purposes of this order, "agency" shall have the meaning set forth in section 3(b) of Executive Order 12866.

(b) Nothing in this order shall be construed to impair or otherwise affect:

(i) authority granted by law to a department or agency, or the head thereof; or

(ii) functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(c) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(d) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

THE WHITE HOUSE,
January 18, 2011.

[FR Doc. 2011–1385
Filed 1–20–11; 8:45 am]
Billing code 3195–W1–P

Guidance on Considering Environmental Justice During the Development of Regulatory Actions

May 2015

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

05991

Message from the Administrator

Guidance on Considering Environmental Justice During the Development of Regulatory Actions

Making a visible difference in communities across America means that we should consider the impacts of our decisions on all populations. In particular, the U.S. Environmental Protection Agency has a responsibility under Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* to consider the impacts of our regulatory actions on populations documented as frequently bearing the greatest burdens imposed by environmental pollution. Recently, the EPA celebrated the 20th anniversary of the groundbreaking executive order, and we are privileged to continue working to advance environmental justice in every corner of our great nation.

The EPA's *Guidance on Considering Environmental Justice During the Development of Regulatory Actions* is the Agency's guide for determining when environmental justice should be considered during the Action Development Process when developing regulations. This guide outlines critical steps that rule-writers can take to consider the needs of minority populations, low-income populations and indigenous peoples—those most impacted by environmental and public-health concerns—and provide specific strategies for giving those populations a voice in shaping the EPA's rules and regulations. The companion *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) provides information on how to analytically consider environmental justice in rules. Together, these documents provide consistency and rigor in how the Agency considers environmental justice in regulatory actions.

Our work under *Plan EJ 2014* has paved the way to understanding and integrating environmental justice into the EPA's policies and programs. Through increased analysis, informed decision making and expanded community engagement, we can secure the EPA's place at the forefront in addressing the environmental justice issues that challenge the health and vitality of our most vulnerable citizens and their communities.

The EPA strives to set the standard for addressing the environmental challenges that burden so many of our communities. In doing so, we realize that the future of our efforts will be built on our federal and state agencies working together with academia and our community partners to foster communication, support innovation and promote tremendous growth and understanding of environmental justice issues. I call upon you, the EPA family, to reaffirm the spirit of Executive Order 12898 and to commit to strengthening our mission to protect our environment and every American's fundamental right to breathe clean air, drink clean water and live on clean land.

Gina McCarthy, Administrator

EPA's Action Development Process:

Guidance on Considering Environmental Justice During the Development of Regulatory Actions

Foreword

The Environmental Protection Agency (EPA) is authorized by Congress to create and enforce regulations that put our nation's environmental laws into effect. Exercising this authority is one of the EPA's most important and powerful tools for protecting our environment and the health of our people. The EPA's regulations cover a range of environmental and public health issues, from setting standards for clean water to controlling air pollution from industry and other sources. When the EPA identifies the need to develop or revise a regulation, it forms a workgroup that is led by the EPA office that will be writing the regulation. The workgroup may work for months, even years, employing EPA expert scientists, economists, and other analysts, before an appropriate course of action is decided upon and a regulation is promulgated and implemented.

A number of laws, executive orders and policies direct the EPA to consider issues of concern to the President, Congress and the American public when developing regulations. To achieve the goals of Executive Order (EO) 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, it is critical that EPA rule-writers consider environmental justice (EJ) when developing a regulation. EO 12898 and EPA policy identify population groups of concern, specifically minority populations, low-income populations and indigenous peoples. This Guide is designed to help EPA staff incorporate EJ into the process followed at the EPA for developing regulations, also known as the Action Development Process (ADP), by:

- Describing the legal and policy frameworks at the EPA for rule-writers to consider EJ;
- Identifying the information rule-writers should consider to determine whether there are EJ concerns involved in the regulation being developed;
- Highlighting the kinds of questions about EJ that rule-writers should ask and address in each step of developing a regulation; and
- Providing strategies and techniques for achieving meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples at key stages in the rule development process.

This Guide explicitly integrates EJ considerations into the fabric of the ADP—from the point when the Agency first starts considering a rule, then through its promulgation and implementation. The analyses needed to implement this Guide may include quantitative and/or qualitative elements. See a companion document, Draft Technical Guidance for Assessing Environmental Justice in Regulatory

Analysis (U.S. EPA 2013),[1] for recommendations on how to evaluate potential EJ concerns using quantitative and qualitative methods for regulatory actions.

This Guide empowers decision-makers responsible for developing rules to determine early in the process the level of focus and effort that is necessary and appropriate to achieve the EO 12898 goals. This approach can and should balance the need to make sure that strong, environmentally-protective rules are promulgated in a timely way while ensuring EJ is considered to the maximum extent practicable where it has potential to impact regulatory decisions. To achieve these goals, the Guide directs rule-writers and decision-makers to respond to three core EJ questions throughout the ADP:

1. How did the public participation process provide transparency and meaningful participation for minority populations, low-income populations, tribes, and indigenous peoples?[2]
2. How did the rule-writers identify and address existing and/or new disproportionate environmental and public health impacts on minority populations, low-income populations, and/or indigenous peoples?
3. How did actions taken under #1 and #2 impact the outcome or final decision?

Questions 1 and 2 use slightly different wording in referencing the subject entities (populations, peoples, tribes). Throughout this Guide, statements associated with engagement activities use the wording “minority populations, low-income populations, tribes, and indigenous peoples,” whereas statements associated with analysis, assessment and/or consideration of environmental and human health impacts use the wording “minority populations, low-income populations, and/or indigenous peoples.” When discussing public participation and meaningful involvement, Agency protocols specify inclusion of tribal organizations as well as indigenous peoples, and specifically define those terms. However, when discussing analysis, assessment and/or consideration of impacts, attention in the Guide is focused on impacts on populations rather than on governmental or other types of organizations.

This Guide helps rule-writers and decision-makers understand and identify potential EJ concerns, and advises on how to integrate the consideration of EJ into the rule development process and to meaningfully engage minority populations, low-income populations, tribes, and indigenous peoples during the rule development process. Further assistance is provided in references throughout the Guide linking rule-writers and decision-makers to the wealth of other information resources that they can turn to in seeking to consider EJ throughout all stages of the EPA’s ADP.

Disclaimer: This document identifies internal Agency policies and recommended procedures for EPA employees or decision-makers developing or reviewing regulatory actions in the ADP. This document is not a rule or regulation and it may not apply to a particular situation based upon the circumstances. This Guide does not change or substitute for any law, regulation, or any other legally binding requirement and is not legally enforceable. As indicated by the use of non-mandatory language such as “guidance,” “recommend,” “may,” “should,” and “can,” it identifies policies and provides recommendations and does not impose any legally-binding requirements.

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[1] http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/ejtg.html

[2] It is important to solicit input from indigenous people and tribal governments that may be impacted by an action. Consultation with tribal governments should be offered as appropriate and in accordance with the Agency’s Tribal Consultation Policy.

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Appendices

Acronyms and Abbreviations

ABP	Analytic Blueprint
ADP	Action Development Process
CEQ	Council on Environmental Quality
DABP	Detailed Analytic Blueprint
EA	Economic Analysis
EIS	Environmental Impact Statement
EJ	Environmental Justice
EO	Executive Order
EPA	Environmental Protection Agency
FAR	Final Agency Review
FR	Federal Register
IT	Information Technology
MATS	Mercury Air Toxics Standards
NAAQS	National Ambient Air Quality Standards
NEJAC	National Environmental Justice Advisory Council
NEPA	National Environmental Policy Act
OAR	Office of Air and Radiation
OECA	Office of Enforcement and Compliance Assistance
OEJ	Office of Environmental Justice
OGC	Office of General Counsel
OMB	Office of Management and Budget
OP	Office of Policy
PABP	Preliminary Analytic Blueprint
PM	Particulate Matter
RegDaRRT	Regulatory Development and Retrospective Review Tracker
RRP	Renovation, Repair and Painting
RTR	Risk and Technology Review
UMCR	Unregulated Contaminant Monitoring Regulation
WPS	Worker Protection Standards

Overview and Background

A. What Is the Purpose of This Guide?

Achieving environmental justice is an EPA priority and should be factored into Agency regulatory decisions to ensure that all Americans, regardless of race, economic status or ethnicity, have access to clean water, clean air, and healthy communities.[3] The EPA is committed to using existing environmental statutes and regulations to consider and address potential environmental justice (EJ) concerns when possible. To aid in achieving this goal, it is vital that Agency rule-writers identify and address potentially disproportionate environmental and public health impacts experienced by minority populations, low-income populations, and/or indigenous peoples. This Guide will help Agency rule-writers consider EJ during the development of regulatory actions under the Agency's Action Development Process (ADP),[4] consistent with existing environmental and civil rights laws and their implementing regulations, as well as Executive Order (EO) 12898, *Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations* (59 FR 7629, Feb. 16, 1994), the EPA's EJ policies, Plan EJ 2014, and EJ strategies in the EPA's strategic plans.[5]

In addition to providing guidance on the importance of identifying potential EJ concerns during the development of regulatory actions (Part 1), this Guide identifies key steps throughout the ADP where EJ should be considered (Part 2). While this Guide applies specifically to the rule-making stages in the development of regulatory actions, rule-writers consider EJ in the development of risk assessments, analytical tools, guidance documents and other actions that support development of regulatory actions. Rule-making efforts are likely to be more effective and timely if EJ is considered in such "up-front" activities. For example, the development of some EPA regulations is prompted by the findings of risk assessments. If EJ was not considered in the development of those assessments, the rule-writers will not have the benefit of the information that might have been provided and may need to examine options for developing such information during specific stages of the ADP, as specified

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[3] See EPA Strategic Plan Cross Cutting Strategies (http://www2.epa.gov/planandbudget/fy-2014-2018-strategic-plan), Plan EJ 2014 (http://www.epa.gov/environmentaljustice/plan-ej/index.html) and EPA's Themes – Meeting the Challenge Ahead (http://www.epa.gov/environmentaljustice/plan-ej/index.html).

[4] EPA's Action Development Process: Guidance for EPA Staff on Developing Quality Actions Process (http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/5088B3878A90053E8525788E005EC8D8/$File/adp03-00-11.pdf).

[5] Under Plan EJ 2014, EPA developed a set of basic guidances, policies and tools for integrating environmental justice into EPA programs and policies, available at http://www.epa.gov/environmentaljustice/plan-ej/index.html. EPA's historical EJ policies include: EPA's Environmental Justice Strategy (1995), Environmental Justice Implementation Plan (1996), Environmental Justice: Guidance Under the National Environmental Policy Act (1997), Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses (1998), Toolkit for Assessing Potential Allegations of Environmental Justice (2004), and Memo from Lisa P. Jackson: Next Steps: Environmental Justice and Civil Rights (2009).

in this Guide. As a supplement to this Guide, Agency staff may find it useful to refer to other EPA guidance documents related to risk assessment, public involvement and economic analysis, as referenced throughout this Guide and in Appendix E.

This Guide complements existing EPA requirements or recommendations for integrating children's health considerations into the ADP (see Text Box 1) and for consulting with federally-recognized tribes when Agency actions may impact their citizens or resources (see Text Box 2).[6] These issues are addressed in other Agency guides, which are available online at http://intranet.epa.gov/adplibrary.

Text Box 1: Children's Health

Refer to Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks and EPA's Guide to Considering Children's Health When Developing EPA Actions*. Note the important intersection between EJ concerns and children's health issues, since children in minority, low-income and indigenous population groups are more likely to be exposed to, and have increased health risks from, environmental pollution than the general population.

Text Box 2: Indigenous Peoples and Tribes

Refer to Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments and the Agency's Policy on Consultation and Coordination with Indian Tribes*. The Agency's responsibilities under EO 13175 and its own Consultation Policy are separate from the responsibilities under EO 12898 and stem from federally-recognized tribes' unique status as sovereign governments. To better understand how to integrate EJ principles in a consistent manner in the Agency's work with federally recognized tribes and indigenous peoples, refer to EPA's Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples.

B. Who Is the Audience for This Guide?

This Guide is for EPA rule-writers and decision-makers:

- Rule-writers include: lead-program staff and managers charged with leading development of regulatory actions (who often also serve as leaders [chairs] of regulatory action development workgroups); members of regulatory action development workgroups; Agency staff and managers that perform the analyses that may be used to support Agency decision-making; and any other Agency staff and managers who assist in developing regulatory actions. Workgroup chairs have particular responsibilities under the ADP, including the responsibilities outlined in this Guide with respect to identifying and addressing potential EJ concerns. However, each regulatory action development workgroup member has the responsibility for being familiar with, and understanding, the various statutes and executive orders that impact the regulatory action they are developing. Other staff responsible for the development of regulatory actions, who may not be workgroup members, are also responsible for being familiar with these requirements.
- Decision-makers include: program managers, Office Directors, Assistant Administrators/National Program Managers, the Administrator, and other members of the Agency's decision-making team with respect to Agency regulatory actions. Decision-makers are responsible for helping to ensure that potential EJ concerns are appropriately identified and addressed in the development of regulatory actions under the ADP.

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[6] See EPA Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples. (2014), http://www.epa.gov/environmentaljustice/resources/policy/indigenous/ej-indigenous-policy.pdf. For purposes of this cited policy, EPA defines the terms "federally recognized tribes" and "indigenous peoples." A "federally recognized tribe" is defined as an "Indian or Alaska Native tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges to exist as an Indian tribe pursuant to the Federally Recognized Indian Tribe List Act of 1944, 25 U.S.C.479a. The elected officials for the federally recognized tribe and the government structure they administer are referred to as the federally recognized tribal government." The term "indigenous peoples" includes "state-recognized tribes; indigenous and tribal community-based organizations; individual members of federally recognized tribes, including those living on a different reservation or living outside Indian country; individual members of state-recognized tribes; Native Hawaiians; Native Pacific Islanders; and individual Native Americans." When used in this document, the term "tribes" refers to federally recognized tribes unless otherwise specified.

C. How Is This Guide Organized?

This guidance document is organized into four parts:

- Part 1 presents the key concepts and policies that are critical for understanding EJ and determining whether regulatory actions involve potential EJ concerns.
- Part 2 provides a step-by-step walk-through of what rule-writers and decision-makers should do to consider EJ in each stage of the EPA's ADP.
- Part 3 provides strategies and techniques for achieving meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples at key stages in the rule development process.
- Appendices A through E provide more detailed information and guidance elaborating on information presented in the main body of this Guide.

In addition, a separate document, *Templates for Regulatory Preambles to Address EO 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, explains how to address EO 12898 in rule preambles covering various situations. It is available in the Office of Policy's (OP's) ADP library at http://intranet.epa.gov/adplibrary. It is important to note that the preamble discussion should also focus on how the EPA identified and addressed potential EJ concerns as well as how the regulatory action complies with EO 12898 and the Agency's EJ policies.

Part 1: Key Concepts for Understanding Whether Regulatory Actions Involve an Environmental Justice Concern

A. What Is Environmental Justice?

Environmental justice is central to the Agency's mission and is the responsibility of everyone at the EPA. In particular, those who are involved in the development of regulatory actions need to understand the principles of EJ and how they relate to the development of an Agency regulatory action.

The EPA defines "environmental justice" as the ***fair treatment*** and ***meaningful involvement*** of all people regardless of race, color, national origin or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies.[7]

- *Fair Treatment* means that no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental and commercial operations or programs and policies.
- *Meaningful Involvement* means that: (1) potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory Agency's decision; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the rule-writers and decision-makers seek out and facilitate the involvement of those potentially affected.

Throughout this Guide, as noted in the Foreword, statements associated with engagement activities use the wording "minority populations, low-income populations, tribes, and indigenous peoples," whereas statements associated with analysis, assessment and/or consideration of environmental and human health impacts use the wording "minority populations, low-income populations, and/or indigenous peoples." When discussing public participation and meaningful involvement, Agency protocols specify inclusion of tribal organizations as well as indigenous peoples, and specifically define those terms. However, when discussing analysis, assessment and/or consideration of impacts, attention in the Guide is focused on impacts on populations rather than on governmental or other types of organizations.

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[7] EPA's definition of EJ can be found at http://www.epa.gov/compliance/environmentaljustice/basics/index.html. EPA's definition of EJ was informed by Executive Order 12898, which is discussed in full detail in Part 1, Section D of this Guide. Background information on EPA's EJ program can also be found on this website.

In implementing its EJ program, the EPA has expanded the concept of fair treatment to include not only consideration of how burdens are distributed across all populations, but the distribution of benefits as well. Thus, to the extent data are initially available or can be developed through timely data needs assessment and planning, rule-writers should not only evaluate the distribution of burdens by paying special attention to populations that have historically borne a disproportionate share of environmental harms and risks, but should also evaluate the distribution of the positive environmental and health consequences resulting from their regulatory actions.

B. Which Populations Groups Are the Focus of EO 12898 and the Agency's EJ Policies?

Executive Order 12898 and EPA policy identify the populations of concern for the EO and for the Agency; specifically: minority populations, low-income populations and indigenous peoples.[8,9] To help achieve the EPA's goals for EJ (i.e., the fair treatment and meaningful involvement of all people), the EPA places particular emphasis on the public health and environmental conditions affecting minority populations, low-income populations, and/or indigenous peoples. In recognizing that these populations frequently bear a disproportionate burden of environmental harms and risks (see Text Box 3 for an example), the EPA works to protect them from adverse public health and environmental effects of its programs. Thus, the focus in this Guide is on minority populations, low-income populations and indigenous peoples, who may be disproportionately impacted by environmental pollution.

Text Box 3: I-710 Freeway Los Angeles

The densely populated communities closest to the I-710 freeway in Los Angeles County are severely impacted by pollution from goods movement and industrial activity. The Ports of Long Beach and Los Angeles are the entry point of 40% of all imports to the U.S. and account for 20% of diesel particulate emissions in Southern California. Approximately 2,000 premature deaths annually are associated with diesel emissions from goods movement in the South Coast Air Basin. The I-710 freeway passes through 15 cities and unincorporated areas with a population of over 1 million residents—about 70% of which are minority and disproportionately low-income populations. The area is dense with truck traffic, industrial facilities, residences, schools, daycares and senior centers. The region exceeds national ambient air quality standards for particulate matter and has some of the worst ozone air pollution in the country. The South Coast Air Quality Management District, California Air Resources Board, and EPA are working vigorously to address the air quality issues in the region.

Source: http://www.epa.gov/region9/tri/report/09/TRI-2009-I710Corridor.pdf

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[8] Executive Order 12898 also mentions "populations with differential patterns of subsistence consumption of fish and wildlife" as populations of concern. This population category largely overlaps with those defined on the basis of income and race/ethnicity, as it identifies particular pathways of exposure. Accordingly, it is not separately identified as a population of concern in this Guide.

[9] See *EPA Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples*. (2014), http://www.epa.gov/environmentaljustice/resources/policy/indigenous/ej-indigenous-policy.pdf.

These population groups are briefly described below. See the *Guidelines for Preparing Economic Analyses* (U.S. EPA 2010) and *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for detailed discussions of how these populations may be defined for analytic purposes.

Minority and Indigenous Peoples

The White House Office of Management and Budget (OMB) defines six distinct race and ethnic categories:

- American Indian or Alaska Native;
- Asian;
- Black or African American;
- Native Hawaiian or Other Pacific Islander;
- White; and
- Hispanic or Latino.

Statistical data collected by the federal government, such as the U.S. Census, use this classification system.[10]

Low-Income Populations

OMB has designated the Census Bureau's annual poverty measure as the official metric for program planning and analysis by all Executive branch federal agencies, though it does not preclude the use of other measures (OMB 1978).

However, unlike its treatment of poverty, the Census Bureau does not have an official or standard definition of what constitutes "low income." It is therefore appropriate to characterize low-income in a variety of ways. Rule-writers may examine several different low-income categories, such as families whose income falls above the poverty threshold but below the average household income for the United States, or below two times the poverty threshold. Additional socioeconomic characteristics such as educational attainment, baseline health status and health insurance coverage may also be useful for identifying, characterizing and developing strategies for assessing and engaging low-income populations in the context of specific regulatory actions.

C. What Are Disproportionate Impacts?

In accordance with EO 12898, each covered federal agency "shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects…" of its policies. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) under development for a detailed discussion of the concept of disproportionate impacts.

It is important to note that the role of the analyst is to assess and present differences in anticipated impacts across population groups of concern to the decision-maker and the public. The determination of whether there is a potential disproportionate impact that may merit Agency action is ultimately a policy judgment informed by analysis, and is the responsibility of the decision-maker. These analyses will depend on the availability of the scientific and technical data. As noted in the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013), examples of the

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[10] See http://www.whitehouse.gov/omb/fedreg_1997standards/ for the specific OMB definitions.

type of information that may be useful to provide to decision-makers for considering whether or not effects are disproportionate include: the severity and nature of health consequences; the magnitude of the estimated differences in impacts between population groups; mean or median exposures or risks to relevant population groups; distributions of exposures or risk to relevant population groups; characterization of the uncertainty; and a discussion of factors that may make population groups more vulnerable.

Also note that the Agency's statutory and regulatory authorities provide a broader basis for protecting human health and the environment than EO 12898 and do not require a demonstration of disproportionate impacts in order to protect the health or environment of any population, including minority populations, low-income populations, and/or indigenous peoples. Consistent with its mission, the Agency may address adverse impacts in the context of developing an action without the need for showing that the impacts are disproportionate. Evidence of potential adverse impacts on populations of concern may be more likely to be addressed, however, if there is also evidence that the adverse impacts may fall disproportionately on populations of concern. Thus, this Guide recommends that analysts evaluate the potential for disproportionate impacts and present the relevant data to decision-makers, who will determine what actions to take.

D. What Is the Agency's Statutory and Policy Framework for Considering Environmental Justice?

For over a decade, the EPA has developed strategies, guidance documents and implementation plans to move the Agency closer to its goal of achieving environmental justice. These documents, along with Executive Order 12898 and existing environmental statutes and regulations, provide the framework for the rule-writers to consider EJ during the development of the regulatory action.

EO 12898 applies to agency "programs, policies and activities" and in general calls on each covered federal agency to make achieving EJ part of its mission. It directs agencies such as the EPA, "[t]o the greatest extent practicable and permitted by law" to "identify […] and address […], as appropriate, disproportionately high and adverse human health or environmental effects" of agency programs, policies and actions on minority populations and low-income populations.[11] Because minority populations, low-income populations, tribes, and indigenous peoples have historically been underrepresented in federal agency decision making, EO 12898 also aims to improve public participation of these populations in the decision-making process.

EO 12898 has informed the development and implementation of the EPA's EJ program and EJ policies. Consistent with the EO and the Presidential Memorandum accompanying it, the Agency's EJ policies promote human health and environmental protection by focusing attention and Agency efforts on addressing the types of environmental harms and risks that are prevalent among minority populations, low-income populations, and/or indigenous peoples. EO 12898 and the Agency's EJ policies do not mandate particular outcomes for regulatory actions, but they demand that decisions

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[11] In addition, the Presidential Memorandum accompanying EO 12898 directs federal agencies to analyze environmental effects, including human health, economic and social effects, of federal actions when such analysis is required under the National Environmental Policy Act. See *Memorandum for the Heads of All Departments and Agencies: Executive Order on Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (1994). Similarly, the EPA promotes the consideration of economic or social effects in developing its actions to better inform and manage the process of implementing Agency actions and policies, where allowed by underlying statutory authority.

involving the action be informed by a consideration of EJ issues. Where feasible, regulatory actions should prevent or address and mitigate potential EJ concerns.

Consistent with the emphasis in the Presidential Memorandum accompanying EO 12898 on using existing environmental laws to help achieve the goal of EJ, the EPA uses existing environmental statutes and regulations to consider and address potential EJ concerns.[12] See Text Box 4 for some examples of statutory authorities used to help achieve EJ goals. These authorities encompass the breadth of the Agency's activities, including setting standards. Early in the rule writing process, rule-writers should become familiar with the specific authorities governing their rule's development and the opportunities they provide to address EJ concerns. Some of the EPA's legal authorities direct the Agency to consider specific populations when setting standards, whereas other authorities provide discretionary opportunities. Where discretionary authority exists, the decision to take a particular regulatory action to address potential EJ concerns is a policy call that may involve consideration of questions beyond the action's legal basis, such as data availability, time and resource constraints or the associated human health or environmental benefits.

Text Box 4: Examples of Statutory Authority

Under the Resource Conservation and Recovery Act sections 3002 through 3004, EPA is directed to establish requirements applicable to generation, transport, treatment, storage and disposal of hazardous waste "as may be necessary to protect human health and the environment." This provides EPA with broad discretion to consider impacts on minority populations, low-income populations, and/or indigenous populations when developing RCRA regulations.

As a starting point, rule-writers should consult the Agency's *EJ Legal Tools* document, which identifies discretionary legal authorities that are or may be available to the EPA to incorporate EJ into rules.[13] *EJ Legal Tools* notes that some authorities to promote EJ are clear, where others may involve interpretive issues that call for further analysis. Rule-writers may need to work closely with OGC and/or the appropriate regional or program office staff to understand how to use a specific authority to address potential EJ concerns in a particular set of circumstances. These conversations may influence the types of data collected and methods used to evaluate potential EJ concerns in a rule.

Existing statutory and regulatory authorities can be applied to prevent and mitigate adverse or disproportionate health and environmental impacts on all populations, including minority populations, low-income populations, and/or indigenous peoples. In applying these authorities to address potential EJ concerns, it is important to understand the appropriate role of demographic information when evaluating EJ. Demographic information can be used to identify existing or potential impacts on minority populations, low-income populations, and/or indigenous peoples and may be a factor in the design and implementation of regulatory actions. However, a decision to act (such as developing a more protective rule or standard) would be based on a human health or environmental factor, and not the racial composition or economic status of the impacted populations. Following this approach, demographic data will be used in conjunction with health or environmental information to identify

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[12] The Presidential Memorandum also states that existing civil rights statutes provide opportunities to address environmental hazards in minority and low-income communities. It directs agencies as follows: "In accordance with Title VI of the Civil Rights Act of 1964, each Federal agency shall ensure that all programs or activities receiving Federal financial assistance that affect human health or the environment do not directly, or through contractual or other arrangements, use criteria, methods, or practices that discriminate on the basis of race, color, or national origin."

[13] The *EJ Legal Tools* document was developed under EPA's Plan EJ 2014 and can be accessed at http://www.epa.gov/environmentaljustice/plan-ej/law.html.

differences, and those health or environmental impacts (not demographics) are the rationale for the Agency's decision.

It is important, however, to recognize that the Agency's statutory and regulatory authorities provide a broad basis for protecting human health and the environment and do not require a demonstration of disproportionate impacts in order to protect the health or environment of any population, including minority populations, low-income populations, and/or indigenous peoples. Thus, consistent with its mission, the Agency may address adverse impacts in the context of developing regulatory actions without the need to show that the impacts are disproportionate. Unless prohibited by statutory or regulatory authority, the EPA can and should consider action to address adverse health and environmental impacts on populations of concern, consistent with this guidance. Rule-writers should focus attention on the health of and environmental conditions affecting minority populations, low-income populations, and/or indigenous peoples, both before and after implementation of a rule and/or for the regulatory options under consideration. This will allow decision-makers to make more informed choices between different regulatory options. An important consideration for regulatory options is the extent to which they improve the adverse health and environmental impacts in minority populations, low-income populations, and/or indigenous peoples.

E. What Is an "Environmental Justice Concern"?

Throughout this Guide, the phrase "potential environmental justice (EJ) concern" is used to indicate the actual or potential lack of fair treatment or meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples in the development, implementation and enforcement of environmental laws, regulations and policies. This section will provide general guidelines on how to identify regulatory actions that may involve potential EJ concerns. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) how to evaluate potential EJ concerns.

Decision-makers determine early in the rule-making process the appropriate level of analysis and engagement with stakeholders, including minority populations, low-income populations, tribes, and indigenous peoples, considering factors such as the legal framework governing the action, the availability of relevant data and analytical methodologies, stakeholder interest, and the impacts that potential EJ concerns are likely to have on the actual decisions involving the action (see Section G below). Based on the application of these criteria, some regulatory actions will be identified for enhanced efforts that may require the development of new data, application of more advanced analytical methodologies and more extensive and targeted engagement of stakeholders, including minority populations, low-income populations, tribes, and indigenous peoples. As detailed more thoroughly in Part 2, decision-makers should convey their determinations on the appropriate level of analysis and stakeholder engagement to the rule-writers. It is important to document decisions regarding the screening-level analysis described in Section G and any further analyses, including the information upon which these decisions are based.

1. A potential EJ concern refers to disproportionate and adverse impacts on minority populations, low-income populations, and/or indigenous peoples that may exist prior to or that may be created by the proposed regulatory action.

The regulatory action may involve a potential EJ concern if it could:

- Create new disproportionate impacts on minority populations, low-income populations, and/or indigenous peoples;
- Exacerbate existing disproportionate impacts on minority populations, low-income populations, and/or indigenous peoples; or
- Present opportunities to address existing disproportionate impacts on minority populations, low-income populations, and/or indigenous peoples through the action under development.

For some Agency regulatory actions, it may also be useful and appropriate to assess the distribution of the benefits of the rulemaking action under consideration. Data limitations may, however, constrain rule-writers' ability to gauge how the distribution of existing pollution control program benefits may be changed by the new regulatory action. Rule-writers are encouraged to consult the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for information on potential considerations and methodologies and conduct timely assessment and planning for data needs during the rule-making process.

The assessment of whether the regulatory action involves potential disproportionate impacts may include qualitative and/or quantitative elements. To begin this assessment, rule-writers should first understand what an action is accomplishing and why it is necessary. As rule-writers gather this preliminary information and set the context for the action, they can begin to articulate the framework for analyzing whether there are potentially disproportionate impacts on minority populations, low-income populations, and/or indigenous peoples. The level of analysis appropriate for the regulatory action will depend on a variety of factors, including preliminary evidence of public health or environmental impacts on minority populations, low-income populations, and/or indigenous peoples, the legal framework governing the action, the availability of relevant data and analytical methodologies, a history of EJ issues in communities likely to be affected by the rule (e.g., history of significant non-compliance or recognized health effects due to polluting sources) or stakeholder interest, and the impacts that potential EJ concerns are likely to have on the actual decisions involving the action.

2. A potential EJ concern refers to lack of opportunities for minority populations, low-income populations, tribes, and indigenous peoples to meaningfully participate in the development of the regulatory action.

Regulatory actions may create a potential EJ concern if the Agency does not provide meaningful involvement opportunities to minority populations, low-income populations, tribes, and indigenous peoples during the development of the action. To provide meaningful involvement opportunities that are consistent with the Agency's definition of EJ, the rule-writers will likely need to go beyond the minimum requirements of standard notice and comment procedures and engage minority populations, low-income populations, tribes, and indigenous peoples early in the process. It is often unrealistic to expect meaningful involvement if the rule-writers have not targeted outreach efforts to these populations or tribes prior to proposing the action. Part 3 of this Guide describes the Agency's policies and resources related to meaningful involvement, and notes the difference between meaningful involvement of tribes and indigenous peoples as it is used in the EJ context versus formal consultation with tribes.

Rule-writers should think broadly about how regulatory actions may impact minority populations, low-income populations, and/or indigenous peoples. For regulatory actions that may impact these populations, the rule-writers should assess what steps will be taken to ensure there are sufficient opportunities for meaningful involvement during the development of the action. This includes regulatory actions that directly impact the health or environmental conditions of these populations as well as regulatory actions that involve the collection of information or data (information or data collection actions may impact these populations or tribes if the information or data are later used for inspection and enforcement or to assess potential health or environmental impacts).[14] Meaningful involvement is discussed in more detail in Part 3 of this document.

3. A potential EJ concern may arise when there is an actual or potential lack of fair treatment or meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples when implementing an agency regulatory action.

Rule-writers should assess how to consider EJ not only in the *development* of the action, but in the *implementation* of the action as well. The rule-writers should consider whether and how they can craft the action to influence its implementation in a manner that considers EJ. For example, listed below are common implementation issues that may be of particular concern to minority populations, low-income populations, tribes, and indigenous peoples.

What approaches should be included in the regulatory action to make sure it is effective with high compliance by the regulated community? Consider whether the regulatory action, when implemented, will itself promote compliance, to ensure that regulated facilities are complying. Rule-writers should try to make the rule self-implementing to drive compliance, using approaches such as enhanced monitoring, reporting and record-keeping requirements. These tools can help ensure compliance where needed to protect adversely affected populations, including minority populations, low-income populations, and/or indigenous peoples. Rule-writers should also draw on the expertise of the workgroup members, including representatives from OECA, in considering ways of ensuring effective program implementation and pursuing innovative ideas on how to achieve greater compliance and effectiveness of the action in reducing pollution and human and environmental risks. Information technologies in conjunction with public disclosure and accountability and other Next Generation Compliance concepts can be used to make rules more effective and enforceable.[15]

Does the regulatory action support compliance and enforcement? Non-compliance issues may impact the public health and environmental conditions affecting minority populations, low-income populations, and/or indigenous peoples, particularly when violations are occurring in areas already disproportionately impacted by environmental hazards. Structuring the action with compliance

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[14] Agency actions involving monitoring requirements are often viewed as important data gathering opportunities that inform the development of future actions. Also, a test rule that requires the submission of certain data that may subsequently be used in an analysis about impacts presents an important opportunity. Rule-writers should offer affected minority populations, low-income populations, tribes, and indigenous peoples meaningful opportunities to influence the type of data and information collected through such actions, how the data or information may be made available to the public, and how the Agency plans to use that data or information in future actions. For example, while the Agency often makes data available for the public to consider by issuing a Notice of Data Availability or as part of an Advanced Notice of Proposed Rulemaking, Rule-writers may consider and solicit feedback on other mechanisms for making the data or information available to these populations.

[15] For further information on such concepts, rule-writers are encouraged to consult the Rule Implementation, Compliance and Effectiveness Screening Tool, available at http://intranet.epa.gov/gis/ejscreen/.

considerations built in will improve the Agency's ability to detect and respond to non-compliance and will help improve the action's effectiveness and efficiency in achieving its intended results. Ensuring that the action is written to be enforceable is critically important to address EJ concerns that may arise as a result of program implementation issues and non-compliance. For example, regulatory actions should define what constitutes a violation, clearly outline what industry should do to comply with the action and identify how compliance will be measured and by whom. The rule-writers should also consider available information regarding industry-specific non-compliance histories (and underlying causal factors) to determine whether the rule could be designed—or coordinated with other efforts—in ways that improve compliance rates and overall rule effectiveness. See Text Box 5.

Does the regulatory action promote transparency and meaningful involvement? Regulatory actions that promote transparency and meaningful involvement during implementation can make it easier to engage and inform minority populations, low-income populations, tribes, and indigenous peoples throughout the action lifecycle, including after regulations are promulgated and being implemented. These actions may in turn improve their ability to spot non-compliance issues or identify ways in which implementation may be improved. For example, rule-writers should seek to design actions to maximize appropriate public availability of post-promulgation compliance information readily available and accessible to the affected public. The rule-writers should also assess how the action impacts the ability of minority populations, low-income populations, tribes, and indigenous peoples to meaningfully participate in subsequent environmental decision-making processes, e.g., permits, NEPA assessments, State Implementation Plans and reassessments of Agency regulatory actions.

Text Box 5: Nitrogen Dioxide (NO_2) Ambient Air Quality Monitoring

In 2010, EPA strengthened the health-based NAAQS established new ambient air monitoring and reporting requirements for NO_2. To determine attainment of the new standard, EPA established new ambient air monitoring and reporting requirements for NO_2. Ambient NO_2 monitoring data are collected by state, local and tribal monitoring agencies in accordance with monitoring requirements contained in 40 CFR parts 50, 53 and 58. Under these monitoring requirements, EPA required Regional Administrators to work with states to site a minimum of 40 NO_2 monitors, above the minimum number required in the area-wide and near-road network design, focused primarily on collecting NO_2 air quality data in areas where susceptible or vulnerable populations may be exposed to ambient NO_2 concentrations that have the potential to approach or exceed the NAAQS. Additional information is available at http://www.epa.gov/ttn/amtic/svpop.html.

Does the regulatory action encourage or require state, local and tribal governments to consider EJ as they implement federal programs? State, local and tribal governments are the primary implementers of many programs that the Agency administers.[16] If rule-writers have identified potential EJ concerns that may arise during state, local or tribal implementation, they should then consider how the action should address those issues. See Text Box 5 for an example of how this has been done successfully in a prior EPA rulemaking.

Does the regulatory action provide sufficient background information for drafting subsequent individual permits? Permits are an important vehicle through which Agency regulatory actions are implemented within a specific location.[17] Permits implement generally applicable regulatory standards

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[16] EPA reviews state, local, and tribal programs to determine if they meet applicable requirements for federal approval. If EPA finds that the program meets those requirements, it approves the state, local, or tribal government to implement the federal program. State and local governments which receive grants to implement federal programs are also subject to Title VI of the Civil Rights Act of 1964, as amended. Title VI prohibits recipients from discriminating on the basis of race, color, or national origin. A recipient's obligation under Title VI of the Civil Rights Act of 1964, is layered upon separate, but related, obligations under the federal or state environmental laws.

[17] For more information on considering EJ in permitting, see http://www.epa.gov/environmentaljustice/plan-ej/permitting.html.

by applying those standards to specific discharges and emissions of pollutants, which in some cases may take into account estimates of exposure experienced by minority populations, low-income populations, and/or indigenous peoples in that location. To facilitate the drafting of subsequent permits, it is important to consider, where feasible and appropriate, whether the data and assumptions that form the basis of the regulatory standard being developed account for exposure to multiple stressors,[18] impacts on vulnerable or susceptible populations, or other issues related to potential EJ concerns (see next section for discussion of factors that contribute to potential EJ concerns).[19, 20]

F. What Are the Factors That Contribute to Potential Environmental Justice Concerns?

Identifying the presence of potential EJ concerns goes beyond simply characterizing potentially impacted populations. Several factors, summarized below, will help in assessing whether potential EJ concerns may be associated with regulatory actions (i.e., whether disproportionate impacts on, or distribution of benefits to, minority populations, low-income populations, and/or indigenous peoples exist prior to or are created by the proposed action). These factors may contribute to the higher health and environmental risks or lower environmental benefits in these populations. EJ concerns may result from a combination of several, if not all, of the subsequently listed factors. However, in some circumstances, the presence of one or two of these factors alone could be sufficient to result in a potential EJ concern (i.e., potentially disproportionate impact on minority populations, low-income populations, and/or indigenous peoples). The rule-writers should note that disproportionate impacts may also arise from factors not included here. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for a more detailed discussion.

Proximity and Exposure to Emission Sources. Proximity to emission sources is the most studied indicator of high exposure in environmental justice literature. Disproportionate public health and environmental effects may be related to a population's differential proximity and associated exposure to environmental stressors, often stemming from evolving mixed land use patterns (i.e., encroachment of industrial/commercial facilities/infrastructure on residential communities or recreation areas, or expansion of residential areas into current or former industrial/commercial sites).

Unique Exposure Pathways. Unique exposure pathways are non-traditional pathways through which exposure to a given stressor occurs. Some populations sustain unique environmental exposures because of practices linked to their cultural background or socioeconomic status. For example, subsistence diets may expose these populations to toxic chemicals, such as exposures to mercury from a fish diet or exposures to other chemicals from a diet high in contaminated vegetation.[21] There are also non-dietary exposure pathways that may be unique to some indigenous peoples, such as the practice of basket weaving, where exposures to toxic chemicals may occur when contaminated materials are

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[18] This Guide uses the term "environmental stressor" or "stressor" to encompass the range of chemical, physical or biological agents, contaminants, or pollutants that may be subject to a rulemaking.

[19] In some situations, it may be appropriate for EPA to seek information about specific exposure pathways associated with cultural or traditional practices before formulating assumptions or making a determination of whether the assumptions account for a population's vulnerability. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis*.

[20] For a more detailed discussion of EJ and permitting, see EPA's Plan EJ 2014 webpage at http://www.epa.gov/environmentaljustice/plan-ej/permitting.html. The resources developed under the EJ in Permitting Initiative are housed on this website. The purpose of the EJ in Permitting Initiative is to enable overburdened communities to have full and meaningful access to the permitting process and to develop permits that address environmental justice issues to the greatest extent practicable under existing environmental laws.

[21] In the case of subsistence fishing, these populations may be exercising legal rights, based on treaties, to do so.

placed in the mouth during the weaving process. Unique exposure pathways can also be identified based on other factors, such as behavioral and physiological stages of growth and development which may occur during a particular life stage.[22]

Physical Infrastructure. Physical infrastructure is a very important source of environmental stressors. The physical infrastructure, such as poor housing, poorly maintained public buildings (e.g., schools) or presence of legacy pollutants such as lead in paint and PCBs in building materials, may contribute to making certain populations more vulnerable to environmental hazards.

Multiple Stressors and Cumulative Impacts. Exposures to, and risks from, multiple stressors from one or more sources or pathways can be accumulated over time and result in one or multiple effects. In addition, such risks may be modified by other stressors affecting the exposed population, such as nutritional or health status, smoking, or other factors. However, the science supporting assessments of such cumulative impacts is evolving and the data and analytical tools needed to develop informative, scientifically sound analyses of these effects may not be available. Under these circumstances, estimated exposures or risks associated with environmental pollutants from a given source may not reflect the potential health risks to populations exposed to multiple environmental stressors, particularly if the emissions, exposures or risks being targeted by the action under consideration have significant interaction effects with these other stressors. Minority populations, low-income populations, and/or indigenous peoples are likely to suffer a wide range of environmental stressors, ranging from poor air quality to poor housing. Numerous empirical studies and anecdotal accounts describe minority populations, low-income populations, and/or indigenous peoples that are impacted by multiple environmental hazards, such as industrial facilities, landfills, transportation-related air pollution, poor housing, leaking underground tanks, pesticides and incompatible land uses. Analyzing cumulative impacts from multiple stressors allows a more complete evaluation of a population's risk from pollutants targeted by the action under consideration, particularly when there may be important interaction effects among these multiple stressors and adequate data and methods are available. The EPA's *Framework for Cumulative Risk Assessment*[23] can enhance an evaluation of the various aspects of cumulative risk experienced by these populations. See also the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for a more detailed discussion.

Capacity to Participate in Decision Making. The ability, or inability, to participate in the environmental decision-making process may contribute to disproportionate impacts. Factors which contribute to the inability of minority populations, low-income populations, tribes, and indigenous peoples in particular to participate fully in the decision-making process include:

- Lack of trust;
- Availability or lack of information;
- Language barriers;
- Socio-cultural issues;
- Inability to access traditional communication channels; and
- Limited capacity to access technical and legal resources.

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[22] EPA defines lifestages as the "time frame in an individual's life characterized by unique and relatively stable behavioral and/or physiological characteristics that are associated with development and growth." For more information on lifestages, please visit http://yosemite.epa.gov/ochp/ochpweb.nsf/content/lifestage.htm.

[23] See http://www.epa.gov/raf/publications/framework-cra.htm.

Higher Risk in Response to Exposure Among Minority Populations, Low-Income Populations, and/or Indigenous Peoples. At-risk populations are groups who have a greater likelihood of experiencing effects related to environmental exposures.[24] Certain factors may render different groups less able to resist or tolerate an environmental stressor. These risk factors may be intrinsic in nature, based on age, sex, genetics, race or ethnicity, or acquired (such as chronic medical conditions, or smoking status); as well as extrinsic, non-biological factors such as those related to socioeconomic status, reduced access to health-care, health-care, nutrition, fitness and/or exposures related factors.[25]

If the rule-writers conclude that one or more of the previously listed factors is relevant to the action, they should then consider whether the action involves potentially disproportionate impacts on minority populations, low-income populations, and/or indigenous peoples and thus raises a potential EJ concern. To characterize and better understand the populations affected by the proposed action, the rule-writers may want to look at demographic data and consult with program and/or regional office EJ coordinators.[26] The rule-writers should also consider reaching out to these populations and tribes directly to assess potential concerns and issues associated with the proposed action (see Part 3 below for guidance on meaningfully engaging minority populations, low-income populations, tribes, and indigenous peoples). Where a screening analysis indicates the need for further analysis and engagement, the previously listed factors can be considered to determine the extent to which adverse health or environmental risks may be higher or concentrated within minority populations, low-income populations, and/or indigenous peoples. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for how to evaluate potential EJ concerns. Rule-writers may also want to draw on the expertise of representatives in their workgroup from the Office of Research and Development.[27]

G. How Do the Decision-Makers Determine What Degree of Assessment of Potential EJ Concerns Is Feasible and Appropriate?

In determining whether potential EJ concerns may be at issue in regulatory actions, some level of analysis is needed, be it qualitative, quantitative, or some combination of both. For many regulatory actions, including actions that strengthen environmental protection, it is not possible to rule out potential EJ concerns without some level of assessment. The extent to which an analysis of potential EJ concerns is feasible and appropriate also will be affected by data, budget and analytical constraints specific to the action and circumstance. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for more information.

This Guide encourages offices to utilize a "screening–level" analysis when feasible and appropriate to help determine the extent to which regulatory actions may raise potential EJ concerns that need

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[24] This Guide uses the term "environmental stressor" or "stressor" to encompass the range of chemical, physical or biological agents, contaminants, or pollutants that may be subject to a rulemaking.

[25] For example, in the final PM2.5 National Ambient Air Quality Standards rule, based on information presented in the *Integrated Science Assessment for Particulate Matter* (U.S. EPA, 2009, sections 2.2.1 and 8.1.7), the EPA made a finding that persons with lower socioeconomic status are at increased risk for experiencing adverse health effects related to PM exposures (78 FR 3104). Persons with lower socioeconomic status (SES) have been generally found to have a higher prevalence of pre-existing diseases, limited access to medical treatment, and increased nutritional deficiencies, which can increase this population's risk of PM-related effects (77 FR 38911, June 29, 2012).

[26] For a listing of media EJ Coordinators, please visit http://epa.gov/environmentaljustice/contact/ej-contacts-media.html. For a listing of Regional EJ Coordinators, please visit http://epa.gov/environmentaljustice/contact/ej-contacts-regional.html.

[27] The recently-released *American Journal of Public Health* Supplement "Environmental Justice and Disparities in Health" may be useful in gaining a more complete understanding of how these factors influence health outcomes. See http://ajph.aphapublications.org/toc/ajph/101/S1.

to be evaluated further as rule-writers advance through the ADP.[28] Rule-writers are encouraged to check with the lead office's EJ Coordinator, Agency memoranda relating to prioritization of rules for EJ consideration/analysis and updates to the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) to assess whether specific guidance or screening tools are available to support decision-makers as they determine the appropriate methods and approaches for assessing potential EJ concerns in the context of the rule-making action.

Screening-level analyses can help offices focus their resources and efforts on regulatory actions where there are opportunities to identify and address potential EJ concerns. As is often the case in the development of many of EPA's regulations, screening-level analyses may need to be updated or reconsidered in the beginning stages of the ADP as more information becomes available. Rule-writers should also consult with OGC if there are questions about the opportunities for addressing potential EJ concerns that are provided by the statutes that govern the action.

Current EPA guidance does not prescribe or recommend a specific approach or methodology for conducting screening-level analysis. A screening-level analysis should provide information related to whether there may be potential EJ concerns associated with regulatory actions, and may include elements such as the following:

1. A description of the potential impacts on, and existing risks to, minority populations, low-income populations, and/or indigenous peoples. This may involve a description of:
    - The proximity of sources being regulated to these populations
    - The number of sources that may be impacting these populations
    - The nature and amount of pollutants that may be impacting these populations
    - Whether there are any unique exposure pathways involved
    - Combinations of the various EJ factors occurring in conjunction with one another
    - Expressed stakeholder concerns about the action, if any.
2. A description of potential impediments to meaningful involvement. This may involve understanding whether the action presents opportunities to improve public involvement requirements or limits opportunities in some way.

To assist decision-makers in their efforts to determine what degree of assessment of potential EJ concerns is feasible and appropriate, rule-writers should consider the data that would be needed to support a quantitative analysis and estimate the resources that would be needed to develop the data and carry out a quantitative analysis. Rule-writers should then provide this information to decision-makers to support their determinations regarding the analysis of EJ issues in the rulemaking effort. In some circumstances, decision-makers might determine that there are insufficient data available to do a quantitative evaluation or such analysis is otherwise infeasible or unnecessary. In such cases, it may nonetheless be possible to develop a meaningful qualitative analysis (see example in Text Box 6).

There may also be circumstances where decision-makers elect not to go beyond a screening level analysis to evaluate potential EJ concerns because it is impracticable to do so or initial screening or other information indicates that EJ concerns are unlikely to be manifest.

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[28] In October 2012, the Deputy Administrator announced that EJSCREEN is EPA's official environmental justice screening tool for Agency work. EJSCREEN is available within EPA at http://ejscreen.epa.gov/mapper/.

Text Box 6: DSW Analysis

Although EPA's *Analysis for the Definition of Solid Waste* (DSW) relies on both quantitative and qualitative analyses, it demonstrates how a qualitative approach can be used. The DSW analysis showcases how EPA used data on vulnerabilities and impacts to support a proposed rule revision that would prevent and mitigate adverse impacts that disproportionately affect minority populations, low-income populations, and/or indigenous populations. This analysis made qualitative connections between the increased incidence of vulnerability factors (relating to increased proximity and increased susceptibility) and the likelihood that populations impacted by the rule, which included minority populations, low-income populations, and/or indigenous populations, would potentially face increased risk of negative health and environmental outcomes. The vulnerability factors considered in the DSW analysis are multiple and cumulative impacts; ability to participate in the decision-making process; physical infrastructure; susceptible populations; and unique exposure pathways. The analysis concluded that the underlying vulnerabilities traditionally associated with minority and low-income communities may exacerbate potential adverse impacts of the DSW rule (see http://www.regulations.gov/#!documentDetail;D=EPA-HQ-RCRA-2010-0742-0004).

It is important to document the decision-makers' determinations regarding the screening-level analysis and any further analyses, including the information upon which these decisions are based. This documentation should become part of the record for the action and will help the rule-writers and associated programs establish compliance with the directives of EO 12898 and EJ policies. Decision-makers may want to review this documentation and discuss whether further consideration of potential EJ concerns is appropriate.

H. Exploring Regulatory Responses to Potential EJ Concerns

A regulatory response to an identified potential EJ concern may require rule-writers to consider whether the regulatory action can and should set a stricter standard or go beyond the basic and ordinarily protective norms to require additional measures in a rule. The Agency's ability to do this, and the appropriateness of doing so, will depend on the Agency's legal authority and whether sufficient evidence of a potential EJ concern has been established, and whether circumstances or factors exist with respect to the particular emissions, exposures or risks addressed by the action that justify setting a stricter standard. An example of the latter might be the need to set a lower threshold of concern for exposure to a pollutant because the exposure-response for that pollutant is altered by disproportionately high exposure to other environmental stressors. These opportunities will become clearer as the Agency gains more experience in this area and as the data, tools and methods to evaluate potential EJ concerns evolve.

Examples of regulatory responses that could serve as starting points for rule-writer's consideration are discussed in Appendix E. The appendix includes examples in which responses to potential EJ concerns strengthened the defensibility of the rule, generated better data on differential exposure levels, increased benefits for all population groups, reduced disparities in risk, improved oversight of facilities, and improved compliance.

In some cases, rule-writers may identify a potential EJ concern for which the Agency's ability to explore a regulatory response is limited. It is important for rule-writers to alert their decision-makers to potential EJ concerns that cannot be addressed through the rule under development. This information allows decision-makers to look for other resources and tools to address potential EJ concerns as appropriate and as time, resources and data allow. In addition, rule-writers should pass along the information they have gathered about potential EJ concerns to other EPA offices as they consider EJ as they implement their own programs. See example in Text Box 7.

Text Box 7: National Emissions Standards for Hazardous Air Pollutants: Mineral Wool Production and Wool Fiberglass Manufacturing

Proposed Rule Development Example

As part of OAR's development of the Wool Fiberglass Manufacturing rulemaking proposal, EPA sent requests to 29 fiberglass manufacturing plants across the nation, asking them to provide emissions data. From this information, EPA learned that the CertainTeed plant in the Fairfax Industrial District of Kansas City, Kansas, was emitting chromium VI emissions that were higher than any other facility in the industry.

Region 7 proactively engaged the local community and identified the potential environmental concerns, opening lines of communication and launching several opportunities for the community to voice concerns, ask questions and receive additional information. At least ten face-to-face sessions were held, including stakeholders meetings, technical discussions, as well as a round table discussion with the Region 7 Regional Administrator.

Concurrently, Region 7 conducted air monitoring at John Garland Park, located between the facilities and nearby residential areas. The results of the air monitoring did not indicate that the plant emissions were a health concern for the community. The monitoring was conducted for approximately five months, however the furnace associated with the high chromium VI emissions was idled shortly after the monitoring began, and remains idled to this day.

Due to the high level of local interest regarding this rulemaking, a public hearing was also held in the Kansas City area giving the community an opportunity to submit verbal and written comments on the pending rulemaking. Much like the air monitoring events, holding a public hearing in the vicinity of an active community is not typically a direct result of the rulemaking process.

Rule-writers should also assess whether additional compliance drivers and tools for ensuring transparency (such as those discussed in section E.3) should be included in the regulations they are developing to ensure that the rules are as effective as possible in addressing the EJ Factors identified in Section F above. These tools can complement enforcement programs and enhance public involvement in rule implementation.

Part 2: Considering Environmental Justice During the Development of Regulatory Actions Under the Action Development Process

This section of the Guide describes the key issues related to considering EJ during the development of regulatory actions under the ADP (see Text Box 8). It is designed to help the rule-writers identify opportunities in the ADP where they can:

1. Identify potential EJ concerns;
2. Plan to achieve meaningful involvement;
3. Plan to evaluate and address potential EJ concerns;
4. Discuss potential EJ concerns with decision-makers;
5. Compare how options under consideration would change the environmental and public health impacts on minority populations, low-income populations, and/or indigenous peoples; and
6. Document the rule-writers' efforts to achieve meaningful involvement and address potential EJ concerns.

Text Box 8: What Is the Action Development Process?

The ADP is a method for producing quality actions, such as regulations, policies, guidance, strategies and reports. It ensures that EPA uses the best available information to support its actions and that scientific, economic and policy issues are adequately coordinated across the Agency during the various stages of action development. Activities that implement EO 12898 should be undertaken within the framework of this process. For more information, see EPA's *Action Development Process: Guidance for EPA Staff on Developing Quality Actions* available on OP's intranet site at http://intranet.epa.gov/adplibrary.

A. Who Is Responsible for Considering EJ During the Development of Regulatory Actions Under the ADP?

Rule-writers and decision-makers (see definitions provided in subsection B of the Overview and Background section) should use this Guide in the development of regulatory actions. In addition, rule-writers and decision-makers may seek assistance from other EPA resources, such as EJ Coordinators. Based on the level of participation in the development of regulatory actions, they may have additional specific responsibilities. See EPA's *Action Development Process: Guidance for EPA Staff on Developing Quality Actions* for general information about the roles and responsibilities of the different participants in the development of regulatory actions. Following is guidance for key actors in the ADP:

Text Box 9: Decision-Makers

Decision-makers establish policy priorities, communicate expectations to the workgroup and decide whether or not a potential EJ concern warrants further evaluation, the level of analysis and public involvement, and the resources available for those activities.

1. Decision-Makers. Relying on information provided by the rule-writers, EPA decision-makers determine what needs to be done to identify and address potential EJ concerns for Agency regulatory actions under development (see Text Box 9). They communicate expectations to the rule-writers, establish policy priorities, identify issues of significant concern and guide the process of developing the action. As a result, decision-makers play a key role in ensuring that the potential EJ implications of regulatory actions are considered during the development of those actions, and that populations affected by those actions have an opportunity to participate.

In particular, decision-makers determine early in the process the appropriate level of analysis and engagement of stakeholders, including minority populations, low-income populations, tribes, and indigenous peoples, considering factors such as the legal framework governing the regulatory action, the availability of relevant data and feasibility of analytical methodologies, stakeholder interest and the impacts that EJ concerns are likely to have on the actual decisions involving the action. Based on the application of these criteria, some regulatory actions will be identified for enhanced efforts that may require the development of new data, application of more advanced analytical methodologies and more extensive and targeted engagement of minority populations, low-income populations, tribes, and indigenous peoples. Decision-makers convey determinations on the appropriate level of analysis and stakeholder engagement to the workgroup.

Decision-makers are responsible for ensuring rule-writers address the following three core EJ questions at the appropriate points during the development of the regulatory action under the ADP (as described below in this section):

1. How will (or did) the public participation process provide transparency and meaningful participation for minority populations, low-income population, tribes, and indigenous peoples?
2. How do the rule-writers plan to (or how did the rule-writers) identify and address existing and new disproportionate environmental and public health impacts on minority populations, low-income populations, and/or indigenous peoples during the rulemaking process?
3. How did the actions taken under #1 and #2 impact the outcome or final decision?

Appendix B provides a quick reference for EPA decision-makers on when and how they can participate in the action's development to ensure that the rule-writers identify and evaluate potential EJ concerns.

2. The Workgroup Chair. The role of the workgroup chair is to facilitate and oversee the efforts of the rule-writers to achieve meaningful involvement and to consider EJ concerns during the development of the action. Appendix C provides a checklist to identify what the chair may need to know and/or do in order to integrate EJ into the development of the action.

3. The Rule-Writing Workgroup. The rule-writing workgroup is responsible for assuring meaningful involvement and consideration of EJ concerns during the development of the regulatory action under the ADP (see Text Box 10). Workgroup members influence the scope and content of analyses of EJ concerns that support regulatory actions. Workgroup members, as representatives of their program offices or regional offices, should keep decision-makers in their organizations informed of EJ concerns and workgroup actions in a timely manner so that they can formulate appropriate responses.

4. The Analysts. For the most part, the analysts—those doing the economic or scientific supporting analyses—are likely to be members of the workgroup. In some cases, however, the analysts may only be involved in the analytic work performed as part of the development of regulatory actions. In either case, the analyst plays a key role in identifying the analytical topics that will need to be addressed during the development of regulatory actions, as well as leading or actively participating in the analytical efforts, including considering whether one or more scientific or economic analyses are needed to support those actions.[29] It is also important to note that these analyses may be quantitative, qualitative, or both. See the *Guidelines for Preparing Economic Analyses* and the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) under development for more information on conducting an analysis of potential EJ concerns for regulatory actions.

Text Box 10: What Is the Workgroup?

The workgroup consists of representatives from interested program offices and Regions. The workgroup develops the draft regulation, involving its members throughout the ADP. Workgroup members represent the position of their program office or Region. Tier 1 and Tier 2 actions call for formation of action development workgroups. Even though Tier 3 actions do not normally call for teams/workgroups, the lead program should consider the level of assistance needed from Regions and other offices to produce a quality regulatory action.

B. When Should Potential EJ Concerns Be Considered During the Development of Regulatory Actions Under the ADP?

The following is a description of the opportunities for considering potential EJ concerns at the specific steps in developing regulatory actions under the ADP. If the workgroup is unable to follow the activities described below for a particular step of the ADP, those activities may be performed at later steps, as appropriate.

The procedural steps under the Agency's ADP may vary based on the specific tier designation. The procedural steps described in this Guide primarily apply to regulatory actions developed under Tier 1 and 2 of the ADP because Tier 3 regulatory actions, such as regional office regulatory actions, may not follow all the same procedural steps. For example, an Analytic Blueprint (preliminary or detailed) is optional for Tier 3 actions. Even though a particular ADP step may not apply to the action, rule-writers should consider potential EJ concerns regardless of the tier level assigned to the regulatory action. Note that some regional offices regulatory actions are developed under the ADP as Tier 3 actions while some are developed under a separate process from the ADP. This Guide can also help workgroups consider EJ concerns for those regional offices regulatory actions that are developed under a separate process from the ADP.

Appendix A includes a flowchart, entitled "Incorporating Environmental Justice into Tier 1 and Tier 2 Actions Under the ADP," which outlines the ADP procedural steps for Tier 1 and 2 actions to illustrate when EJ concerns might be integrated at various steps throughout the ADP (see blue text boxes). The discussion that follows in this Guide is linked to the numbered steps used in the Tier 1 and 2 process

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[29] See EPA's *Action Development Process Guidelines for Preparing Analytic Blueprints*, p. 14, available electronically at http://intranet.epa.gov/adplibrary/documents/abp09-30-04.pdf.

flowchart. This information is also provided on the EPA intranet in the form of tool at http://intranet.epa.gov/oswer/policy/ejr/index.html.

ADP Steps 1 and 2 – Action Initiation and Tiering

Once the Agency decides to initiate a regulatory action (Step 1), the next step of the ADP is tiering (Step 2). At this point, the lead EPA Program Office must fill out a tiering form in the ADP TRACKER that provides basic information about the action being initiated. Table 1 displays the EJ question currently in the ADP TRACKER. These questions can be used to help determine whether regulatory actions may involve a subject that is of particular interest to or may have particular impacts on these populations.

Table 1: EJ Question in ADP TRACKER

Environmental Justice *Does this action involve a topic that is likely to be of particular interest to or have particular impact upon minority populations, low-income populations, or indigenous populations, or tribes?*		
☐ Yes	If the answer is Yes, please check a minimum of one of the following options: ☐ The action is likely to impact the health of these populations. ☐ The action is likely to impact the environmental conditions of these populations. ☐ The action is likely to present an opportunity to address an existing disproportionate impact on these populations. ☐ The action is likely to result in the collection of information or data that could be used to assess potential impacts on the health or environmental conditions of these populations or tribes. ☐ The action is likely to affect the availability of information to these populations or tribes. ☐ Other reasons. *Explain*:	**Comments:**
☐ No	Selecting No means that this action is not likely to be of any particular interest to these populations or tribes. *Explain*:	**Comments**:
☐ TBD	Selecting TBD means that, given the information available at this time, the Agency does not know if these populations or tribes will be particularly interested in this action.	**Comments:**

For some offices, the EJ question asked at tiering might also be the impetus for an initial screening analysis, as discussed in Part 1 of this document. For other offices, there may already be a screening process in place that can inform how rule-writers answer this question at tiering.

As the lead program office prepares to answer the EJ question displayed in Table 1, there are some important points to keep in mind.

- Rule-writers are expected to make an informed assessment about whether regulatory actions will have potential impacts on minority populations, low-income populations, and/or indigenous peoples based on readily accessible information and what the rule-writers already know about a regulatory action and its potential EJ implications, recognizing that at this early step in the ADP they may not have sufficient information to determine whether a potential EJ concern is associated with the action.
- The question also asks about actions that may be of *particular interest* to minority populations, low-income populations, tribes, and indigenous peoples. A regulatory action may be of particular interest if it concerns a topic that these populations or tribes have identified as important. For example, a rule that affects the availability of information may be of interest even though it

may not have particular impacts on these populations or tribes. If a regulatory action may be of particular interest to these populations or tribes, rule-writers may need to provide opportunities for meaningful involvement in the development of those actions.

- Answering yes to this question signals that potential EJ concerns are likely to be involved in the regulatory action. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for guidance on analytic expectations. If rule-writers believe that the action may involve a potential EJ concern, they may request that an EJ coordinator be assigned to join the workgroup or otherwise support the action. This can be done by requesting OEJ assistance in assigning an EJ coordinator in the "Workgroup" section of the tiering form or by describing the potential concerns in the section labeled "Additional information or assistance needed."
- Answering TBD to this question signals that the rule-writers should consider whether there are potential EJ concerns associated with the regulatory action as they go through the ADP. Rule-writers are expected to conduct proper outreach and evaluation activities to make a determination of whether potential EJ concerns are involved and how those concerns can be addressed before they develop the final action. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for guidance on analytic expectations.
- The lead program office's answer to this question (along with other information on the tiering form) will be part of the Agency's Regulatory Development and Retrospective Review Tracker (Reg DaRRT) Reg DaRRT offers the public a means of learning about and tracking rulemakings (see Text Box 11). One of the features allows rule-writers and the public to sort actions based on the responses to the EJ question displayed in Table 1. Reg DaRRT is updated regularly, so any updates rule-writers make to the action in the ADP TRACKER is reflected on Reg DaRRT throughout the life of the action. Rule-writers can access the Reg DaRRT website at http://yosemite.epa.gov/opei/RuleGate.nsf/.
- Program Offices will be asked to reconsider their answer for this question during the semi-annual update of the Agency's Regulatory Agenda. This provides rule-writers with an opportunity discuss whether the answer should be changed based on new information or the results of the evaluation.

Text Box 11: What Is Reg DaRRT?

The Regulatory Development and Retrospective Review Tracker (Reg DaRRT) provides information to the public on the status of EPA's priority rulemakings and retrospective reviews of existing regulations. Reg DaRRT includes rulemakings that have not yet been proposed, those that are open for public comment, those for which EPA is working on a final rule, and those that have been recently finalized.

ADP Step 3 – Preliminary Analytic Blueprint (PABP)

The PABP, which is required for all Tier 1 and 2 actions, provides an opportunity to review the rule-writers' screening decision and to identify what steps they will take to ensure that EJ concerns are considered in the development of regulatory actions. This opportunity to revisit EJ considerations is similar to the opportunity the PABP provides to revisit other assumptions or decisions made regarding other aspects of the regulation development effort. It is important to document the potential EJ concerns and how rule-writers will develop needed information and how they will use that existing and new information to explore and address them in the action.

Careful consideration of EJ concerns in the PABP can improve regulatory actions by ensuring appropriate consideration in planning rule-writers' activities, including early attention to data gathering, facilitating cross-agency sharing of valuable information, expertise and perspectives and by fostering early agreement on the three core EJ questions through a structured, documented process. It is likely that information to describe baseline conditions for minority populations, low-income populations and indigenous peoples may be lacking, potentially limiting the ability to assess the impacts of the regulation on those populations. However, timely assessment and planning for these information needs will help rule-writers develop a well-supported and documented regulatory action and avoid last minute concerns over the type of information or analyses that should be available or might need to be developed (see Text Box 12). The rule-writers should also be aware of opportunities to coordinate data collection and analytical efforts with children's and other health impacts analyses conducted in developing the rule.[30]

Text Box 12: Consider a broad array of opportunities to integrate the meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples in the development and implementation of a regulatory action

When developing actions:

- Reach out to potentially affected populations and tribes early;
- Include them in data gathering;
- Engage them in developing options to address the issue(s); and
- Consider their role in future activities.

If the action establishes a framework or regulatory standards for subsequent actions, make sure to:

- Provide opportunities for public involvement in the subsequent actions; and
- Engage potentially affected populations and tribes in the subsequent actions.

When implementing the action:

- Continue to manage the ongoing program
- Build awareness;
- Provide information;
- Involve potentially affected populations and tribes in program activities;
- Seek feedback; and
- Be transparent.

To determine whether the regulatory action may have potential EJ concerns, and to ensure appropriate and timely information is provided to decision-makers, the PABP should (to the extent relevant and appropriate):

- Identify potentially affected populations and tribes, as well as others who might be interested in the action;
- Outline plans and resource needs for achieving meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples;
- Describe the plans and resource needs for evaluating impacts on of minority populations, low-income populations and indigenous peoples;

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[30] See EO 13045 Protection of Children from Environmental Health Risks and Safety Risks. Rule-makers should also be aware of the requirements in EPA's Guide to Considering Children's Health When Developing EPA Actions: Implementing Executive Order 13045 and EPA's Policy on Evaluating Health Risks to Children.

- Identify available EJ assessment tools, as well as related needs for data collection, expertise and resources; and
- Identify potential analytical issues that will need to be raised to decision-makers or addressed.

Please note that the PABP does not have to describe the details of the analyses that might be needed to evaluate EJ concerns.

It may be beneficial to develop a separate scoping document that becomes part of the PABP for purposes of increasing accountability and visibility of evaluating EJ concerns. For example, a scoping document may be a useful vehicle to provide an opportunity for meaningful involvement early in the regulatory action's development.

The framework for identifying and addressing EJ concerns is part of an iterative process. It is therefore important to revisit in later stages of the ADP as information and ideas continue to develop, similarly to revisiting assumptions or decisions made regarding other aspects of the regulation development effort, the scope of inquiry relating to evaluation of EJ concerns.

The PABP is an important vehicle for raising EJ concerns to decision-makers. Once developed, rule-writers should submit the PABP to senior management decision-makers as part of the request for Early Guidance.

ADP Step 4 – Early Guidance

At this step, decision-makers convey their expectation that rule-writers consider potential EJ concerns during regulatory action development. Early Guidance always comes from senior management decision-makers, although the level of management giving guidance differs for Tier 1 and Tier 2 actions. See Text Box 13 and EPA's *Action Development Process: Guidance for EPA Staff on Developing Quality Actions*, available on OP's intranet site http://intranet.epa.gov/adplibrary, for more information on Early Guidance.

Text Box 13: Early Guidance from Decision-Makers

Early guidance from decision-makers determines the appropriate level of analysis and engagement of stakeholders, based on:

- Stakeholder interest;
- The legal framework governing the action;
- The availability of data;
- The availability of resources and the timeline for developing the action; and
- The impacts that EJ concerns are likely to have on the actual decisions involving the action.

In addition, at Early Guidance rule-writers should obtain input from decision-makers on the proposed approaches for considering potential EJ concerns and any potential complications or issues in doing so. Rule-writers should be prepared to respond to decision-makers' questions about whether the regulatory action may involve a potential EJ concern, and how this was or will be ascertained. This will ensure that decision-makers provide the direction that rule-writers need to respond to the three core EJ questions outlined in Part 2, Section A (and repeated in the guidance for Step 5). Rule-writers also should be prepared to explain what resources are required to identify and evaluate potential EJ concerns, including data needs.

ADP Step 5 – Detailed Analytic Blueprint (DABP)

The DABP should incorporate the directions received through Early Guidance from senior management decision-makers. The preparation of the DABP provides rule-writers with another opportunity to plan key activities for determining whether and how potential EJ concerns will be identified and considered during the development of the regulatory action, including scientific and economic analysis, information gathering and defining alternative approaches to be considered. If there are potential EJ concerns, the rule-writers should also develop a detailed public involvement plan that provides transparency and meaningful participation for minority populations, low-income populations, tribes, and indigenous peoples (e.g., by considering their needs, capacities, cultural practices and languages).

The DABP may identify a preliminary plan to determine to what extent the regulatory action involves EJ concerns, estimate the magnitude of such concerns and guide the initial development of any options regarding those concerns. When preparing a quantitative or qualitative evaluation of potential EJ concerns, the DABP should describe the:

- Rule-writers with lead responsibility for the preliminary and detailed assessments of EJ concerns;
- Data needs and data sources for the EJ assessment;
- Scope and basic methodology of the EJ assessment;
- Outputs of the EJ assessment; and
- Schedule and resources required to prepare the EJ assessment.

In addition, the DABP should describe the rule-writers' planned activities to ensure that they can answer the first two of the three core EJ questions at key stages in the ADP:

1. **How did/will the public participation process provide transparency and meaningful participation for minority populations, low-income populations, tribes, and indigenous peoples?**

   This question asks rule-writers to document the proactive steps taken, beyond minimum notice and comment opportunities, to meaningfully engage these populations, tribes and peoples in the development of the regulatory action. This would include any outreach to state, tribal, and local governments and to national- and community-level non-governmental organizations, among others. Rule-writers should document planned public meetings, information sessions, workshops or other activities designed to identify and encourage the participation of these populations, tribes and peoples.

2. **How did the rule-writers identify and address existing and/or new disproportionate environmental and public health impacts on minority populations, low-income populations, and/or indigenous peoples?**

   This question asks rule-writers to document the proactive steps taken to identify and address potentially disproportionate impacts on the public health and environment of these populations. This could include any investigation and characterization the rule-writers performed of geographic areas or populations that are likely to be most affected by the action. As part of this evaluation, rule-writers are encouraged to look at the distribution of the positive environmental and health consequences from the EPA's activities. Rule-writers should ensure that they have identified and addressed issues that are of concern to minority populations, low-income populations, tribes and indigenous peoples.

Rule-writers should note that not all regulatory actions will raise potential EJ concerns. For regulatory actions that do not raise EJ concerns, rule-writers can answer the three core EJ questions by showing that the action either:

- Underwent a screening-level analysis designed to identify those regulatory actions that may raise potential EJ concerns and those that do not; or
- Has been shown—through thorough research and analysis—to support a determination that the action does not involve any potential EJ concerns.

ADP Step 6 – Management Approval of the DABP

The review and approval of the DABP provides another important opportunity for the rule-writers to check in with decision-makers to determine whether and how potential EJ concerns will be identified and considered during the development of the regulatory action. For example, during the formal cross-agency review of the draft DABP, the rule-writers and other reviewers of the draft DABP (e.g., OEJ or the lead office's EJ Coordinator) can assess whether the DABP outlines activities for identifying or considering potential EJ concerns. The decision-makers can also use this as an opportunity to consider how well the DABP addresses potential EJ concerns before approving the DABP (see Text Box 14).

Text Box 14: Management Approval of DABP

During the course of developing the PABP and DABP, an office may alter its determination that an action might be of particular interest to or have particular impacts upon minority populations, low-income populations, and/ or indigenous peoples. Should such a change occur, alter the answer provided to the EJ Question in the ADP TRACKER (illustrated in the section titled "ADP Steps 1 and 2"). The EJ Question in the TRACKER can be altered at any time. Changes to Tier 1 and Tier 2 actions are updated regularly so the public can access EPA's latest thinking about an action.

Once the DABP is approved, decision-makers have determined the appropriate level of analysis and engagement for the regulatory action. In the absence of any compelling circumstances that would cause decision-makers to revisit this or other non-EJ determinations, rule-writers should follow the direction provided by decision-makers in the DABP for the remaining steps of the ADP.

ADP Step 7 – Data Collection, Analysis and Consultation, and Development of Regulatory Options

In this step, rule-writers should implement the DABP and investigate the regulatory problem that the action is intended to address, gather relevant information, consult with stakeholders, including minority populations, low-income populations, tribes, and indigenous peoples, and develop options for resolving the problem.[31] Integrated into all of these activities should be the consideration of the extent to which there are potential EJ concerns, and how those concerns may be addressed. Rule-writers should use the Agency's available EJ assessment tools to determine the extent to which the action has potential EJ concerns, complete EJ-related consultation or public participation, as appropriate, and analyze any potential EJ concerns.

Although analyses to evaluate potential EJ concerns will vary across regulatory actions, they typically have the same starting point. Rule-writers should attempt to describe the regulatory baseline and the anticipated changes in emissions, exposures, and/or risks to be achieved by an action. It is important, where appropriate and when data permit, to characterize the potential changes in emissions, exposures and/or risks on minority populations, low-income populations, and/or indigenous peoples. The analysis should cover the appropriate range of options considered to address those impacts and should provide a sufficient level of detail to distinguish major environmental or public health impacts across the options for these population groups. Rule-writers should consider the data needed to support such analyses when developing their Preliminary and Detailed Analytical Blue Prints in order to maximize their opportunities to describe these baselines and the projected impacts of their regulatory actions. See the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013) for guidance on analytic expectations.

ADP Step 8 – Options Selection

Options selection is the last step in the ADP before rule-writers finish drafting the regulatory action. In this step, the rule-writers can identify the significant issues and several options to resolve each issue. Senior management decision-makers then selects those options that would best achieve the goals of the action. Selecting a regulatory action from among many options is a complex process. The extent to which potential EJ concerns factor into the process will vary considerably across regulatory actions, and will depend in large part on the operative requirements of the statute under which the action is being taken.

In presenting the options to senior management decision-makers for final decision-making, rule-writers have another opportunity to consider whether potential EJ concerns have been addressed. Decision-makers will also have an opportunity to confirm that the rule-writers have considered and addressed potential EJ concerns, including any necessary consultations to achieve meaningful involvement. The options selection presentation should describe the rule-writers' activities and efforts to assess potential EJ concerns and to involve affected populations, including minority populations, low-income populations, tribes, and indigenous peoples. The presentation should also describe what actions are recommended to ensure that potential EJ concerns are addressed by each of the options being presented (see Text Box 15). Rule-writers should be prepared to discuss the options under consideration in the regulatory action (such as pollution control options) in

Text Box 15: Does the DABP Address EJ?

The DABP presents the plan that implements the management decision regarding the level of analysis and engagement of stakeholders.

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[31] See previous discussion about preparing the DABP, which should include a consultation plan that describes how the workgroup will achieve meaningful involvement, particularly for those stakeholders that may have historically not been able to participate. In addition, the workgroup should consult the Agency's Risk Characterization Handbook, which provides a single, centralized body of risk characterization implementation guidance for Agency risk assessors and risk managers to help make the risk characterization process transparent and the risk characterization products clear, consistent and reasonable, at http://www.epa.gov/osa/spc/pdfs/rchandbk.pdf.

light of their impacts on minority populations, low-income populations, and/or indigenous peoples, including reductions in exposure or risk.

In presenting the results of the analysis evaluating potential EJ concerns to decision-makers, rule-writers should be aware of the specific statutory and other important criteria they will use to select an option. Where EJ concerns represent the major consideration for selecting an option, it is vital that the nature and magnitude of impacts be clearly presented in some detail. For example, the following questions might be answered:

- Are there studies documenting impacts? How complete are the studies?
- Is there indication that certain populations are particularly sensitive?
- What are the qualitative and quantitative differences?

In addition, rule-writers should be prepared to discuss the first two of the three core EJ questions outlined above in Part 2, Section A. The rule-writers should also note that regulatory actions that impact the availability of information or the ability to participate meaningfully in the implementation of a program might have indirect impacts on these populations that should be considered. For example, a rule that modifies reporting requirements for regulated industries may make it easier or harder to effectively monitor facilities that are of concern to these populations and understand whether the rule is achieving the intended results. This type of impact should be considered.

ADP Step 9 – Preparation of the Action and Supporting Documents

In this step, rule-writers prepare the regulatory action, consistent with decision-maker direction. This step includes preparing the rule and preamble and the supporting documents. The evaluation of potential EJ concerns is part of this step.

At this stage, the rule-writers may document how they identified, assessed and addressed potential EJ concerns and how they achieved the meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples. Even if the rule-writers concluded there were no EJ concerns, the activities that led to that conclusion should be documented. It is important that pertinent documents relating to potential EJ concerns are understandable and readily accessible to the public in the docket for the regulatory action.

In general, the preamble for the regulatory action should clearly state how the action is supported by the results of the analyses to evaluate potential EJ concerns. If the data to characterize potential EJ concerns was insufficient or inadequate, the preamble should describe clearly the Agency's efforts to search for data to characterize risks and how the regulatory decision addressed the data gaps and any qualitative information available on potential EJ concerns. Suggested template language for addressing EO 12898 in preambles is available in the ADP library (http://intranet.epa.gov/adplibrary) and covers both proposed and final rules. However, the rule-writers' documentation is not limited to the inclusion of appropriate language in the preamble to address compliance with EO 12898.

ADP Step 10 – Final Agency Review (FAR)

Once the regulatory action has been developed, a package is presented to the decision-makers for Final Agency Review (FAR). The FAR package consists of the final drafts of the action itself (e.g., the Federal Register [FR] document that represents the proposed rule), the supporting documents (e.g., the economic analysis and, if prepared separately, any assessment of potential EJ concerns), the Action Memorandum and any other relevant documents (e.g., the Information Collection Request, Communications Plan, etc.).

As part of the draft Action Memorandum, rule-writers should specifically address the three core EJ questions identified in Part 2, Section A (and repeated in ADP Step 5 above). These answers will accompany the action when it is presented to the Administrator or other Agency decision-maker for signature.

This is the final opportunity for rule-writers and decision-makers to consider whether potential EJ concerns have been considered and addressed, and to ensure that the rule-writers have properly documented those efforts.

ADP Steps 11 & 12 – Office of Management and Budget (OMB) Review (if "significant" under EO 12866)

If the regulatory action requires OMB review, rule-writers will have to prepare a package for submission to OMB. For more details, see the EPA's *Action Development Process: Guidance for EPA Staff on Developing Quality Actions* (http://intranet.epa.gov/adplibrary).

ADP Steps 13 & 14 – Signature and Publication

The lead program prepares the action for signature by the designated Agency official and subsequent publication in the Federal Register. For more details, see Text Box 16 and the EPA's *Action Development Process: Guidance for EPA Staff on Developing Quality Actions* (http://intranet.epa.gov/adplibrary).

Once signed by the appropriate official, the FR document is transmitted to the Office of the Federal Register for final publication. Rule-writers should ensure that all relevant documentation regarding the consideration of potential EJ concerns during the development of the action is included in the docket for the action.

Text Box 16: OMB Review

During OMB review, an office may alter its conclusion that an action might be of particular interest to or have particular impacts upon minority populations, low-income populations, and/or indigenous populations. Should such a change occur, alter the answer provided to the EJ Question in the ADP TRACKER (illustrated in the section titled "ADP Steps 1 and 2"). The EJ Question in the TRACKER can be altered at any time. Changes to Tier 1 and Tier 2 actions are regularly updated so the public can access EPA's latest thinking about an action.

ADP Step 15 – Soliciting and Accepting Public Comment

This step in the process provides another opportunity for the rule-writers to consider ways to ensure that the public comment process allows for meaningful involvement of minority populations, low-income population, tribes, and indigenous peoples, both in terms of providing a sufficient comment period and in terms of notification, communication or outreach to actively engage affected populations or tribes. This may include holding one or more public meetings or hearings in or near affected populations and tribes. If a public meeting and/or hearing is held, the rule-writers and lead program office should ensure there is sufficient notice about the meeting and/or hearing, and the meeting and/or hearing is scheduled at a time and place convenient to affected populations and tribes, with appropriate translation services, as appropriate. These activities may also be scheduled prior to the public comment period. See Part 3 of this Guide for ideas on how rule-writers can achieve meaningful involvement.

ADP Step 16 – Developing the Final Regulatory action

When preparing for the final stage of the regulatory action, the first step is to evaluate the public comments, which provides another opportunity for rule-writers to consider potential EJ concerns that were identified and discussed in the preamble, as well as an opportunity to consider potential EJ concerns raised in public comments.

In considering comments, rule-writers should evaluate whether the consideration of potential EJ concerns in the analyses performed for the proposed action needs to be refined or revised, and if so, how. If the EPA did not consider potential EJ concerns in their analyses, rule-writers should consider whether the public comments raise issues that may warrant reconsideration.

Rule-writers should then brief decision-makers on the scope of the EJ-related comments received and recommend how to respond to them. Decision-makers will consider the recommendations and will then provide guidance on how to proceed in developing the final action (e.g., this is equivalent to Early Guidance as discussed previously). Decision-maker guidance will also identify which process steps the rule-writers should follow in preparing the final action, which may vary based on the nature and extent of comments or other factors.

As with all significant public comments, rule-writers are expected to consider and respond to all significant public comments on EJ-related topics that are relevant to the proposal and submitted during the applicable comment period. For more details on responding to public comments, see the EPA's *Action Development Process: Guidance for EPA Staff on Developing Quality Actions* (http://intranet.epa.gov/adplibrary). It is also important to update responses to the EJ Question in the ADP TRACKER as needed and appropriate.

In general, rule-writers will be expected to follow the same basic process steps to finalize the action, thereby having additional opportunities to ensure that they satisfy the Agency's commitments to both identify and address potential EJ concerns, and to provide meaningful involvement in the ADP.

Part 3: Achieving Meaningful Involvement

A. What Is Meaningful Involvement?

The EPA defines EJ as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies. Meaningful involvement means that: (1) potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity (i.e., rulemaking) that may affect their environment and/or health; (2) the populations' contributions can influence the EPA's rulemaking decisions; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the EPA will seek out and facilitate the involvement of populations potentially affected by the EPA's rulemaking process.

Executive Order 12898 *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* and other policies[32] direct federal agencies to improve public participation among minority populations, low-income populations, tribes, and indigenous peoples. Consistent with the Agency's definition of EJ and EO 12898, Agency policy directs staff to take proactive steps to provide opportunities for potentially affected populations to participate in decisions that may affect their environment or health.

As EPA rule-writers identify opportunities for public involvement, they should also consider EO 13166 *Improving Access to Services for Persons with Limited English Proficiency*, which addresses the need to give voice to populations who historically may have been excluded from consideration during the decision-making process.

Public involvement works best when rule-writers consult with stakeholders, including minority populations, low-income populations, tribes, and indigenous peoples early and often and when their efforts follow a decision-making process that the potentially impacted populations understand and, to the extent feasible, have had a role in designing. Minority populations, low-income populations, tribes, and indigenous peoples have unique knowledge of their goals, needs and vulnerabilities. Through early public involvement, rule-writers can obtain information on issues affecting these populations and other entities and increase the understanding of such issues in the context of developing the action.

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[32] For example, see *EPA Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples*. (2014), http://www.epa.gov/environmentaljustice/resources/policy/indigenous/ej-indigenous-policy.pdf.

Rule-writers should develop a public involvement plan early in the rulemaking process, optimally as a part of the analytic blueprint stage so that the plan ensures that (1) opportunities for meaningful involvement have been appropriately addressed without delaying the rulemaking process, (2) input is considered early in the process so impacted populations may influence the Agency's decision-making process, where appropriate, and (3) the rule-writers get direction on the appropriate level of outreach and other activities given the nature of the rule, its potential impacts, and available resources.

B. Existing Guidance on Meaningful Public Involvement

The EPA is committed to engaging all stakeholders as it develops and implements Agency actions, but recognizes that special attention is often required in ensuring meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples. There are numerous resources that rule-writers can use to help determine what type and level of public involvement is appropriate for their regulatory actions.[33] See Text Box 17 for an overview of basic steps for effective public involvement. For some regulatory actions, it may be appropriate to reach out to affected populations, while for others it may be appropriate to go further and invite them to the table to develop alternatives for consideration.

Also, statutory and regulatory authorities set minimum standards for public involvement, so it is important to be familiar with the specific requirements for public notice and involvement that are associated with the development of the action. However, relying on the minimum notice and comment requirements is often not enough to achieve meaningful involvement for minority populations, low-income populations, tribes, and indigenous peoples.

Text Box 17: 7 Basic Steps for Effective Public Involvement

1. Plan and budget for public involvement activities;
2. Identify the interested and affected public;
3. Consider providing technical or financial assistance to the public to facilitate involvement;
4. Provide information and outreach to the public;
5. Conduct public consultation and involvement activities;
6. Review and use input and provide feedback to the public; and
7. Evaluate public involvement activities.

Promoting meaningful involvement often requires special efforts to connect with populations that have been historically underrepresented in decision-making and that have a wide range of educational levels, literacy, or proficiency in English. It will likely be necessary to tailor outreach materials to be concise, understandable and readily accessible to the populations that rule-writers are trying to reach.[34]

Involving these populations in a meaningful way presents challenges and opportunities that are different than those presented by a general public involvement effort, such as:

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[33] For example, the International Association for Public Participation has developed materials that discuss the spectrum of public involvement ranging from informing the public to empowering the public. Their publications and public involvement training opportunities can be found at www.IAP2.org.

[34] For more information, see the "*Model Plan for Public Participation*" developed by the National Environmental Justice Advisory Council (http://www.epa.gov/environmentaljustice/resources/publications/nejac/model-public-part-plan.pdf).

- Conveying issues in ways that are tailored (for example, translation, timing, location) to each population;
- Bridging cultural and economic differences that affect participation;
- Using communication techniques that enable more effective interaction with other participants;
- Developing partnerships on a one-to-one or small group basis to ensure representation;
- Developing trust between government and potentially affected populations; and
- Developing stakeholder capacity to effectively participate in future decision-making processes.

In planning public involvement, rule-writers should identify different ways to engage minority populations, low-income populations, tribes, and indigenous peoples meaningfully and effectively. Rule-writers should consider using Web-based information technology (IT) tools, particularly those that are more user-centered, collaborative or interactive (see Text Box 18). However, some populations have only rudimentary access to the most modern communications tools. Remote towns and villages disseminate information using local radio stations, CB radio, local newspapers, placing posters at grocery stores, trading posts, or at village/community center/chapter meetings (see Text Box 2). In many instances, reaching parents of school-age children may be facilitated through schools.

Text Box 18: Web-based IT Tools

Referred to as "web 2.0 tools," these tools generally include tools that:

- Emphasize participation;
- Harness collective intelligence;
- Reach a variety of audiences by facilitating customer self-service;
- Redesign information and services based on the features that customers are using most;
- Provide information that can be accessed by more devices that just a computer (e.g., mobile phone, MP3 player); and
- Develop and deploy applications that can scale quickly to meet the size of the task.

It is important to note the difference between the meaningful involvement of tribes and indigenous peoples as it is used in the EJ context versus formal consultation with tribes.[35] The federal government has a unique government-to-government relationship with federally-recognized tribes, which arises from Indian treaties, statutes, executive orders and the historical relations between the United States and Indian Nations. The federal government has a trust responsibility to federally-recognized tribes, and the EPA, like other federal agencies, must act consistently with the federal trust responsibility when taking actions that affect tribes. Part of this responsibility includes consulting with tribes and considering their interests when taking regulatory actions that may affect tribes or their resources. Tribal consultation is the subject of EO 13175 and the Agency's Tribal Consultation Policy (http://www.epa.gov/tribal/consultation/consult-policy.htm).

Two additional documents finalized in 2013 may be useful resources for rule-writers considering appropriate outreach techniques and approaches: the "Notice of Availability of Regional Actions to Promote Public Participation in the Permitting Process" and "Promising Practices for Permit

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[35] For information on the development of EPA's Tribal Consultation Policy, please contact the office's tribal coordinator or the American Indian Environmental Office. Also see EPA *Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples* (2014). This policy establishes principles and affirms EPA's commitment to provide to federally recognized tribes and indigenous peoples in all areas of the United States and its territories and possessions, the District of Columbia, the Commonwealth of Puerto Rico, and the Commonwealth of the Mariana Islands, and others living in Indian country, fair treatment and meaningful involvement in EPA decisions that may affect their health or environment.

Applicants Seeking EPA-Issued Permits," 78 FR 27,220 (May 9, 2013).[36] While intended for use in permitting actions, these documents identify useful strategies for promoting greater public involvement and improving communication and understanding between facility operators and potentially-affected populations.

C. Assessment of Best Practices and Recommendations

The EPA identified examples of best practices on how to promote meaningful involvement in a September 2012 report entitled *Recommendations for Opportunities for Including Meaningful Environmental Justice Public Involvement in Agency Rulemaking Activities: Achieving Environmental Justice Results in Rules and Rule Implementation*.[37] The document provides recommendations regarding several important factors that rule-writers should consider when developing opportunities for meaningful involvement in the rulemaking process. For example, some of the factors include: careful consideration of cultural implications, linguistics, effective stakeholder outreach techniques, pre-meeting stakeholder capacity building efforts and carefully planned logistical strategies which promote successful meeting participation by minority populations, low-income populations, tribes, and indigenous peoples with the EPA.

Recommendations for rule-writers include:

- Identify and utilize Agency EJ staff and others who are trained in cultural, linguistic and stakeholder outreach techniques.
- Draw on available tools, expertise and resources. For example, investigate whether other EPA offices have developed training modules rule-writers may need or whether they have experts who can provide some of the increased support needed through interoffice technology transfer.
- Provide capacity building for minority populations, low-income populations, tribes, and indigenous peoples to help them participate more effectively in the rulemaking process.
- Work closely with EPA headquarters program and regional office EJ Coordinators and consider contacting the National Environmental Justice Advisory Council (NEJAC) and/or other federal/state agencies that may have relevant and useful lessons learned, best practices or approaches to providing opportunities for meaningful involvement for overburdened populations.

More information is available in the report, which can be accessed at http://intranet.epa.gov/oeca/oej/rulemaking.html#involvement. In addition, the Agency developed 11 case studies of EPA rules that appropriately reflect a range of meaningful involvement opportunities provided to minority populations, low-income populations, tribes, and indigenous peoples and may be instructional for rule-writers that are looking for assistance or ideas on how to meaningfully engage these and other stakeholders in the development of their rule.

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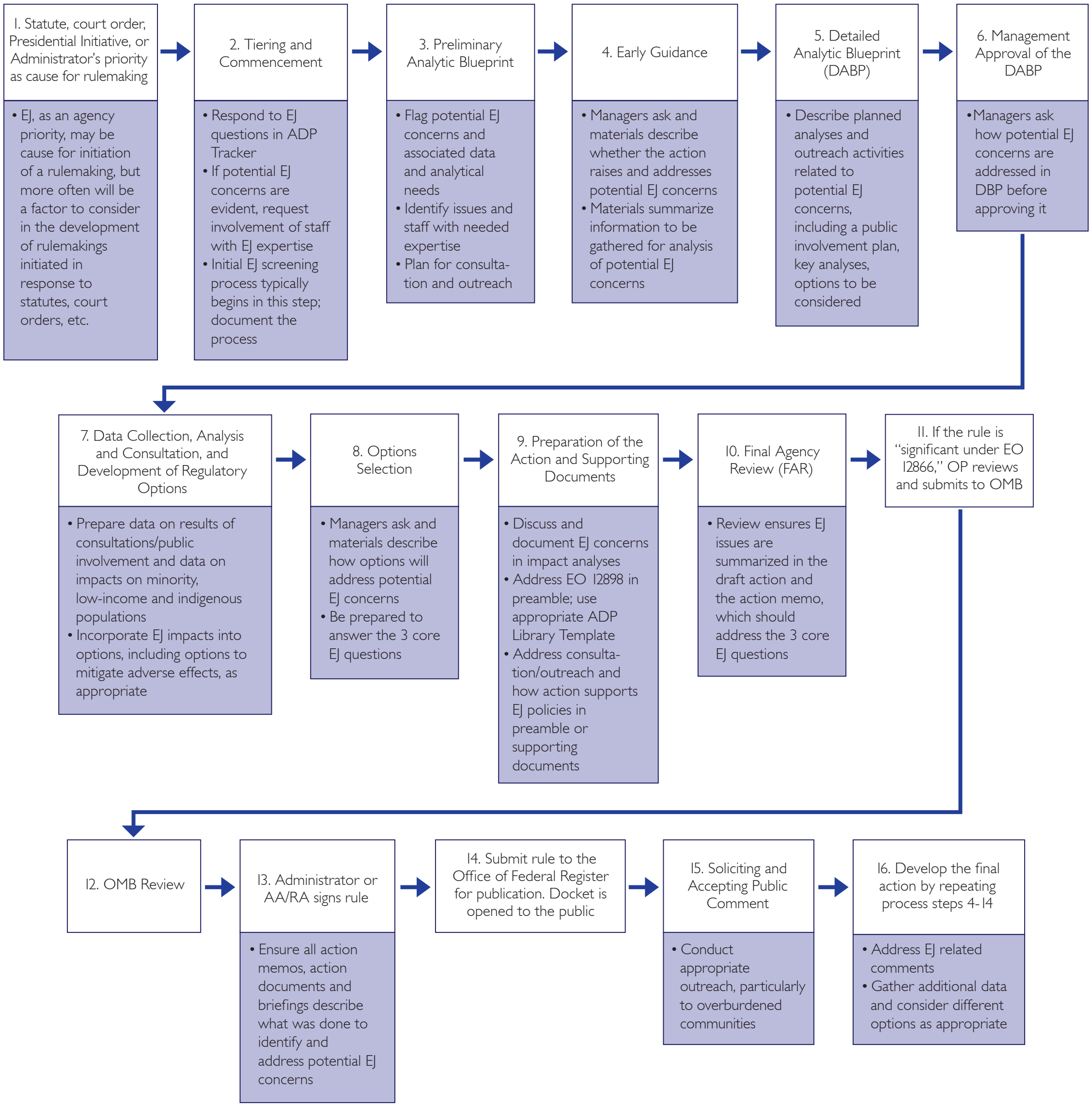
[36] Available at https://www.federalregister.gov/articles/2013/05/09/2013-10945/epa-activities-to-promote-environmental-justice-in-the-permit-application-process.

[37] This report was produced by the Public Involvement (PI) Sub-Team of EPA's Cross Agency Environmental Justice in Rulemaking (EJR) Team. This team was made up of rulemaking experts from each NPM.

Appendix A: Incorporating Environmental Justice into Tier 1 and 2 Actions Under the ADP[38]



1. Statute, court order, Presidential Initiative, or Administrator's priority as cause for rulemaking
   - EJ, as an agency priority, may be cause for initiation of a rulemaking, but more often will be a factor to consider in the development of rulemakings initiated in response to statutes, court orders, etc.

2. Tiering and Commencement
   - Respond to EJ questions in ADP Tracker
   - If potential EJ concerns are evident, request involvement of staff with EJ expertise
   - Initial EJ screening process typically begins in this step; document the process

3. Preliminary Analytic Blueprint
   - Flag potential EJ concerns and associated data and analytical needs
   - Identify issues and staff with needed expertise
   - Plan for consultation and outreach

4. Early Guidance
   - Managers ask and materials describe whether the action raises and addresses potential EJ concerns
   - Materials summarize information to be gathered for analysis of potential EJ concerns

5. Detailed Analytic Blueprint (DABP)
   - Describe planned analyses and outreach activities related to potential EJ concerns, including a public involvement plan, key analyses, options to be considered

6. Management Approval of the DABP
   - Managers ask how potential EJ concerns are addressed in DBP before approving it

7. Data Collection, Analysis and Consultation, and Development of Regulatory Options
   - Prepare data on results of consultations/public involvement and data on impacts on minority, low-income and indigenous populations
   - Incorporate EJ impacts into options, including options to mitigate adverse effects, as appropriate

8. Options Selection
   - Managers ask and materials describe how options will address potential EJ concerns
   - Be prepared to answer the 3 core EJ questions

9. Preparation of the Action and Supporting Documents
   - Discuss and document EJ concerns in impact analyses
   - Address EO 12898 in preamble; use appropriate ADP Library Template
   - Address consultation/outreach and how action supports EJ policies in preamble or supporting documents

10. Final Agency Review (FAR)
    - Review ensures EJ issues are summarized in the draft action and the action memo, which should address the 3 core EJ questions

11. If the rule is "significant under EO 12866," OP reviews and submits to OMB

12. OMB Review

13. Administrator or AA/RA signs rule
    - Ensure all action memos, action documents and briefings describe what was done to identify and address potential EJ concerns

14. Submit rule to the Office of Federal Register for publication. Docket is opened to the public

15. Soliciting and Accepting Public Comment
    - Conduct appropriate outreach, particularly to overburdened communities

16. Develop the final action by repeating process steps 4-14
    - Address EJ related comments
    - Gather additional data and consider different options as appropriate

Note: While some of the ADP steps described above may be relevant only to Tier 1 and 2 actions, tiering level does not preclude the applicability of either EO 13045 or the Children's Health Policy. See *Guide to Considering Children's Health When Developing EPA Actions* (http://www2.epa.gov/children/guide-considering-childrens-health-when-developing-epa-actions-implementing-executive-order) for more information. Additional information may also be obtained from consultation with the Office of Children's Health and Protection (OCHP).

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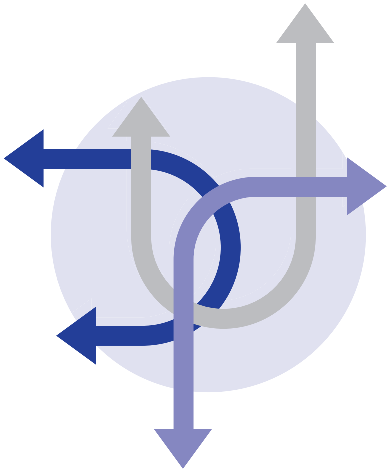
[38] See http://intranet.epa.gov/adplibrary.

Appendix B: A Quick Reference Guide for EPA Decision-Makers: Integrating EJ into the Development of Regulatory Actions Under the ADP

This document is intended to serve as a quick reference for EPA decision-makers by providing a ***brief overview*** of the guidance provided in this Guide. It is not intended to replace the information provided in main body of the Guide and does not, therefore, repeat the details provided there or elsewhere.[39]



What is meant by "environmental justice"?

The EPA defines "environmental justice" as the ***fair treatment*** and ***meaningful involvement*** of all people, particularly minority populations, low-income populations, tribes, and indigenous peoples in the development, implementation and enforcement of environmental laws, regulations and policies.[40]

What is the decision-maker's overall role?

The EPA decision-makers direct workgroup activities related to identifying potential EJ concerns for Agency regulatory actions under development. This direction may be made in the context of a particular action, or can also be made for a category of actions that are similar and have the same general impacts. Decisions-makers communicate expectations to the rule-writers, establish policy priorities, identify issues of significant concern and guide the process of developing the action. As a result, decision-makers play a key role in ensuring that the potential EJ implications of a regulatory action are considered during the development of that action, and that populations affected by the action have an opportunity to participate.

When and how can decision-makers participate?

- **Consider EJ when decisions are made regarding which regulatory actions to pursue**. The decision to initiate regulatory actions is an opportunity to consider whether the actions under consideration involve—or have the potential to involve—potential EJ concerns.

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[39] A refresher on the process steps involved in the ADP is provided in the chart in Appendix A of the Guide.

[40] See Part 1, Section A.

- **Identify the potential for EJ concerns at the beginning**. Potential EJ concerns may arise when a proposed regulatory action would: a) create new, exacerbate existing, or present an opportunity to address existing disproportionate impacts; b) not create sufficient opportunities for meaningful participation in the development of the action; or c) involve an actual or potential lack of fair treatment or meaningful involvement in the implementation or enforcement of the action.
- **Set clear expectations about potential EJ concerns in the Early Guidance provided to the rule-writers.** To start, provide the "three core EJ questions," which the rule-writers will be expected to answer at the end of their effort. Consider also providing guidance on the level of analysis needed to make decisions later, as well as the level of outreach to and involvement of populations affected by the regulatory action. Consider asking for an assessment of resource needs to perform different levels of analyses and/or outreach.
- **Review the analytic blueprint (ABP) to ensure the rule-writers address potential EJ concerns.** The review and approval of the ABP may be the final opportunity to provide direction before resources are committed. In this review, consider whether the ABP includes the following information:
    - The identification of potentially affected populations and related stakeholders, along with a plan for how the rule-writers will ensure outreach and meaningful involvement of these populations, including minority populations, low-income populations, tribes, and indigenous peoples.
    - The identification of analytical needs (scientific and economic), and a plan for ensuring the consideration of EJ in those analyses.
    - An identification of related resources needed to address both the outreach activities and analytical needs, along with whether additional resources are needed to meet expectations.
- **Consider potential EJ concerns related to the options presented.** Different options may involve different potential EJ concerns, or provide different opportunities to address existing disproportionate impacts. The rule-writers should highlight this information for consideration in decisions-making about the options.

What are the "three core EJ questions"?

The Guide suggests that decision-makers ask rule-writers about their efforts to address the following three core EJ questions at key points during the development of regulatory actions under the ADP (such as at Early Guidance, options selection or Final Agency Review):

1. How will (or did) the public participation process provide transparency and meaningful participation for minority populations, low-income populations, tribes, and indigenous peoples?
2. How do the rule-writers plan to (or how did the rule-writers) identify and address existing and new disproportionate environmental and public health impacts on minority populations, low-income populations, and/or indigenous peoples during the rulemaking process?
3. How did the actions taken under #1 and #2 impact the outcome or final decision?

Appendix C: A Checklist for EPA Rule-Writers: Integrating EJ into the Development of Regulations Under the ADP

EPA rule-writers can use this checklist to identify what they may need to know and/or do in order to integrate EJ into the development of their regulatory action. The checklist is based on available guidance, including that provided in this Guide. This checklist is not intended to replace the information provided in main body of the Guide and does not, therefore, repeat the details provided there or elsewhere.

Activity
1. BEFORE THE ADP PROCESS STARTS – Learn the basics about the ADP and EJ.
☐ Are rule-writers familiar with the process steps under the ADP?[41] *If a refresher on the process steps involved in the ADP is needed, please see the charts provided in Appendix A of the Guide.*
☐ Have the rule-writers read the Guide?
☐ Do the rule-writers know what the Executive Order on EJ requires?
☐ What is meant by "environmental justice"?
☐ What is meant by an "EJ concern"?
☐ Do the rule-writers know how it can identify, assess and address potential EJ concerns during the development of the action?
☐ Do the rule-writers know their different roles?
☐ Do the rule-writers know the "three core EJ questions"? (See item #5 on this checklist)
☐ Does the office have any applicable program specific requirements or guidance on EJ?
☐ Are the rule-writers familiar with the *Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (U.S. EPA 2013)?
2. GETTING STARTED – Screen the action.
☐ Have the rule-writers responded to the EJ question in ADP TRACKER?
☐ Have the rule-writers completed an initial screening process to evaluate whether the action has the potential to raise or address potential EJ concerns and documented the analytic basis for the conclusions?

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[41] Agency Guidance on the ADP is available at http://intranet.epa.gov/adplibrary/.

Activity
3. PLANNING – Complete an Analytic Blueprint (ABP) for the action.
☐ Have the rule-writers identified the potentially impacted minority populations, low-income populations, tribes, and/or indigenous peoples and their concerns?[42]
☐ Does the ABP address its plans for achieving meaningful involvement and contain plans for effectively engaging the minority populations, low-income populations, tribes, and indigenous peoples affected by the action?
☐ Have the rule-writers identified the factors that contribute to potential EJ concerns?
☐ Have the rule-writers identified the data needs and data sources for an appropriate EJ assessment, the scope and basic methodology of the EJ assessment and the outputs of the EJ assessment?
☐ Have the rule-writers explored alternative approaches for addressing potential EJ concerns (regulatory, voluntary and/or innovative approaches)?
☐ Have the rule-writers identified the resources needed to achieve meaningful involvement, gather needed data and conduct identified analyses?
☐ Have the rule-writers identified the key activities, analyses, consultation activities (including those called for by relevant statutes and EOs), contributors and timeline?
4. OPTIONS SELECTION – Identify and prepare options for decision-makers.
☐ Is input from affected minority populations, low-income populations and/or indigenous peoples reflected in the analysis of options, both in terms of potential impacts and options to consider?
☐ Have the rule-writers incorporated potential impacts on minority populations, low-income populations, and/or indigenous peoples into the analysis of options? ☐ Have the rule-writers described the ways in which the action can address any existing potentially disproportionate impacts? ☐ If the action has the potential to create new disproportionate impacts, has the rule-writers identified options that will avoid or mitigate those impacts?
☐ Are the rule-writers prepared to address how to answer the three core EJ questions?
5. DOCUMENTATION – Prepare the action and final documents.
☐ Have the rule-writers documented their outreach and consultation efforts, as well as the results of those efforts?
☐ Have the rule-writers used the appropriate ADP Library Template for the preamble discussion of EO 12898?
☐ Do the final economic and scientific analyses clearly present the potential EJ concerns?
☐ Have the rule-writers described in the preamble or supporting documents any identified potential disproportionate impacts and potential EJ concerns and how they are addressed by the action?
☐ Have the rule-writers addressed the "Three Core EJ Questions" in the Action Memo: 1. How did the public participation process provide transparency and meaningful participation for minority populations, low-income populations, tribes, and indigenous peoples? 2. How did the rule-writers identify and address existing and/or new disproportionate environmental and public health impacts on minority populations, low-income populations, and/or indigenous peoples? 3. How did the actions taken under #1 and #2 impact the outcome or final decision?

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[42] In addition to providing meaningful involvement opportunities for indigenous communities and tribes, rule-writers should consider whether it is appropriate to offer tribes the opportunity for government-to-government consultation on the action. For additional information, see EPA's Tribal Consultation Policy.

Appendix D: References/ Resources

Please note that this document is written for EPA employees and contains links to resources on the EPA's intranet website. Those resources are inaccessible from non-EPA computers.

Policy and Guidance Documents

Title and URL	Description
Executive Order 12898: Environmental Justice http://www.epa.gov/environmentaljustice/resources/policy/exec_order_12898.pdf	Text of EO directing agencies to address Environmental Justice in minority populations and low-income populations.
EPA's Definition of Environmental Justice http://www.epa.gov/environmentaljustice/basics/index.html	Environmental Justice and related terms defined for use at EPA.
Memorandum for the Heads of All Departments and Agencies: Executive Order on Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (1994) http://www.epa.gov/environmentaljustice/resources/policy/clinton_memo_12898.pdf	President's cover memorandum for Executive Order 12898.
EPA's Environmental Justice Strategy (1995) http://www.epa.gov/environmentaljustice/resources/policy/ej_strategy_1995.pdf	Strategy developed in response to EO 12898.
Environmental Justice Implementation Plan http://www.epa.gov/environmentaljustice/resources/policy/implementation_plan_ej_1996.pdf	Plan to integrate environmental justice into the Agency's work under Carol Browner (1996).
Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analysis (1998) http://www.epa.gov/environmentaljustice/resources/policy/ej_guidance_nepa_epa0498.pdf	Guidance for incorporating environmental justice goals into the EPA's preparation of environmental impact statements (EISs) and environmental assessments (EAs) under NEPA.
Environmental Justice: Guidance under the National Environmental Policy Act (1997) http://www.epa.gov/environmentaljustice/resources/policy/ej_guidance_nepa_ceq1297.pdf	Original guidance provided by CEQ.
Toolkit for Assessing Potential Allegations of Environmental Justice (2004) http://www.epa.gov/environmentaljustice/resources/policy/ej-toolkit.pdf	Reference guide to assist Agency personnel in assessing potential allegations of environmental injustice and to provide a framework for understanding national policy on environmental justice.
Strengthening EPA's Environmental Justice Program (June 9, 2008) http://www.epa.gov/environmentaljustice/resources/policy/admin-ej-strength-memo-060908.pdf	Administrator Johnson directs the EPA to conduct EJ reviews of its program, policies and activities.

Title and URL	Description
Reaffirming the U.S. EPA's Commitment to Environmental Justice – Memo from Stephen L. Johnson (November 4, 2005) http://www.epa.gov/environmentaljustice/resources/policy/admin-ej-commit-letter-110305.pdf	Administrator Johnson outlines the Agency's commitment to Environmental Justice and its integration into all programs, policies, and activities.
Plan EJ 2014 http://www.epa.gov/environmentaljustice/plan-ej/index.html	Roadmap for how EPA will integrate EJ into the Agency's programs, policies, and activities.
EJ Legal Tools http://www.epa.gov/environmentaljustice/plan-ej/law.html	Identifies existing legal tools to help EPA advance the goal of EJ and provides an overview of a number of discretionary legal authorities that are or may be available to EPA under federal statutes and programs.
Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis (U.S. EPA 2013) http://www.epa.gov/environmentaljustice/plan-ej/rulemaking.html	Helps analysts assess potential EJ concerns associated with EPA rules.
Plan EJ 2014: EJ in Permitting http://www.epa.gov/environmentaljustice/plan-ej/permitting.html	The EJ in Permitting Initiative seeks to enable overburdened communities to have full and meaningful access to the permitting process and to develop permits that address environmental justice issues to the greatest extent practicable under existing environmental laws.
EPA Policy on Environmental Justice for Tribes and Indigenous Peoples http://www.epa.gov/environmentaljustice/resources/policy/indigenous/ej-indigenous-policy.pdf	Clarifies and integrates environmental justice principles in a consistent manner in the Agency's work with federally recognized tribes and indigenous peoples throughout the United States, and with others living in Indian country to protect their environment and public health.
American Journal of Public Health Supplement "Environmental Justice and Disparities in Health" http://ajph.aphapublications.org/toc/ajph/101/S1	Useful resource for gaining a more complete understanding of how disproportionate impact factors can influence health outcomes.
EPA's Policy of Evaluating Health Risks to Children http://yosemite.epa.gov/ochp/ochpweb.nsf/content/riskpolicy.htm/$File/riskpolicy.pdf	Policy applied to assessments started or revised on or after November 1, 1995.
Executive Order 13175: Consultation and Coordination with Indian Tribal Governments http://www.epa.gov/tp/pdf/eo-13175.pdf	EO directing Federal agencies to establish regular and meaningful consultation and collaboration with tribal officials in the development of Federal policies that have tribal implications.
EPA's Public Involvement Policy http://www.epa.gov/publicinvolvement/pdf/policy2003.pdf	Complete Agency policy with four appendices and two addenda.
Public Involvement http://www.epa.gov/publicinvolvement	Information on the full range of activities that EPA uses to engage the American people in the Agency's decision-making.
International Association for Public Participation www.IAP2.org	Provides discussion on the spectrum of public involvement; identifies useful publications and training opportunities.
Web 2.0 http://www2.epa.gov/webguide/epa-and-web-20-technologies-2007-memo	Provides information about the EPA's social media use and necessary steps for setting up Web 2.0 applications such as wikis and blogs.

Other Useful Resources

Title and URL	Description
Environmental Justice Coordinators – Media Offices http://epa.gov/environmentaljustice/contact/ej-contacts-media.html	List of contacts with name, phone, location, and areas of expertise identified.
Environmental Justice Coordinators – Regional Offices http://epa.gov/environmentaljustice/contact/ej-contacts-regional.html	List of contacts with name, phone, and address identified.
Action Development Process http://intranet.epa.gov/adplibrary/adp/index.htm	Information about each particular aspect of EPA's ADP.
Action Development Process: Guidance for EPA Staff on Developing Quality Actions http://intranet.epa.gov/adplibrary/documents/adp03-00-11.pdf	Lays out the ADP and where to get additional information and guidance as Agency actions are developed.
Action Development Checklist See Appendix C of this Guidance on Considering Environmental Justice During the Development of an Action	Illustrative list to help rule-writers determine whether the action being developed may involve a subject of particular interest to—or may have particular impacts on—vulnerable populations.
Environmental Justice Regulatory Preamble Templates http://intranet.epa.gov/adplibrary/adp-templates/index.htm#stat	Suggested language for addressing EO 12898 in preambles for proposed and final rules.
Action Development Guidelines for Preparing Analytic Blueprints http://intranet.epa.gov/adplibrary/documents/abp09-30-04.pdf	Discusses the timing and steps for the drafting and approval of Analytic Blueprints (applicable to all Tiers 1 and 2 actions); directs reader to resources for more information and guidance.
RegDaRRT http://yosemite.epa.gov/opei/RuleGate.nsf/	Offers the public a means of learning about and tracking EPA actions.
Cross-Agency EJ in Rulemaking Team's Resources for Incorporating EJ in Agency Rules http://intranet.epa.gov/oeca/oej/rulemaking.html	Resources identify opportunities for the Agency to advance the integration of EJ in rules.

Appendix E: Examples of Regulatory Responses That Directly or Indirectly Address Potential EJ Concerns

Significant progress in making EJ a part of the Agency's rulemaking process has already been made, as evidenced by the following examples:

- **Definition of Solid Waste 2015 (DSW)**: On January 13, 2015, EPA published the final revisions to the Definition of Solid Waste Rule, also known as the DSW rule. It represents a major environmental justice milestone by directly addressing impacts to communities, disproportionately borne by minority and low-income populations from the mismanagement of hazardous materials sent to recycling. EPA conducted a rigorous environmental justice analysis that examined the location of recycling facilities and their proximity and potential impact to adjacent residents. The methodology and scope was developed through a broad public engagement and expert peer review process. The analysis identified significant regulatory gaps in the previous DSW rule which could negatively impact communities adjacent to third party recyclers, including minority and low-income populations.

  EPA identified mismanagement that could pose a risk of fires, explosions, accidents and releases of hazardous constituents to the environment. The economics of commercial recycling contain market disincentives that encourage over-accumulation and mismanagement of hazardous secondary material. The 2008 DSW rule lacked the tools needed for proper oversight of these facilities by EPA, states and the communities affected by them. The final rule addresses the market disincentives in a way that helps encourage safe and legitimate recycling while addressing the need to protect communities. The final rule also includes a public participation component so that communities are notified prior to recycling operations beginning and have a chance to weigh in on the environmental decisions that affect them, which was a major issue identified in the environmental justice analysis.

- **Mercury and Air Toxics Standard (MATS)**: In December 2011, EPA finalized the first federal standards that require power plants to limit their emissions of toxic air pollutants like mercury, arsenic and metals. The Mercury and Air Toxics Standard (MATS) was supported by EPA's study of the public health hazards from power plant emissions as required by the Clean Air Act. EPA used data on subsistence fishing and potential health impacts of mercury deposition on the minority, low-income and indigenous populations engaged in subsistence fishing to arrive at an "appropriate and necessary" finding that moved the rulemaking forward. In addition, EPA held a series of webinars, community calls, and consultations with tribal leadership on this rule. Most plants will come into compliance in April 2015, with full implementation by April 2016. EPA projects that mercury emissions from sources covered by MATS are expected to be reduced from 27 tons without MATS in 2016 to 7 tons in 2016 with MATS, approximately a 74 percent reduction. Overall, the MATS rule will improve public health by lowering mercury exposure, especially for children and the elderly and for low-income, minority and indigenous populations that rely on subsistence fishing.

- **National Ambient Air Quality Standards for Particulate Matter**: In December 2012, EPA strengthened the annual health National Ambient Air Quality Standard (NAAQS) for fine particulate matter (PM). Under Section 109 of the Clean Air Act, EPA set the primary standard to protect public health with an adequate margin of safety, considering "sensitive or susceptible individuals or groups." People most at risk from PM exposure include people with heart or lung disease (including asthma), older adults, children and people of lower socioeconomic status. In writing the PM NAAQS Implementation Rule, EPA engaged with communities to help identify areas to provide guidance to states on targeting activities that address the impact on low-income communities. EPA met with the National Environmental Justice Advisory Committee (NEJAC) and had a training in North Carolina on this issue. The proposal for the Implementation Rule was put forth in March 2015 and will provide suggestions to the states on targeting emissions reductions in environmental justice communities as well as suggestions on how to engage communities in the development of the PM State Implementation Plans.

- **Petroleum Refinery Residual Risk and Technology Review**: In June 2014, EPA proposed the Petroleum Refinery Residual Risk and Technology Review (RTR) rule to achieve further controls on toxic air emissions from petroleum refineries. Early engagement with communities indicated a particular interest in fence-line monitoring, which was supported by EPA's emissions inventory data indicating a significant portion of emissions from refineries come from fugitive sources. Based on this community input and the risk and technology review analyses, EPA proposed requirements for:

    - Additional emission control requirements for storage tanks, flares and coking units;
    - Higher combustion efficiency for flaring operations; and
    - Monitoring of air concentrations at the fence-line of refinery facilities.

  After the proposal was released, EPA held community calls and webinars and conducted trainings in New Orleans, Louisiana, and in Oakland, California. As a result, a significant number of communities provided more substantive comments for consideration during the development of the final rule. Additionally, in the summer of 2014 the Agency held two public hearings on this rulemaking (one in Wilmington, California and one in Houston, Texas). The comment period for this rulemaking closed on October 28, 2014 and EPA is under a consent decree with environmental litigants to finalize this rule by June 16, 2015. EPA received 100,000 comments on this rulemaking. EPA is currently reviewing the comments received and will be considering all comments as we move forward with the final rulemaking.

- **Revisions to Agricultural Worker Protection Standards**: On March 19, 2014, EPA published a proposed rule to revise the current Worker Protection Standard (WPS), designed to protect workers on agricultural establishments from occupational exposure to pesticides. EPA recognizes that individuals working with pesticides, or contacting crop products on which pesticides have been used, are at greater risk of exposure. The estimated two million farmworkers are potentially exposed to pesticide residues, both during applications as well as when they re-enter treated areas for hand labor activities. The core concepts of EJ have been part the fundamental basis of the rule since its inception. EPA sought and received extensive input from the farmworker community over many years to help the Agency formulate the best set of improved protections in the proposed rule. Improvements where EJ consideration made a difference include training and notifications to workers, requirements to support the enforcement of required protections, and enhancements to decontamination supplies and emergency assistance requirements.

- **Implementation of Lead Renovation Repair and Painting Program**: In April 2008, EPA issued its final Lead Renovation, Repair, and Painting Program (RRP) rule that addressed lead-based paint hazards created by renovation, repair, and painting activities in target housing and child-occupied facilities. Recognizing that children in minority populations and children whose families are poor have an increased risk of exposure to harmful lead levels, EPA determined that effective implementation was one of the best ways to ensure that these populations are not exposed to additional leaded dust resulting from common, but improperly-performed, home renovation, repair, and painting work. EPA's Dust Study supported this approach because it demonstrated that renovation activities result in dust lead levels that can be orders of magnitude above the hazard standard and higher than the levels achievable if the RRP requirements were followed. EPA concluded that fully implementing the regulations can be a successful tool in addressing elevated blood lead levels in children. Implementation of the RRP rule is expected to minimize exposure to lead-based paint hazards and protect children and others. Because minority and low-income children are already at higher risk of lead poisoning, we expect that this activity will have specific benefits to populations with EJ concerns.

- **Unregulated Contaminant Monitoring Regulation (UCMR 3) for Public Water Systems Final Rule**: EPA uses the Unregulated Contaminant Monitoring program to collect data for contaminants suspected to be present in drinking water, but that do not have health-based standards or treatment technique regulations established under the Safe Drinking Water Act. After conducting an EJ analysis of the rule, EPA updated it to require that all public water systems report U.S. Postal Service zip codes in their service area. This additional data will enable EPA to identify areas that may have disproportionately high and adverse human health or environmental impacts on minority or low-income population water supplies.

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Notes

Notes

Guidance on Considering Environmental Justice During the
Development of Regulatory Actions

EPA's ACTION DEVELOPMENT PROCESS

Guidance on Executive Order 13132: Federalism

November 2008

The statements in this document are intended solely as guidance. This document is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation with the United States. This guidance may be revised without public notice to reflect changes in EPA's approach to implementing Executive Order 13132, Federalism, or to clarify and update text.

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List of Acronyms or Abbreviations in this Guidance

Big 10	The ten largest national representative organizations for State and local governments, including those commonly called the "Big 7," plus two other organizations with whom OMB has asked agencies to consult. EPA also includes the Environmental Council of the States (ECOS) in this list, although consultation with this organization alone does not constitute compliance with the EO since it is not comprised of elected officials. The organizations and their contacts are listed in Attachment C.
EO	Executive Order. When used alone, it refers to EO 13132.
FI	Federalism implications. Under EO 13132, these are "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."
OCIR	EPA Office of Congressional and Intergovernmental Relations
OGC	EPA Office of General Counsel
OMB	Office of Management and Budget
OPEI	EPA Office of Policy, Economics and Innovation
ORC	EPA Office of Regional Counsel
Order	Executive Order 13132
RNOs	Representative National Organizations
SLEOs	State and Local Elected Representatives
S/L	State and local

How this Guidance Applies to You

This guidance is for EPA managers and staff who are planning or developing actions such as regulations, policies, legislative proposals, adjudications, and waivers. It summarizes the provisions of Executive Order 13132, "Federalism."

The guidance also provides the parameters of EPA's policy on consulting with State and local governments under this Executive Order. For some actions, including those which may not have federalism implications (FI), EPA policy is broader than the Executive Order, reflecting EPA's commitment to early and meaningful intergovernmental consultation.

Even if you believe your action will have either no effects or minimal effects on State and local governments, you still need to read further. A short introduction to the Executive Order follows. Then, a table directs you to the part of the guidance that applies to your action.

Introduction to Executive Order 13132

President Clinton issued Executive Order 13132, “Federalism,” on August 4, 1999[1]. It became effective on November 2, 1999. The Executive Order ("EO" or "Order") stresses consultation with State and local ("S/L") governments and more sensitivity to their concerns. It also sets up a specific process for agencies to follow as they develop and implement actions that affect S/L governments. EO 13132 revokes Executive Order 12875, "Enhancing the Intergovernmental Partnership," and all previous Executive Orders on Federalism. The full text of the Order is attached at the end of this guidance.

What is "Federalism?"

> “Federalism is rooted in the belief that issues that are not national in scope or significance are most appropriately addressed by the level of government closest to the people." [Sec.2.(a)]. The EO lists nine principles that convey the "spirit" of the Order. These principles guide agencies in formulating and implementing **"policies that have federalism implications" (FI).**

What actions are subject to the Order?

EO 13132 generally applies to policies that have FI, which refers to regulations, legislative comments or proposed legislation, and other policy statements that have "substantial direct effects" on:

(1) the States (the definition of "States" includes local governments);[2]
(2) the relationship between the national government and the States; or
(3) the distribution of power and responsibilities among the various levels of government.

The EO also applies to adjudications that preempt S/L law. An adjudication is the Agency’s process for formulating an order. An order is final agency action that is not a rulemaking, such as a permit, administrative order, license, registration, or determination of applicability.

What should I do if my action is subject to the Order?

What you should do depends on the type of action you have. In general, EO 13132 puts a strong emphasis on consulting with S/L officials, which are defined as **"elected officials or their representative national organizations."** Of course, you should continue to work with your professional S/L government counterparts, but consulting them alone will

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[1] 64 FR 43255 (August 10, 1999).

[2] The definition of States does not include Tribal governments. Tribal governments are addressed by EO 13175.

not satisfy the requirements of EO 13132.

OMB has specifically designated nine national organizations as being representative of S/L officials for purposes of complying with the consultation requirements of the Order. It is EPA's policy that you also consult with a tenth organization – the Environmental Council of the States (ECOS) – if your action triggers the Order's requirements. However, consultation with ECOS alone does not constitute compliance with the EO since it is not comprised of elected officials. The Big 10 organizations offer the largest constituencies of elected and senior appointed officials in State and local government[3]. Attachment C includes addresses and websites for the Big 10 organizations.

The following table tells you where to continue reading, based on the type of action you have:

If your action is a	**Then go here for more information about whether the Order applies and what to do...**	
Regulation (or "rule")	Part 1	(page 7)
Legislative comments or proposed legislation	Part 2	(page 26)
Policy statement, guidance document, interpretive rule, or similar action	Part 3	(page 26)
Adjudication that preempts S/L law (such as a permit, registration, license, determination of applicability, etc.)	Part 4	(page 28)
S/L government request to waive some or all of the statutory or regulatory requirements that apply to it.	Part 5	(page 31)

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[3] The Big 10 include the National Governors' Association, National Conference of State Legislatures, U.S. Conference of Mayors, National League of Cities, Council of State Governments, International City/County Management Association, and National Association of Counties, plus the National Association of Towns and Townships, County Executives of America, and the Environmental Council of the States.

Part 1 - Regulations (or "Rules")

1.1 How will I know if my rule is subject to the Order?

EO 13132 applies to rules with Federalism implications. As noted previously, this means a rule that has substantial direct effects on:

(1) the States (the definition of "States" includes local governments);
(2) the relationship between the national government and the States; or
(3) the distribution of power and responsibilities among the various levels of government.

Part 1.2 of this guidance, below, will help you identify several thresholds for determining whether your rule has FI (that is, *substantial direct effects*...). Later, part 1.5 of the guidance shows the steps in EPA's regulatory process where you determine FI. But, in short, work closely with your program office's Regulatory Steering Committee Representative or your Region's Regulatory Contact, and the attorney assigned to your rule from the Office of General Counsel (OGC). Or, if you are in a Region, work with your Regional Regulatory Contact and the attorney assigned to your rule by the Office of Regional Counsel (ORC). As you develop the rule and make preliminary regulatory decisions, continue to work with these contacts to review and revise, if necessary, your Federalism determination. If you determine your rule has FI, you should inform OCIR and Regulatory Steering Committee Representatives.[4]

1.2 What are the thresholds for determining if my rule has FI?

In most cases, EPA rules would have FI because they:

- impose substantial compliance costs, unless they are expressly required by statute or there are federal funds available to cover the S/L compliance costs; and

- preempt S/L law.

Even if your rule is not one of these two types, you still may determine that it meets the definition for FI. That is, the rule has "substantial direct effects" on S/L governments, even though these effects are unrelated to compliance costs or preemption.

OGC has created helpful flowcharts summarizing the EO's thresholds and requirements. These flowcharts are in Attachment B of this guidance.

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[4] To see the list of Regulatory Steering Committee Representatives or Regional Regulatory Contacts, go to "Intranet.epa.gov/adplibrary" and click on "Reg Steering Committee."

The threshold for each type of FI follows in paragraphs A, B, and C.

A. Substantial compliance costs

As described below, there are two ways an EPA rule can be deemed to have FI due to substantial compliance costs.

1. Annual State/local expenditures of $25 million or more

If your rule contains a federal intergovernmental mandate– i.e., it is likely to result in the expenditure by State and/or local, governments in the aggregate of $25 million or more in any one year -- **then EPA may conclude the rule has FI, unless:**

- the rule is expressly required by statute without the use of any discretion by EPA, or
- federal funds are available to cover the S/L governments' compliance costs for the rule.

The term, "required by statute," is a narrow test; such rules are very rare. We interpret this to mean "specifically and explicitly compelled by statute without the use of any discretion by EPA." While our rules are authorized by statute, most provide the Administrator with some discretion regarding content.

2. Impact on small governments

If the impact of your rule on small governments is likely to equal or exceed 1% of their annual revenues, then as a policy matter, **EPA may conclude the rule also has FI, unless:**

- the rule is expressly required by statute without the use of any discretion by EPA; or,
- federal funds are available to cover the S/L governments' compliance costs for the rule.

EPA's National Center for Environmental Economics has developed technical guidance for economists on how to conduct the 1% test. See Attachment A.

B. Preemption of S/L law

Generally, preemption is the doctrine that holds that certain matters are of such a national character that federal laws take precedence over S/L laws. When preemption occurs, an S/L government may not pass a law that is inconsistent with the federal law. There are three types of preemption:

- **Express preemption:** occurs when Congress' intent to preempt S/L law is stated expressly in the Federal statute.

- **Field preemption:** occurs when Congress' creation of a pervasive system of Federal regulation makes reasonable the inference that Congress left no room for S/L governments to supplement it, or where an act of Congress touches a field in which the Federal interest is so dominant that the federal system is assumed to preclude enforcement of S/L laws on the same subject.

- **Conflict preemption:** occurs when Federal and S/L law are in direct conflict or where S/L law stands as an obstacle to the achievement of Federal objectives.

In general, minor amendments to an existing preemptive program probably will not have FI. On the other hand, a significant new preemptive program may create FI.

Consult with your OGC workgroup representative and your Regulatory Steering Committee Representative or Regional Regulatory Contact to determine whether your rule preempts S/L law and has FI.

C. General FI (not addressed in A. or B. above)

We expect that the vast majority of rules determined to have FI will be rules that either have substantial compliance costs or that preempt S/L law. However, as stated earlier, there may be some rules that do not meet either of these thresholds yet you still determine have FI. This determination requires a judgment call.

As with preemptive rules in general, minor amendments to an existing program probably will not have Federalism implications. On the other hand, a significant new program may have Federalism implications. Consult with the attorney assigned to your rule and your Regulatory Steering Committee Representative or Regional Regulatory Contact (RRC).

1.3 What do I do if my rule has FI ?

A. All rules with FI

If you determine that your rule has FI under any of the three thresholds that are summarized above in part 1.2, then the following general policymaking criteria apply to your rule:

- With respect to Federal statutes and regulations administered by the States, grant the States the maximum administrative discretion possible;

- Encourage States to develop their own policies to achieve program objectives and to work with appropriate officials in other States;

- Where possible, defer to the States to establish standards;

- In determining whether to establish uniform national standards, consult with appropriate S/L elected officials or their representative national organizations as to the need for national standards and any alternatives that would limit the scope of national standards or otherwise preserve State prerogatives and authority; and

- Where national standards are required by Federal statutes, consult with appropriate S/L elected officials or their representative national organizations, prior to proposal, in developing those standards.

- If you are limiting the policy discretion of S/L governments in formulating or implementing the policy, then:

    - ▪ Carefully assess the necessity for such action. To the extent practicable, consult with S/L elected officials or their representative national organizations before implementing such action;

    - Only take the action if there is constitutional and statutory authority for the action and the national activity is appropriate in light of the presence of a problem of national significance; and

    - If you are uncertain as to whether national action is authorized or appropriate, consult with S/L elected officials or their representative national organizations to determine whether Federal objectives can be attained by other means.

Finally, if your rule has substantial compliance costs or preemption, go to the next paragraph (1.3 B). If your rule doesn't have substantial compliance costs or preemption, then under EPA policy you should consult to the extent practicable with either elected officials or other representatives of S/L governments (such as your professional counterparts). At a minimum, you should consult with the Big 10.
The Big 10 offers the largest constituencies of elected and senior appointed officials in S/L government and are considered "representative national organizations" for purposes of the EO 13132. (The exception is ECOS, which is not comprised of elected officials.) As with all rules, discuss Federalism in your preamble.

B. Rules with FI and substantial compliance costs or preemption

The following are additional requirements that apply if your rule has FI because of substantial compliance costs not expressly required by statute or covered by federal funds, or if your rule preempts S/L law and has FI[5]. For any such rule, the EO, Administration policy, and EPA policy direct you as follows:

- Consult with S/L elected officials or their Big 10 representative organizations

- Your consultation should be "meaningful and timely." Generally, we interpret "meaningful and timely" to mean that consultation should begin as early as possible and continue as you develop the proposed rule. This helps to ensure that S/L elected officials or their representative national organizations are given an opportunity to consider and comment on your proposed approach for the issues that are of concern to them. That is why it is important to identify, as soon as possible, any Federalism effects your action may have. If EPA substantially changes its selected approach on these issues after the proposed rule's comment period, you should let those you consulted know about the change and why you made it, as appropriate.

- In a separately identified portion of the preamble to the regulation, provide a "Federalism Summary Impact Statement", which consists of: (1) a description of the extent of the Agency's prior consultation with S/L elected officials or their representative national organizations, (2) a summary of the nature of their concerns and the Agency's position supporting the need to issue the regulation, and (3) a statement of the extent to which the concerns of S/L elected officials or their representative national organizations have been addressed.

- If your draft final rule is subject to OMB review under EO 12866, you must include in the package you send to OMB a **Federalism Certification Form** signed by EPA’s **Designated Federalism Official** (the AA for the Office of Policy, Economics and Innovation) that EPA has met the requirements of the Order in a meaningful and timely manner in promulgating the rule.

Process for Federalism certification: For Tier 1 & 2 rules, OPEI's Regulatory Management Division (RMD) will generate the Federalism Certification Form in preparation for the Final Agency Review meeting and coordinate signature by the Designated Federalism Official. For Tier 3 rules, the Regulatory Steering Committee Representative or Regional Regulatory Contact will send the rule and an unsigned certification form to RMD when the rule is ready for certification and submission to OMB.

When submitting a draft final regulation to OMB for review, you must provide a copy of any formal policy-related correspondence from S/L elected officials or their representative national organizations, and must, upon request, make available a copy of any other written communications submitted to the agency by

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[5] Preemption may cause the FI, or be in addition to any FI the rule otherwise has.

S/L elected officials or their representative national organizations.

The table in part 1.5 of this guidance shows where each of these requirements fits within EPA's process for developing regulations.

1.4 What do I do if my rule does *not* have FI?

The answer to this question depends on whether your rule has any adverse impacts on S/L governments that are above a minimal level.

A. No FI, but your rule has more than minimal adverse impacts on S/L governments

Even if your rule does not have FI, if it has any adverse impact on S/L governments above a minimal level, then you are subject to EPA’s consultation requirements. In the spirit of EO 13132, it is EPA’s policy to promote communications between EPA and S/L governments and solicit input from S/L government representatives when developing a regulation that will have any adverse impact above a minimal level on S/L governments. This internal policy is broader than EO 13132. It is EPA policy that, at a minimum, you:

- consult early, to the extent practicable given the nature and the timing of the action, with appropriate S/L government representatives. These can be elected officials, their representative national organizations, or your professional counterparts; and,

- discuss briefly in the preamble to your rule why the Order did not apply, any consultation that occurred, the nature of S/L government concerns, and how you addressed those concerns or why EPA decided not to implement the changes suggested.

B. No FI, and your rule does not have more than minimal adverse impacts on S/L governments

There are no special requirements or policies that apply to your rule, other than to discuss briefly in the preamble to your rule why the Order did *not* apply. Also, follow the steps that part 1.5 below identifies as applying to all rules.

1.5 What steps do I need to follow for my rule?

EPA's existing rulemaking process will serve as the vehicle for identifying Federalism impacts and complying with the Order.[6]

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[6] If you're not familiar with EPA's rulemaking process, you can refer to the 2008 Action Development Process Guidance. The 2008 guidance is posted on the Intranet at "intranet.epa.gov/adplibrary". Click on "Action Development Process." Alternatively, you can call your Regulatory Steering Committee Representative, Regional Regulatory Contact, or OPEI's Regulatory Management Division, 202-564-5480, for information.

The table that follows (pages 12-18) shows you where in EPA's regulatory process you comply with the Order's requirements and EPA policy. The table includes all the requirements discussed up to this point in this guidance.

Table for Rules: What To Do for Federalism at each Step in EPA's Regulatory Process

How to use this table

Λ After you determine whether your rule has FI, it will fall into one of the five categories below. Pick the category that fits your rule. Look for that category, or the word "all," in the table on the next page to see the Federalism procedures that apply to your rule at each step of EPA's regulatory process.

Category	Description	Where it was discussed in guidance
A	**Federalism implications/cost impacts.** Rule has FI because it is likely to result in expenditures by State and/or local governments, in the aggregate, of $25 million or more in any one year, or it might impact small governments (populations of 50,000 or less) at 1% or more of their revenues and the rule is not specifically and explicitly compelled by statute without the use of any discretion by EPA and federal funds are not available to cover the S/L governments' compliance costs for the rule.	Part 1.2A (Thresholds) Part 1.3A & B (Requirements)
B	**Federalism implications/preemption**. Rule has FI either because of, or in addition to, the rule's preemption of S/L law.	Part 1.2B (Thresholds) Part 1.3A & B (Requirements)
C	**Federalism implications/general.** Rule has FI because it meets the general definition of FI in the Order, but not because of cost impacts with preemption.	Part 1.2C (Thresholds) Part 1.3A (Requirements)
D	**No Federalism implications/more than minimal impacts.** Rule doesn't have FI, but has some adverse impact above the minimal level on S/L governments.	Part 1.4A
E	**No Federalism implications/only minimal impacts.** Rule doesn't have FI, and has no adverse impacts that are above a minimal level on S/L governments.	Part 1.4B

Important abbreviations in this Table

DFO = EPA's Designated Federalism Official (the AA for the Office of Policy, Economics and Innovation)

SLEO/RNOs = "State and local [elected] officials," which the Order defines and limits to **state and local government elected officials** *or* their **representative national organizations.** For purposes of this EO, representative national organizations refers to the Big 10. Attachment C of this guidance includes a contact list.

SLG Reps = State and local government representatives. We are using this term to refer to non-elected representatives of State and local governments, such as our professional counterparts.

Regulatory Development Step...	**Category to which it applies.....**	**Prior to proposal, the following Federalism activities apply.**	**If you have a Final Rule, the following Federalism activities apply.**
Tiering	All	This first step of the rulemaking process begins with filling out an "Action Information Form" (also called the "Tiering Form"). The form will prompt you to identify if your rule will have **any** adverse effect on S/L governments, including preempting S/L law to any degree. Fill out the form as well as you can at this early stage.	N/A
Workgroup convenes to develop proposal (This applies to any workgroup, whether it's a formal Tier 1 or 2 workgroup or an informal Tier 3 workgroup).	All	Consult with your program's Regulatory Steering Committee Representative *and* the attorney assigned to your rule, and OCIR about Federalism. As the workgroup plans and develops the rule, begin to determine whether the Order applies to your rule and advise OGC/ORC about **any** adverse effects you think the rule may have on S/L governments. Inform OCIR and your Regulatory Steering Committee Representative as soon as possible if you determine your rule has FI.	N/A

Regulatory Development Step...	**Category to which it applies.....**	**Prior to proposal, the following Federalism activities apply.**	**If you have a Final Rule, the following Federalism activities apply.**
Analytic Blueprint if your rule is Tier 1 or 2, or your office develops a Blueprint -- OR -- **"State/local Consultation Plan"** if your rule is Tier 3 and your office doesn't use a Blueprint.	A, B, C	Write down how you will consult with SLEO/RNOs. Put this in your Analytic Blueprint or in a document titled "State/local Consultation Plan." Part 1.7 has guidance on consultation. **Complete the Blueprint or State/local Consultation Plan as soon as possible after Tiering the action.** This advance planning is critical to allocate resources for your rule and to develop a realistic timeline for completing it. Begin consulting as soon as possible.	N/A
	D, E	If your rule has an Analytic Blueprint, you are encouraged to address S/L government consultation. You don't have to develop an ABP for Tier 3 rules, but a "State/local Consultation Plan" is encouraged.	N/A
Consultation	A, B	Review the Federalism policymaking criteria in part 1.3A of this guidance. Consult with SLEO/RNOs. At a minimum it is the Administration's policy to consult with the nine national organizations and ECOS, often referred to as the Big 10. The Big 10 offers the largest constituencies of elected and senior appointed S/L government officials and are considered "representative national organizations" for purposes of the Federalism EO. See Attachment C of this guidance for the list of contact persons. Your consultation should be "meaningful and timely." Generally, we interpret "meaningful and timely" to mean that consultation should begin as early as possible and continue as you develop the proposed rule to ensure S/L elected officials or their representative national organizations are given an opportunity to consider and comment on our proposed approach for the issues that are of concern to them. That is why it is important to identify, as soon as possible, any Federalism effects your action may have. If EPA substantially changes its selected approach on these issues after the proposed rule's comment period, you should let those you consulted know about the change and why we made it, as appropriate.	

Regulatory Development Step...	**Category to which it applies.....**	**Prior to proposal, the following Federalism activities apply.**	**If you have a Final Rule, the following Federalism activities apply.**
	C	Review the Federalism policymaking criteria in part 1.3A of this guidance. Consult to the extent practicable with SLEO/RNOs or SLG reps [EPA policy]. At a minimum, you should consult with the Big 10. See Attachment C of this guidance for the list of contacts.	
	D	**Consult** early, to the extent practicable given the nature and the timing of the action, with appropriate SLG reps. These can be elected officials, their representative national organizations, *or* your professional counterparts.	
	E	This step does not apply to your rule.	
Drafting Preamble - Federalism Discussion	A, B	After consulting with SLEO/RNOs, OMB "strongly recommends" that you develop a preliminary "Federalism summary impact statement"(FSIS) to include in a separately identified portion of the preamble. The FSIS should have the following: (1) A description of the extent of the Agency's prior consultation with SLEO/RNOs; (2) A summary of the nature of their concerns; (3) The Agency's position supporting the need to issue the rule; and (4) A statement of the extent to which the concerns of SLEO/RNOs elected officials have been met.	Finalize the FSIS you developed for your proposed rule, addressing each of the four points.
	C, D, E	EPA policy: briefly summarize whether the EO applies, any consultation that occurred, the nature of S/L government concerns, and how you addressed them.	

Regulatory Development Step...	**Category to which it applies.....**	**Prior to proposal, the following Federalism activities apply.**	**If you have a Final Rule, the following Federalism activities apply.**
Final Agency Review OR other closure process for Tier 3 rules	A, B	In the preamble you send to your workgroup, include the FSIS you developed. If OCIR requests, you should also send them the rule for review prior to signature.	In the preamble you send to your workgroup, include the FSIS you developed. If OCIR requests, you must also send them the rule for review prior to signature. If you know your rule must go to OMB for review under EO 12866, you must get a Federalism Certification Form signed by EPA's Designated Federalism Official. See the following step concerning OMB review.
	C, D, E	In the preamble you send to your workgroup, include a discussion of Federalism. If OCIR requests, you must also send them the rule for review prior to signature.	
For Rules that will have OMB Review under EO 12866: Federalism Certification and Submission Requirements	A, B	N/A. No Federalism certification is required for proposed rules, and no Federalism-specific submission requirements apply.	You must include a Federalism Certification Form signed by EPA's Designated Federalism Official (the AA for OPEI) in the package that you send to OMB for review. For Tier 1 & 2 rules, OPEI's Regulatory Management Division (RMD) will generate the Federalism Certification Form in preparation for the Final Agency Review meeting. RMD will coordinate signature by the Designated Federalism Official. For Tier 3 rules, the Regulatory Steering Committee Representative or Regional Regulatory Contact will send the rule and an unsigned certification form to RMD when the rule is ready for certification and submission to OMB. You must also give OMB a copy of any formal policy-related correspondence from SLEO/RNO officials and, on request, a copy of any other written communications sent to EPA by SLEO/RNO officials.

Regulatory Development Step...	**Category to which it applies.....**	**Prior to proposal, the following Federalism activities apply.**	**If you have a Final Rule, the following Federalism activities apply.**
	C, D, E	These categories don't need Federalism certification, and no Federalism-specific submission requirements apply.	
Action Memo Applies to rules for the Administrator's signature	All	Summarize your consultation, and give an assessment of any reactions you received about your rule or the adequacy of your consultation on the proposed rule from S/L governments, OMB, or OCIR.	Same as proposal. If EPA's Federalism Official certified your final rule, for category A or B rules that OMB reviewed under EO 12866, state that too.
Workgroup Reconvenes after Proposal This applies to a formal Tier 1 or 2 workgroup, or an informal Tier 3 workgroup.	All	N/A	If EPA substantially changes its **selected** approach on these issues after the proposed rule comment period, you should explain these changes in the preamble to the final rule.

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1.6 What help and participation can I expect from OCIR as I develop my rule?

OCIR is EPA's principal point of contact for Congress, States and local governments. It is also the coordination point for other EPA offices and officials to interact with these entities. OCIR staff can help you assess issues of concern to other government entities, identify interested government officials, suggest ways for achieving their education and involvement, tailor information about rules for S/L government audiences, and develop and implement consultation plans. OCIR also can provide information about the various national associations representing S/L elected officials and governments, their membership and how to contact them. **Make sure you contact OCIR, through your Regulatory Steering Committee representative, regarding your plans to consult with elected S/L officials pursuant to the EO.**

As part of EPA's Regulatory Steering Committee, OCIR will be reviewing Tiering forms, Regulatory Agenda entries, and other reports to identify rules in which they want to participate. You are encouraged to contact OCIR about any help they can give you as you plan or conduct your consultation.[7]

It's important that you give OCIR timely information they may request, such as drafts of consultation plans or draft Federalism Summary Impact Statements, and that you carefully consider and respond, as appropriate, to their comments at the earliest stages of rulemaking. Here's a summary of the stages in the rulemaking process where you will interact with OCIR:

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[7] OCIR's Regulatory Steering Committee Representative is available to assist with your outreach to EPA's intergovernmental partners. To see an updated list of Regulatory Steering Committee Representatives or Regional Regulatory Contacts, go to "intranet.epa.gov/adplibrary" and click on "Regulatory Steering Committee."

Step	OCIR Participation on Rules
Tiering ...	OCIR may participate on your workgroup either as an active member or through a “side agreement” that asks the lead office to forward its consultation plan to OCIR. OCIR should participate in all rules that have FI. If you can’t make an FI determination at the tiering stage, and for many rules you won’t be able to, **inform OCIR’s Regulatory Steering Committee Representative as soon as you determine your rule has FI.**
Analytic Blueprint/-Consultation Plan	OCIR may review your consultation plan and give you comments.
Final Agency Review (Tier 1 and 2 rules only)	If OCIR participates on your Tier 1 or Tier 2 workgroup, they will participate in Final Agency Review of your rule. Like all participating offices, OCIR will be asked to concur, concur with comment, or non-concur on the draft rule and preamble. If they non-concur, you should include their comments in the Action Memo you send the Administrator or the memo you send to your AA requesting his/her signature on your rule.
OMB Review under EO 12866	Under EO 13132, EPA’s Designated Federalism Official [the AA for OPEI] must certify each final rule with FI that will be reviewed by OMB. OPEI will notify OCIR whenever a rule is certified.

1.7 About consulting with S/L elected officials...

EO 13132 is not meant to replace one type of outreach or interaction with another. Rather, it puts a strong emphasis on engaging elected officials or their representative national organizations. To this end, most existing techniques and practices are still useful. And, as stated earlier, you should continue to work with your S/L professional counterparts. But the challenge here is expanding the venues to encourage and highlight involvement by elected officials.

Why consult?

Consulting with officials from other levels of government:

- informs EPA about potential impacts on S/L governments and, therefore, helps us develop regulations that will work better in the field. This is particularly important because S/L governments carry out most of the day-to-day administration of many national environmental programs. Local governments often both manage environmental activities and operate regulated entities, such as waste and drinking water treatment facilities.

- can also help EPA develop proposed regulations that reflect approaches used in existing S/L government programs, taking advantage of existing mechanisms and lessons learned.

How much consultation is enough?

EPA's general policy is that the amount and type of intergovernmental outreach and consultation for a rule should be commensurate with its estimated impacts on S/L governments, its complexity, and the level of interest in the issues involved. This policy focuses the most extensive outreach and intensive consultation efforts on those regulations of greatest interest to, and potential effect on, S/L governments.

Recognizing that S/Ls are often in a better position than EPA to identify the potential political and resource implications of regulations EPA is considering, you are strongly encouraged to consult with potentially affected S/L leaders or their national organizations before deciding how much consultation would be appropriate and before preparing a final consultation plan. Consultation is especially important at key points in the process, such as just prior to options selection. OCIR can help you to determine appropriate levels of consultation.

For rules with FI as defined under the Order, at a minimum you should consult, to the extent practicable, with each of the relevant representative national organizations in the Big 10. You should also inform OCIR of any contacts you have with these organizations. See Attachment C for White House direction on consultation and a list of contacts for the Big 10.

How do I communicate with elected officials?

You should carefully consider what information to prepare and send to S/L government stakeholders. Information can serve two purposes: to promote understanding of what EPA is planning and why; and, to foster participation of these officials in the rulemaking process.

The Agency has a number of routine means to alert the public – including elected officials – that EPA is developing regulations. **EPA's Action Initiation List,** a web-based roster of regulatory actions that are entering the beginning stages of development, is made available to the public each month. http://www.epa.gov/regulations/documents/ail-epa Twice a year, EPA publishes the *Unified Agenda of Regulatory and Deregulatory Actions*, which describes EPA's planned rulemakings, indicates which rules are likely to have FI, and gives schedules for proposed and final rules.

In general, you will need to design information specifically for S/Ls needs and interests. You can begin your consultations with limited, preliminary information and provide more data as it becomes available. S/L government officials suggest that materials designed for them should be in plain language and, to the extent such information is available:

- Describe clearly the problem the rule is intended to address
- Explain the basis for determining there is a problem
- Indicate whether the problem is regional or national in scope
- Explain how the rule will improve on present conditions
- Identify who will benefit from the rule
- Identify what facilities or operations will be subject to the requirements
- Explain whether and how the benefits of the rule can be measured
- Identify who will be required to pay for the rule
- Provide cost information, such as cost per unit of compliance, cost to various sizes of governments, and cost versus benefits to be achieved
- Explain any flexibility in the rule that would allow for adjustments to local conditions or circumstances.

Some of this information will not be available until later in the development of a proposed rule. You can, however, begin your consultations with less than complete information and provide updates as more information becomes available.

Be sure to involve your OGC workgroup member when discussing these approaches in your outreach and consultation plans. You will need to be aware of any legal requirements, e.g., the Paperwork Reduction Act, that may apply to your approach and ensure your outreach and consultation activities are consistent with the law.

What types of consultation should I consider?

EPA officials can meet with external parties throughout the regulation development process. You should explore a variety of approaches for involving S/L government officials in developing a regulation – including one-on-one discussions, public meetings, and interest group forums.

Be sure to involve your OGC workgroup member when discussing these approaches in your outreach and consultation plans. You will need to be aware of any legal requirements that may constrain your approach and ensure your outreach and consultation activities are consistent with the law.

Does the Federal Advisory Committee Act (FACA) apply to consultations with S/L government representatives?

Under UMRA's FACA exemption, FACA does not apply to meetings that are "exclusively between federal officials and elected officials of S/L governments (or their designated employees authorized to act on their behalf) acting in their official capacities [if the] meetings are solely for the purposes of exchanging views, information, or advice relating to the management or implementation of federal programs established pursuant to public law that explicitly or inherently share intergovernmental responsibilities." [UMRA 204(b)].

OMB has construed this UMRA exemption broadly and has applied it to the Order: "This exemption applies to meetings between Federal officials and employees and State, local, or tribal government, acting through their elected officers, officials, employees, and Washington representatives, at which views, information, or advice are exchanged concerning the implementation of intergovernmental responsibilities or administration, including those that arise explicitly or implicitly under statute, regulation, or Executive Order. The scope of meetings covered by the exemption should be construed broadly to include any meetings called for any purpose relating to intergovernmental responsibilities or administration. Such meetings include, but are not limited to, meetings called for the purpose of seeking consensus; exchanging views, information, advice, and/or recommendations; or facilitating any other interaction relating to intergovernmental responsibilities or administration.[8]

Do I need to keep records of Federalism consultations?

Yes. You should keep good records of all consultation activities that you undertake related to the Order, and place them in the docket at the conclusion of the rulemaking. This helps to readily document compliance in the event of questions, either from EPA's Designated Federalism Official, OCIR, or from OMB.

What issues are most likely to be of interest to elected officials?

These are typical interests elected officials have expressed to EPA. They are concerned about rules that:

- Require money in the budget for program implementation;
- Require the S/L government to comply as a regulated party;
- May interfere with long standing divisions of responsibilities between levels of government;

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[8] OMB's Guidance on Implementing Federalism, p.6. Available on the intranet at "intranet.epa.gov/adplibrary". Click "Statutes and Executive Orders".

- Appear to direct one single method of accomplishing a particular environmental objective;
- Impact industry or employment in the state or locality;
- Impact land use in the state or locality; and
- Raise controversial issues

What should be in a consultation plan?

The consultation plan will serve as the road map for implementing your outreach activities. See Attachment E for suggestions and recommendations in developing your plan.

Other sources of help

Rulewriters. Contact your office's Regulatory Steering Committee representative or Regional Regulatory Contact. You may also contact OPEI's Regulatory Management Division (RMD), (202) 564-5480, for general information about the EO 13132 and for help integrating consultation efforts into the regulatory development process. RMD supports the Agency's Designated Federalism Official and submits packages to OMB under the Order. Finally, OCIR has ongoing involvement with the Big 10 and other officials. They can help you throughout the consultation process, from planning to implementation.

Attorneys. If you have questions, contact OGC's Cross-Cutting Issues Law Office at (202) 564-7622 and ask to speak to the lead attorney for Federalism.

1.8 How will EPA ensure compliance with the Order?

OPEI will gather the following information as we prepare EPA's semi-annual Regulatory Agenda:

1. A listing of all rules that will have **any** adverse effect on S/L governments above a minimal level;
2. A listing of all rules under development with FI;
3. The status of Federalism consultation plans (e.g., under development, consulting with OCIR, etc.); and
4. Any reported problems in carrying out the consultation plan that may affect the Designated Federalism Official's ability to certify that EPA has met the requirements of the order in a meaningful and timely manner.

OPEI will provide reports and a summary of any issues and recommended actions to the Designated Federalism Official, who has principal responsibility for EPA's implementation of the Order.

Part 2 - Legislative Comments or Proposed Legislation

2.1 How does the Order apply to proposed legislation or legislative comments submitted by EPA?

The Order defines, “**policies that have federalism implications”** as including *legislative comments or proposed legislation* that have *substantial direct effects* on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government.

Accordingly, if EPA is submitting official agency legislative comments or proposed legislation to Congress or OMB, and the comments or proposed legislation have FI, the general policymaking criteria provided in Section 3 of the Order would apply (see part 1.3 of this guidance for a list of those criteria).

In addition, Section 5 of EO 13132 contains “Special Requirements for Legislative Proposals.” It says that *agencies shall not submit to the Congress* legislation that would:

- directly regulate the States in ways that would interfere with functions essential to the States’ separate existence or be inconsistent with the fundamental Federalism principles;
- attach to Federal grants conditions that are not reasonably related to the purpose of the grant; or
- otherwise preempt State law, unless such preemption is consistent with the Federalism policies in the Order, and unless a clearly legitimate national purpose, consistent with the Order’s Federalism policymaking criteria cannot otherwise be met.

EPA is interpreting these provisions as applying to proposed legislation or legislative comments *that are official Agency positions with Administration clearance*. At EPA, OCIR is the Agency’s principal point of contact with Congress, and has responsibility for developing and implementing the legislative agenda of the Agency.

Legislative comments or proposals that would fall within the scope of the Order are typically those on which OCIR has worked with all Agency offices to develop and/or draft, has worked with other departments and agencies within the Executive Branch to obtain Administration-wide concurrence and clearance through OMB, and has communicated to Congress.

As an example, if a Congressman or Senator has draft legislation he or she is planning to introduce, and sends a letter to the Administrator or an Assistant Administrator asking for *the Agency’s position* on that legislation, our legislative comments on that bill potentially would be subject to the requirements of Sections 3 and 5 of the Order. Similarly, if a Congressman or Senator asks EPA to submit draft legislation to him or her for consideration, this potentially would be subject to the Order.

As with draft final rules that are subject to OMB review under EO 12866, when OCIR transmits to OMB for clearance any proposed legislation that has FI, OCIR must include a Federalism Certification Form signed by EPA's Designated Federalism Official that states EPA has met the requirements of the Order. In this case, the certification would be stating we have met the "Special Requirements for Legislative Proposals" contained in the Order.

Within EPA, the responsibility for determining whether there are FI and following the Order's requirements falls on the office that has the lead for drafting the substance of the draft legislation or legislative comments. The lead office should work closely with its OGC or ORC attorneys.

2.2 Does the Order apply when EPA provides comments to another agency on its draft legislation or provides technical assistance to congressional staff?

No. Responding to another agency's request for comments on its draft legislation or testimony would *not* be subject to the Order, as these are *not* comments *submitted by EPA* to Congress. The duty to determine whether there are any FI for the draft bill or legislative comments falls upon the agency that is submitting the bill or comments.

Similarly, responding to a Hill staffer's request for technical assistance on how to craft or word a bill would *not* be subject to the Order, as EPA is merely responding to the request for technical assistance, not submitting to Congress draft legislation or official agency legislative comments.

Part 3 - Other Policy Statements or Actions

3.1 Are EPA's policy statements, guidance documents, and similar actions covered by EO 13132?

EO 13132 applies to regulatory policies that have FI, which includes policies, guidelines, guidance, and interpretive documents ("guidance documents"). In general, EPA's guidance documents **do *not establish* legally binding requirements,** and thus, they probably will *not* have FI. If the guidance document doesn't establish any legally binding requirements, then it won't have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government." Nonetheless, EPA's internal policy on consultation with S/L governments may apply to your guidance document. See part 3.3 below.

3.2 What consultation should take place if my policy statement, guidance document, or similar action contains legally binding requirements?

Regardless of what it is called, if your document ***does* establish legally binding requirements,** you must determine in consultation with your program's Regulatory Steering Committee Representative and the OGC workgroup member whether your document has FI. Guidance documents that establish legally binding requirements are subject to the same FI analysis and consultation provisions that rules are subject to, as discussed in part 1 of this guidance. As with rules, the only clear-cut thresholds for FI are cost impacts on S/L governments (that is, whether your action either imposes $25 million or more in costs on State and/or local governments in any one year, or will impact small governments at or above 1% of their revenues).[9] As a reminder, applying the threshold for preemption and FI should be done with assistance from OGC.

3.3 An important note about EPA's internal policy on consulting with S/L governments on certain documents...

As noted in 3.1, EPA's guidance documents generally do not establish legally binding requirements and will not have FI. However, some guidance documents, while not

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[9] In general, grant guidelines do not have FI under the substantial cost threshold (see part 1.2A) because conditions of federal assistance are excluded from the definition of federal intergovernmental mandate under Section 421(5) of UMRA. But you still need to determine whether your guideline meets any of the thresholds for determining FI (see part 1.2 B and C).

establishing legally binding requirements or FI, still may address matters *likely to be of significant interest* to S/L governments. While many EPA guidance documents are of *some* interest to S/L governments, we refer here to non-binding guidance documents or policy statements that may result in a higher level of interest to S/L governments because, for example, they announce for the first time how EPA is planning to address a significant environmental problem nationally and S/L governments may view our plan as having significant implications for them. Determining if your guidance document meets this threshold is a judgment call you should make in conjunction with your Regulatory Steering Committee Representative or Regional Regulatory Contact.

If your guidance document is likely to be of significant interest to S/L governments...

Even if your guidance document is exempt from EO 13132 because it doesn't have FI, in the spirit of EO 13132, and consistent with EPA's objective of promoting communication between EPA and S/L governments, EPA's policy is to solicit input from S/L officials on those guidance documents that are *likely to be of significant interest* to S/L governments. If you determine your guidance document meets this threshold, then EPA's policy is to:

- **Consult** early, to the extent practicable, given the nature and the timing of the action, with appropriate S/L government representatives. These can be elected officials, their representative national organizations, **<u>or</u>**, your professional counterparts. At a minimum, notify each of the Big 10 organizations (see part 1.7 of this guidance) and consult with them if they so desire; and

- **Discuss** briefly in your document any consultation that occurred, the nature of S/L government representatives' concerns, and how you addressed those concerns or why EPA decided not to implement suggested changes.

Part 4 - Adjudications

How will I know if my adjudication is subject to the Order?

Section 4 of the Order establishes requirements for adjudications *that preempt S/L law*. An adjudication is any agency's process for formulating an order. An order is the whole or part of a final agency action that is *not* a rulemaking, whether affirmative, negative, injunctive, or declaratory in form. Examples of some EPA orders are applicability determinations, administrative orders, permits, licenses, and registrations.

In general, EPA's adjudications do not preempt S/L law. To the extent the S/L law is preempted, it is the statute or regulation that affects the preemption. Thus, the requirements of Section 4 of the Order generally do not apply to EPA's adjudications. If you have questions about the applicability of Section 4 to your adjudication, consult with the attorney assigned to your action.

Part 5 - Waivers

What does the Order require for waivers?

Section 5 of EO 13132 contains requirements that apply to applications submitted to EPA by S/L governments seeking to waive some or all of the statutory or regulatory requirements that apply to them. These are the same requirements that previously were contained in EO 12875.

Specifically, if the authorizing statute gives EPA discretion to waive some or all of the statutory or regulatory requirements as applied to S/L governments, EO 13132 requires EPA, to the extent practicable and permitted by law, to:

- Consider any application by a S/L government for a waiver of statutory or regulatory requirements with a general view toward increasing flexible policy approaches at the S/L level, to the extent that the proposed waiver is consistent with applicable Federal policy objectives and is otherwise appropriate;

- Issue a decision within 120 days of receipt of a complete waiver application; and

- Provide timely written notice of the decision and rationale in the event that EPA denies any such waiver application.

Attachments

Attachment A –	Guidance for Implementing the Federalism “1% Test”
Attachment B –	OGC Flowcharts Summarizing EO 13132's Requirements
Attachment C –	White House Letter on Consultation and List of "Representative National Organizations" Contacts
Attachment D –	More Forums for Contacting Elected Officials
Attachment E –	Building a Consultation Plan: Key Elements
Attachment F –	Federalism Executive Order

- Attachment A -

Guidance for Implementing the Federalism "1% Test"

Introduction

EPA's Guidance on Executive Order 13132, "Federalism", identifies various triggers for determining Federalism implications:

> "...[I]f the impact of your rule on small governments is likely to equal or exceed 1% of their revenues, then as a policy matter, EPA will conclude the rule also has Federalism implications..."

This document serves as a starting point in the implementation of the Federalism 1% test by providing Agency analysts a consistent framework for carrying out this analytical test. In order to provide meaningful advice to analysts, this document incorporates a number of working assumptions. As the Agency gains experience applying the Federalism 1% test, the approach presented here will be revisited and revised if necessary.

Applying the Federalism 1% Test

Before presenting guidance on implementing this test, at least one caveat is in order. The language contained in the Federalism Guidance suggests an "aggregate" test – the analyst should calculate total annualized costs as a percent of total revenues for the local governments that must conform to the rule. The "aggregate" test does not consider any information on the distribution of impacts among the small governments. The impacts may be very small for a majority of the small governments, but hit a number (probably the smallest of the small due to economies of scale) of small governments very hard without triggering Federalism implications. No single test can capture all situations of concern. Therefore, the analyst is encouraged to develop information that will signal other possible scenarios that may provide enough concern to warrant consultation with representatives of small governments.

The following questions outline the steps analysts will need to take as they apply the Federalism 1% test.

1.*Will any small governments be subject to the rule's requirements?*

The default definition of small government is a government of a city, county, town, village, school district or special district which serves a population of less than 50,000. This is the same definition used by the Regulatory Flexibility Act, as amended by the Small Business Regulatory Enforcement Fairness Act (RFA/SBREFA), and similar to the definition of small government in the Unfunded Mandates Reform Act (UMRA).[10]

If no small governments are subject to the rule's requirements, then the Federalism 1% test is not applicable. If there are only a few (less than 50) local governments affected by this rule, then a 1% test is not applicable. Rather, the program office should consult with a meaningful segment of these governments directly in the course of developing the rule.

2. What are the total annualized compliance costs of all small governments subject to the rule's requirements?

This cost estimate should be an aggregate measure of the annualized direct compliance costs faced by all small governments subject to the rule's requirements. In many cases, this cost estimate may already be contained in the economic impact analysis done for the rule. To the extent possible, the small government cost estimate should be based on the same assumptions (e.g., concerning a baseline, a discount rate, etc.) made in the rule's economic analysis. If there is some reason why those assumptions should be different within this analysis, the analyst should highlight the assumptions that are different and provide a detailed description of why different assumptions were made. The rulewriter then should consult with his/her program's Regulatory Steering Committee (RSC) representative or Regional Regulation Contact (RRC) and the attorney assigned to the rule. EPA's Guidelines for Preparing Economic Analysis specifies the basic, broad principles that all EPA economic analyses should embody.

In most cases, it will be necessary to use a range to represent plausible estimates of annualized direct compliance costs. This range will reflect different assumptions about the extent of the environmental problem, the ease or difficulty of achieving meaningful reductions in pollution, the costs of abatement equipment, the interest rate, the growth in population, etc. EPA's Guidelines for Preparing Economic Analysis discusses these uncertainty drivers and how best to incorporate them into analyses. The Guidelines also stress the importance of incorporating all plausible estimates. In general, the analyst will not be able to conduct appropriate Monte Carlo analyses without additional information about the underlying statistical distributions of these uncertainty drivers. Therefore, the analyst must take great care explaining and selecting ranges that capture both high and low reasonable bounds.

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[10] UMRA also includes tribal governments in its definition of small government.

In order to apply the Federalism 1% test, the midpoint or "best" estimate of that range should be used. A qualitative or quantitative description of the uncertainty surrounding the midpoint or "best" estimate should accompany the results of the test. Finally, if a non-trivial portion of the range exceeds 1% of revenues, then the analyst should discuss these findings with their RSC/RRC and attorney assigned to the rule before presenting the findings to the appropriate decision maker.

Note that, consistent with the guidance for RFA/SBREFA, the Federalism 1% test will not consider the indirect impacts of a rule on small governments (e.g., social service costs rising due to a plant closure in a community). These types of impacts should be explored in the full economic analysis of a rule but are not considered when determining whether a rule will impose substantial compliance costs on small governments for purposes of Federalism, and thus be deemed by EPA as having Federalism implications.

3. What are the total annual revenues of all small governments subject to the rule's requirements?

Data on "general revenue" can be found in the Census of Governments from the U.S. Census Bureau. General revenue is made up of intergovernmental revenue plus revenue from their own sources and excludes utility, liquor store and employee retirement revenue.

It is important that the analyst include all the revenues (and costs) from the same set of communities – those that must comply with the rule. For example, demonstrating compliance with a rule (e.g., monitoring) can be costly, even if abatement activities are not needed. In these situations, the analyst should include these costs in the direct cost totals and also include the revenue of these small governments in the revenue totals. The analyst cannot count the revenues of one set of governments and the costs faced by a different set.

In situations where the number of governments that must comply with this rule is unknown, then a range of revenue estimates reflecting this uncertainty should be quantified.

4. Is the ratio of small governments' costs to revenues equal to or greater than 1%?

The statement contained in the Federalism Guidance can be rephrased as follows:

$$\text{If } \frac{\text{total annualized compliance costs of all small governments subject to the rule's requirements}}{\text{total annual revenues of all small governments subject to the rule's requirements}} \exists 1\%, \quad \text{then EPA concludes that the rule has Federalism implications.}$$

- Attachment B -

OGC Flowcharts Summarizing EO 13132's Requirements

These flowcharts summarize the Federalism Executive Order. The section citations in the flowchart (for example, Section 5) refer to the text of the Executive Order, not to this guidance.

OGC Flowcharts For EPA Actions

To determine . . .	See Flowchart
if you have a rule with FI based on substantial compliance costs	1-A
if you have a rule with FI that preempts S/L law	1-B
if you have a rule with FI that doesn't meet either of the above thresholds	1-C
the requirements that apply to "policies with FI"	1-D
the requirements that apply to legislative comments or proposed legislation	2
if you have a policy statement, guidance document or similar action with FI	3
the requirements that apply to requests from S/L governments to waive some or all statutory or regulatory requirements	4

Important abbreviations in flowcharts

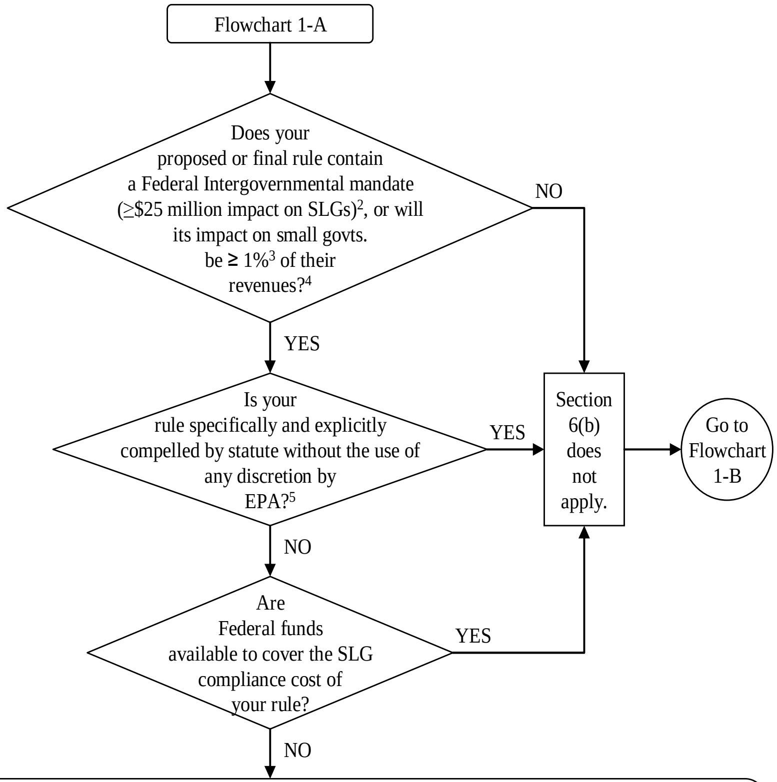
DFO = EPA's Designated Federalism Official (the AA for the Office of Policy, Economics and Innovation).

SLEO/RNOs = "State and local [elected] officials," which the Order defines as **state and local government elected officials** or their **representative national organizations**. For purposes of this EO, representative national organizations refers to the Big10. Attachment C of this guidance includes a contact list.

SLG Reps = State and local government representatives. We are using this term to refer to non-elected representatives of State and local governments, such as our professional counterparts.

Flowchart 1-A

To Determine If You Have a Rule with Federalism Implications (FI)[1]



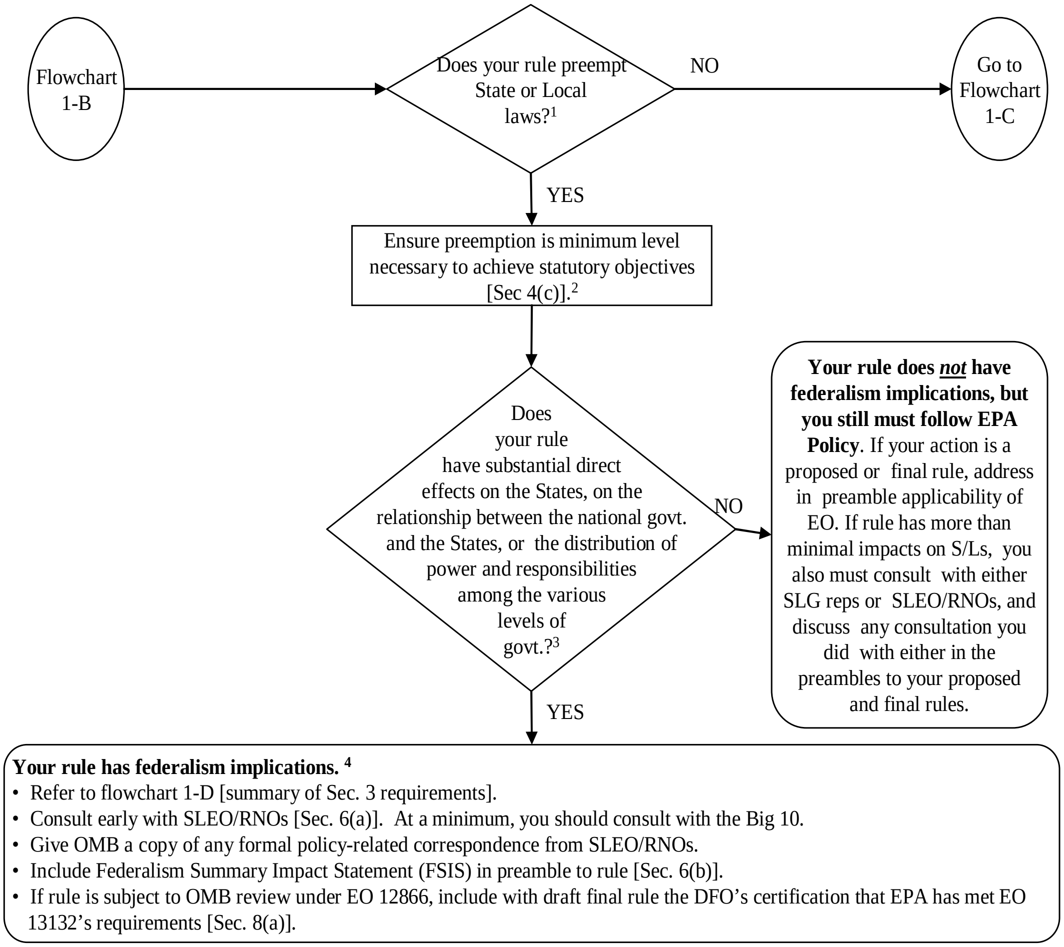
Your rule has federalism implications.
- Refer to flowchart 1-D [summary of Sec. 3 requirements].
- Consult early with SLEO/RNOs [Sec. 6(a)]. At a minimum, you should consult with the Big 10.
- Give OMB a copy of any formal policy-related correspondence from SLEO/RNOs.
- Include Federalism Summary Impact Statement (FSIS) in preamble to rule [Sec. 6(b)].
- If rule is subject to OMB review under EO 12866, include with draft final rule the DFO's certification that EPA has met EO 13132's requirements [Sec. 8(a)].

1. Section 1(a) of EO 13132 defines "federalism implications" as "substantial direct effects on States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."
2. If your rule contains a Federal intergovernmental mandate that may result in expenditures of $25 million or more in any one year by State and/or local governments, we consider it to have federalism implications and to impose substantial direct compliance costs under Section 6(b) of the Order.
3. For guidance on the >1% threshold for impacts on small governments, see attachment A of EPA Federalism guidance.
4. We interpret "required by Statute" in Section 6(b) of the Order to mean "specifically and explicitly compelled by statute without the use of any discretion by EPA." This is intended to be a very narrow test. While our rules generally are authorized by statute, most are not specifically and explicitly compelled by statute without the use of any discretion by EPA. Examples of rules that are "require by statue" include: if the statute says, "Use Form X," and the rule says "Use form X" and does not impose any other requirements; or if the statute says , "Set the emission limit at 100 ppm," and rule does only that.

Flowchart 1-B

To Determine If You Have a Rule with Federalism Implications (FI)

(continued)



Ensure preemption is minimum level necessary to achieve statutory objectives [Sec 4(c)].[2]

Your rule does *not* have federalism implications, but you still must follow EPA Policy. If your action is a proposed or final rule, address in preamble applicability of EO. If rule has more than minimal impacts on S/Ls, you also must consult with either SLG reps or SLEO/RNOs, and discuss any consultation you did with either in the preambles to your proposed and final rules.

Your rule has federalism implications. [4]

- Refer to flowchart 1-D [summary of Sec. 3 requirements].
- Consult early with SLEO/RNOs [Sec. 6(a)]. At a minimum, you should consult with the Big 10.
- Give OMB a copy of any formal policy-related correspondence from SLEO/RNOs.
- Include Federalism Summary Impact Statement (FSIS) in preamble to rule [Sec. 6(b)].
- If rule is subject to OMB review under EO 12866, include with draft final rule the DFO's certification that EPA has met EO 13132's requirements [Sec. 8(a)].

1. The question of whether your rule preempts State or local (S/L) law is a legal question. You should consult the OGC or ORC attorney assigned to your rule for a preemption determination.

2. An action may preempt S/L law in whole (e.g., States may not have any statutes or rules in an area once EPA enacts a rule in that area) or in part (e.g., States may not have any law that is less stringent than the federal law). Preemption may be: (1) express preemption—Congress' intent to preempt S/L law is stated expressly in the federal statute; (2) field preemption—Congress' creation of a pervasive system of federal regulation makes reasonable the inference that Congress left no room for S/L governments to supplement it, or Act of Congress touches a field in which the federal interest is so dominant that the federal system is assumed to preclude enforcement of S/L laws on the same subject; or (3) conflict preemption—federal and S/L law are in direct conflict, or S/L law stands as an obstacle to the achievement of federal objectives.

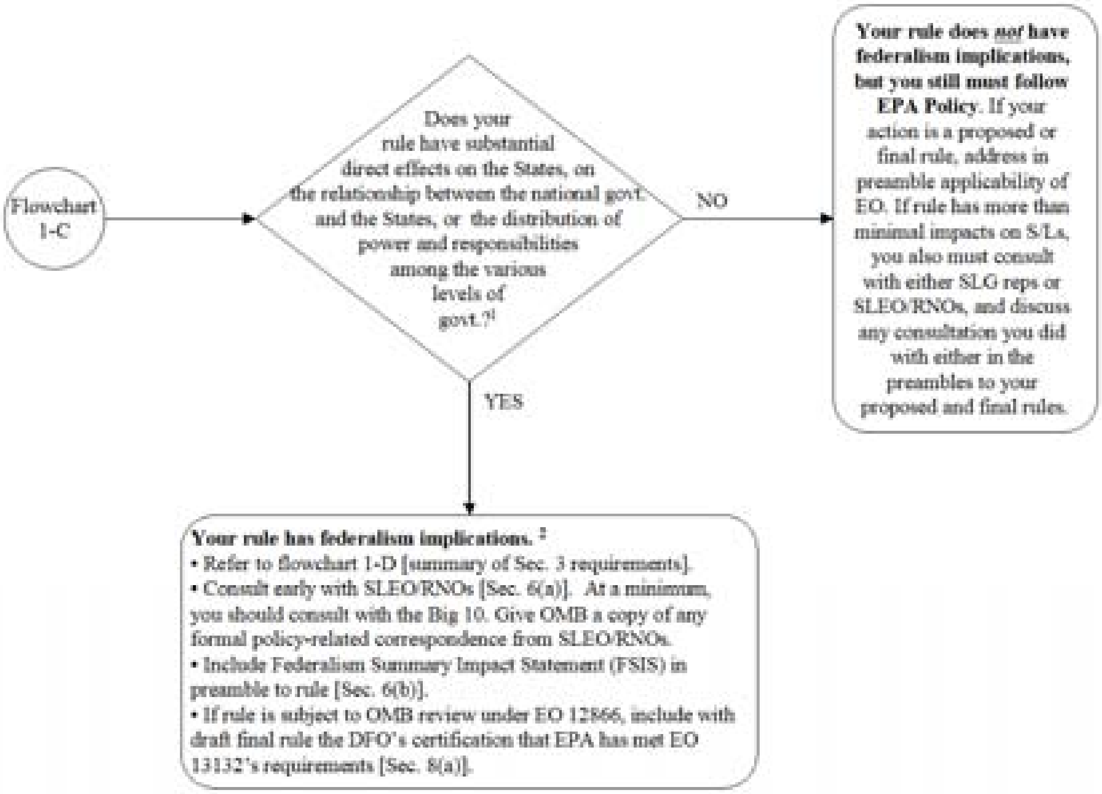
3. As shown on this flowchart, if the rule preempts S/L law to such a degree that it has federalism implications (i.e., "substantial direct effects…" [see large diamond]), or if the rule otherwise has federalism implications and also preempts S/L law, we must comply with the consultation requirements of Section 6(c). Determining whether the preemption creates federalism implications requires a judgment call. In general, minor amendments to an existing preemptive program probably will not have federalism implications. On the other hand, a significant new preemptive program may have federalism implications. You should consult with OGC/ORC and your program office's Regulatory Steering Committee representative or your Regional Regulatory Contact to determine whether the preemption creates federalism implications.

4. Determining whether a rule may have federalism implications for reasons other than compliance costs or preemption requires a judgment call. As with preemptive rules, in general, minor amendments to an existing program probably will not have federalism implications. On the other hand, a significant new program may have federalism implications. You should consult with OGC/ORC and your program office's Regulatory Steering Committee representative or your Regional Regulatory Contact to determine whether your rule may have federalism implications.

Flowchart 1-C

To Determine If You Have a Rule with Federalism Implications (FI)

(continued)



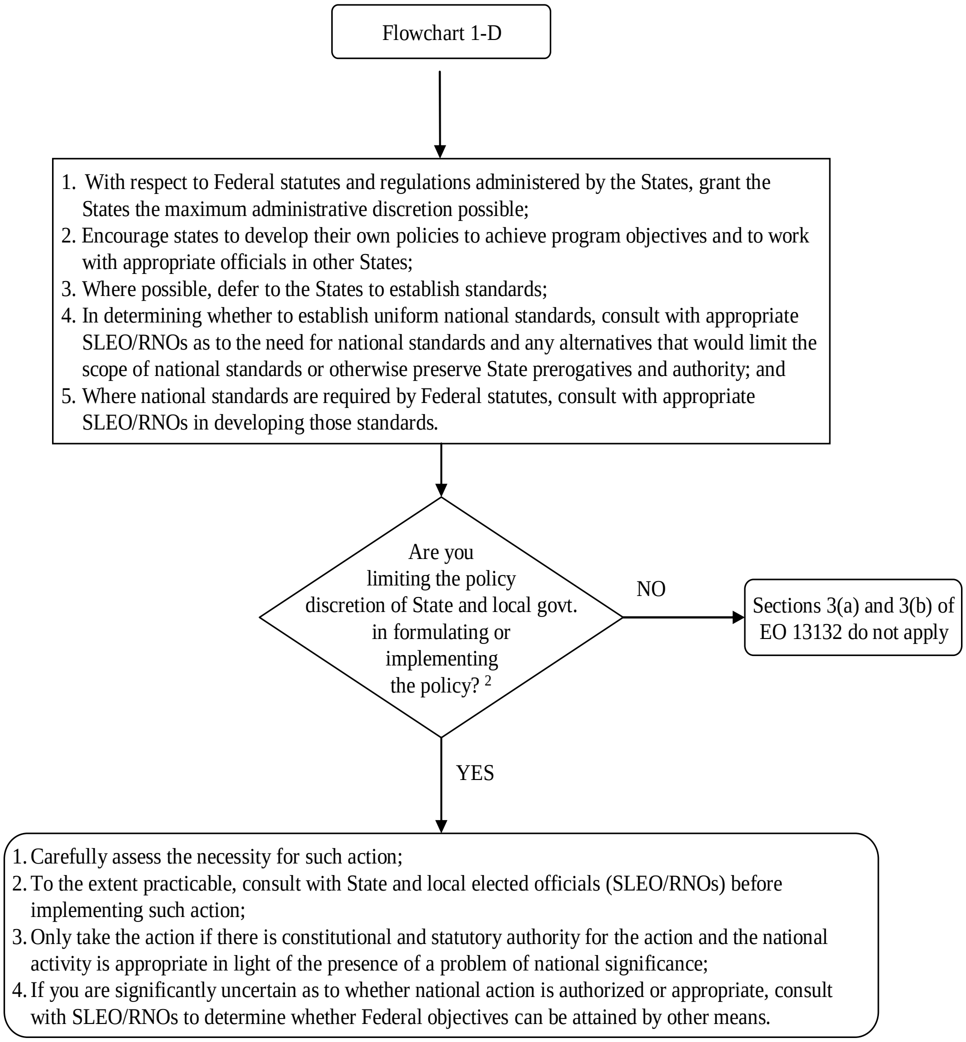
1. As shown on this flowchart, if the rule preempts S/L law to such a degree that it has federalism implications (i.e., "substantial direct effects…" [see large diamond]), or if the rule otherwise has federalism implications and also preempts S/L law, we must comply with the consultation requirements of Section 6(c). Determining whether the preemption creates federalism implications requires a judgment call. In general, minor amendments to an existing preemptive program probably will not have federalism implications. On the other hand, a significant new preemptive program may have federalism implications. You should consult with OGC/ORC and your program office's Regulatory Steering Committee representative or your Regional Regulatory Contact to determine whether the preemption creates federalism implications.

2. Determining whether a rule may have federalism implications for reasons other than compliance costs or preemption requires a judgment call. As with preemptive rules, in general, minor amendments to an existing program probably will not have federalism implications. On the other hand, a significant new program may have federalism implications. You should consult with OGC/ORC and your program office's Regulatory Steering Committee representative or your Regional Regulatory Contact to determine whether your rule may have federalism implications.

Flowchart 1-D

To Determine If You Have a Rule with Federalism Implications (FI)

(continued)



1. With respect to Federal statutes and regulations administered by the States, grant the States the maximum administrative discretion possible;
2. Encourage states to develop their own policies to achieve program objectives and to work with appropriate officials in other States;
3. Where possible, defer to the States to establish standards;
4. In determining whether to establish uniform national standards, consult with appropriate SLEO/RNOs as to the need for national standards and any alternatives that would limit the scope of national standards or otherwise preserve State prerogatives and authority; and
5. Where national standards are required by Federal statutes, consult with appropriate SLEO/RNOs in developing those standards.

Are you limiting the policy discretion of State and local govt. in formulating or implementing the policy? [2]

Sections 3(a) and 3(b) of EO 13132 do not apply

1. Carefully assess the necessity for such action;
2. To the extent practicable, consult with State and local elected officials (SLEO/RNOs) before implementing such action;
3. Only take the action if there is constitutional and statutory authority for the action and the national activity is appropriate in light of the presence of a problem of national significance;
4. If you are significantly uncertain as to whether national action is authorized or appropriate, consult with SLEO/RNOs to determine whether Federal objectives can be attained by other means.

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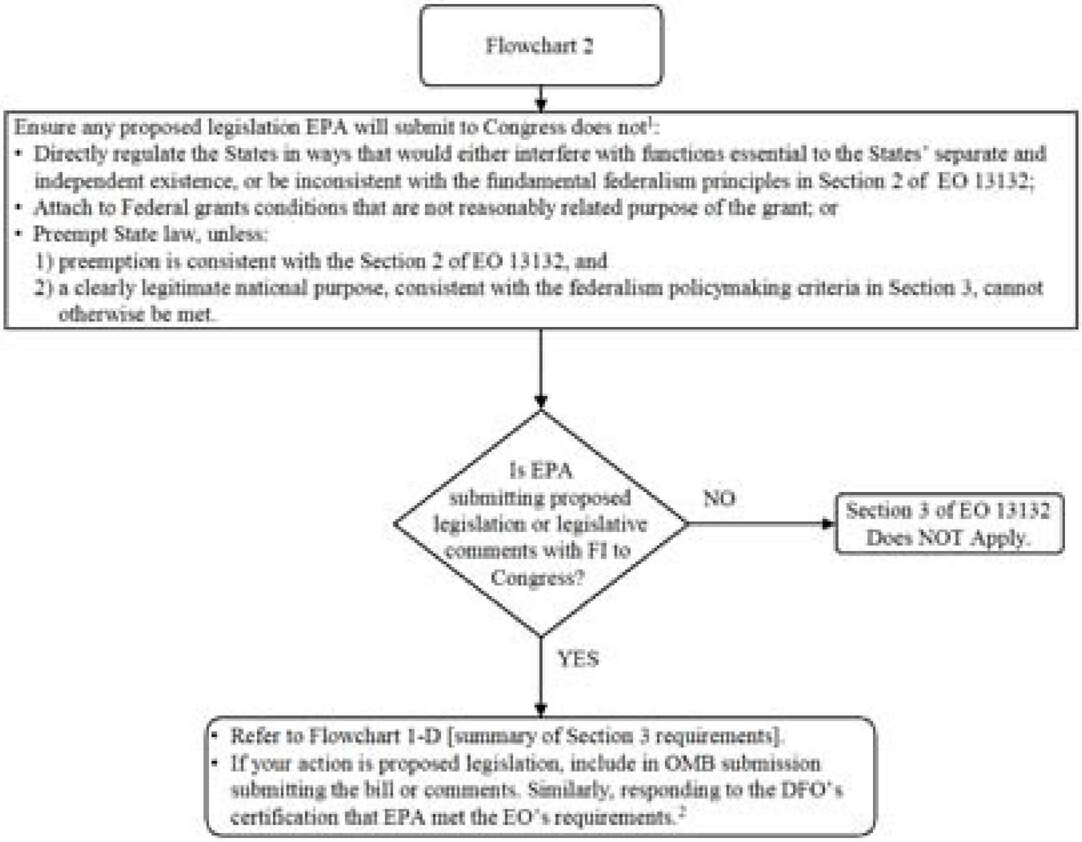
1. If you determine that your action has FI from Flowcharts 1-A, 1-B, 1-C, or 2, then the requirements of Section 3 of the Order, which are summarized here, apply. "Policies that have federalism implications (FI)" is broadly defined in the Order to include regulations, legislative comments or proposed legislation, and other policy statements or actions that have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government.

2. SLEO/RNOs = "State and local [elected] officials," which the Order defines and limits to state and local government elected officials or their representative national organizations. Representative national organizations for purposes of EO 13132 are the Big 10. The Big 10 offers the largest constituencies of elected and senior appointed officials in State and local government. Attachment C of EPA's interim Federalism guidance includes a contact list. At minimum, you must consult with each of these organizations if your action is a rule with federalism implications.

Flowchart 2
To Determine If You Have a Rule with Federalism Implications (FI)
(continued)



Ensure any proposed legislation EPA will submit to Congress does not[1]:

- Directly regulate the States in ways that would either interfere with functions essential to the States' separate and independent existence, or be inconsistent with the fundamental federalism principles in Section 2 of EO 13132;
- Attach to Federal grants conditions that are not reasonably related purpose of the grant; or
- Preempt State law, unless:
  1) preemption is consistent with the Section 2 of EO 13132, and
  2) a clearly legitimate national purpose, consistent with the federalism policymaking criteria in Section 3, cannot otherwise be met.

Is EPA submitting proposed legislation or legislative comments with FI to Congress?

Section 3 of EO 13132 Does NOT Apply.

- Refer to Flowchart 1-D [summary of Section 3 requirements].
- If your action is proposed legislation, include in OMB submission submitting the bill or comments. Similarly, responding to the DFO's certification that EPA met the EO's requirements.[2]

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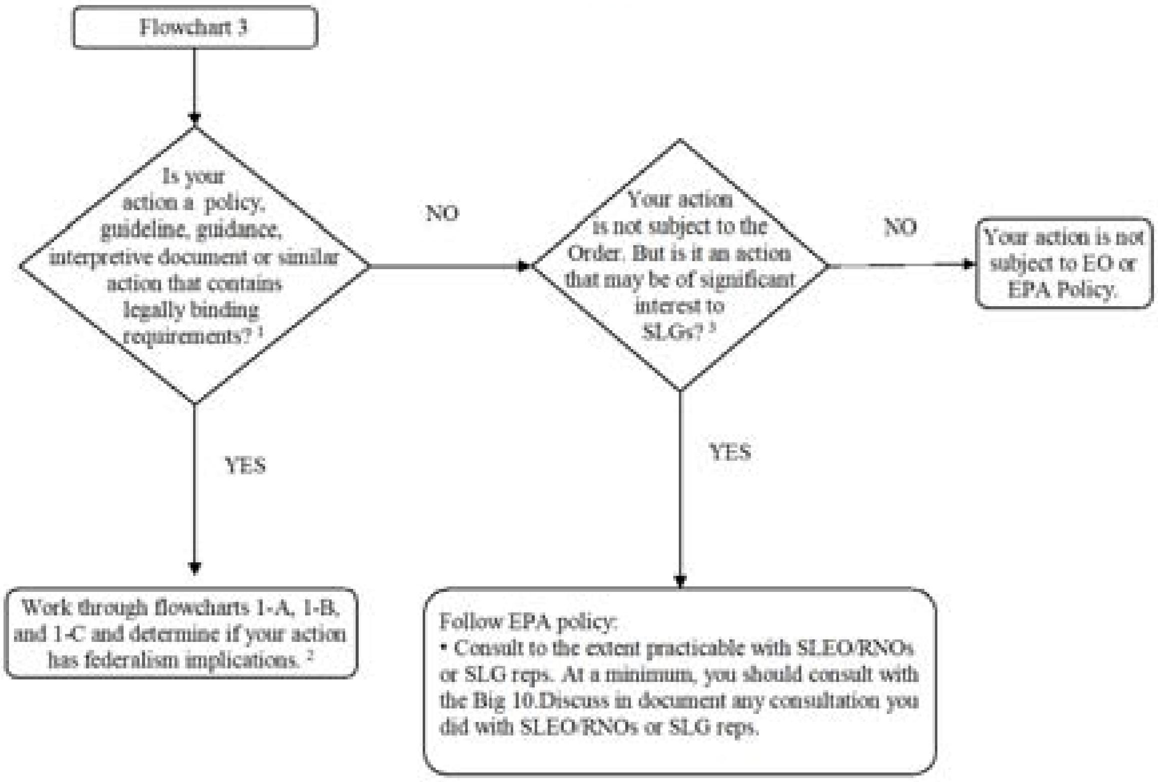
1. Official agency legislative comments or proposed legislation that have federalism implications (i.e., have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government) are subject to Section 3 of the Order (see Flowchart 1-D for summary of requirements). Section 5 also contains specific requirements that pertain to proposed legislation submitted by agencies to Congress (top box to the right).

   EPA is interpreting these provisions as applying only to proposed legislation or legislative comments that are official Agency positions with Administration clearance. As an example, if a Congressman or Senator has draft legislation he or she is planning to introduce, and sends a letter to the Administrator or an Assistant Administrator Is EPA asking for the Agency's position on that legislation, our submitting proposed legislative comments on that bill potentially would be legislation or legislative subject to the requirements of Section 3 of the Order.

   The Order does not apply when you are responding to another agency's request for comments on their draft legislation or testimony, as these are not comments submitted by EPA to Congress. The duty to determine whether there are federalism implications on the draft bill.

2. EPA's legislative **comments** don't have to be certified.

Flowchart 3
To Determine If You Have a Rule with Federalism Implications (FI)
(continued)



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1. In general, EPA's policies, guidelines, guidance, interpretive documents, or similar actions ("guidance documents") do not contain legally binding requirements, and thus, they will not have federalism implications. This is because if the guidance document does not contain legally binding requirements, it will not have "substantial direct effects" on: (1) the States (the definition for "States" includes local governments); (2) the relationship between the national government and the States; or (3) the distribution of power and responsibilities among the various levels of government.

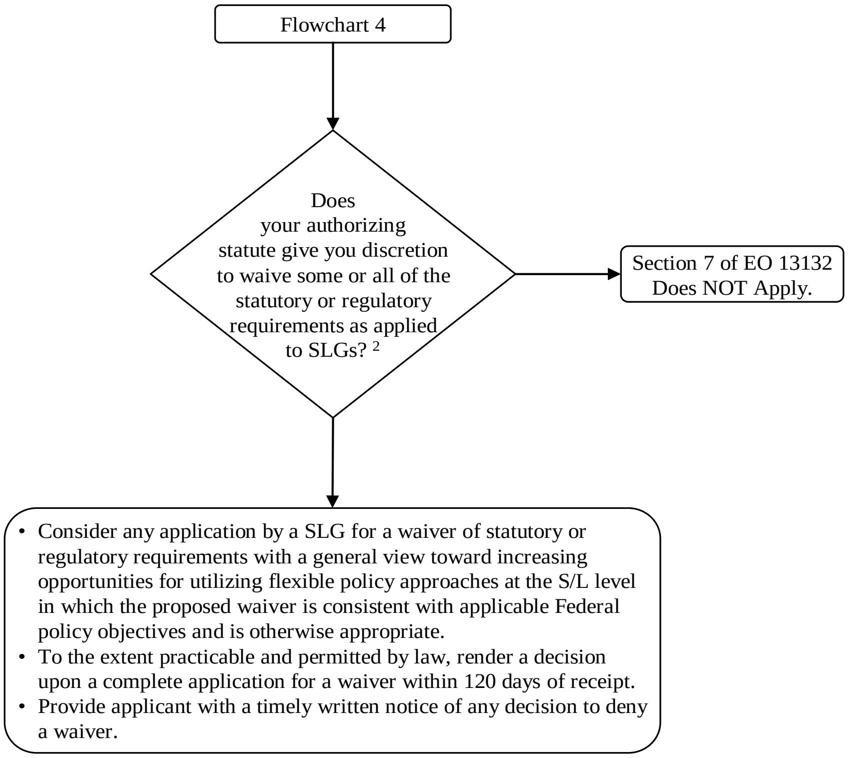
2. If your guidance document does contain legally binding requirements, it is subject to the same federalism implications analysis that rules are. Thus, you should refer to flowcharts 1-A, 1-B, and 1-C to make this determination. If you determine that your guidance document does contain legally binding requirements, and has federalism implications, it is subject to the same requirements that rules are.

3. Even if your guidance document does not contain legally binding requirements, if it may be of significant interest to SLGs, it is subject to EPA's internal policy on consultation with State and local governments.

Flowchart 4

To Determine If You Have a Rule with Federalism Implications (FI)

(continued)



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1. Section 7 of EO 13132 contains requirements that apply to applications submitted to EPA by State or local governments seeking to waive some or all of the statutory or regulatory requirements that apply to them.

2. *If the authorizing statute gives EPA discretion* to waive some or all of the statutory or regulatory requirements as applied to State or local governments [e.g., Clean Air Act Section 111(d)], you must look to increase opportunities for using flexible policy approaches at the State or local level in which the proposed waiver is consistent with the program administered by EPA. See part 3.3 of EPA's Federalism guidance for details.

- Attachment C -

White House Letter on Consultation and List of "Representative National Organizations" Contacts

The White House
Washington

March 9, 2000

Mr. Donald J. Borut
Chair, Big 7 Organizations
Executive Director, National League of Cities
1301 Pennsylvania Ave, NW
Washington, DC 20004-3043

Dear Don:

Thank you for your January 13 letter making further suggestions concerning the implementation of Executive Order 13132.

We see no problem in having agency Federalism officials begin to notify and provide information to the Federalism contact person at each of the relevant Big 7 organizations, as well as the chair of the Big 7, when the agency identifies Federalism implications in a draft regulation for which consultations have not already occurred. There will, of course, be circumstances when it also would be appropriate for an agency to notify other representative national organizations of State and local elected officials.

Once this notification occurs, we would ask that each Big 7 organization promptly advise the agency's Federalism official whether it intends to provide comments on the Federalism issues presented by the rulemaking and to provide those comments as soon as possible, taking into account the length and complexity of the regulation. In order not to delay the regulatory process unnecessarily, it is the agencies' hope that concerned Big 7 organizations normally will provide those comments within three or four weeks.

The Big 7 organizations may also wish to review the semiannual Unified Agenda of Federal Regulatory and Deregulatory Actions in order to identify regulatory projects that they believe might raise FI. In this way, a concerned Big 7 organization could advise an agency's Federalism official of its potential interest in a particular regulation and facilitate early consultations.

Enclosed is our listing of Federalism officials. Please forward a list of the Federalism contact person for each of the Big 7 organizations at your earliest convenience.

Thank you again for suggestions.

Sincerely,

//// signed 3/9/00 ////

Mickey Ibarra
Assistant to the President and
Director of Intergovernmental Affairs

"Big 10" Organizations

Mr. Raymond Sheppach
National Governors' Association
444 North Capitol Street, NW
Suite 267
Washington, DC 20001
fax 202/624-5313
(staff: Beth Strobridge)

Mr. William Pound
National Conference of State Legislatures
444 North Capitol Street, NW
Suite 515
Washington, DC 20001
fax 202/737-1069
(staff: Tamra Spielvogel)

Mr. Daniel Sprague
Council of State Governments
444 North Capitol Street, NW
Suite 401
Washington, DC 20001
fax 202/624-5452
(staff: Gene Slusher)

Mr. Donald Borut
National League of Cities
1301 Pennsylvania Avenue, NW
Suite 550
Washington, DC 20004
fax 202/626-3043
(staff: Ken Rosenfeld)

Mr. Tom Cochran
U.S. Conference of Mayors
1620 Eye Street, NW
Fourth Floor
Washington, DC 20006
fax 202/293-2352
(staff: Judy Sheahan)

Mr. Larry Naake
National Association of Counties
25 Massachusetts Avenue, NW
Washington, DC 20001
fax 202/942-4281
(staff: Julie Uffner)

Mr. Robert O'Neill
International City/County Management Association
777 North Capitol Street, NE
Suite 500
Washington, DC   20002-4201
fax 202//962-3500
(staff: Mosi Kitwana)

Mr. Keith Hite
National Association of Towns and Townships
1130 Connecticut Ave, NW
Suite 300
Washington, DC   20001
fax 202/331-1598
(staff: Andrew Seth)

Mr. Mike Griffin
County Executives of America
1100 H Street, NW
Suite 910
Washington, DC 20001
fax 202/737-0556
(staff: Mike Griffin)

Mr. R. Steven Brown
Environmental Council of States
444 North Capitol Street, NW
Suite 445
Washington, DC   20001
fax 202/624-3666
(staff Lee Garrigan)

- Attachment D -

More Forums for Contacting Elected Officials

The Office of Congressional and Intergovernmental Relations (OCIR) is EPA's principal point of contact for Congress, States and local governments and is the coordination point for other EPA offices and officials to interact with these entities. [11] You are encouraged to contact OCIR as you develop your outreach and consultation plan.

Associations' Sponsored Activities

National associations of elected officials sponsor many forums, most of which are scheduled months in advance. These include:

- Policy Development Meetings
- National Meetings (in DC and elsewhere)
- Environment/Natural Resource Committee Sessions
- Program to Program Interactions
- Joint Sessions with EPA on Management Issues
- Association public policy research organizations' advisory groups
- Events and committees for stand-alone organizations created by S/L government associations (for example, Public Technology Inc).

National associations also produce publications, newsletters, "issue briefs," regulatory tracking reports, etc., which may be easy forums for communicating with elected officials.

EPA Sponsored Activities

EPA sponsors activities that can help you develop contacts or "leads" to contacts for consulting with S/L elected officials. Existing FACA committees may be a starting point. Individual members can point you toward potential work group members and resources for distributing information. OCIR can help identify those committees that might be best suited for involvement.

- Joint EPA-State Management Meetings [Such as the Water Directors, NEPPS]
- Work Group Memberships or Adjunct Memberships
- FACA Committees, especially the Local Government Advisory Committee, which is comprised principally of elected officials
- Specific Subject Meetings
- Technical Sessions
- OCIR association outreach meetings (monthly)

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[11] OCIR's Regulatory Steering Committee Representative is available to assist with your outreach to EPA's intergovernmental partners. To see an updated list of Regulatory Steering Committee Representatives or Regional Contacts, go to "intranet.epa.gov/adplibrary" and click on "Reg Steering Committee".

- Federal Register Announcements and Solicitations
- Publications for Comment, Press Notices
- Presentations, Speeches, Appearances, etc., by the Administrator or Senior Officials
- Grant and Contract Financed Subject Development Efforts
- Open Forums

Regional/State Specific Activities

EPA regions interact routinely with, and do a great deal of outreach to, State and local organizations and elected officials. Generally, for the purposes of EO 13132, these contacts are not usually focused on regulatory and policy development, but on day to day program operations. These interactions, however, do offer: (1) an opportunity for expanding consultation under the Order; and (2) a base to build from to strengthen contacts with State and local contacts.

Regionally Sponsored Activities

- State Director/Mayors' Meetings
- State Commissioners/Directors' Meetings
- Mayors' Forums
- Intergovernmental Forums
- Topical Discussion Sessions
- Regional Administrator Appearances

Other Regional Meetings

There are many regional meetings of associations of elected and appointed officials (e.g. New England Governors, Western Governors, NCSL Southern Legislative Conference, etc). Many of these groups have working environmental and natural resource committees. Again, advance planning offers an opportunity to work with association staffers and officers to include specific issues as meeting topics. Such input can prove particularly valuable when a forthcoming rule is likely to have a significant or "disproportionate" effect on certain regions of the country.

- State/Municipal Leagues, County Associations Meetings
- Regional Elected Official Meetings [Western Governor's Association, etc.]

More S/L Government Venues

- Annual Planning and Community Development Sessions
- Intergovernmental Association Meetings
- Regional Governmental Meetings
- State Agency Strategic Planning Hearings

- Attachment E -

Building a Consultation Plan: Key Elements

The Office of Congressional and Intergovernmental Relations (OCIR) is EPA's principal point of contact for Congress, States and local governments and is the coordination point for other EPA offices and officials to interact with these entities. You are encouraged to contact OCIR about your consultation plans.[12]

General Recommendations

Identify Issues, Interests and Impacts

- What are the issues?
- What are the critical time lines and events?
- Who is involved?
- Who has an interest?
- Who will be impacted and how?

Involve from the beginning

- Early consultation is ideal.
- Carefully construct work groups to ensure needed expertise.
- Consider recruiting State and local representatives as participants on work groups, particularly on rules for which states serve as principal implementers. (see ADP guidance)
- Avoid prejudgment.
- Consultation schedules should reflect critical and appropriate points for interaction.
- Allow for a full spectrum of opinion and interaction.

Plan Outreach Strategies and Mechanisms

- The outreach process also requires planning, with strategies as to audience, method of communication and content.

Involve Regional Offices

- Regional Offices should be actively involved in identifying and working with elected officials from their own States and localities.

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[12] OCIR's Regulatory Steering Committee Repsentative is available to assist with your outreach to EPA's intergovernmental partners. To see an updated list of Regulatory Steering Committee Representatives or Regional Contacts, go to “intranet.epa.gov/adplibrary” and click on “Reg Steering Committee”.

Questions to Consider

The Intergovernmental Stakeholders

- Who are the principal S/L government stakeholders likely to be affected by and interested in this rule?
- Is the rule likely to be of interest to policy-level elected and appointed officials?
- Are there particular elected officials who have expressed interest in the subject area under development?
- Which environmental or technical agencies will administer the rule?
- What other governmental entities will have to take action (e.g., pass legislation, raise funds, be subject to requirements) because of the rule?
- Are any other government agencies (e.g., economic development, transportation, agriculture) likely to be affected or have an interest?

Intergovernmental Impacts

- What is known about costs and other implications of the rule?
- Will the rule impact different government entities to different degrees or in different ways?

Unique Impacts

- Will the rule have disproportionate impacts on any particular region of the country?
- Will the rule affect urban, rural, or other types of communities differently?
- How will outreach and consultation efforts be targeted and tailored in light of these unique or disproportionate impacts?
- Will small or very small communities be affected or be presented with unique compliance issues?
- What steps will be taken to notify small governments of the planned rule and to secure their participation?

Major Issues/Areas of Concern

- What information will S/L government officials need to help them understand the potential implications of the proposed rule and why they should be interested?
- What issues are likely to be of major concern to the various categories of government officials?
- What steps should be taken to identify additional issues?

S/L Participants

- What national associations represent the interests of the various government stakeholders?
- Is there an existing EPA advisory or operations committee that can provide intergovernmental perspectives?
- What other ways can EPA solicit S/L government input?

- How will other individual S/L officials interested in the rule be identified?
- How can Regional offices assist in securing their participation?

Outreach/Consultation Activities

- What outreach and consultation efforts have already been undertaken?
- Are there more categories of potentially interested government stakeholders who have not yet been informed about the proposed rulemaking?
- What is the plan for disseminating information about the rule?
- What kinds of information/briefing materials will be needed? (key issues should be communicated in a way that elicits meaningful feedback from "policy generalists" and/or "political" audiences.)
- How will S/L government officials be involved in resolving issues and areas of concern?
- How and when will S/L officials be informed about the results of cost and other impact analyses?
- Will the Paperwork Reduction Act apply to the outreach/consultation activities?

Expertise Needed

- What kinds of expertise from S/L officials would be especially helpful in designing this regulation or policy?
  Examples include:
  -- Experts in particular technologies, industries, or scientific disciplines;
  -- Economists, lawyers, or policy analysts specializing in particular areas;
  -- Managers with experience in administering comparable programs at another level of government.
  -- How can EPA enlist the help of experts at other levels of government?

Schedule/Resources

- What is the schedule for key outreach and consultation activities?
- What resources -- staff, extramural funds, or other resources -- will be needed to carry out the consultation plan?
- What assistance is needed from other EPA offices (e.g., Regions, OCIR, OGC, OPEI?)

- Attachment F -

Presidential Documents

Federal Register
Vol. 64, No. 153
Tuesday, August 10, 1999

Title 3— Executive Order 13132 of August 4, 1999

The President **Federalism**

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to guarantee the division of governmental responsibilities between the national government and the States that was intended by the Framers of the Constitution, to ensure that the principles of federalism established by the Framers guide the executive departments and agencies in the formulation and implementation of policies, and to further the policies of the Unfunded Mandates Reform Act, it is hereby ordered as follows:

Section 1. *Definitions*. For purposes of this order:

(a) ''Policies that have federalism implications'' refers to regulations, legislative comments or proposed legislation, and other policy statements or actions that have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government

(b) ''State'' or ''States'' refer to the States of the United States of America, individually or collectively, and, where relevant, to State governments, including units of local government and other political subdivisions established by the States.

(c) ''Agency'' means any authority of the United States that is an ''agency'' under 44 U.S.C. 3502(1), other than those considered to be independent regulatory agencies, as defined in 44 U.S.C. 3502(5).

(d) ''State and local officials'' means elected officials of State and local governments or their representative national organizations.

Section 2. Fundamental Federalism Principles. In formulating and implementing policies that have federalism implications, agencies shall be guided by the following fundamental federalism principles:

(a) Federalism is rooted in the belief that issues that are not national in scope or significance are most appropriately addressed by the level of government closest to the people.

(b) The people of the States created the national government and delegated to it enumerated governmental powers. All other sovereign powers, save those expressly prohibited the States by the Constitution, are reserved to the States or to the people.

(c) The constitutional relationship among sovereign governments, State and national, is inherent in the very structure of the Constitution and is formalized in and protected by the Tenth Amendment to the Constitution.

(d) The people of the States are free, subject only to restrictions in the Constitution itself or in constitutionally authorized Acts of Congress, to define the moral, political, and legal character of their lives.

(e) The Framers recognized that the States possess unique authorities, qualities, and abilities to meet the needs of the people and should function as laboratories of democracy.

(f) The nature of our constitutional system encourages a healthy diversity in the public policies adopted by the people of the several States according to their own conditions, needs, and desires. In the search for enlightened public policy, individual States and communities are free to experiment with a variety of approaches to public issues. One-size-fits-all approaches to public policy problems can inhibit the creation of effective solutions to those problems.

(g) Acts of the national government—whether legislative, executive, or judicial in nature—that exceed the enumerated powers of that government under the Constitution violate the principle of federalism established by the Framers.

(h) Policies of the national government should recognize the responsibility of—and should encourage opportunities for—individuals, families, neighborhoods, local governments, and private associations to achieve their personal, social, and economic objectives through cooperative effort.

(i) The national government should be deferential to the States when taking action that affects the policymaking discretion of the States and should act only with the greatest caution where State or local governments have identified uncertainties regarding the constitutional or statutory authority of the national government.

Section. 3. *Federalism Policymaking Criteria*. In addition to adhering to the fundamental federalism principles set forth in section 2, agencies shall adhere, to the extent permitted by law, to the following criteria when formulating and implementing policies that have federalism implications:

(a) There shall be strict adherence to constitutional principles. Agencies shall closely examine the constitutional and statutory authority supporting any action that would limit the policymaking discretion of the States and shall carefully assess the necessity for such action. To the extent practicable, State and local officials shall be consulted before any such action is implemented. Executive Order 12372 of July 14, 1982 (‘‘Intergovernmental Review of Federal Programs’’) remains in effect for the programs and activities to which it is applicable.

(b) National action limiting the policymaking discretion of the States shall be taken only where there is constitutional and statutory authority for the action and the national activity is appropriate in light of the presence of a problem of national significance. Where there are significant uncertainties as to whether national action is authorized or appropriate, agencies shall consult with appropriate State and local officials to determine whether Federal objectives can be attained by other means.

(c) With respect to Federal statutes and regulations administered by the States, the national government shall grant the States the maximum administrative discretion possible. Intrusive Federal oversight of State administration is neither necessary nor desirable.

(d) When undertaking to formulate and implement policies that have federalism implications, agencies shall:

(1) encourage States to develop their own policies to achieve program objectives and to work with appropriate officials in other States;

(2) where possible, defer to the States to establish standards;

(3) in determining whether to establish uniform national standards, consult with appropriate State and local officials as to the need for national standards and any alternatives that would limit the scope of national standards or otherwise preserve State prerogatives and authority; and

(4) where national standards are required by Federal statutes, consult with appropriate State and local officials in developing those standards.

Section 4. *Special Requirements for Preemption.* Agencies, in taking action that preempts State law, shall act in strict accordance with governing law.

(a) Agencies shall construe, in regulations and otherwise, a Federal statute to preempt State law only where the statute contains an express preemption provision or there is some other clear evidence that the Congress intended preemption of State law, or where the exercise of State authority conflicts with the exercise of Federal authority under the Federal statute.

(b) Where a Federal statute does not preempt State law (as addressed in subsection (a) of this section), agencies shall construe any authorization in the statute for the issuance of regulations as authorizing preemption of State law by rulemaking only when the exercise of State authority directly conflicts with the exercise of Federal authority under the Federal statute or there is clear evidence to conclude that the Congress intended the agency to have the authority to preempt State law.

(c) Any regulatory preemption of State law shall be restricted to the minimum level necessary to achieve the objectives of the statute pursuant to which the regulations are promulgated.

(d) When an agency foresees the possibility of a conflict between State law and Federally protected interests within its area of regulatory responsibility, the agency shall consult, to the extent practicable, with appropriate State and local officials in an effort to avoid such a conflict.

(e) When an agency proposes to act through adjudication or rulemaking to preempt State law, the agency shall provide all affected State and local officials notice and an opportunity for appropriate participation in the proceedings.

Section 5. *Special Requirements for Legislative Proposals*. Agencies shall not submit to the Congress legislation that would:

(a) directly regulate the States in ways that would either interfere with functions essential to the States' separate and independent existence or be inconsistent with the fundamental federalism principles in section 2;

(b) attach to Federal grants conditions that are not reasonably related to the purpose of the grant; or

(c) preempt State law, unless preemption is consistent with the fundamental federalism principles set forth in section 2, and unless a clearly legitimate national purpose, consistent with the federalism policymaking criteria set forth in section 3, cannot otherwise be met.

Section 6. *Consultation.*

(a) Each agency shall have an accountable process to ensure meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications. Within 90 days after the effective date of this order, the head of each agency shall designate an official with principal responsibility for the agency's implementation of this order and that designated official shall submit to the Office of Management and Budget a description of the agency's consultation process.

(b) To the extent practicable and permitted by law, no agency shall promulgate any regulation that has federalism implications, that imposes substantial direct compliance costs on State and local governments, and that is not required by statute, unless:

(1) funds necessary to pay the direct costs incurred by the State and local governments in complying with the regulation are provided by the Federal Government; or

(2) the agency, prior to the formal promulgation of the regulation,

> (A) consulted with State and local officials early in the process of developing the proposed regulation;

(B) in a separately identified portion of the preamble to the regulation as it is to be issued in the Federal Register, provides to the Director of the Office of Management and Budget a federalism summary impact statement, which consists of a description of the extent of the agency's prior consultation with State and local officials, a summary of the nature of their concerns and the agency's position supporting the need to issue the regulation, and a statement of the extent to which the concerns of State and local officials have been met; and

© makes available to the Director of the Office of Management and Budget any written communications submitted to the agency by State and local officials.

© To the extent practicable and permitted by law, no agency shall promulgate any regulation that has federalism implications and that preempts State law, unless the agency, prior to the formal promulgation of the regulation,

(b) consulted with State and local officials early in the process of developing the proposed regulation;

(2) in a separately identified portion of the preamble to the regulation as it is to be issued in the Federal Register, provides to the Director of the Office of Management and Budget a federalism summary impact statement, which consists of a description of the extent of the agency's prior consultation with State and local officials, a summary of the nature of their concerns and the agency's position supporting the need to issue the regulation, and a statement of the extent to which the concerns of State and local officials have been met; and

(3) makes available to the Director of the Office of Management and Budget any written communications submitted to the agency by State and local officials.

Section 7. **Increasing Flexibility for State and Local Waivers.**

(b) Agencies shall review the processes under which State and local governments apply for waivers of statutory and regulatory requirements and take appropriate steps to streamline those processes.

(b) Each agency shall, to the extent practicable and permitted by law, consider any application by a State for a waiver of statutory or regulatory requirements in connection with any program administered by that agency with a general view toward increasing opportunities for utilizing flexible policy approaches at the State or local level in cases in which the proposed waiver is consistent with applicable Federal policy objectives and is otherwise appropriate.

© Each agency shall, to the extent practicable and permitted by law, render a decision upon a complete application for a waiver within 120 days of receipt of such application by the agency. If the application for a waiver is not granted, the agency shall provide the applicant with timely written notice of the decision and the reasons therefore.

(d) This section applies only to statutory or regulatory requirements that are discretionary and subject to waiver by the agency.

Section 8. *Accountability.*

(b) In transmitting any draft final regulation that has federalism implications to the Office of Management and Budget pursuant to Executive Order 12866 of September 30, 1993, each agency shall include a certification from the official designated to ensure compliance with this order stating that the requirements of this order have been met in a meaningful and timely manner.

(b) In transmitting proposed legislation that has federalism implications to the Office of Management and Budget, each agency shall include a certification from the official designated to ensure compliance with this order that all relevant requirements of this order have been met.

(c) Within 180 days after the effective date of this order, the Director of the Office of Management and Budget and the Assistant to the President for Intergovernmental Affairs shall confer with State and local officials to ensure that this order is being properly and effectively implemented.

Section 9. *Independent Agencies*. Independent regulatory agencies are encouraged to comply with the provisions of this order.

Section 10. *General Provisions*.
(a) This order shall supplement but not supersede the requirements contained in Executive Order 12372 (‘‘Intergovernmental Review of Federal Programs’’), Executive Order 12866 (‘‘Regulatory Planning and Review’’), Executive Order 12988 (‘‘Civil Justice Reform’’), and OMB Circular A–19.
(b) Executive Order 12612 (‘‘Federalism’’), Executive Order 12875 (‘‘Enhancing the Intergovernmental Partnership’’), Executive Order 13083 (‘‘Federalism’’), and Executive Order 13095 (‘‘Suspension of Executive Order 13083’’) are revoked.
(c) This order shall be effective 90 days after the date of this order. Sec. 11. Judicial Review. This order is intended only to improve the internal management of the executive branch, and is not intended to create any right or benefit, substantive or procedural, enforceable at law by a party against the United States, its agencies, its officers, or any person.

THE WHITE HOUSE,
August 4, 1999.

[FR Doc. 99–20729
Filed 8–9–99; 8:45 am]
Billing code 3195–01–P

MEETING SUMMARY

of the

EXECUTIVE COUNCIL

of the

NATIONAL ENVIRONMENTAL JUSTICE ADVISORY COUNCIL

December 3, 4, and 6 2001
Seattle, Washington

Meeting Summary Accepted By:

Charles Lee

Peggy M. Shepard

Charles Lee
Designated Federal Officer

Peggy Shepard
Acting Chair

United States
Environmental Protection
Agency

Enforcement and
Compliance Assurance
(2201A)

December 2001
http://www.epa.gov/oeca/ej

Office of Environmental Justice

To Obtain Copies

Copies of this report may be obtained by writing or calling:

U.S. Environmental Protection Agency
Office of Environmental Justice
1200 Pennsylvania Avenue (MC 2201A)
Washington, DC 20460
Telephone: (202) 564-2515

and requesting: NEJAC Meeting Summary December 2001

You may also review this report it, along with the previously published reports, on the web site: <*http://www.epa.gov/compliance/environmental justice*>

This report and recommendations has been written as a part of the activities of the National Environmental Justice Advisory Council (NEJAC), a public advisory committee providing extramural policy information and advice to the Administrator and other officials of the Environmental Protection Agency (EPA). The Council is structured to provide balanced, expert assessment of matters related to the Environmental Justice program. This report has not been reviewed for approval by the EPA and, hence, the contents of this report and recommendations do not necessarily represent the views and policies of the EPA, nor of other agencies in the Executive Branch of the federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

PREFACE

The National Environmental Justice Advisory Council (NEJAC) is a federal advisory committee that was established by charter on September 30, 1993, to provide independent advice, consultation, and recommendations to the Administrator of the U.S. Environmental Protection Agency (EPA) on matters related to environmental justice. The NEJAC is made up of 24 members, and one DFO, who serve on a parent council that has six subcommittees. Along with the NEJAC members who fill subcommittee posts, an additional 32 individuals serve on the various subcommittees. To date, NEJAC has held seventeen meetings in the following locations:

- Washington, D.C., May 20, 1994
- Albuquerque, New Mexico, August 3 through 5, 1994
- Herndon, Virginia, October 25 through 27, 1994
- Atlanta, Georgia, January 17 and 18, 1995
- Arlington, Virginia, July 25 and 26, 1995
- Washington, D.C., December 12 through 14, 1995
- Detroit, Michigan, May 29 through 31, 1996
- Baltimore, Maryland, December 10 through 12, 1996
- Wabeno, Wisconsin, May 13 through 15, 1997
- Durham, North Carolina, December 8 through 10, 1997
- Arlington, Virginia, February 23 through 24, 1998 (Special Business Meeting)
- Oakland, California, May 31 through June 2, 1998
- Baton Rouge, Louisiana, December 7 through 10, 1998
- Arlington, Virginia, November 30 through December 2, 1999
- Atlanta, Georgia, May 23 through 26, 2000
- Arlington, Virginia, December 11 through 14, 2000
- Washington, DC, August 8 through 10, 2001
- Seattle, Washington, December 3 through 6, 2001

The NEJAC also has held other meetings which include:

- Public Dialogues on Urban Revitalization and Brownfields: Envisioning Healthy and Sustainable Communities, held in Boston, Massachusetts; Philadelphia, Pennsylvania; Detroit, Michigan; Oakland, California; and Atlanta, Georgia in the Summer 1995
- Relocation Roundtable, Pensacola, Florida, May 2 through 4, 1996

- Environmental Justice Enforcement and Compliance Assurance Roundtable, San Antonio, Texas, October 17 through 19, 1996

- Environmental Justice Enforcement Roundtable, Durham, North Carolina, December 11 through 13, 1997

- International Roundtable on Environmental Justice on the U.S./Mexico Border, San Diego, California, August 19 through 21, 1999

As a federal advisory committee, the NEJAC is governed by all provisions of the Federal Advisory Committee Act (FACA) of October 6, 1972. Those requirements include:

- Members must be selected and appointed by EPA

- Members must attend and participate fully in meetings of the NEJAC

- Meetings must be open to the public, except as specified by the EPA Administrator

- All meetings must be announced in the Federal Register

- Public participation must be allowed at all public meetings

- The public must be provided access to materials distributed during the meeting

- Meeting minutes must be kept and made available to the public

- A designated federal official (DFO) must be present at all meetings of the NEJAC (and its subcommittees)

- The NEJAC must provide independent judgment that is not influenced by special interest groups

Each subcommittee, formed to deal with a specific topic and to facilitate the conduct of the business of the NEJAC, has a DFO and is governed by the provisions of FACA. Subcommittees of the NEJAC meet independently of the full NEJAC and present their findings to the NEJAC for review. Subcommittees cannot make recommendations independently to EPA. In addition to the six subcommittees, the NEJAC has established a Protocol Committee, the members of which are the chair of the NEJAC and the chair of each subcommittee.

Members of the Executive Council of the NEJAC are presented in the table on the following page. A list of the members of each of the six subcommittees are presented in the appropriate chapters of the report.

EPA's Office of Environmental Justice (OEJ) maintains transcripts of, summary reports on the meetings of the NEJAC, and copies of material distributed during the meetings. Those documents are available to the public upon request.

Comments or questions can be directed to OEJ through the Internet. OEJ's e-mail address is:

environmental-justice-epa@.epa.gov

Executive summaries of the reports on the meetings of the NEJAC are available in English and Spanish on the Internet at the NEJAC's World Wide Web home page:

<http://www.epa.gov/compliance/environmentaljustice/index.html> (click on the link to the National Environmental Justice Advisory Council)

NATIONAL ENVIRONMENTAL JUSTICE ADVISORY COUNCIL
MEMBERS OF THE EXECUTIVE COUNCIL
(2001)

Designated Federal Official:
Mr. Charles Lee, Associate Director for Policy and Interagency Liasion, U.S. Environmental Protection Agency Office of Environmental Justice

Chair:
Ms. Peggy Shepard

Members

Ms. Rose Augustine
Mr. Larry Charles
Mr. Fernando Cuevas
Ms. Anna Frazier
Mr. Michel Gelobter
Ms. Eileen Guana
Mr. Richard Gragg
Ms. Savonala Horne
Ms. Jennifer Hill-Kelly
Mr. Robert Harris
Ms. Annabelle Jaramillo
Mr. Harold Mitchell
Mr. David Moore
Ms. Mary Nelson
Ms. Graciela Ramirez-Toro
Mr. Alberto Saldamando
Ms. Jane Stahl
Ms. Wilma Subra
Ms. Jana Walker
Mr. Kenneth Warren
Ms. Pat K. Wood
Mr. Tseming Yang

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EXECUTIVE SUMMARY

INTRODUCTION

This executive summary presents highlights of the sixteenth meeting of the National Environmental Justice Advisory Council (NEJAC), held December 3 through 5, 2001 at the Renaissance Madison Hotel in Seattle, Washington. Each of the six subcommittees of the NEJAC met for a full day on December 5, 2001. On December 4, the NEJAC hosted a public comment period that focused on fish consumption and contamination of fish populations. Approximately 300 persons attended the meetings and the public comment period.

The NEJAC is a federal advisory committee that was established by charter on September 30, 1993 to provide independent advice, consultation, and recommendations to the Administrator of the U.S. Environmental Protection Agency (EPA) on matters related to environmental justice. Ms. Peggy Shepard, West Harlem Environmental Action, serves as the chair of the Executive Council of the NEJAC. Mr. Charles Lee, Associate Director for Policy and Interagency Liaison, EPA Office of Environmental Justice (OEJ), serves as the Designated Federal Officer (DFO) for the Executive Council. Exhibit ES-1 lists the chair, the vice-chair, and the DFO of the Executive Council, as well as the individuals who serve as chairs and vice-chairs of the six subcommittees of the NEJAC and the EPA staff appointed to serve as DFOs for those subcommittees.

OEJ maintains transcripts and summary reports of the proceedings of the meetings of the NEJAC. Those documents are available to the public upon request. The public also has access to the executive summaries of reports of previous meetings, as well as other publications of the NEJAC, through the World Wide Web at <*http://www.epa.gov/oeca/main/ej/nejac/index.html*> (click on the publications icon). The summaries are available in both English and Spanish.

Exhibit ES-1

NATIONAL ENVIRONMENTAL JUSTICE ADVISORY COUNCIL CHAIRS AND DESIGNATED FEDERAL OFFICERS (DFO)

Executive Council:
- Ms. Peggy Shepard, **Chair**
- Mr. Charles Lee, **DFO**

Air and Water Subcommittee:
- Ms. Annabelle Jaramillo, **Chair**
- Ms. Eileen Guana, **Vice-Chair**
- Ms. Alice Walker, **co-DFO**
- Dr. Wil Wilson, **co-DFO**

Enforcement Subcommittee:
- Ms. Savonala Horne, **Chair**
- Mr. Robert Kuehn, **Vice-Chair**
- Ms. Shirley Pate, **DFO**

Health and Research Subcommittee:
- Ms. Rose Marie Augustine, **Chair**
- Ms . Jane Stahl, **Vice-Chair**
- Ms. Brenda Washington, **co-DFO**
- Ms. Aretha Brockett, **co-DFO**

Indigenous Peoples Subcommittee:
- Ms. Jennifer Hill-Kelly, **Chair**
- Ms. Jana Walker, **Vice-Chair**
- Mr. Daniel Gogal, **DFO**
- Mr. Bob Smith, **alternate-DFO**

International Subcommittee:
- Mr. Alberto Saldamando, **Chair**
- Mr. Tseming Yang, **Vice-Chair**
- Ms. Wendy Graham, **DFO**

Puerto Rico Subcommittee:
- Dr. Graciela Ramirez-Toro, **Chair**
- Ms. Teresita Rodriguez, **DFO**

Waste and Facility Siting Subcommittee:
- Ms. Veronica Eady, **Chair**
- Mr. Reiniero Rivera, **DFO**

REMARKS

Mr. Ron Kreizenbeck, Deputy Regional Administrator, EPA Region 10, welcomed the participants in the meeting of the NEJAC to Seattle. He stated that EPA Region 10 includes the states of Washington, Oregon, Idaho, and Alaska and is home to many diverse, low-income communities; communities of color; and more than 270 native tribes, the members of which subsist on fish, plants, and wildlife. The degradation of habitats and depletion of resources threatens the very way of life of those people, he continued. Mr. Kreizenbeck then stated that issues related to subsistence life styles must be addressed to ensure equal environmental protection, regardless of race, income, culture, or ethnicity.

Governor Gary Locke, (D), sent greetings to the members of the NEJAC, welcoming them to Seattle. In his letter, Governor Locke emphasized that the issues related to water quality and fish consumption were especially important to the residents of Washington. Exhibit 1-2 in Chapter One of this report contains a copy of that letter.

Ms. Rosa Franklin, State Senator, Washington State Legislature and former member of the NEJAC, commented on the timeliness of the current meeting of the NEJAC, held to discuss the relationship between among water quality, fish consumption, and environmental justice. While contaminated air and toxic streams affect all citizens, she continued, the changing demographics in the state of Washington and the Pacific Northwest have brought a new urgency to the issue of fish consumption. Therefore, she said, there is an urgent need in the region to further identify and quantify the types and magnitudes of risks to communities and tribes that subsist on wild fish, plants, and other wildlife. Ms. Franklin stressed that the activities of the NEJAC could have a long-term effect on the health of those communities.

Ms Velma Veloria, Washington State Representatives and former member of the NEJAC, explained that the state of Washington had worked over the past three years to ensure that water is clean and that fish populations continue to flourish in the state of Washington. She discussed environmental justice legislation passed in the state, including a bill that charged the state's Department of Ecology and Department of Health with jointly preparing a report on environmental risks faced by low-income and minority groups; legislation that reformed the way work at cleanup sites is taxed; and legislation that requires the Department of Health to examine the health effects of noise, particularly in the vicinity of the city of Seattle's international airport.

Ms. Yalonda Sinde, Community Coalition for Environmental Justice, stated that her organization had been the first non-profit environmental justice group in the Seattle area. She then expressed her excitement about the opportunity to bring issues related to fish consumption and water quality before the NEJAC during the current meeting.

Mr. Moses Squeochs, Yakima Nation and member of the Indigenous Peoples Subcommittee, stated his appreciation for the efforts of the NEJAC, but he also expressed concern that such a federal advisory committee is needed to carry out the laws related to environmental justice enacted by the Congress of the United States. Continuing, he said that the "hunter-gatherer" way of life continues to be practiced and that there is a strong intent to preserve that way of life. He then stated that the search for justice, fairness, and equality in relation to environmental issues must continue.

REPORTS AND PRESENTATIONS

The members of the Executive Council received the following presentations:

Members of the NEJAC Fish Consumption Work Group provided an update on the NEJAC's *Draft Fish Consumption Report*. During their presentation, the members of the work group reviewed the findings of the work group, as outlined in the *Draft Fish Consumption Report* that had been compiled in preparation for the December 2001 meeting of the NEJAC. The members of the Fish Consumption Work Group also presented a number of "overarching recommendations" based on the conclusions presented in the draft report. The members of the NEJAC then discussed the report and the recommendations at length, suggesting revisions in the draft report and identifying additional recommendations. Members of the NEJAC requested that final comments on the *Draft Fish Consumption Report* be submitted to OEJ by January 31, 2002. The anticipated date for completion of the report is March 15, 2002. Mr. Lee stated that a conference call was to be scheduled with affected communities, tribes, and stakeholders to discuss the report.

Ms. Shepard presented the NEJAC's *Strategic Plan* to the members of the Executive Council. The plan incorporates the issues raised and conclusions reached during the special business meeting of the Executive Council of the NEJAC, held in Washington, D.C. in August 2001, and outlines the strategy of the NEJAC for: (1) redesigning its activities to better fulfill its role as an advisor; (2) collaborating with EPA to provide alternative mechanisms through which communities can bring site-specific issues to the attention of EPA; and (3) developing, through a deliberative process that involves all stakeholders, an effective work product that addressed issues related to environmental justice that are of principal concern to communities. The *strategic plan* will guide the work of the NEJAC through September 27, 2003, Ms. Shepard announced.

Mr. Lee identified a series of tasks and provided assignments to members of the NEJAC to assist in implementing the strategic plan. The tasks are:

Finalization of the NEJAC Policy Advice Development Model
Finalization of the NEJAC Model for incorporating community issues and concerns into the NEJAC policy dialogue
Development of definitions of consensus and consensus-building
Development of a scoping report from the Ad Hoc Scoping Work Group on Cumulative Risk Issues

WORK GROUP REPORTS AND COMMENTS

The members of the Executive Council of the NEJAC received reports and comments from the following individuals:

- Ms. Eileen Guana, Southwestern University School of Lawn and Vice-Chair of the Air and Water Subcommittee, made a presentation on the Interagency Environmental Justice Implementation Work Group.

- Mr. Brandon Carter, EPA Federal Facilities Restoration and Reuse Office (FFRRO), provided an update on the Federal Facilities Work Group.

- Ms. Wilma Subra, Louisiana Environmental Action Now, member of the Air and Water Subcommittee, and chair of the newly formed Pollution Prevention Work Group, presented an update on the status of the development of the work group.

Mr. Lee reported that the Federal Facilities Work Group will work in coordination with and report to the NEJAC Waste and Facility Siting Subcommittee because the primary support for this work group is being provided by the Office of Solid Waste and Emergency Response (OSWER), which also supports that subcommittee. OSWER has committed to adding another member to the subcommittee to provide interface with the work group, he said.

Other presentations received by the Executive Council of the NEJAC were:

- Mr. Barry Hill, Director, EPA OEJ, reported on the status of EPA's efforts to implement recommendations included in the report of the Environmental Law Institute (ELI) report titled *Opportunities for Advancing Environmental Justice: An Analysis of U.S. EPA Statutory Authorities*. The ELI report reviews EPA's major environmental regulations that govern air and water quality, waste management, use of pesticides and other chemicals, and the public's right to know. The report identifies specific statutory authorities that can be used to promote environmental justice in the full range of EPA program functions, including the establishment of standards and the permitting process.

- Ms. Ann Goode, Senior Consultant, Center for the Economy and Environment, National Academy of Public Administration (NAPA), made a presentation on NAPA's research and evaluation of EPA's efforts to address the widely recognized fact that low-income communities and communities of people of color that are exposed to significantly greater environmental and public health hazards than other communities face. NAPA's research and associated recommendations, reported Ms. Goode, are presented in a report titled *Environmental Justice in EPA Permitting: Reducing Pollution in High-Risk Communities is Integral to the Agency's Mission."* In the report, she continued, NAPA recommends that EPA make changes in four distinct areas related to environmental justice: leadership, permitting procedures, setting of priorities, and public participation.

- Mr. Martin Halper, Senior Science Advisor, EPA OEJ, provided an overview of EPA's draft *Framework for Cumulative Risk Assessment* prepared by the Cumulative Risk Technical Panel of the EPA Risk Assessment Forum, a standing committee of senior EPA scientists. The purpose of this briefing is to help NEJAC prepare to address the issues of cumulative risk, which will be the policy issue area to be discussed in 2003.

VIRTUAL TOUR AND RELATED DIALOGUE

Members of the NEJAC participated in a "virtual tour" dialogue of selected communities that are affected by issues related to environmental justice, fish consumption, and water quality. Representatives of five community organizations presented information about the contamination of waterways on which Native Americans and impoverished people depend for survival and the loss of Native American heritage and culture, as well as issues related to the exposure of farm workers to pesticides and herbicides. The topics discussed are described briefly below.

Mr. Frank Roberts, Coeur d'Alene Tribe, Idaho, discussed the exposure of the Coeur d'Alene Tribe to contamination caused by strip mining practices carried out on properties located near tribal lands. Mr. Roberts explained that, although contamination currently is being cleaned up, preservation of tribal culture has been threatened because the tribe cannot use the land for traditional purposes.

Mr. Daniel Morfin, Granger, Washington, explained that the application of herbicides and pesticides for agriculture use is contaminating rivers and exposing farm workers to contaminants. The incidence of respiratory ailments in the Granger area is high, and existing regulations are not being enforced, said Mr. Morfin.

Ms. Jeri Sundvall, Environmental Justice Action Group of Portland, Portland, Oregon, pointed out the high rate of cancer among Native American fishermen. In addition, she charged, Native Americans are being robbed of their heritage and are expected to become assimilated into the broader culture.

Ms. Rosemary Ahtuangaruak Inupiat Community of Arctic Slope, Barrow, Alaska, expressed concern that state agencies often "favor profit" over protection of the interests and concerns of tribes. Ms. Ahtuangaruak explained that, although federal agencies have declared fish populations safe to eat, the methodology for assessing risk does not consider the higher-than-average rates of fish consumption among Native Americans.

Ms. Lee Tanuvasa, Korean Woman's Association, Tacoma, Washington, reported that her organization was conducting a study to determine the safety of shellfish consumed by communities of Asian Pacific Island people. She requested assistance in overcoming the language barrier and in determining how best to present the findings of the study to the communities affected by the issue.

PUBLIC COMMENT PERIOD

The Executive Council of the NEJAC hosted a public comment period on December 4, 2001, at which approximately 29 people participated. Described below are a summary of key concerns citizens expressed during the evening session.

- A majority of the public comments focused on the issue of contaminated waterways and the land on which Native Americans and other impoverished people depend for living a subsistence life style. Commenters pointed to rates of cancer and respiratory ailments among Native American populations that are higher than the rates among non-Native populations in the United States. The commenters stated that the inability of Native peoples to "live off the land" has led to a decline in the transfer of spiritual and cultural values from generation to generation. The best way to reduce contamination in waterways is to eliminate the source of the pollution, declared a number of commenters.

- Several commenters spoke about the ineffectiveness of risk assessments. Risk assessments, as currently conducted, do not account for the cumulative effect of numerous chemicals on the environment, they stated. Rather, those risk assessments examine only a single chemical, they claimed. Risk assessments focus only on cancer and fail to consider other health issues, they added. Further, they do not account for the effect of chemicals on sensitive populations, several commenters noted.

- A number of commenters criticized EPA for failing to make an adequate effort to hold the U.S. Department of Defense (DoD) accountable for the contamination of communities located on or near military installations. EPA is not enforcing existing environmental regulations that govern DoD facilities, the commenters claimed.

OTHER CONCERNS AND COMMITMENTS OF THE NEJAC

During their meeting, the members of the Executive Council of the NEJAC recommended that a work group be established to address communications within the NEJAC and between the NEJAC and EPA program offices. In addition, the members agreed to review and provide comments on the *Framework for Cumulative Risk Assessment.* Formal development of the guidance will begin in 2002.

SUMMARIES OF THE SUBCOMMITTEE MEETINGS

Summarized below are the deliberations of the subcommittees of the NEJAC held on December 5, 2001.

Air and Water Subcommittee

The members of the Air and Water Subcommittee of the NEJAC received the presentations and reports described below and discussed the topics summarized.

Mr. James Hanlon, EPA Office of Science and Technology (OST), provided preliminary comment on the feasibility of implementing the recommendations presented in the NEJAC's *Draft Fish Consumption Report*. Mr. Hanlon commended the Fish Consumption Work Group for its efforts and emphasized that the availability of resources for the most part will determine what EPA can accomplish. Mr. Hanlon also reviewed the logistics associated with the completion of the report and its submittal to the EPA Administrator.

Mr. Lee presented an overview of and led discussions about the NEJAC *Strategic Plan*. He also discussed the meeting of the NEJAC scheduled for December 2002 that will focus on issues related to pollution prevention and environmental justice.

Mr. Jeff Bigler, EPA OST, provided to the Fish Consumption Work Group an update on plans to revise volume four of EPA's *Guidance Document for Assessing Chemical Contamination Data for Use in Fish Advisories* to incorporate awareness of issues related to environmental justice.

Mr. Peter Murchie, EPA Region 10 Office of Air Quality Planning and Standards (OAQPS), presented to the Air Toxics Work Group an overview of EPA's air toxics program.

The members of the subcommittee discussed the need to establish priorities among the recommendations presented in the *Draft Fish Consumption Report* to (1) help EPA focus its efforts and (2) avoid overwhelming the agency with numerous recommendations. The members agreed that, although the list of recommendations may appear lengthy, individual items can be grouped under a few overall themes.

The members of the subcommittee discussed the potential effect of the *NEJAC Strategic Plan* on the manner in which the subcommittee conducts its business. The members agreed that the subcommittee must focus its efforts on only a few key issues, rather than attempting to "cover the whole waterfront" as it had done in its early days. The members also agreed to explore methods of evaluating the effectiveness of the subcommittee's work groups on specific issues.

The members of the subcommittee emphasized that the work of the Fish Consumption Work Group must be used as a model to guide planning for the meeting of the NEJAC to be held in December 2002. The members also requested that, in preparation for that meeting, the newly formed Pollution Prevention Work

Group should examine issues related to (1) environmental restoration, (2) clean production, (3) low-impact development, and (3) the costs and benefits of pollution prevention.

Members of the Fish Consumption Work Group discussed the plans of EPA's Office of Water to revise volume four of its *Guidance Document for Assessing Chemical Contamination Data for Use in Fish Advisories*. The members of the work group agreed to (1) review the document and provide comment on it to EPA and (2) identify and recommend individuals to serve on various EPA stakeholder work groups and as technical consultants for the issuance of fish advisories. The members of the subcommittee also discussed the future of the Fish Consumption Work Group, once the *Draft Fish Consumption Report* has been completed. The members recommended that the work group expand its scope to explore other issues related to water quality, such as total maximum daily loads (TMDL), confined animal feeding operations (CAFO), and water permits.

The Permitting and Public Utilities work groups participated in a joint session, during which they agreed to combine the two groups into a single work group. The members of the work groups discussed EPA's White Paper No. 3 on flexible permitting, a report on a new source review study prepared by EPA's Office of Air and Radiation (OAR), and other issues related to the permitting process. The members of the newly combined work group agreed to develop a document that will describe "best practices" for permitting that are sensitive to environmental justice issues, as well as review and provide comment on the report on a new source review study the release of which is expected in January or February 2002. Members of the work group also expressed concern that staffing of the work group was inadequate, in light of the number of issues the group had taken under consideration.

The members of the Air Toxics Work Group discussed EPA's air toxics program. The members agreed to review and provide comment on EPA OAR's *Work Plan for the National Air Toxics and Integrated Air Toxics Strategy.*

Health and Research Subcommittee

The members of the Health and Research Subcommittee of the NEJAC received the presentations and reports described below and discussed the topics summarized.

Mr. Patrick C. West, Emeritus Faculty, Environmental Sociology, School of Natural Resources and Environment, University of Michigan, commented on research needed in the realm of environmental justice and application of that research. Mr. West stated that lack of research should not be a barrier to action, that existing information can be used, and that current research must be investigated to identify the information to support action. Mr. West stressed that systematic and qualitative assessment of both cumulative effects and co-risk factors must be included in the assessment of risks for such sensitive groups as communities of color, low-income communities, and Native American tribes.

Ms. Tala Henry, Mid-Continent Ecology Division, EPA National Health and Environmental Effects Research Laboratory, provided information about the parameters that are factors in the calculation of risk. She emphasized that there is no specific procedure for the calculation of risk and that the default parameters are not applicable under certain circumstances, such as assessment of the risks to sensitive groups. Therefore, she explained, partnerships between experts and communities must be fostered so that defensible and appropriate risk parameters can be established.

Mr. Wardner G. Penberthy, EPA Chemical Control Division, presented an overview of Section 4 of the Toxic Substances and Control Act, which focuses on chemical testing. He provided detailed information about EPA's High Production Volume (HPV) Challenge program, a voluntary testing program for facilities that produce large volumes of chemicals. The goal of the program is to increase the availability to the public of baseline data on the effects on health and the environment for approximately 2,800 HPV chemicals, reported Mr. Penberthy.

Mr. Jeffrey Morris, EPA Office of Science Policy, Office of Research and Development (ORD), recommended a change in the structure of the subcommittees of the NEJAC. Citing EPA's goals related to the Government Performance and Results Act (GPRA), Mr. Morris explained that, because health and research issues related to environmental justice cross boundaries among the various subcommittees, such issues should be handled by a special interest work group, rather than an individual subcommittee.

The members of the subcommittee conducted a number of discussions about the accurate calculation of risk for sensitive groups. The specific recommendations they agreed upon are:

- It is essential that various factors related to cultural and spiritual concerns be included in models for assessing risk. In addition, such factors as culture shock and cultural disintegration must be addressed.
- Parameters used in the calculation of risk must be specific to each particular community. Parameters that currently are not included in risk assessment models include peak exposure and consumption of whole fish, rather than the more widely used parameters of chronic exposure and consumption of only the fillet of a fish.
- The types of foods identified as components of a subsistence diet should include many more foods that are not consumed by the general population.
- Co-risk and cumulative risk factors should be used as a more accurate gauge of “true risk” because people are exposed to more than one chemical at a time.
- If the recommendations of the subcommittee on the subject of calculation of risk are to be adopted, the definitions of “health” for a community and of what is to be considered “normal” must be reconsidered.

The subcommittee recommended that the NEJAC consider the subsistence consumption needs of such groups as Native Hawaiians and people in the Virgin Islands who were not considered as the report was developed. The members of the subcommittee agreed that inclusion of those groups would help achieve recognition of cultural groups that traditionally have been ignored in research related to environmental justice.

The members of the subcommittee agreed that the need for research often is used as a barrier to action and acknowledged that the information available is adequate to support the initiation of work. There is an abundance of information that, although originally was not applied to issues of environmental justice, can be reevaluated for its significance in the field of environmental justice, they noted. In addition, the members recommended that extensive investigation of previous research be conducted to identify available resources.

The members of the subcommittee agreed that the evaluation of HPV chemicals and the distribution to the public of the baseline health data are crucial actions. Although some members expressed concern about whether industry could be trusted to report reliably on production, the members agreed that there are many safeguards related to testing and that the penalty for falsification is severe.

The subcommittee recommended increased cooperation between government agencies and local organizations in sharing data and calling upon the expertise of indigenous organizations. Noting that local people have first-hand knowledge and understanding of their communities and can gather information more efficiently than outsiders, the members recommended that research be best conducted by local groups, with the assistance and support of EPA.

Indigenous Peoples Subcommittee

The members of the Indigenous Peoples Subcommittee of the NEJAC received the presentations and reports described below and discussed the topics summarized.

Mr. Merv George, Administrator, Klamath River Inter-Tribal Fish and Water Council and member of the Hupa Tribe, provided background information about the history of the council, outlined the five issues the council addresses, and submitted his recommendations for improving the *Draft Fish Consumption Report*.

He stressed that the Hupa and Yura tribes constantly must balance environmental and economic issues when developing standards for water quality.

Ms. Gillian Mittelsteadt, Environmental Policy Analyst, Tulalip Tribes Natural Resource Program, and Mr. Daryl Williams, Developer, Tulalip Tribes Natural Resource Program, presented the results of their study that examined the consumption by members of the Tulalip Tribe of fish taken from Puget Sound. Ms. Mittelsteadt described the statistical framework of the study and outlined the benefits and lessons learned through completion of the study. Mr. Williams discussed the problems that arise because, he said, programs allow the trading of pollution emissions credits. Mr. Williams emphasized the negative effects such programs have on tribal communities.

Mr. Tom Goldtooth, Executive Director, Indigenous Environmental Network and former chair of the Indigenous Peoples Subcommittee, presented his recommendations for improving the *Draft Fish Consumption Report*. He urged that the NEJAC consider the negative effects of radioactive contaminants on habitats and focus attention on precautionary actions, rather than traditional risk assessment. He also recommended that the NEJAC promote outreach to tribal communities to help those communities develop a better understanding of the mission and responsibilities of the NEJAC.

Dr. Roseanne Lorenzana, liaison between Region 10 and EPA ORD, presented a list of five specific recommendations for consideration by the subcommittee. She also presented the report *Comparative Dietary Risks: Balancing the Risks and Benefits of Fish Consumption*, for which a risk assessment model was used to define the conditions under which consumption of fish is a healthful dietary choice. She urged that the subcommittee advise EPA to work with tribes to develop guidelines on cumulative risk that are appropriate to the needs of tribes.

Ms. June Martin, Alaska Community Action on Toxics, began her presentation by telling the story of Annie Aloa, a health aide in her village who had spoken out on behalf of the tribal community and who had been awarded a grant by the National Institute for Environmental Health Sciences (NIEHS) to survey the health problems of members of the tribe. Ms. Martin then discussed the failure of the U.S. Army Corps of Engineers to clean up the military facility located near her village.

Ms. Ahtuangaruak, who is a native of the village of Nuigant, Alaska, expressed her concern about and recommendations for improving the representation of Alaskan Natives on the Indigenous Peoples Subcommittee. She also urged that, in the *Draft Fish Consumption Report*, the subcommittee address the tribal lands of Alaskan Natives, such as Prudhoe Bay. Residents of those lands, she pointed out, rely on fishing and whaling for subsistence.

Ms. Pam Miller, Alaska Community Action on Toxics, expressed concern about the health of Alaskan Natives tribal communities that are located on or near sites that have been abandoned by DoD. She also voiced the concern of tribes about persistent organic pollutants (POP) that originate thousands of miles south of Alaska, travel northward, and accumulate over northern Alaska. She requested that the subcommittee advise EPA to hold DoD accountable for previous contamination and to focus on the phased elimination of POPs.

Mr. Enoch Sheidt, Subsistence Coordinator, Maniilaq Association, and Mr. Francis Chin, Environmental Justice Coordinator, Maniilaq Association, emphasized the importance of a subsistence lifestyle to Alaskan Natives who are nomadic and migrate to locations where food is available. Consequently, the presenters reported, tribes do not recognize the concept of “on reservation” and “off reservation.” To an Alaskan Natives, fishing is not merely a method of obtaining food, but rather is a spiritual experience, they explained. In addition, Mr. Chin stated that the unemployment rate in the Indian community is 90 to 95 percent. Therefore, a subsistence lifestyle is an essential way of life that cannot be compromised, he said.

Mr. Art C. Ivanoff, Native Village of Unalakleet, expressed his concern about the effects of climate change on the health of Alaskan Natives. Mr. Ivanoff requested that the *Draft Fish Consumption Report* include climate change as a factor that affects the quality of fish. Climate change has depleted greatly the running stock of salmon, while the migration patterns of salmon and animals used for food have not been studied sufficiently, he explained.

Ms. Cheryl Steele, Elem Indian Colony, stated that fish advisories do not address issues related to the consumption of fish sufficiently. She urged that EPA provide indigenous peoples better guidance about contaminated fish populations and that the agency work with local communities to eliminate sources of contamination.

Mr. Kevin McKernan, Yurok Tribe, urged EPA to acknowledge those tribes that have developed and adopted water quality standards. He stated that the use of EPA core standards might direct resources away from tribes that have their own standards.

Ms. August Rozema, Swinomish Tribe, stated that the subcommittee and the NEJAC must "spread the word" about its future meetings. She also encouraged the subcommittee to clarify the definition of the word "fish" provided in the *Draft Fish Consumption Report* to include both fin- and shellfish.

The members of the subcommittee requested that the Alaskan Native community provide them more information about issues related to fish consumption and water quality standards. After listening to testimony offered by representatives of Alaskan Native communities, the members recognized that the concerns of all indigenous peoples throughout the world, including those of Hawaii and the Caribbean, also must be represented equally.

The members of the subcommittee discussed the effectiveness of risk assessment in adequately addressing issues related to fish consumption, noting that traditional risk assessment models currently do not include reference to pollution prevention and sustainability. The members recommended that a "precautionary principle" approach to risk assessment replace the traditional model to account for the benefits of preservation. The members also noted that risk assessment currently does not take into account the fact that the variable average grams per day (gpd) used in most models cannot be extrapolated to the lifestyle of members of indigenous communities, who consume many more fish in a much shorter period of time than do members of other groups, thereby increasing their risk to a level disproportionate to that affecting other groups.

The members expressed concern that fewer than 20 WQSs created by individual tribal communities have been approved. Additional discussion focused on the difficulties tribal communities encounter in their efforts to achieve the standards outlined in the WQSs because of economic setbacks.

The members of the subcommittee agreed to advise the NEJAC to urge EPA to augment its education programs for tribal communities by providing more information about the role of the NEJAC. In addition, the members recommended that tribes be included regularly in the deliberative process and that the subcommittee change its role from that of "consultation" to that of "collaboration," a role that would include deliberative dialogue. Such a change would improve communication between the NEJAC and indigenous communities, they suggested.

International Subcommittee

The members of the International Subcommittee of the NEJAC received the presentations and reports described below and discussed the topics summarized.

Mr. Goldtooth discussed the need to focus on issues of environmental justice related to transborder matters that affect the First Peoples of North America and indigenous tribes in the Great Lakes basin. He reported that First Nations and tribes in the Great Lakes basin suffer a disproportionate share of environmental problems associated with the transport of POPs. The effects of POPs are intensified among people who rely on a subsistence diet, he pointed out.

Ms. Katy Taylor, Assistant Director of Community Health Services, Alaska Native Tribal Health Services, presented an overview of recent studies of the effects of POPs on the health of Alaskan Native women and children who rely on subsistence consumption as the mainstay of their diets.

Ms. Miller provided information about the movement of POPs, facilitated by air and ocean currents, into Alaska and the Arctic region. She also discussed contamination of DoD sites in Alaska.

Ms. Amy Fraenkel, EPA Office of International Activities (OIA), addressed the transborder risks associated with exposure to POPs. She also presented information about progress toward completion of the Global Persistent Organic Pollutants Treaty (also known as the Stockholm POPs Convention). She emphasized that environmental justice groups must work to influence the process of planning how the United States will implement the provisions of the treaty.

Ms. Eileen Henninger, EPA OIA, stated that it is important that the NEJAC provide comment to OIA on issues related to biodiversity. Some of the work in that area will bring about major worldwide reductions in the use of key harmful chemicals in farming and industrial applications, she said.

Mr. Lionel L. Brown Jr., Senior Information Management Officer, EPA OIA, presented an update on the efforts of OIA to promote environmental awareness in Africa. Many areas in Africa are experiencing rapid urbanization, he reported, adding that OIA has been working to educate local communities about issues related to environmental justice. Mr. Brown also emphasized the heavy reliance on fish in the diets of African people.

Mr. Enrique Manzanilla, Director, Cross Media Division, EPA Region 9, provided background information about EPA's work related to the border areas of the United States and Mexico. He reviewed the activities undertaken by Region 9 during the two years since the Roundtable on Environmental Justice on the U.S.-Mexico Border was held in San Diego, California and reported on the success of outreach efforts conducted by the Region 9 Border Liaison Office, located in San Diego.

Ms. Olivia Balandran, Office of the Regional Administrator, EPA Region 6, presented an update on the outreach activities of the region's border office. She reported that the recent activities of that office included efforts to respond to the recommendations presented at the roundtable meeting on the U.S.-Mexico border.

Ms. Nelda Pérez, Small Grants Coordinator, EPA Region 6 OEJ, presented information about activities related to grants awarded to groups located in the U.S.-Mexico border area.

Mr. Richard Moore, Executive Director, Southwest Network for Environmental and Economic Justice, and former chair of the NEJAC, described letters his organization had written to EPA Administrator Christine Todd Whitman and President Bush. Mr. Moore discussed the effects of increased militarization along the U.S.-Mexico border that has taken place since the terrorist attacks of September 11, 2001. He also requested that the subcommittee complete the reports produced for the Roundtable on Environmental Justice on the U.S.-Mexico Border and prepared by the NEJAC Farm Worker Work Group.

Mr. Apichart Thongyou, Secretary General, Thailand Research and Action for Development Institute, discussed efforts undertaken in Thailand to reduce adverse effects on conditions of concern to the environmental justice community that are caused by modernization and the development of heavy industry. He and several other members of the delegation of visitors from Thailand discussed several studies that examined heavy contamination by industry and its effect on fishermen who rely on fishing for subsistence. Mr. Thongyou also described the work of EPA and its counterpart in Thailand to create a public participation process, reauthorize environmental laws, and create a new ministry for the environment.

The members of the subcommittee also participated in discussions related to various topics:

- The members of the subcommittee identified similarities in the shortcomings of enforcement and public participation efforts in Thailand and other nations. They discussed the value of, and the need for, an international environmental network to support the transfer of information and data.

- The members of the subcommittee concluded that the NEJAC and OIA should collaborate to build a strong relationship between the work of OIA in Africa and the environmental issues addressed by the NEJAC.

- The members of the subcommittee discussed OIA's strategy of deploying culturally diverse teams to represent EPA in international discussions. The members concluded that such a strategy is essential in engaging communities in discussions of treaties and encouraging collaboration between the United States and other countries in the sharing of resources.

- The members agreed that practices that contaminate water in one country and thereby affect the health of residents of another country illustrate the "interconnectedness" of the global environment. The members noted the similarity of the predicaments of subsistence fisherman in the United States and other nations.

- The members of the subcommittee concluded that there is a significant opportunity for the NEJAC to participate in the development of the plan for the implementation by the United States of the Stockholm POPs Convention. They also agreed to provide comment to OIA about the level of implementation of the treaty. In addition, the members discussed the need to include in the treaty provisions for a system for tracking the movement of POPs across the borders of the United States.

Waste and Facility Siting Subcommittee

The members of the Waste and Facility Siting Subcommittee of the NEJAC received the presentations and reports described below and discussed the topics summarized.

Mr. Michael Shapiro, Deputy Assistant Administrator, EPA Office of Solid Waste and Emergency Response (OSWER), and Ms. Linda Garczynski, EPA OSWER, provided an overview of the direction new senior managers plan for OSWER. They discussed the vision, mission, priorities, and values of the office, reviewed changes that are taking place, and identified several key priorities for OSWER:

- Pursuit of the One Cleanup Program Initiative, which is designed to make the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) programs more consistent with one another and to increase the right-to-know component of each.

- Establishment of revitalization and reuse as core issues of the OSWER action agenda.

- Implementation of recycling and pollution prevention programs to encourage partnerships and demonstration pilot projects in the area of reduction in source contamination.

- Implementation of the Retail Initiative, which is designed to increase focus on public involvement in the use of solid and hazardous waste and improve dialogue among communities.

- Implementation of work force development programs to strengthen the effort to train new staff of OSWER to meet its future challenges.

Mr. Samuel J. Coleman, EPA Region 6, provided an update on issues of environmental justice that affect the community of Mossville, Calcasieu Parish, Louisiana. Mr. Coleman identified several specific milestones:

- Installation of an enhanced air monitoring network sanctioned by the Lake Area Industrial Alliance and the Louisiana Department of Environmental Protection (LDEP).

- Achievement of overall compliance with the requirements of LDEP and establishment of parishwide dioxin screening as a standard procedure.

- Creation of an advisory council that works closely with the community, industry, and LDEP.

- Conduct a pilot health symposium designed to address health problems associated with exposure to environmental hazards and contaminants.

Ms. Sharon Beard, NIEHS, made a presentation on worker education and training.

Mr. Carter; Dr. Mildred McClain, Executive Director, Citizens for Environmental Justice; and Ms. Doris Bradshaw, Executive Director, Defense Depot Memphis Tennessee Concerned Citizens Committee, made a presentation on the role of FFRRO in working with communities affected by adverse environmental conditions. They explained that FFRRO plans to:

- Identify and evaluate key issues of concern to such communities.
- Provide a forum for dialogue between members of local communities and representatives of government agencies.
- Compile a list of resources available to communities and stakeholders that can help support increased public participation.
- Formulate a set of recommendations to the NEJAC, including the identification of “best practices” for improving environmental cleanups and ways in which the NEJAC can best address issues related to federal facilities.

The members of the subcommittee discussed the development of a strategic plan for the subcommittee. Key issues they identified included the creation of a work force development committee and examination of the role of the subcommittee on the Pollution Prevention Working Group. Additional themes they identified included exploration of EPA’s role in fostering strategic planning by communities for the re-use and revitalization of contaminated sites, action to be taken after cleanup has been completed, and use of lessons learned through demonstration projects conducted by the Integrated Work Group on Environmental Justice and other outstanding projects.

The members of the subcommittee discussed at length three pending action items for 2002:

- Transfer of the Federal Facilities Work Group to the Waste and Facility Siting Subcommittee and addition of another member to that work group.
- Provision of assistance to FFRRO in its efforts to integrate issues related to land use, development, and redevelopment into the programs and procedures of EPA.
- Identification of models, such as the Washington Naval Yard and other sites, to be used as positive examples of OSWER’s work with communities to achieve revitalization and reuse.

NEXT MEETING

The next meeting of the NEJAC is scheduled for December 9 through 12, 2002 in Baltimore, Maryland. The meeting will focus on pollution prevention. Planned activities include one opportunity for the public to offer comments. More information about the upcoming meeting will be available on the NEJAC’s Internet home page at <*http://www.epa.gov/compliance/environmentaljustice/index.html*> (click on the link to the National Environmental Justice Advisory Council) or by telephone on EPA’s toll-free environmental justice hotline at 1 (800) 962-6215.

CHAPTER ONE
MEETING
OF THE
EXECUTIVE COUNCIL

1.0 INTRODUCTION

The sixteenth meeting of the Executive Council of the National Environmental Justice Advisory Council (NEJAC) took place Thursday, December 3 through 6, 2001, in Seattle, Washington. Ms. Peggy Shepard, West Harlem Environmental Action, serves as the newly appointed chair of the Executive Council. Mr. Charles Lee, Associate Director for Policy and Interagency Liaison, U.S., Environmental Protection Agency (EPA) Office of Environmental Justice (OEJ), continues to serve as the Designated Federal Officer (DFO) for the Executive Council. Exhibit 1-1 presents a list of members of the Executive Council who were present and identifies those members who were unable to attend. Approximately 300 people attended the meeting.

Exhibit 1-1

EXECUTIVE COUNCIL

Members Who Attended the Meeting
December 3 through December 6, 2001

Ms. Peggy Shepard, Chair
Mr. Charles Lee, DFO

Mr. Larry Charles
Ms. Veronica Eady
Ms. Anna Frazier**
Ms. Eileen Guana
Dr. Richard Gragg, III
Dr. Michael Gelobter*
Mr. Robert Harris*
Ms. Savonala “Savi” Horne
Ms. Annabelle Jaramillo
Ms. Mary Nelson
Dr. Graciela Ramirez-Toro
Ms. Jane Stahl
Mr. Dean Suagee
Ms. Wilma Subra
Ms. Jana Walker
Mr. Kenneth Warren

List of Members
Who Were Unable To Attend

Ms. Rose Augustine
Mr. Fernando Cuevas
Ms. Jennifer Hill-Kelley
Mr. Harold Mitchell
Mr. David Moore
Mr. Alberto Saldamondo
Ms. Pat Wood
Mr. Tseming Yang

*Attended December 3 and 4, 2001 only
**Attended December 4 and 6, 2001 only

On December 5, 2001, each member of the Executive Council who was present on that day participated in the deliberations of the NEJAC subcommittees. Chapters Three through Seven of this meeting summary describe those deliberations. In addition, the Executive Council hosted one public comment period on the evening of December 4, 2001, as well as participated in a "virtual tour" of environmental justice sites in EPA Region 10 on December 3, 2001. Approximately 30 people offered comments during the public comment session. Chapter Two presents a summary of the public comments offered and the presentations made during the virtual tour.

This chapter, which provides a summary of the deliberations of the Executive Council, is organized in six sections, including this *Introduction*. Section 2.0, *Remarks*, summarizes the remarks offered by various speakers. Section 3.0, *Discussion of the Relationship Between Water Quality, Fish Consumption, and Environmental Justice*, provides a summary of the testimony provided by the Fish Consumption Work Group of the NEJAC and describes the recommendations discussed by the members of the work group and the members of the Executive Council. Section 4.0, *Draft Strategic Plan of the NEJAC,* presents a summary of the discussions of the members of the Executive Council about matters related to the NEJAC strategic plan. Section 5.0, *Presentations and Reports*, provides summaries of reports and presentations made to the Executive Council on various other topics. Section 6.0, *Miscellaneous Business*, presents summaries of discussions by the members of the Executive Council of other items before the council, including recognition of those members whose terms were soon to expire.

Chapter Two of this report presents a summary of the virtual tour and public comment sessions held December 3 and 4, 2001. Chapters Three through Seven of this report present summaries of the deliberations of each of the subcommittees that met on December 5, 2001. Appendix A presents a list of the proposed revisions of the draft Fish Consumption Report and recommendations proposed for additions to it.

2.0 REMARKS

This section summarizes the remarks of the Deputy Regional Administrator of EPA Region 10 and representatives of local community organizations and the Washington State legislature. Exhibit 1-2 provides a copy of the letter sent by Washington Governor Gary Locke to the NEJAC.

2.1 Remarks of the Deputy Regional Administrator, U.S. Environmental Protection Agency Region 10

Mr. Ron Kreizenbeck, Deputy Regional Administrator, EPA Region 10, welcomed the members of the NEJAC, commenting on the appropriateness of the selection of Region 10 to host the current meeting, with its focus on subsistence fish consumption, water quality, and environmental justice. He explained that EPA Region 10, which includes the states of Washington, Oregon, Idaho, and Alaska, is home to many diverse, low-income communities, communities of color, and more than 270 Native American tribes and Alaskan Native villages. Many of those communities and tribes subsist on fish, plants, and wildlife, he said, and the harvesting, preparation, and consumption of wild species is prevalent, as well as fundamental to the heritage and traditions of their cultures. Mr. Kreizenbeck stressed that the degradation of habitats and the depletion of resources threatens the very way of life of those communities and tribes.

Mr. Kreizenbeck also pointed out that, for many such communities, there is no practicable alternative to the resources of the land. Therefore, he continued, it is not feasible to switch to or substitute other food resources if the resources of their land are contaminated. Moreover, he stated, for the communities of concern, to abstain from consumption of such resources is unimaginable for cultural, traditional, or religious reasons. A subsistence lifestyle, he stressed, is more than simply a tradition — it is fundamental to the very concept of self-determination.

Continuing, Mr. Kreizenbeck stated that issues of environmental justice arise during the everyday work at EPA Region 10, as the Agency issues and reviews permits, reviews and approves water quality standards, works on environmental impact statements, performs risk assessments, and develops monitoring plans. Addressing subsistence issues as the Agency pursues those activities is necessary to ensure that all communities receive equal environmental protection, he said. Lacking equal environmental protection for all, regardless of race, income, culture, or ethnicity, he declared, there can be no environmental justice.

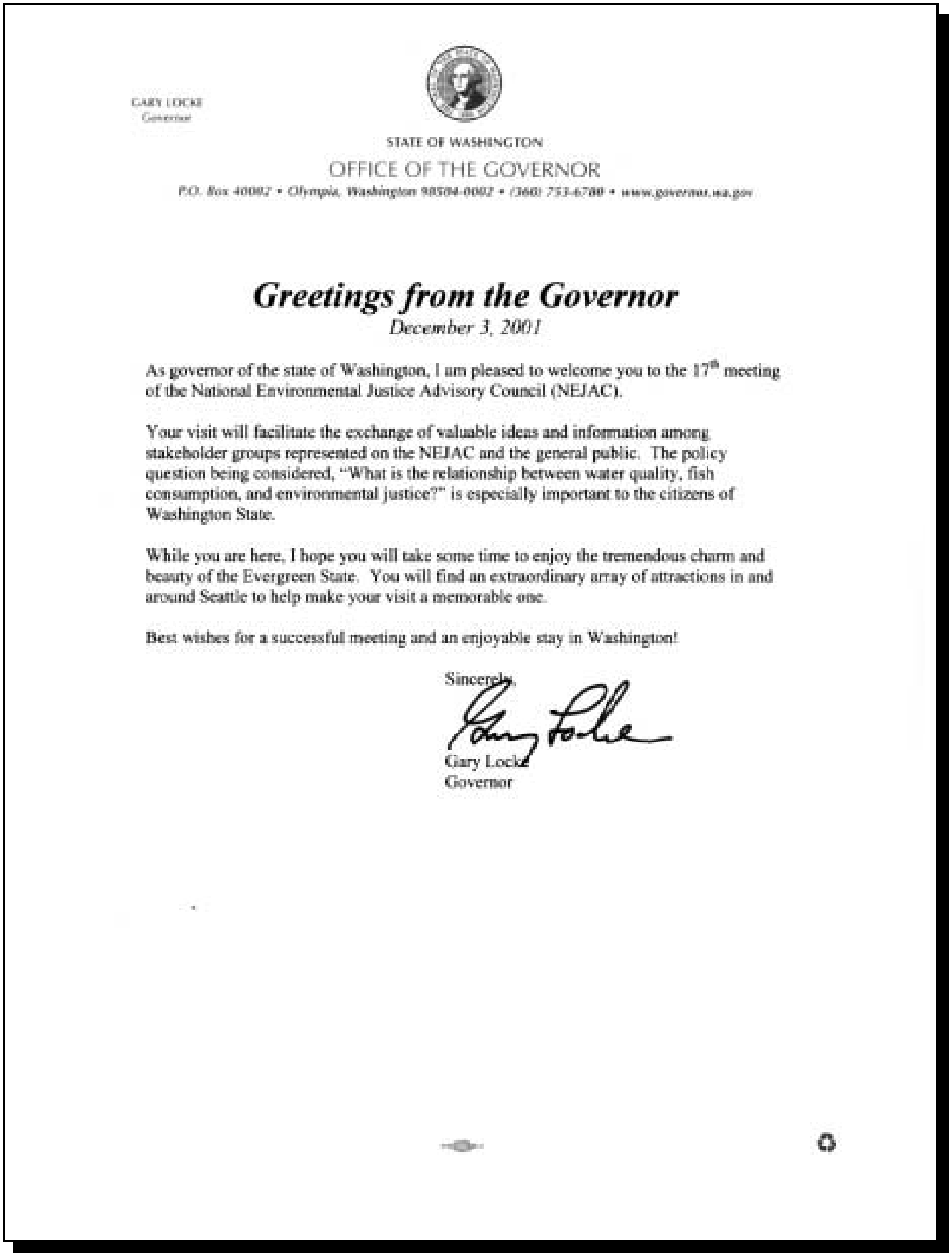
2.2 Remarks of Local Elected Officials, Community Members, and Tribal Leaders

Ms. Rosa Franklin, State Senator, Washington State Legislature and former member of the NEJAC, commented on the timeliness of the current meeting of the NEJAC, held to discuss the relationship between among water quality, fish consumption, and environmental justice. While contaminated air and toxic streams affect all citizens, she continued, the changing demographics in the state of Washington and the Pacific Northwest have brought a new urgency to the issue of fish consumption. Therefore, she said, there is an urgent need in the region to further identify and quantify the types and magnitudes of risks to communities and tribes that subsist on wild fish, plants, and other wildlife. Ms. Franklin stressed that the activities of the NEJAC could have a long-term effect on the health of those communities.

Ms. Velma Veloria, State Representative, Washington State Legislature and former member of the NEJAC, noted that the convening of the NEJAC in the state of Washington to discuss this issue of fish consumption and environmental justice reaffirmed that the quality of salmon and fish is a concern not only of the fishing industry, but also of tribes and other minority populations.

Ms. Veloria informed the members of the NEJAC that the state of Washington had done much to ensure that its water is clean and that fish remain healthy. She explained that, in 1994, she, Ms. Franklin, and several other legislators had introduced a bill before the state legislature that requested that the Washington Department of Ecology and the Washington Department of Health jointly prepare a report on the environmental risks that threaten low-income and minority groups. She noted that the initial funding to support the work had been obtained. Ms. Veloria commented that the victory had been “an incredible first step” in addressing the disproportionate adverse effects of hazardous and solid waste sites on low-income communities and peoples of color.

Exhibit 1-2



GARY LOCKE
Governor

STATE OF WASHINGTON
OFFICE OF THE GOVERNOR
P.O. Box 40002 • Olympia, Washington 98504-0002 • (360) 753-6780 • www.governor.wa.gov

Greetings from the Governor

December 3, 2001

As governor of the state of Washington, I am pleased to welcome you to the 17th meeting of the National Environmental Justice Advisory Council (NEJAC).

Your visit will facilitate the exchange of valuable ideas and information among stakeholder groups represented on the NEJAC and the general public. The policy question being considered, "What is the relationship between water quality, fish consumption, and environmental justice?" is especially important to the citizens of Washington State.

While you are here, I hope you will take some time to enjoy the tremendous charm and beauty of the Evergreen State. You will find an extraordinary array of attractions in and around Seattle to help make your visit a memorable one.

Best wishes for a successful meeting and an enjoyable stay in Washington!

Sincerely,

Gary Locke
Governor

In 1997, Ms. Veloria continued, the legislature worked to incorporate environmental health into the state's overall public health improvement plan. That effort, she explained, had allowed the Washington Department of Health to consider environmental health risks to communities when performing assessments of public health. She added that, in that same year, legislation had been enacted that reformed the way in which the work at clean-up sites is taxed.

Ms. Veloria explained that, before the legislation was passed, the owner of a cleanup site was taxed at a particular rate if the owner cleaned up the site voluntarily, but was taxed at a lower rate if the owner waited until the Washington Department of Ecology formally placed the site on a list of sites that required cleanup. Such a tax system, she pointed out, encouraged owners to delay cleanup, thereby increasing the potential that contamination from the sites would spread. By changing the system to include a uniform tax for cleanups, she added, the legislature removed site owners' incentive to delay cleanup.

Continuing, Ms. Veloria stated that, in 1998, the Washington state legislature enacted legislation that requested that the Washington Department of Health investigate the health effects of noise, particularly in the vicinity of Washington's Seattle-Tacoma International Airport (SEATAC) and review existing studies of noise pollution to evaluate whether disadvantaged groups are subject to disproportionately high levels of exposure to unhealthy noise pollution. Further, she continued, in early 2001, the legislature's Agriculture and Ecology Committee conducted a hearing on proposed legislation that would require that the public be notified of releases of hazardous substances. Specifically, she explained, notices would be mailed to residents, land owners, and businesses located within one mile of a facility involved in such a release and would provide detailed information about the chemicals involved, the address of the facility, and the date of the release. While the legislation has not yet been enacted, she added, it is to be reintroduced in 2002.

Mr. Moses Squeochs, Yakama Nation and member of the NEJAC Indigenous Peoples Subcommittee, observed that, while he appreciates the responsibility and effort of the NEJAC, he is troubled that such an "extra effort" is necessary to enforce legislation that has been enacted by the Congress of the United States. For example, he pointed out, federal law requires that federal agencies identify the need to ensure the protection of populations that exhibit patterns of subsistence consumption of fish and wildlife and to assist in providing such protection. Federal law also requires that federal agencies collect, maintain, and analyze information about the consumption patterns of populations that rely primarily on fish or wildlife for subsistence, added Mr. Squeochs. He stressed that EPA has been charged with implementation of federal environmental statutes. He asked why it has been so difficult for EPA to carry out that responsibility.

Continuing, Mr. Squeochs explained that he represents the 14 Confederated Tribes and Bands of the Yakama Nation that reside in the interior mid-Columbia River basin. After reciting the names of the 14 tribes and bands, he explained that each of those communities, along with many other indigenous communities, continue to maintain a subsistence, or "hunter-gatherer," way of life and sustain the customs and practices of their valuable and rich heritage. He also commented that there is a renewed and important effort among indigenous peoples to restore their language and preserve their culture, which reflects and maintains a deep connection to the Earth, "their Mother."

Mr. Squeochs shared his remembrance of the first time he had recited as a small child in school the words of the Pledge of Allegiance "...with liberty and justice for all." Ironically, he continued, more than 50 years later, he finds himself participating as a member of the Indigenous Peoples Subcommittee in an attempt to make such justice a reality for all and to achieve some sense of fairness and equality. In closing, Mr. Squeochs, stated his hope that the NEJAC would continue to make history in the search for justice.

Ms. Yolanda Sinde, Community Coalition for Environmental Justice, also welcomed the members of the NEJAC to the city of Seattle. She first noted that the Community Coalition for Environmental Justice, a multiracial organization, had been the first official nonprofit environmental justice group formed in the Seattle area. She then invited the members of the NEJAC to attend a community reception to be held that evening.

Ms. Sinde then briefly expressed her concern about rumors that the NEJAC might be dissolved. She stressed the importance of maintaining the connection the NEJAC provides between EPA and environmental justice communities and asked that representatives of EPA or members of the NEJAC address the concern during the meeting.

3.0 POLICY DIALOGUE ABOUT THE RELATIONSHIP BETWEEN WATER QUALITY, FISH CONSUMPTION, AND ENVIRONMENTAL JUSTICE

The NEJAC, in its continuing efforts to provide independent advice to the Administrator of EPA in areas related to environmental justice, focused its sixteenth meeting on the relationship between water quality, fish consumption, and environmental justice. On Tuesday, December 4, the members of the NEJAC heard a panel presentation by the members of the Fish Consumption Work Group of the NEJAC. The NEJAC had established the work group to assist in developing a report and recommendations on this issue.

Ms. Annabelle Jaramillo, Benton County Board of Commissioners and chair of the Air and Water Subcommittee, served as facilitator during the policy dialogue. She began the discussion by reminding the members of the NEJAC of the purpose of the current meeting of the NEJAC. She explained that the issue that the NEJAC had been asked to consider and provide recommendations on was:

> *"How should EPA improve the quality, quantity, and integrity of our Nation's aquatic ecosystems in order to protect the health and safety of people consuming or using fish, aquatic plants, and wildlife?"*

Ms. Jaramillo then stated that, in preparation for the meeting, a report, Fish Consumption Report: Pre-meeting Discussion Draft, had been developed to provide a context for the discussions. The Fish Consumption Work Group, she continued, had prepared the report, with the assistance of Ms. Catherine O'Neill, Associate Professor, Seattle University School of Law.

3.1 Overview of the Fish Consumption Report

Ms. Jana Walker, Law Offices of Jana Walker and vice-chair of the Indigenous Peoples Subcommittee, provided an overview of the fish consumption report. Ms. Walker first explained that the report is a discussion draft intended to promote open dialogue among the members of the NEJAC, as well as to encourage public comment on its content. She stated that the work group would welcome comments on the draft report through January 2002.

Members of the NEJAC discuss presentations made by the members of the NEJAC Fish Consumption Work Group.

Ms. Walker reported that the draft report includes a background section and four chapters. The background section explores the reasons contamination of fish and aquatic ecosystems causes concern about environmental justice. It does so, she continued, through the perspectives of real people who have suffered the harmful effects of such contamination. She explained that, while there are important differences among affected groups, communities of color, low-income communities, and tribes generally consume greater quantities of fish than do other segments of the population and depend on healthy fish and aquatic ecosystems to a greater extent and in different ways than does the general population. Therefore, she continued, these communities and tribes are forced to bear a disproportionate share of the environmental effects that result from pollution of the waters.

Continuing, Ms. Walker explained that fish not caught commercially are a healthy, cheap, and readily available source of protein in the diet. Persons who subsist chiefly or solely on such fish therefore are more likely to be members of communities of color, low-income communities, or tribes. Affected groups also may consume or use fish, aquatic plants, and wildlife for cultural, traditional, or religious reasons. They also may eat different parts of the fish than do other segments of the population, and they may prepare the fish in different ways, as well. Conventional understandings about catching, harvesting, preparing, and eating fish do not capture such practices adequately.

Ms. Walker then pointed out that communities of color, low-income communities, and tribes also may be exposed to different, and often numerous, types of exposures to environmental pollutants than is the case among the general population. Many toxins and toxic chemicals persist in the environment for very long periods of time and bioaccumulate in fish, plants, wildlife, and ultimately the people who eat them, she explained. Although the specific health risks posed by such multiple exposures are unknown, she said, it has been documented that many of the chemicals of concern are highly toxic to humans. Such chemicals, continued Ms. Walker, can cause reproductive, neurological, and endocrine disorders; cancer; and negative developmental effects in children.

Ms. Walker stressed that "healthy waters and watersheds mean healthy people." She acknowledged that EPA has made progress in addressing water pollution over the past 30 years, but declared that much more must be done because, today, only 60 percent of the nation's lakes, rivers, and estuaries are clean enough to be used for fishing and swimming. Continuing, Ms. Walker pointed out that 40 percent of assessed waters are degraded to the point that they no longer support their designated uses. Further, some 300,000 miles of rivers and streams and more than 5 million acres of lakes do not meet water quality goals, she added. Many of those waters are not safe for swimming and cannot support healthy fish, she said.

Ms. Walker then reported that Chapter 1 of the draft fish consumption report evaluates the tools that EPA uses to define, evaluate, and respond to the adverse health effects of exposure to contaminated aquatic ecosystems. She explained that fish consumption is the primary route of exposure to many toxic contaminants. To establish environmental standards, EPA uses exposure data related to the ingestion of contaminated fish, she said. To develop those national water quality standards and criteria, she went on, certain assumptions must be made about how much fish people eat, which parts of the fish they eat, and which people are eating those fish. However, such exposure assumptions often reflect only the habits of the general population; the increased potential for exposure among populations that consume larger quantities of fish, such as communities of color, low-income communities, and tribes, are not considered.

Providing an example, Ms. Walker stated that, until recently, federal water quality standards were based on the exposure assumption that the average person consumes only 6.5 grams per day (g/day) of fish. However, studies of rates of consumption of fish in tribal, low-income, and minority communities have revealed rates that are more than 100 times the value assumed by EPA. Ms. Walker added that the draft report provides ample evidence that ethnic minorities and tribes are more likely to eat the whole fish, including the skin, head, and tail, and that those parts contain higher levels of pollutants than the filet, which is the part of the fish most likely to be consumed by individuals in the general population.

Continuing, Ms. Walker said that Chapter 1 of the report also discusses the issues related to aggregate or multiple exposures and cumulative risks, noting that current EPA methodologies proceed as if humans are exposed to only one contaminant at a time.

In summary, Chapter 1 of the fish consumption report addresses issues related to assumptions made by EPA about patterns of fish consumption, said Ms. Walker. Exposure assumptions must be revised to reflect the lives and circumstances of all people, including those subject to high levels of exposure, she emphasized.

Chapter 2 of the fish consumption report focuses on EPA's risk reduction strategies that require risk producers, usually the polluters, to clean up, reduce, or prevent environmental contamination, Ms. Walker then reported. The chapter also examines existing legal authorities under federal environmental statutes that might be exercised more effectively to address contaminants of concern and to protect the health of people who consume large quantities of fish, she added.

Chapter 3 of the fish consumption report, continued Ms. Walker, examines EPA's risk avoidance strategies, under which affected communities and tribes are asked to change their practices to avoid exposure to harmful contaminants. She explained that the chapter examines the role fish consumption advisories should play in protecting the health of people who consume or use fish and concludes that the role of such an advisory varies, depending on the community or tribe affected by it. Chapter 3 also identifies several significant concerns related to reliance on fish advisories, she said.

Ms. Walker then stated that Chapter 4 of the fish consumption report addresses considerations unique to the 556 federally recognized tribes, including 229 Alaskan Native villages. She explained that, while tribes share many of the concerns described in the preceding chapters, their unique political and legal status distinguishes them from all other affected groups in many ways and warrants separate treatment in the report. Unlike other affected groups, tribes also are government entities and regulators that exercise broad inherent sovereignty over their members, territories, and resources, she said. Chapter 4 also discusses the unique susceptibilities of tribes to the adverse effects of pollution on health.

In closing, Ms. Walker stressed that the fish consumption report is not intended to ignore or belittle the progress EPA has made in addressing water pollution. However, she stated, it is clear that many obligations remain unfulfilled and much work remains to be done. As the members of the NEJAC continue their discussions over the coming months, she suggested, their challenge will be to develop meaningful advice about the approach EPA should take in the effort to improve the quality of aquatic ecosystems, thereby protecting the health of all people who consume fish, especially highly exposed communities and tribes.

In response to the overview of the fish consumption report provided by Ms. Walker, Mr. Jim Hanlon, EPA Office of Water (OW) Office of Science and Technology recognized the high quality of the work produced by the work group. He then expressed his belief that the report will be important to EPA as the Agency works to address issues related to fish contamination. He remarked that EPA had made great strides in improving water quality over the past 10 years, but acknowledged that much work remains to be done. Mr. Hanlon reminded the audience that the objectives of EPA OW are to ensure that water is safe to drink; that water resources are safe for aquatic recreation; that fish are safe to eat; and that our water resources provide a balanced, high-quality system that supports aquatic life.

Mr. Hanlon then stated that, only 10 years earlier, fewer than five states in the country used risk-based methodologies to develop fish consumption advisories. However, he continued, through cooperation with the states, EPA OW had developed a set of guidelines that states used in developing the fish consumption advisories that are now in place. The guidelines include guidance on sampling methodologies, analytical methodologies of laboratories, risk management, and risk communication. Mr. Hanlon then reported that more than 40 states now use risk-based methodologies to develop fish consumption advisories for their populations.

In conjunction with the Minnesota Department of Health, Mr. Hanlon continued, EPA recently had sponsored a conference in Chicago, Illinois, that was attended by more than 400 people, representing all 50 states and more than 50 tribal entities. The focus of the conference was risk communication related to fish consumption. The proceedings of that conference had been released, he said, and would be discussed during the meeting of the Air and Water Subcommittee to be held on December 5, 2001. Mr. Hanlon added that he also would discuss with the members of the Air and Water Subcommittee the further actions that the agency is considering. Those actions would focus on the development of additional tools to assist states in improving their risk communication capabilities.

Responding to Ms. Walker's comments about outdated methodology for the development of human health criteria, Mr. Hanlon stated that EPA recently had replaced a document that had been in use since the early 1980s with updated information that is based on available statistical information about average consumption levels for general populations, sport fishers, and subsistence populations. He noted that the release of the updated information represented an important transition from the use of historical bioconcentration factors to the use of bioaccumulation factors in the derivation of water quality criteria. The new approach has the effect of lowering the acceptable criteria by a factor of as much as 100. Mr. Hanlon added that the new methodology also recognizes, for the first time, the concept of relative source contribution. That is, he explained, individuals do not receive their entire body burden of a particular toxic pollutant from consumption of fish tissue alone, but rather from a combination of exposure routes, all of which must be considered.

Continuing his discussion of the activities of EPA OW, Mr. Hanlon stated that the office, in cooperation with the U.S. Department of Health and Human Services (HHS), recently completed its second mailing to health care providers. Through the mailing, he explained, packages of information about the contamination of fish was disseminated to more than 135,000 health care providers across the United States, including pediatricians, obstetricians, gynecologists, family physicians, physician's assistants, and midwives. Mr. Hanlon then stated that EPA does not believe that consumption advisories are the solution to problems related to the contamination of fish. Rather, he said, such advisories are temporary measures taken to advise the public about health risks that may be associated with the consumption of contaminated fish.

Mr. Hanlon then reported that EPA's Total Maximum Daily Load (TMDL) Program is making "giant steps forward." Exhibit 1-3 presents the definition of TMDL. During 2002, he continued, some 2,000 TMDL projects will be underway nationwide. He added that approximately 33 states operate under consent agreements or court orders that require that the states and EPA step forward and complete development schedules reflecting the priority ranking of each pollutant.

Concluding his remarks, Mr. Hanlon emphasized that the "Achilles heel" of the national water program continues to be the lack of robust information or data about watersheds throughout the United States. Referring to Ms. Walker's comment that 40 percent of assessed water bodies do not meet standards for their designated uses, Mr. Hanlon pointed out that only 20 to 25 percent of the nation's water bodies have been assessed.

Ms. Shepard also offered several comments about the information presented in the draft fish consumption report. She stated that in her own state, New York, many groups have been in consultation with the state Department of Environmental Conservation about fish advisories for the Hudson River, in which contamination has been known to exist for many years. However, she pointed out, authorities have posted no fish consumption advisories related to the river. Ms. Shepard said that, along the Hudson River, subsistence fishers are selling fish to local fish markets. EPA, she suggested, should find a way to mandate that fish advisories be posted. She suggested further that a public information campaign be mounted to reach affected communities. Ms. Shepard then stated that the glaring disparity between how water quality standards, enforcement, and cleanup are implemented confirms continuing unequal enforcement in communities that are among the most highly exposed to contaminants — communities of color, low-income communities, and tribes. She then stated her belief that the information presented in the draft report reinforces recognition of the need for accelerated investigation projects and protocols for determining the cumulative effects of multiple exposures.

Finally, Ms. Shepard commented that financial resources should be made available to affected groups so that they can educate their own communities in their own languages and in a manner that reflects their own cultures and customs.

3.2 Fish Consumption, Research Methods, and Approaches to Risk Assessment

Dr. Patrick West, Professor Emeritus, University of Michigan, provided a detailed summary of information about research methods and approaches to risk assessment that agencies use to define, evaluate, and respond to the adverse health effects caused by contamination of aquatic environments. Chapter 1 of the draft fish consumption report presents that information.

Dr. West stated that the contamination of fish, aquatic plants, and wildlife is an especially pressing concern for many communities of color, low-income communities, and tribes, whose consumption and use practices differ, often profoundly so, from those of the general population. He explained that members of those communities often consume far greater quantities of fish, aquatic plants, and wildlife than does the general population. Further, they consume and use different species and parts than the general population, and they employ culturally different methods of procuring and preparing the fish, aquatic plants, and wildlife that they use. Therefore, continued Dr. West, communities of color, low-income communities, and tribes are among the segments of the population that are most highly exposed to contaminants in the fish, plants, wildlife, and aquatic environment. He explained that available literature documents that the 95th percentile fish consumption rates for various affected communities and tribes range from 225 g/day to 489 g/day. Yet, he pointed out, EPA regularly and routinely approves a human consumption rate of 6.5 g/day in risk assessment methodologies.

Dr. West then discussed policy related to fish consumption in a legal and cultural context. He stated that the contamination of fish, aquatic plants, and wildlife also is troubling to many communities of color, low-income communities, and tribes because such groups consume and use fish, aquatic plants, and wildlife in different cultural, traditional, religious, historical, economic, and legal contexts than what agencies have defined as the general population. For example, tribes have rights guaranteed by treaty to take fish. The unique legal obligations established under such treaties are relevant to EPA's decisions that affect the health of the fish and the fishery resource, he said.

Dr. West explained that fish consumption and use of fish often is prescribed by the culture and tied closely to the collective and individual identity of a community or tribe. The existence of such different contexts is demonstrated abundantly by both testimonial evidence and study in social science, he continued. For the reasons he had identified, said Dr. West, current fish consumption practices are, in an important sense, indispensable for many communities and tribes.

Dr. West then discussed the possibility of a "suppression effect" related to fish consumption. He explained that a suppression effect occurs when a fish consumption rate for a given group reflects a current level of consumption that is diminished artificially from the appropriate baseline level for the group. Suppression effects may occur because of contamination or fear of consuming contaminated items (members of a group consume fewer fish than they naturally would because they fear that the fish are contaminated) or depletion of resources (members of a group consume fewer fish than they naturally would because fewer fish are available for consumption), he said. He explained that, when standards are based on fish consumption rates that are not adjusted for suppressed consumption, the standards initiate a "downward spiral," with more contamination permitted, leading to a greater suppression effect, and so on.

Continuing, Dr. West stated that current risk assessment methods do not account adequately for susceptibilities and co-risk factors that affect individual responses to environmental contaminants. Co-risk factors include underlying health status, quality of diet, genetics, socioeconomic status, access to health care, and other factors. For example, he said, low-income socioeconomic status may combine with and intensify health effects of consuming contaminated fish in environmental justice communities.

Dr. West then stated that current risk assessment methods also evaluate risks as if humans were exposed to a single contaminant at a time by a single route of exposure. He explained that members of environmental justice communities, however, often are exposed to numerous contaminants, at a given time or in succession, often by more than one route of exposure. For example, he stated, the 13 Confederated Bands of the Yakama Nation fish in the Columbia River; more than 100 contaminants have been identified in the tissues of fish taken from that river.

Dr. West then observed that the efforts of affected communities and tribes are integral in producing relevant, accurate, scientifically defensible data. He said that affected communities and tribes therefore must be involved at every stage of research on the issues he had discussed, from identifying research needs to designing research methods; interpreting the policy implications of the finding of such research; and determining the importance of the research to the agency's risk assessment, management, remediation, and emission permitting processes.

Continuing his remarks, Dr. West stated that environmental justice communities also have a broader policy role to play beyond the arena of research. He stated that tribal populations throughout the country have challenged the NEJAC and EPA to "walk in their moccasins" — to see and experience the importance of fish consumption and related use of subsistence resources taken from the waters and the land and the harsh effects of pollution and pollution policy as the tribes themselves experience them. The same ideal, Dr. West added, holds true for other environmental justice communities and cultures.

Dr. West then stated that, at the recent conference in Chicago that Mr. Hanlon had mentioned, he had heard members of tribes and other environmental justice communities repeatedly urge EPA to take a broader, more holistic view that goes beyond the very important, but very short-term, narrow, and focused, policy of exclusive reliance on advisories.

Dr. West then asked the members of the NEJAC if they would be willing to "walk in the moccasins" of affected communities and, with renewed determination, take on the difficult issues of prevention and remediation.

3.3 Fish Consumption and the Exercise of Existing Legal Authorities

Ms. Walker provided a summary of the information presented in Chapter 2 of the fish consumption report. She stated that approximately 40 percent of assessed waters in the United States do not support use for fishing or swimming. She added that some 10 percent by volume of all sediments under waters in the United States are contaminated heavily; the list of sediments in surface waters that require cleanup is long, she said, and the number of fish consumption advisories rises each year. Ms. Walker explained that, because people of color, low-income people, and American Indians and Alaskan Natives are disproportionately among the populations that experience the greatest exposure to contamination, any lapses in the efforts of agencies to prevent, reduce, clean up, and restore contaminated aquatic environments will impose a disproportionate burden on those affected groups. Referring to the regulation of mercury emissions, Ms. Walker noted her understanding that, in the near future, EPA was to address rule-making for the regulation of mercury emissions from institutional, industrial, and commercial boilers. She stated that such regulation is needed.

Continuing, Ms. Walker stated that a rule regulating mercury emissions from coal-fired power plants might not be proposed until December 2003. Meanwhile, she pointed out, coal-fired power plants are the single largest source of air emissions of mercury in the country. She then stated that a rule regulating emissions of mercury from chloroalkaline plants is needed. Although only approximately one dozen such plants are located in the United States, she explained, each plant is a very significant source of such emissions. In some cases, a plant may be the most significant local source of emissions of mercury. She then cited as an example two chloroalkaline plants in Louisiana that contribute more mercury emissions than all the coal-fired power plants in the state combined.

Continuing her presentation, Ms. Walker stated that EPA's guidance documents and standards consider a higher level of cancer risk to be "acceptable" for "more highly exposed subgroups" than for the general population. That standard is inequitable and deeply troubling, as a matter of environmental justice, because it is people of color, low-income people, and American Indians and Alaskan Natives who make up the "more highly exposed subgroups," she said.

3.4 Fish and Wildlife Consumption Advisories

Ms. Marianne Yamaguchi Santa Monica Bay Restoration Project provided a summary of the information about fish and wildlife consumption advisories that Chapter 3 of the fish consumption report presents. Ms. Yamaguchi pointed out that fish advisories are just one component of a comprehensive strategy for the management of health risks. She also noted that fish advisories are a strategy for risk avoidance rather than risk reduction. She explained that, typically, advisories are intended to provide information about the nature and the extent of contamination and its potential adverse effects on health. Their purpose, she noted, is to encourage consumers to avoid consuming contaminated species and to suggest alternative ways in which people could continue to eat fish. However, she added, fish advisories are not effective in many environmental justice communities because fish substitutes are not readily available or because changes in fish consumption practices may cause great anguish or cultural harm. Therefore, said Ms. Yamaguchi, a comprehensive strategy for the control of health risks should go beyond the issuance of fish advisories.

Continuing, Ms. Yamaguchi observed that, while advisories are useful, if they are to be effective, they must be tailored to the specific locations and communities of concern. She pointed out that there is no "one-size-fits-all" strategy and suggested that attempts to ensure consistency across broad regions or among population groups may not be useful or appropriate.

She stated that affected communities and tribes play an integral role in relevant, appropriate, and effective risk communication efforts. Affected communities and tribes, she continued, therefore must be involved as partners, or in the case of tribal governments, as "co-managers," at every stage of the communication process — in identifying needs and priorities, in developing content for advisories that is appropriate for the groups of concern, in helping to prepare translations and communicate the message, and in helping to interpret communities' responses to risk management efforts.

3.5 Fish Consumption Concerns Among American Indian Tribes and Alaskan Native Villagers

Mr. Dean Suagee, Vermont Law School discussed information presented in Chapter 4 of the fish consumption report. Mr. Suagee stated that the political and legal status of tribes is unique among affected groups and so warrants separate treatment. As sovereign entities, federally recognized tribes maintain a government-to-government relationship with the federal government and its agencies, he explained. Continuing, Mr. Suagee stated that the unique legal status of tribes includes a trust responsibility on the part of the federal government and, for many tribes, treaty rights, as well. He then remarked that EPA must demonstrate respect for the unique status of Native American tribes and Alaskan Native villages.

Mr. Suagee explained further that, in general, there is no environmental protection infrastructure in Indian country because Indian country had been overlooked during the development of the first federal environmental laws. He stated that, because tribes do not have the same kinds of resources as states have to devote to program development, tribes are for the most part dependent on EPA and other federal agencies, such as the Bureau of Indian Affairs (BIA), the Indian Health Service (IHS), and the U.S. Department of Housing and Urban Development (HUD).

Turning to the role of tribes as regulators in protecting the environment, Mr. Suagee stated that, although tribal governments and EPA are responsible for implementing water quality standards in Indian County and on Alaskan Native lands, only 16 of the 565 federally recognized tribes and Alaskan Native villages have water quality standards that have been promulgated or approved by EPA. Therefore, continued Mr. Suagee, there are considerable gaps in water quality standards in Indian country, as well as gaps related to other statutes.

Mr. Suagee then noted that EPA had been engaged for some two and one-half years in consultations with tribes related to EPA's proposal to promulgate core federal water quality standards for Indian country. The proposed rule finally was signed on January 19, 2001, he said. However, he continued, the rule became subject to the moratorium on new rules and was "passed back" to EPA by Office of Management and Budget (OMB). Mr. Suagee then explained that, during the November 2001 meeting of the Tribal Caucus of the Tribal Operations Committee (TOC) in Albuquerque, New Mexico, he had been told that OMB provided two suggested options when the rule was returned to EPA. He then noted that he was unsure of the current status of the rule. He remarked, however, that the Tribal Caucus was near consensus that EPA should move forward to promulgate the current rule as a proposed rule.

Mr. Suagee also stated that, because of the historical difference in the way Alaskan Natives have been treated, the implications of the Alaska Native Claims Settlement Act and case law interpreting that act, and the use of the term "reservation" in the provisions of the Clean Water Act and the Clear Air Act that authorize treatment of tribes like states, the solutions for Indian country that are available in the lower 48 states are not available in Alaska.

Mr. Suagee then stated that EPA also should explore the development of more appropriate designated uses for culturally important water bodies in Alaska than those currently in place. Although those issues had not yet been included in the draft fish consumption report, suggested Mr. Suagee, the work group and the NEJAC should revise the report to include a recommendation that is specific to Alaskan Natives.

The members of the Executive Council then discussed the draft fish consumption report and developed proposed revisions and additional recommendations. Appendix A presents a list of those proposed revisions and additional recommendations.

4.0 DRAFT STRATEGIC PLAN OF THE NEJAC

Ms. Shepard presented the strategic plan of the NEJAC to the members of the Executive Council. She explained that the strategic plan incorporates the issues raised and conclusions reached at the August 2001 meeting of the Executive Council, held in Washington, D.C. Ms. Shepard advised that the introduction section of the strategic plan will be revised to reflect the Executive Council's appreciation for the efforts of past NEJAC members, especially the efforts of those who had served as founding members. In addition, these revisions will note the past contributions of NEJAC in advancing policy development within the EPA related to environmental justice.

4.1 Goals and Objectives

Over the previous year, Ms. Shephard noted, the NEJAC had been reviewing its role and discussing how the NEJAC could best promote environmental justice and fulfill the mission set forth in its charter. In general, said Ms. Shepard, the members of the NEJAC had concluded that they can better fulfill the mission of their charter by refocusing their own processes and work products, while redirecting the site-specific issues to the appropriate EPA regional offices that have both the responsibility to address such issues and the authority to do so. She stressed that, during its meetings, the NEJAC would continue to solicit public comment on policy issues before the NEJAC.

Ms. Shepard then read the revised mission statement for the NEJAC that is presented in the strategic plan. The mission statement reads as follows:

> *"The NEJAC is a federal advisory committee that provides timely, relevant, cogent, and independent advice to the EPA Administrator on matters of environmental justice to ensure the fair treatment of all peoples, including minority, low-income, and indigenous populations and federally recognized tribes, and often overlooked populations, such as agricultural workers."*

Continuing, Ms. Shepard explained that the Strategic Plan outlines the strategy of the NEJAC to (1) redesign its activities to better perform the advisory role its charter establishes; (2) collaborate with EPA to provide regional and other alternative mechanisms other than meetings of the NEJAC, such as regional listening sessions, through which communities can bring site-specific issues to the attention of EPA; and (3) develop, through a deliberative process that involves all stakeholders, an effective work product grounded in issues of importance to environmental justice communities. She added that the strategic plan is to guide the work of the NEJAC through September 27, 2003.

Ms. Shepard stressed that disproportionate adverse effects on communities of color, low-income communities, and tribes are at the very heart of environmental justice. They also, she continued, are the impetus of the grassroots activism that prompted the development of several key products, including President Clinton's Executive Order 12898 on Environmental Justice and the subsequent formation of the NEJAC, along with numerous other products over the years. The NEJAC, she declared, will continue to make strong recommendations to EPA on the conduct of regional listening sessions and other mechanisms that will take place in the coming year, as well as recommendations on follow-up to those sessions.

Ms. Shepard then briefly outlined the six goals for the Executive Council of the NEJAC and its subcommittees, which, she noted, are presented in the strategic plan. Those goals, she said, will guide the NEJAC in accomplishing its mission.

First, Ms. Shepard explained, a work product goal was developed to identify several methods of providing cogent, timely, relevant, and effective advice, both formal and informal, to the EPA Administrator. Second, the strategic plan sets forth a process goal aimed at developing and implementing a deliberative, consultative, and collaborative process on which the NEJAC can base its advice to the EPA Administrator, she said. A third goal is the public participation and public input goal that outlines how the NEJAC actively will employ mechanisms for soliciting the views of minority, low-income, indigenous, and agricultural worker populations and of federally recognized tribes, she continued. She explained that the third goal addresses (1) public participation at meetings of the NEJAC, (2) the incorporation of community concerns and issues into the policy dialogue of the NEJAC, and (3) public participation at the regional level.

Continuing, Ms. Shepard stated that a fourth goal included in the strategic plan is an organizational and procedural goal. She explained that, the purpose of the fourth goal is to obtain better briefings from EPA about its initiatives and activities and to become better able to communicate externally with the larger environmental justice movement, communities, other stakeholders, government and industry. The NEJAC, she said, would request that EPA initiate a review of the NEJAC organizational structure and procedures. Implementation of the initiative will enable the NEJAC to more effectively and efficiently develop advice and render it to the EPA Administrator, she said.

A fifth goal presented in the strategic plan, Ms. Shepard continued, is a communications goal that outlines a communication plan for improving the flow of information from EPA to the NEJAC and for creating a listserv to enable members of the Executive Council and DFOs to discuss matters properly between meetings of the NEJAC. Last, she said, the strategic plan includes the goal of developing an effective orientation program for new members of the NEJAC and its subcommittees.

Ms. Shepard then publicly thanked Ms. Jaramillo, who chaired the committee that drafted the strategic plan, and the members of the drafting committee, Mr. Kenneth Warren, Wolf, Block, Schorr and Solis-Cohen and member of the Enforcement Subcommittee; **Ms. Wilma Subra, Louisiana Environmental Action Now and member of the Health and Research Subcommittee; and Ms. Veronica Eady, Massachusetts Executive Office of Environmental Affairs and chair of the Waste and Facility Siting Subcommittee**.

Ms. Jaramillo commented that the development and implementation of the plan would be a dynamic process. That is, she continued, the strategic plan will "grow and move with the times." She also echoed Ms. Shepard's praise for Ms. Subra, Mr. Warren, and Ms. Eady for their hard work in writing the strategic plan.

Ms. Jane Stahl, Connecticut Department of Environmental Protection, stated her belief that the strategic plan would set the stage for a wonderfully productive collaboration between the NEJAC, which was created to help give communities a voice in the world of environmental protection and environmental management, and the organizations and bureaucracies that are supposed to be doing that work on behalf of all communities and constituencies.

The importance of the plan, Ms. Stahl continued, is that it provides the NEJAC and communities with a structure through which they can move forward. Everyone is on the same side, she stressed, but different individuals bring different talents and different views to the table. She stated that all stakeholders must communicate and work with one another, but that they should do so in a structured fashion. In that way, she observed, they will achieve an end result, rather than bringing about increased division and controversy over issues that are important to all stakeholders.

In closing, Ms. Stahl expressed her belief that the organized process presented in the strategic plan would help not only the NEJAC as a group to achieve its goals, but also the communities that the NEJAC serves to accomplish the same outcome.

She added that implementation of the strategic plan also would help EPA move forward in addressing issues that are important to communities that have been "excluded from the table" in the past.

Dr. Graciela Ramirez-Toro, Interamerican University of Puerto Rico and chair of the Puerto Rico Subcommittee, applauded the work of the drafting and writing committee (that developed the draft strategic plan. She then offered several suggestions for revision or clarification of the plan. First, she suggested that the strategic plan include some discussion of the ways in which the work groups will include individuals, such as technical experts, who are not members of the NEJAC. She also suggested that the strategic plan outline at least a general time line and protocol for scheduling conference calls. Finally, Dr. Ramirez-Toro suggested that the strategic plan be revised to identify the role of members who live in a particular region during listening sessions held in that region.

Ms. Savonala "Savi" Horne, Land Loss Prevention Project and chair of the Enforcement Subcommittee, congratulated the members of the Executive Council for dealing with the reality that the NEJAC is a federal advisory committee and therefore must conform to the requirements of the act that governs such a body. She echoed the concern voiced by Dr. Ramirez-Toro that the strategy for and goals of the regional listening sessions should be defined more clearly in the draft strategic plan. In particular, she noted, the plan should describe clearly how comment and advice generated during regional listening sessions would be funneled to the Executive Council of the NEJAC.

Responding to Ms. Horne's concerns, Ms. Stahl, while noting that she was pleased that the EPA regions have moved forward in accepting the notion of regional listening sessions, expressed agreement that a means of conveying information to the NEJAC should be included in the strategy developed for the regional listening sessions. Ms. Stahl added that the NEJAC must monitor the issues that arise during those sessions so that its members will be cognizant of such issues on a national level, rather than leaving them confined only to a regional level.

Expressing concern that EPA might find it necessary to secure state participation, Ms. Shepard asked Ms. Stahl to discuss her perspective on the role of state governments in the regional listening process. Ms. Stahl responded that she believed that the states would want to participate in the listening sessions. She pointed out that there are issues of environmental justice in all states. The states, she said, cannot afford to withhold participation. Ms. Stahl then expressed her belief that the listening sessions would prove to be an effective way for EPA to engage the states on a regional basis. She stated further that she hoped that the regional sessions will be conducted in a manner that will be an opportunity for sharing of concerns and of information, rather than an avenue for the "demonization" of state bureaucracies or state environmental agencies.

Mr. Lee warned against the implementation of the regional listening sessions lacking an "action plan" or guidance on the format of the sessions, how the sessions will be evaluated, and how action taken in response to issues raised during the sessions will be measured. He stressed that it is the business of the NEJAC to encourage and advise EPA to ensure that the agency develops a standard operational and procedural process for the regional listening sessions. He suggested that, in the future, NEJAC may, if it chooses, to provide advice and recommendations on regional listening sessions.

Ms. Subra commented that each EPA regional office had provided the drafting and writing committee with a report on the status of the issues on which that region was working. She suggested that the information provided be disseminated to communities in each region so that members of the communities can review the actions of regional offices. Ms. Subra noted that, if repeated on at least an annual basis, such action also could serve as an effective mechanism by which the EPA regional offices can provide information to the NEJAC on the regional issues and initiatives.

Referring to the involvement of the states in the regional listening sessions, Ms. Subra commented that some state agencies perform at a "less-than-appropriate" level. Therefore, she continued, citizens look to the EPA regional office for assistance. Ms. Subra stressed that it is important that both the EPA regional offices and the states attend the listening sessions, so that tasks and responsibilities can be delegated. She added that it will be important that the NEJAC "keep its finger on the pulse," continuing to be fully cognizant of what issues have been identified, what individual or entity has been assigned to address those issues, and whether the issues are being addressed.

Ms. Eileen Guana, Southwestern University School of Law and vice-chair of the Air and Water Subcommittee, pointed out that the NEJAC does not have oversight authority over the EPA regional offices. However, she added, the NEJAC can work to prompt the establishment of a standard of accountability for the regions and a voluntary mechanism for informing the NEJAC of activities conducted by the regions.

Mr. Warren pointed out two important themes that he said were apparent in the strategic plan. First, the proposed deliberative process, which intends that the NEJAC focus on delivering work products to EPA that can be integrated into EPA policy and practice, is the most effective way the NEJAC can influence environmental justice, he said. Another key theme of the strategic plan, he continued, is that the proposed processes are collaborative — collaborative processes between the NEJAC and EPA and between the NEJAC and communities are envisioned in the strategic plan, he noted. Mr. Warren also stressed that the development of a communication plan is a key element of the strategic plan. He said that a communication plan that provides for a number of channels of communication with EPA will allow the members of the NEJAC to better understand EPA's actions, in turn allowing the NEJAC to act more effectively to accomplish the mission set forth under its charter.

Ms. Anna Frazier, DINE' CARE and member of the Indigenous Peoples Subcommittee, informed the members of the NEJAC that she had talked with several representatives of grassroots organizations who wish to comment on the draft strategic plan. Those individuals would offer their comments during the public comment period to be held in conjunction with the current meeting of the NEJAC, she reported.

Mr. Robert "Bob" Harris, Pacific Gas and Electric Company and member of the Waste and Facility Siting Subcommittee, stressed that the draft strategic plan establishes a foundation that will allow the NEJAC to have influence nationwide in resolving problems because the plan involves all stakeholders. Mr. Harris commended EPA's regional administrators for their understanding of the importance of the role that they must play in developing and implementing the strategic plan and for the role they will play in bringing together all stakeholders in their regions.

Ms. Shepard then turned to Mr. Lee for remarks about specific plans for implementation of the draft strategic plan.

4.2 Implementation of the Strategic Plan

Mr. Lee first pointed out that the decision to "refocus" the NEJAC did not arise from a discussion that had started six months earlier, but had resulted from discussions that began some five or six years ago. He then emphasized that the draft strategic plan effectively incorporates community involvement and public participation. For example, he said, the draft fish consumption report is an excellent example of a work product of the NEJAC that was developed through a deliberative process and based on the views of communities about the issues and concerns of importance to those communities. Such processes and products have the potential to translate effectively into true improvements for communities, he stressed.

Mr. Lee then reviewed the NEJAC's schedule for 2002, as set forth on page 12 of the draft strategic plan. He first stated that the Pollution Prevention Work Group was to be established formally in January 2002. Mr. Lee added that Ms. Subra and Mr. Warren were to serve as co-chairs of the work group.

Continuing, Mr. Lee reported that the Fish Consumption Work Group was to make its report and the recommendations associated with it final by March or April 2002. Similarly, he added, the Interagency Environmental Justice Implementation Work Group was to complete its strategies report and recommendations on the same timetable.

Also in April 2002, Mr. Lee continued, OEJ was to provide a document that sets forth uniform procedures for the operation of subcommittees. He explained that the draft strategic plan of the NEJAC identifies five elements that are key to the successful operation of the subcommittees and work groups of the NEJAC: leadership; membership; the role of DFOs; support from and communication with EPA program offices; and development of strategic goals and plans. Recognizing that there are significant differences among the subcommittees of the NEJAC with respect to the five elements of success, OEJ, in consultation with the NEJAC, will develop procedures that will provide an operational baseline for all subcommittees and work groups, explained Mr. Lee. In developing the procedures, he added, the NEJAC, in consultation with the OEJ and relevant EPA program offices, was to develop a process for evaluating the effectiveness of the subcommittees of the NEJAC. Ms. Shepard would lead that initiative, said Mr. Lee.

Mr. Lee identified a series of tasks and provided assignments to members of the NEJAC to complete these tasks. The tasks are:

- Finalization of NEJAC Policy Advice Development Model

- Finalization of NEJAC Model for Incorporation Community Issues and Concerns into NEJAC Policy Dialogue

- Development of a definition of consensus and consensus-building

- Scoping report from Ad Hoc Scoping Work Group on Cumulative Risk Issue

Continuing, Mr. Lee stated that the NEJAC also would complete its work on the above tasks by June 30, 2002.

Mr. Lee explained that, as prescribed in the draft strategic plan of the NEJAC, the subcommittees of the NEJAC were to be asked to prepare annual strategic plans and progress reports to be submitted to the Executive Council of the NEJAC, OEJ, and the appropriate EPA program offices. He said that each subcommittee should submit a new or revised strategic plan to OEJ by September 30, 2002. Progress reports, he continued, would be due each year at least 30 days before each meeting of the NEJAC. The progress reports should describe in detail the subcommittee's progress in meeting the goals stated in its strategic plan, he noted.

Finally, Mr. Lee stated that the next meeting of the NEJAC was to be held in Baltimore, Maryland in December 2002. The issue that the NEJAC would be asked to consider and provide recommendations about during that meeting, he announced, was to be:

> *"How can EPA promote innovative pollution prevention approaches to ensure a clean and healthy environment and improve the quality of life for all people, including low-income communities, minority communities, and Tribes?"*

Ms. Horne asked how the reports, procedures, and processes developed for implementation of the strategic plan were to be incorporated into the current document. She also noted some ambiguities in the language of the current version of the document, asking whether it would be possible to amend the current text. Mr. Lee responded that suggested revisions of the text and the products developed for implementation over the time period covered by the plan would be incorporated into a revised document after December 2002.

Returning his attention to the implementation of public participation at the regional level, Mr. Lee stated that OEJ is developing a process that EPA regional offices can implement in hosting listening sessions. He stated that many questions must considered during development of the process, including:

- Who should be invited to participate

- How the various regions can integrate the listening sessions into their regional plans

- Whether sub-regional meetings should be conducted, when appropriate

Mr. Lee then stated that, once a draft strategy for conducting the regional sessions has been formulated by OEJ, in conjunction with the EPA regional offices, OEJ was to provide a report to the NEJAC. He stated that the NEJAC then would advise EPA about the implementation of the strategy for the regional listening sessions and provide the agency recommendations about that effort.

Ms. Stahl suggested that members of the NEJAC should be able to work directly with the regional offices of EPA to engage in the regional listening sessions, noting that the Executive Council could glean many "lessons learned" from the public comment period process. She also commented that the members of the NEJAC perhaps could confer with EPA regional administrators during a meeting of the NEJAC.

Dr. Richard Gragg, III, Florida A&M University and member of the Health and Research Subcommittee, commented that the public also should have the opportunity to provide comments on the process for conducting regional listening sessions.

Ms. Eady expressed her belief that the listening sessions would be a useful addition to EPA's strategy for increasing public participation. However, she also expressed concern that the sessions would not lead to action by the EPA regional offices, pointing out that, in the past, citizens often had traveled to address the NEJAC only after regional authorities ignored them. She also expressed concern that the NEJAC would not be able to monitor the activities of 10 EPA regions. Ms. Shepard responded that communities still would have the opportunity to address the NEJAC during public comment periods. Ms. Shepard agreed, however, that reporting to the NEJAC about the progress of the listening sessions would be an important issue to be considered during the development of the process for those sessions.

5.0 PRESENTATIONS AND REPORTS

This section summarizes the presentations and reports made to the Executive Council of the NEJAC.

5.1 Update on the Interagency Environmental Justice Implementation Work Group

Ms. Guana provided an overview of the draft document, The National Environmental Justice Advisory Council's Report on Integration of Environmental Justice in Federal Agency Programs. That document was developed by the Interagency Environmental Justice Implementation Work Group to present information about the progress of the federal government in integrating environmental justice into the policies, programs, and activities of its agencies in a manner consistent with the provisions of existing laws and Executive Order 12898. The draft report, she explained, provides an analysis of information presented during the December 2000 meeting of the NEJAC, which had been held in Arlington, Virginia.

Ms. Guana reported further that the work group faced particular challenges in developing recommendations for EPA about interagency implementation on the basis of the panel discussions heard during the December 2000 meeting. She said that the policy issue related to interagency implementation is broad. Many of the presentations, she continued, did not provide complete descriptions of the pertinent activities of agencies because the presentations, of necessity, were limited in length. Some individuals, Ms. Guana explained further, made very general presentations that failed to provide specific information. Although other presenters provided a few, very specific examples of an agency's activities, time limitations prevented them from providing details about those activities, she added.

The work group faced another challenge in organizing the report, continued Ms. Guana. Different agencies have different missions and work under completely different legal authorities, she explained. She pointed out that it was problematic for the work group to present the report in a way that could capture that diversity without inviting comparisons that may be unfair, given the differing activities and legal authorities of the various agencies of the federal government.

Continuing, Ms. Guana stated that a third challenge that the work group faced in developing the report was that they could not verify independently that agencies were doing what they said they would be doing or to evaluate the effectiveness of the efforts of the agencies.

To meet those challenges, said Ms. Guana, the members of the work group drew on various additional sources in an attempt to obtain more complete information about the actions of federal agencies. Such sources, she noted, included the web sites of the various agencies. She pointed out that the sources were not independently verified sources, a circumstance that introduced yet another limitation on the information included in the report.

Discussing the structure of the report, Ms. Guana stated that, to provide a legal context for the discussion of the activities of the agencies, the report began with a discussion of legal authorities. She noted that the discussion of legal authorities was limited principally to those authorities granted the various agencies under environmental statutes. However, she noted, many agencies have authorities under other statutes. To her knowledge, she said, the agencies have not performed a systematic study of all their legal authorities within the context of environmental justice. Therefore, she reported, in its report, the work group had recommended to the NEJAC that the NEJAC advise EPA to request each federal agency to undertake a review of all its legal authorities.

Ms. Guana then pointed out that the report also included information about legal developments that had taken place since the December 2000 meeting and the potential implications of such developments for the environmental justice movement. She cited the Supreme Court decision in the Sandoval case in which a divided court said the Civil Rights Act of 1964 does not authorize private lawsuits that contend state government policies have a discriminatory effect. Title VI of the act allows a suit only if litigants can prove discrimination was intentional, the court ruled.

Continuing, Ms. Guana noted that the work group had organized the report in a manner that would alert the reader to the differences among agencies in terms of their potential for exerting influence on environmental issues and their varying levels of legal authority. The report includes a table that categorizes the agencies by the nature of their activities, she added. Continuing, she explained that the work group also made an effort to convey an understanding of the types of activities in which the various agencies are engaged, including an analysis of activities the various agencies have in common.

Concluding her remarks, Ms. Guana stated that the intent of the report was to provide the reader with a complete and fair picture, or “baseline snapshot,” of the actions in which the various agencies currently are engaged. The report, she suggested, therefore can be used in the future to measure progress in integrating environmental justice into the policies, programs, and activities of the agencies. She added that the report could be helpful to the agencies themselves by providing information about the activities of sister agencies in areas of common interest that may assist them in determining how they can address environmental concerns related to their own missions. Ms. Guana then stated that the work group welcomes suggestions and comments from the members of the NEJAC about strengthening the report and making it more useful to EPA and other federal agencies.

Ms. Walker suggested that a representative of the Indigenous Peoples Subcommittee be invited to participate in preparing the final report. She stated that the Indigenous Peoples Subcommittee had made several recommendations to the work group as the report was being drafted; she noted that those recommendations had not been included in the report. Ms. Guana responded that the work group had focused first on the organization of the information in the report. She added that the work group would be interested in reviewing the recommendations of the Indigenous Peoples Subcommittee and incorporating those suggestions into the final report.

Ms. Stahl expressed her understanding that all the subcommittees had provided recommendations during the planning stages of the report. She suggested that the recommendations of all the subcommittees be reviewed as the final report is prepared.

Ms. Walker then asked when the final report was expected to be available. Mr. Lee responded that the final report was to be completed and distributed in March or April 2002.

5.2 Report on the Community-Based Health Research Model

Mr. Lee provided an update on the status of the report on the community-based health research model that the NEJAC had undertaken to develop. He reminded the participants in the meeting that, in response to issues discussed during the meeting of the NEJAC in Atlanta, Georgia, in May 2000, a 20-member work group, made up of members of the NEJAC and representatives of HHS and EPA, had been formed to develop such a model. The final report of that work group had been distributed to the Executive Council in early 2001, he added.

Mr. Lee explained that a primary theme of community-based health research models was the need for interagency collaboration. To provide a meaningful response to the recommendations set forth in the health report, EPA’s Office of Research and Development (ORD), in collaboration with OEJ and EPA’s Office of Prevention, Pesticides, and Toxic Substances (OPPTS), had developed a strategy for interagency collaboration in the area of community-based health research. The strategy, continued Mr. Lee, had been forwarded to the office of the EPA Administrator for review. He stated that he expected a response from the Administrator in the near future. That expectation expressed, Mr. Lee then tabled discussion of the proposed strategy, pending receipt of that response.

5.3 Update on the Federal Facilities Work Group

Mr. Brandon Carter, EPA Federal Facilities Restoration and Reuse Office and DFO of the Federal Facilities Work Group of the NEJAC, provided an update on the activities of the work group.

Mr. Carter explained that the task of the work group is to identify and evaluate key issues related to the activities and operations of federal facilities that are of concern to environmental justice communities. The objectives of the work group, he stated, are to:

- Formulate national policy recommendations to address such concerns
- Provide a forum for the conduct of dialogue communities
- Compile a list of resources available to communities and stakeholders
- Produce a written report that summarizes the findings and recommendations of the work group

Mr. Carter stated that the work group had begun reviewing case studies in January 2001 to identify the key issues related to federal facilities that are of concern to environmental justice communities and to gather information that could serve as a basis for the development of the work group’s policy recommendations. He noted that work group also evaluated the effectiveness of previous policy recommendations made by various other federal advisory committees. He also noted that, during the meeting of the NEJAC in December 2000, the U.S. Department of Energy (DOE), the U.S. Department of Defense (DoD), and the U.S. Department of the Interior (DOI) had signed a memorandum of understanding (MOU) that ensured their cooperation with the Federal Facilities Work Group and assigned staff members to collaborate with the work group.

Mr. Carter then announced that the work group expects to submit a final report to the NEJAC before the December 2002 meeting of the NEJAC to be held in Baltimore, Maryland. Mr. Lee reported that the NEJAC Federal Facilities Work Group will work in coordination with and report to the NEJAC Waste and Facility Siting Subcommittee. This will improve coordination between EPA and the NEJAC because the primary support being provided to this work group is being provided by the OSWER, which also supports the NEJAC Waste and Facility Siting Subcommittee. OSWER has committed to adding another member to the subcommittee to provide interface with the work group, he said.

Ms. Subra asked whether the working group was to evaluate the level of consistency between cleanup efforts at federal facilities and those at other cleanup sites, such as Superfund sites. Mr. Carter responded that the work group was reviewing case studies from a representative sample of various types of sites, including a formerly used defense site (FUDS), a base realignment and closure (BRAC) site) site, and a DOE site. The work group, he stated, would compare the principles and recommendations that are being implemented by the various authorities. Mr. Carter added, however, that such a comparison is difficult because the authorities that regulate how and by whom sites are cleaned up differ significantly.

Mr. Subra then asked whether the work group had considered the possibility that inactive federal facilities currently undergoing cleanup will be reactivated in response to the terrorist attacks of September 11, 2001. She asked whether it would be necessary to complete cleanup at a site before new activities could begin. Mr. Carter responded that sites that have been identified by Congress under the BRAC Program would not reopen because those properties are to be transferred out of the ownership of the DoD. Other sites that are put on standby by the federal government could be reactivated, he noted. Many sites on the National Priority List (NPL), a list of national priorities for sites with known or threatened releases of hazardous substances, are active facilities that continue to operate while undergoing cleanup, explained Mr. Carter.

Ms. Stahl reminded Mr. Carter and the members of the Executive Council that the Environmental Council of States (ECOS) also had provided recommendations to the EPA Administrator through resolution. Ms. Stahl suggested that, as it develops its report, the work group draw on staff of ECOS as a resource.

Ms. Eady asked whether the work group was to address the recurring issue of the determination of the lead agency when more than one federal agency has legal authority over cleanup of a federal facility. Mr. Carter responded that the work group planned to address the issue, commenting that issues related to the authority of the lead agency and that of EPA authority under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the National Contingency Plan (NCP) are "implicit in the issues related to federal facility sites."

Ms. Subra pointed out that one issue linked to federal facilities with increasing frequency over the past few years is contamination with perchlorate, a soluble oxidating agent used in the manufacture of explosives. Ms. Subra asked Mr. Carter whether, in its report, the work group would address specifically issues related to perchlorate. Mr. Carter responded that the report was not intended to address issues related to specific contaminants or implementation of measures to address such specific contaminants under cleanup programs. However, he continued, EPA currently is developing a new maximum concentration level (MCL) for perchlorate. He then agreed to provide the Executive Council of the NEJAC updates on the status of the development of the MCL.

Dr. Gragg asked whether the report would identify the number of communities that may be affected directly by environmental conditions at federal facilities and the status of cleanup efforts at the facilities identified. Mr. Carter responded that the work group had examined the possibility of cataloguing environmental justice communities that are located at or near federal facility sites but had discontinued the effort because of constraints imposed by limitations on resources. Instead, the work group decided to focus the report on the implementation of cleanup programs at federal facilities, he said. Mr. Carter added that the work group would be able to identify the total number of federal facility sites.

Ms. Mary Nelson, Bethel New Life and member of the Waste and Facility Siting Subcommittee, commented that, to ensure that contamination does not reoccur at cleanup sites, standards for prevention should be included in the report.

Mr. Lee commented that lessons learned from several positive developments in the cleanup of federal facilities could be incorporated into the report. For example, he said, the cleanup and restoration of the Metlakatla Indian community of Metlakatla, Alaska, an environmental justice and national Brownfields showcase community, successfully involved DoD, the U.S. Coast Guard, and the U.S. Federal Aviation Administration (FAA). He also mentioned the success of Bridges to Friendship, an environmental justice demonstration project underway at the Washington Navy Yard in southeast Washington, D.C. Mr. Lee noted that the progress such efforts illustrate is significant.

5.4 Update on the Pollution Prevention Work Group

Ms. Subra, co-chair of the newly formed Pollution Prevention Work Group, provided a brief overview of the preliminary objectives of that work group.

Ms. Subra stated that the primary objective of the work group would be to evaluate how existing technologies, mechanisms, and programs for pollution prevention can be implemented in environmental justice communities to improve the quality of the environments of those communities. In light of information presented by the Fish Consumption Work Group, she said, her work group will consider how pollution prevention efforts can reduce contamination of aquatic environments. Continuing, Ms. Subra reported that the working group also would investigate mechanisms for measuring the effectiveness of pollution prevention measures.

Ms. Subra informed the members of the Executive Council that she and Mr. Warren, co-chairs of the working group, were to submit to EPA a list of potential members of the work group before the end of 2001. She requested that the members of the Executive Council submit names of suggested members of the work group to her and Mr. Warren. Mr. Barry E. Hill, Director, EPA OEJ, added that the members of the Executive Council also should recommend to EPA consultants that have experience in pollution prevention.

Ms. Walker requested that a representative of the Indigenous Peoples Subcommittee be appointed to serve on the work group. She also asked that the work group consider whether an evaluation of the issue of the "precautionary principle" would be appropriate in light of the objectives of the work group.

Ms. Jaramillo suggested that the work group also evaluate the cost and benefits of environmental restoration, clean production, and low-impact development.

Mr. Suagee reported that his clinic currently is working with three tribes to develop tribal environmental policy and acts, specifically by creating an environmental review process for the tribes. The purpose of the effort, he explained, is to avoid pollution and other environmental degradation that might arise as a result of economic development. Mr. Suagee then volunteered to participate on the work group.

Ms. Eady noted that there are several valuable resources in the state of Massachusetts, including the Toxicities Reduction Institute and the Center for Sustainable Production. She volunteered to suggest some individuals representing those organizations as potential members of the Pollution Prevention Work Group.

Dr. Gragg suggested that the work group also consider pollution prevention at DOE and DoD facilities.

Mr. Larry Charles, ONE/CHANE and member of the International Subcommittee, specifically asked that Ms. Dianne Wilkins, Oklahoma Department of Environmental Quality be selected to represent the International Subcommittee on the Pollution Prevention Work Group.

5.5 Briefing on the Cumulative Risk Technical Panel of the EPA Risk Assessment Forum

Mr. Lee introduced Mr. Martin Halper, EPA OEJ, to provide an overview of the current draft Framework for Cumulative Risk Assessment prepared by the Cumulative Risk Technical Panel of the EPA Risk Assessment Forum, a standing committee of senior EPA scientists. The purpose of this briefing is to help NEJAC prepare to address the policy issue area for 2003, which is slated to be cumulative risk.

Mr. Halper explained that the framework document was developed to provide a basic structure and definition of key principles for EPA's cumulative risk assessments. In the future, he said, the framework document will be used as a foundation for comprehensive guidance for cumulative risk assessment. Mr. Halper noted that, in some cases, concepts introduced in the framework document require the application and knowledge of methods that currently are not available. Therefore, he continued, the document also outlines research and development needs that must be met to support evaluation of cumulative risks.

Mr. Halper singled out two elements of the framework document that he considered particularly significant to the environmental justice movement. First, he said, the chapter on planning, scoping, and formulation of problems requires that public officials, experts on risk, community leaders, and interested and affected parties seek agreement on the purpose, scope, and approach for the risk assessment through extensive dialogue before the assessment begins. Second, he continued, the framework document addresses the concepts of the vulnerability, and specifically the susceptibility, of a population as important factors in the assessment of cumulative risk. Mr. Halper explained that a vulnerable population is a population at increased risk of adverse effect. The concept, he explained further, includes individuals or sensitive subgroups that may be highly susceptible to risk because of a number of possible factors, such as stage of life, prior exposure, or existing state of disease.

Mr. Halper then stated that the framework document, which includes traditional quantitative considerations, as well as qualitative considerations, has the potential to affect the ways in which EPA and other federal agencies operate.

Continuing, Mr. Halper stated that, in general, the framework document has been applauded universally. He then said that a full peer review of the document was to be conducted in the fall of 2002. After the framework document is final, he continued, the first steps in the development of a formal guidance document will include the development of new studies and the evaluation of existing studies that can be used as case studies and the testing of some of the concepts of cumulative risk assessment identified in the case studies. He added that the development of the guidance document would take approximately two years.

Ms. Guana asked whether the framework document addresses the concept of peak periods of exposure as a qualitative consideration in cumulative risk assessment. She also asked whether the framework document identifies an optimal geographic scale at which to assess cumulative risk, noting that an assessment of only large-scale exposures might mask the effects of a number of small sources of exposure.

Mr. Halper reminded the members of the NEJAC that the framework document is not a guidance document. Therefore, specific methods for evaluating peak-period exposures and determining the optimal geographic scale for a risk assessment are not included in the document, he said. However, he continued, the framework document does point out that the duration and geographic scale of exposure are important considerations that should be included in a cumulative risk assessment. He added that such considerations can be site-specific and should be discussed by all stakeholders during the planning and scoping phase of a cumulative risk assessment.

Calling attention to the preface of the framework document, Mr. Suagee pointed out that tribes had not been included in the extensive peer review of the document. He stressed that tribal peoples should be involved in the review process. Dr. Gragg noted that the list of reviewers in the preface did not appear to include representatives of environmental justice communities or other affected groups. Mr. Halper responded that those groups would be included in the formal peer review process. Mr. Lee also stressed to Mr. Halper that the experiences and expertise of the members of the NEJAC and their relationships with tribes, environmental justice communities, states, and other entities make the members important and valuable resources for the panel in developing the framework document and future guidance documents on cumulative risk assessment.

Mr. Lee noted that the NEJAC Ad Hoc Scoping Work Group is being asked to address two questions in preparation for addressing the cumulative risk issue. The questions will address:

- What are some focused approaches (specific definitions, conceptual frameworks, questions, methodologies, areas, etc.) to the issue of cumulative risks (and impacts) that will make a significant contribution at this time to addressing environmental justice concerns related to the issue?

- How can the NEJAC make best use of its own capacities (membership, constituencies, outreach and deliberative processes, knowledge base, etc.) to address the issue of cumulative risks (and impacts)?

Dr. Gragg asked whether the framework document addresses the issue of the “precautionary principle” as a strategy for risk management. Mr. Halper responded that the document does not discuss principles of risk management, but rather addresses issues and considerations that are important in evaluating cumulative risk.

Ms. Shepard asked about the implications of the document for state permitting programs. She asked whether state environmental quality review acts or new legislation that specifically identifies cumulative risk as a required consideration would be necessary before the concepts presented in the framework document could influence state permitting processes. In response, Mr. Halper expressed his belief that the document will provide an impetus to the adoption of the concept of cumulative risk in the approach to assessment.

5.6 Update on the Implementation of Permitting Recommendations

Mr. Hill made a presentation on the status of EPA's implementation of recommendations made in the report of the Environmental Law Institute (ELI) "Opportunities for Advancing Environmental Justice: An Analysis of U.S. EPA Statutory Authorities." The ELI report reviews the principal environmental regulations of EPA) that govern maintenance of air and water quality, management of waste, regulation of the use of pesticides and chemicals, and fulfillment of public right-to-know legislation, reported Mr. Hill. The report also identifies specific statutory authorities for promoting environmental justice in the full range of EPA program functions, including permitting and the setting of standards, he said.

Mr. Hill then described the context in which the ELI report was developed. He first shared an observation of one of the framers of the Constitution of the United States, "This is a government of laws and not of men". Therefore, observed Mr. Hill, if there is no law, there can be no regulations. Because there is no stand-alone federal environmental justice statute, he continued, supporters of the environmental justice movement must look at the existing laws and implementing regulations to determine whether and how environmental justice is in fact embedded in those laws.

Continuing, Mr. Hill noted that, to integrate the concept of environmental justice into the regulatory process, supporters of environmental justice must answer two questions:

- "What is the legal authority?"
- "Assuming the legal authority exists, how can environmental justice be incorporated administratively into permitting programs?"

Mr. Hill then presented the five steps necessary to incorporate environmental justice into EPA's regulatory process. The starting point, he said, is the advice and recommendations of the NEJAC. In response to discussions that took place at its 1999 meeting, he continued, the NEJAC had issued a report in July 2000 that focused on permitting authorities under the Resource Conservation and Recovery Act (RCRA), the Clean Air Act (CAA), and the Clean Water Act (CWA). In that report, he said, the NEJAC had recommended that EPA examine all the statutes under which it exercises regulatory authority to determine whether the legal authority to incorporate environmental justice into the agency's regulations is embedded in those statutes.

Continuing, Mr. Hill stated that the next step in incorporating environmental justice into EPA's regulatory process is legal analysis of existing statutes, as recommended by the NEJAC, and evaluation of how environmental justice can be incorporated in EPA's regulatory process from an administrative point of view. At the request of OEJ, ELI had performed a legal analysis, Mr. Hill explained, examining every statute under which EPA exercises authority, to identify opportunities to use existing statutory authorities to advance environmental justice. He also noted that, in December 2000, Mr. Gary Guzzi, EPA Office of General Counsel, had issued a memorandum that stated that environmental justice indeed is embedded in existing laws and implementing regulations. Therefore, there is no need for a stand-alone environmental justice statute, declared Mr. Hill.

With regard to the incorporation of environmental justice from an administrative point of view, Mr. Hill stated that OEJ had asked the National Academy of Public Administrators (NAPA) to evaluate how environmental justice might be incorporated into the permitting process under RCRA, the CWA, and the CAA. Mr. Hill then announced that, after his presentation, Ms. Ann Goode, senior consultant for NAPA, was to discuss the findings of that organization's evaluation.

The third step, Mr. Hill continued, is training. A training collaborative made up of representatives of EPA headquarters, EPA regional offices, industry, and community groups has been convened to develop a basic course on environmental justice that reflects recommendations made in the ELI and NAPA reports, he said. Further, EPA will develop

CAA and CWA training modules targeted to federal and state permit writers. The modules will train those individuals in integrating considerations of environmental justice into state and federal permits.

Mr. Hill then said that, after training has been provided, the next step is implementation. EPA OEJ would work with senior managers at EPA and EPA's Environmental Justice Steering Committee to implement environmental justice, as recommended in the ELI and NAPA reports, into their daily work under the authority provided by existing laws, he said.

Mr. Hill stated that the last step is evaluation. The EPA Inspector General will be asked to evaluate all programs for success in integrating environmental justice, as outlined in the NAPA and ELI reports, he said.

Ms. Ann Goode then gave a presentation on NAPA's research and evaluation of EPA's efforts to address the widely recognized fact that some communities of low-income people and people of color are exposed to significantly greater environmental and public health hazards that other communities. NAPA's research and associated recommendations are presented in the report "Environmental Justice in EPA Permitting: Reducing Pollution in High-Risk Communities is Integral to the Agency's Mission," she said.

Ms. Goode then explained that NAPA, an independent nonprofit organization that was chartered by Congress in 1967, is made up of some 500 fellows, including former members of Congress, leaders of nonprofit organizations and local government officials. Specifically, she said, NAPA was asked to prepare a report that would help the public better understand how considerations of environmental justice can be incorporated into the permitting process under RCRA, the CWA, and the CAA.

Ms. Goode stated that, in the report, NAPA recommended to EPA that changes be made in four distinct areas related to environmental justice: leadership, permitting procedures, setting of priorities, and public participation.

In the area of EPA's leadership in integrating environmental justice into permitting processes, Ms. Goode stated that President Clinton's Executive Order 12898 on environmental justice, as well as the policy statement Administrator Christine Todd Whitman issued to EPA assistant administrators on August 9, 2001 and statements made by former EPA administrators, clearly articulated a commitment to environmental justice. However, despite the commitment of senior EPA leadership and, in many cases, allocation of substantial resources to the effort, Ms. Goode said, environmental justice has not yet been integrated fully into the agency's core mission or staff functions. There remains a "disconnect" between policy pronouncements and program realities, she added, although EPA has significant statutory and regulatory authority, as well as numerous opportunities to exercise discretion to incorporate considerations of environmental justice into its permitting processes, she added. Specific expectations for outcomes have not accompanied the commitments made, she continued, nor has EPA adopted methods of measuring progress in achieving outcomes or accountability to ensure that EPA managers and staff work to implement policies related to environmental justice.

Ms. Goode stated that NAPA's recommendations for EPA leadership in the area of integrating considerations of environmental justice into the agency's permitting processes are:

- Building on the EPA Administrator's recent environmental justice memorandum, EPA's assistant administrators for air, water, and waste and EPA's regional administrators should reinforce the importance of the policy on the incorporation of considerations of environmental justice, the role of that policy in the accomplishment of EPA's core mission, and the expectation that managers and staff will implement consideration of environmental justice in their projects and activities.

- EPA should complete its draft national guidance on environmental justice and develop practical tools that permit writers can use to identify and address issues of environmental justice related to air, water, and waste permits.

- EPA's offices of Air and Radiation, Water, and Solid Waste and Emergency Response should develop strategic plans that demonstrate how environmental justice is to be integrated into the substance and procedures of their permitting programs. Further, they should explore carefully ways in which they can use the authorities set forth in the General Counsel's legal opinion dated December 1, 2001 to incorporate considerations of environmental justice into permits for new and ongoing projects.

- Each strategic plan for incorporating environmental justice into a permitting program should specify goals, measures of performance, expected outcomes, mechanisms for measuring accountability, and time frames for meeting the goals set forth in the plan.

- EPA should establish an accountability process that includes clear measures of performance for evaluating the success of EPA managers and staff in incorporating considerations of environmental justice into air, water, and waste permits.

- EPA should identify disproportionately affected and other adversely affected communities and establish explicit goals for reducing the risks posed to such communities. Further, EPA should set clear expectations for producing results that are linked directly to the agency's mission and give staff an important measure of performance that the staff can support whole-heartedly. Such tasks also could provide measures of EPA's progress in implementing environmental justice and could be reinforced by agencywide reporting that tracks such progress.

- EPA should develop a communication mechanism for agency wide sharing of information about tools that are effective in addressing environmental justice, including descriptions of best practices and lessons that all media programs, regional offices, and states can learn. The mechanism should coordinate EPA's activities in incorporating considerations of environmental justice into permitting processes, so that permit writers in all EPA's media programs and EPA regional offices can become more effective and efficient in responding to concerns related to environmental justice.

- EPA should evaluate the effectiveness of its national workshop on Fundamentals of Environmental Justice to determine how well the workshop meets its intended objectives, including the effective implementation of environmental justice in permitting.

- EPA should develop a program for rewarding the extra efforts of employees in addressing environmental justice in permitting through recognition under existing national awards programs and through the development of additional recognition programs.

Turning to a discussion of opportunities for integrating considerations of environmental justice into individual permitting programs, Ms. Goode explained that a recent legal opinion issued by EPA's Office of General Counsel (OGC) made it clear that the CAA, the CWA, and RCRA provide permitting staff ample authority to address the concerns of high-risk communities when developing the terms and conditions of individual permits. The EPA Administrator reaffirmed that opinion in her August 9, 2001, memorandum to senior EPA officials, she said. However, EPA managers have not made it routine procedure to provide their permitting staff with straightforward, practical tools and procedures for incorporating community concerns into permits, nor have they directed that staff to ensure that concerns related to environmental justice are considered systematically in the conduct of EPA's permitting programs, continued Ms. Goode. Further, many EPA permit writers have not been provided the opportunity to learn how they can contribute to the resolution of issues related to environmental justice through an increased awareness of the community that may be affected by a proposed permit. Such awareness, said Ms. Goode, would include consideration of the nature of the risks the community faces; the concerns of the community about the activity related to the proposed permit, the capacity of the community to participate in the permitting process, and the best methods of communicating with the community.

Continuing, Ms. Goode pointed out that, because EPA's legal authority to issue permits is based on the provisions of RCRA, the CAA, and the CWA, EPA's ability to address other common concerns among high-risk communities, such as noise pollution, traffic concerns, and odor, is limited. She also explained that, in the area of permitting programs, EPA's credibility in high-risk communities depends upon its ability to visibly use opportunities for enforcing permit conditions, including more frequent inspections, local monitoring of environmental conditions, and reductions in backlogs of permit renewals for existing facilities.

Ms. Goode stated that NAPA's recommendations to EPA in the area of integrating considerations of environmental justice into individual permitting programs are:

- Senior program managers of EPA's air, water, and waste programs should take prompt steps to use their authorities, as outlined in the legal opinion issued by OGC, to prepare guidance documents for staff on how to fully incorporate considerations of environmental justice into their permitting programs. The managers should develop these documents after consulting with representatives of affected communities and regulated entities. The programs also should use legal mandates and discretionary authorities to the fullest extent possible to expand opportunities for public participation in permitting programs; increase monitoring and public reporting; and impose in new, revised, and renewed permits conditions designed to reduce the burdens of pollution and public health hazards on disproportionately affected communities.

- In the short term, EPA should determine whether it can provide communities with earlier notice of permit applications so that the public will have a better opportunity to interact directly with EPA's permit writers and the community's concerns can be considered during the drafting and negotiating stages of the permitting process.

- Over the long term, EPA should revise its permitting regulations to ensure that nearby communities are notified of a permit application as early as possible.

- EPA should revise its public notification practices to ensure that public notices are provided in languages commonly spoken in the affected communities and placed in libraries, churches, community centers, and other locations accessible to members of those communities.

- EPA managers should provide permit writers with check lists or similar tools the permit writers can use in identifying and considering concerns related to environmental justice.

- EPA budget and administrative staff should recognize the additional time and effort that permit writers must devote to developing permit conditions that take into account issues of environmental justice and to working more closely with community groups. The agency's workload models should be adjusted as appropriate to indicate the average number of permits to be handled by a permit writer in light of such additional effort.

Continuing her overview of the NAPA evaluation, Ms. Goode discussed NAPA's findings related to EPA's use of permitting as a strategic element in pollution prevention and risk reduction. She stated that EPA had undertaken efforts to improve the science of cumulative risk assessment so that more tools are available to better assess disproportionate and adverse effects on communities. However, while waiting for advances in the science of cumulative risk assessment, she explained, EPA and states currently have several tools available to support analysis of exposures of disproportionately affected communities to actual or potential multiple pollutants. She also said that EPA could perform more frequent and comprehensive environmental monitoring in communities to determine whether those communities should be given priority attention.

Ms. Goode stated that NAPA's recommendations to EPA in the area of the use of permitting as a strategic element in pollution prevention and risk reduction are:

- EPA should consult with state and local health and environmental officials to address concerns related to environmental justice and identify high-priority communities in which residents are exposed to disproportionately high levels of pollution.

- EPA should evaluate tools that have been developed by its regional and program offices, such as the Office of Policy, the Office of Civil Rights, and OEJ. EPA should identify among those tools potential best practices the Agency can recommend when it develops practical guidance documents to assist permitting staff in incorporating considerations of environmental justice into EPA permits nationwide.

Referring to improvement by EPA in increasing public participation in the permitting process, Ms. Goode stated that the Agency had experimented with various techniques for enhancing public participation. The techniques, however, she noted, have not yet been made standard operating procedure for EPA's permitting processes in the air, water, and waste programs. Ms. Goode then stated that NAPA's recommendations to EPA in the area of the use of permitting as a strategic element in pollution prevention are:

- EPA should expand its Technical Assistance Grant (TAG) and Technical Outreach Services for Communities (TOSC) programs to offer more timely and accessible technical assistance to communities that need such support.

- Using its discretionary authority, EPA should adopt procedures for providing early notice to communities once permit applications have been completed. Such notices should provide the name of an Agency community liaison and solicit comments from the community before the

Agency negotiates the terms and conditions of a permit.

Concluding her remarks, Ms. Goode stated that OEJ also had asked NAPA to next evaluate three state permitting programs. She commented that, while EPA itself performs relatively little permitting compared with the states, EPA could serve as a model for state permitting programs.

Mr. Hill added that the states selected for NAPA's evaluation would fall into the following categories: (1) a state that has passed or enacted environmental justice legislation; (2) a state that has issued an official statement that environmental justice is a policy issue; and (3) a state that has established an environmental justice commission or a body similar to the NEJAC. He explained that the purpose of evaluating states that fall into those categories is to demonstrate how such states can serve as models for their sister states.

Ms. Stahl expressed her belief that the next step should be development of the guidelines and standards to be applied through the appropriate authorities. She explained that, until standards have been developed, permitting and enforcement programs would not have the tools necessary to apply the principles.

Ms. Subra commented that, in the area of public participation, it is not sufficient to give communities

Exhibit 1-3

RETIRING MEMBERS OF THE NATIONAL ENVIRONMENTAL JUSTICE ADVISORY COUNCIL

Ms. Rose Augustine
Ms. Elaine Barron
Ms. Daisy Carter
Mr. Fernando Cuevas
Ms. Denise Feiber
Dr. Michel Gelobter
Mr. Dan Greenbaum
Ms. Rita Harris
Ms. A. Caroline Hotaling
Ms. Jennifer Hill-Kelley
Ms. Savi Horne
Ms. Annabelle Jaramillo
Mr. Philip Lewis
Mr. Neftali Garcia Martinez
Ms. Zulene Mayfield
Mr. David Moore
Mr Carlos Porras
Mr. Leonard Robinson
Mr. Alberto Saldamando
Mr. Mervyn Tano
Mr. Michael Taylor
Ms. Marianne Yamaguchi

Ms. Shephard presents Ms. Horne with a certificate of appreciation for her years of service on the NEJAC.

the opportunity to comment. She stressed that there is a real need, particularly in environmental justice communities, for capacity building and access to technical assistance. Ms. Subra said that the community must understand what the rules are, where the application violates the rule, and how a community can ensure that such information is entered into the record. Ms. Goode responded that the NAPA report includes explicit recommendations about increasing support for technical assistance for communities.

6.0 MISCELLANEOUS BUSINESS

6.1 Acknowledgments

Mr. Lee announced that OEJ would recognize and honor members of the NEJAC whose terms were to expire on December 31, 2001. Exhibit 1-3 presents the names of the retiring members of the NEJAC.

Mr. Lee also commended the efforts of the DFOs of the various subcommittees and work groups of the NEJAC: Ms. Wendy Graham, Ms. Shirley Pate, Mr. Will Wilson, Ms. Alice Walker, Mr. Rey Rivera, Mr. Brandon Carter, Ms. Brenda Washington, Ms. Aretha Brockett, Ms. Teresita Rodriguez, and Mr. Daniel Gogal. He also thanked the staff of EPA Region 10, including Ms. Joyce Kelly, Mr. Michael Letourneau,

Dr. Gragg suggested that the membership of the Puerto Rico Subcommittee of the NEJAC be expanded to include representatives from the Virgin Islands. Dr. Gragg pointed out that other dependencies of the United States, particularly those that are islands, are faced with issues of environmental justice. Ms. Horne commented that she strongly agreed with Dr. Gragg's suggestion. Dr. Ramirez-Toro suggested that the recommendation be communicated to EPA Region 2 office and the Caribbean Field Office, noting that those offices provide financial support for the Puerto Rico Subcommittee.

Ms. Shepard stated that she would like to compile a year-end report on the accomplishments of the NEJAC during 2001. She asked that the chair of each subcommittees e-mail a list of that subcommittee's accomplishments to herself and Ms. Marva King, NEJAC Program Manager, EPA OEJ, by January 15, 2002.

Ms. Victoria Plata, and Ms. Ony Okorna, for their support in coordination of the planning of the meeting of the NEJAC with community groups in the region.

Continuing, Mr. Lee recognized the efforts of the staff of OEJ, especially Mr. Hill, Director of OEJ; Ms. Linda K. Smith, Associate Director for Resources Management, EPA OEJ; Marva E. King, NEJAC Program Manager; and Ms. Jaime Song, OEJ Intern, and thanked them for their hard work.

Ms. Jaramillo personally thanked Mr. Lee for his efforts, stating that the meetings of the NEJAC "could not happen" without his guidance. She then thanked Ms. Shepard for her hard work and for her leadership during the meeting of the NEJAC.

6.2 New Business

This section summarizes items of new business discussed during the closing remarks of the members of the Executive Council of the NEJAC. Ms. Shepard stated that the items should be noted in the record and would be discussed by the members of the Executive Council in the future.

United States
Environmental Protection
Agency

Office of Water
EPA 823-B-94-005a
August 1994

Water Quality Standards Handbook

Chapter 3: Water Quality Criteria

06158

Water Quality Standards Handbook
CHAPTER 3: WATER QUALITY CRITERIA

(40 CFR 131.11)

CHAPTER 3 WATER QUALITY CRITERIA

The term "water quality criteria" has two different definitions under the Clean Water Act (CWA). Under section 304(a), EPA publishes water quality criteria that consist of scientific information regarding concentrations of specific chemicals or levels of parameters in water that protect aquatic life and human health (see section 3.1 of this Handbook). The States may use these contents as the basis for developing enforceable water quality standards. Water quality criteria are also elements of State water quality standards adopted under section 303(c) of the CWA (see sections 3.2 through 3.6 of this Handbook). States are required to adopt water quality criteria that will protect the designated use(s) of a water body. These criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use.

3.1 EPA Section 304(a) Guidance

EPA and a predecessor agency have produced a series of scientific water quality criteria guidance documents. Early Federal efforts were the "Green Book" (FWPCA, 1968) and the "Red Book" (USEPA, 1976). EPA also sponsored a contract effort that resulted in the "Blue Book" (NAS/NAE, 1973). These early efforts were premised on the use of literature reviews and the collective scientific judgment of Agency and advisory panels. However, when faced with the need to develop criteria for human health as well as aquatic life, the Agency determined that new procedures were necessary. Continued reliance solely on existing scientific literature was deemed inadequate because essential information was not available for many pollutants. EPA scientists developed formal methodologies for establishing scientifically defensible criteria. These were subjected to review by the Agency's Science Advisory Board of outside experts and the public. This effort culminated on November 28, 1980, when the Agency published criteria development guidelines for aquatic life and for human health, along with criteria for 64 toxic pollutants (USEPA, 1980a,b). Since that initial publication, the aquatic life methodology was amended (Appendix H), and additional criteria were proposed for public comment and finalized as Agency criteria guidance. EPA summarized the available criteria information in the "*Gold Book*" (USEPA, 1986a), which is updated from time to time. However, the individual criteria documents (see Appendix I), as updated, are the official guidance documents.

EPA's criteria documents provide a comprehensive toxicological evaluation of each chemical. For toxic pollutants, the documents tabulate the relevant acute and chronic toxicity information for aquatic life and derive the criteria maximum concentrations (acute criteria) and criteria continuous concentrations (chronic criteria) that the Agency recommends to protect aquatic life resources. The methodologies for these processes are described in Appendices H and J and outlined in sections 3.1.2 and 3.1.3 of this Handbook

3.1.1 State Use of EPA Criteria Documents

EPA's water quality criteria documents are available to assist States in:

- adopting water quality standards that include appropriate numeric water quality criteria;
- interpreting existing water quality standards that include narrative "no toxics in toxic amounts" criteria;
- making listing decisions under section 304(1) of the CWA;
- writing water quality-based NPDES permits and individual control strategies; and
- providing certification under section 401 of the CWA for any Federal permit or license (e.g., EPA-issued NPDES permits, CWA section 404 permits, or Federal Energy Regulatory Commission licenses).

In these situations, States have primary authority to determine the appropriate level to protect human health or welfare (in accordance with section 303(c)(2) of the CWA) for each water body. However, under the Clean Water Act, EPA must also review and approve State water quality standards; section 304(1) listing decisions and draft and final State-issued individual control strategies; and in States where EPA writes NPDES permits, EPA must develop appropriate water quality-based permit limitations. The States and EPA therefore have a strong interest in assuring that the decisions are legally defensible, are based on the best information available, and are subject to full and meaningful public comment and participation. It is very important that each decision be supported by an adequate record. Such a record is critical to meaningful comment, EPA's review of the State's decision, and any subsequent administrative or judicial review.

Any human health criterion for a toxicant is based on at least three interrelated considerations:

- cancer potency or systemic toxicity,
- exposure, and
- risk characterization.

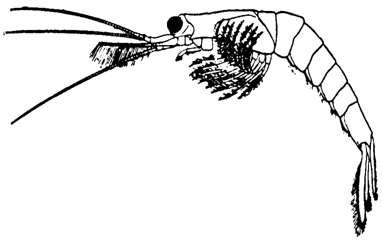
States may make their own judgments on each of these factors within reasonable scientific bounds, but documentation to support their judgments, when different from EPA's recommendation, must be clear and in the public record. If a State relies on EPA's section 304(a) criteria document (or other EPA documents), the State may reference and rely on the data in these documents and need not create duplicative or new material for inclusion in their records. However, where site-specific issues arise or the State decides to adopt an approach to any one of these three factors that differs from the approach in EPA's criteria document, the State must explain its reasons in a manner sufficient for a reviewer to determine that the approach chosen is based on sound scientific rationale (40 CFR 131.11(b)).

3.1.2 Criteria for Aquatic Life Protection

The development of national numerical water quality criteria for the protection of aquatic organisms is a complex process that uses information from many areas of aquatic toxicology. (See Appendix H for a detailed discussion of this process.) After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity to, and bioaccumulation by, aquatic organisms is collected and reviewed for acceptability. If enough acceptable data for 48- to 96-hour toxicity tests on aquatic plants and animals are available, they are used to derive the acute criterion. If sufficient data on the ratio of acute to chronic toxicity concentrations are available, they are used to derive the chronic or long-term exposure criteria. If justified, one or both of the criteria may be related to other water quality characteristics, such as pH, temperature, or hardness. Separate criteria are developed for fresh and salt waters.

The Water Quality Standards Regulation allows States to develop numerical criteria or modify EPA's recommended criteria to account for site-specific or other scientifically defensible factors. Guidance on modifying national criteria is found in sections 3.6 and 3.7. When a criterion must be developed for a chemical for which a national criterion has not been established, the regulatory authority should refer to the EPA guidelines (Appendix H).

Magnitude for Aquatic Life Criteria



Water quality criteria for aquatic life contain two expressions of allowable magnitude: a criterion maximum concentration (CMC) to protect against acute (short-term) effects; and a criterion continuous concentration (CCC) to protect against chronic (long-term) effects. EPA derives acute criteria from 48- to 96-hour tests of lethality or immobilization. EPA derives chronic criteria from longer term (often greater than 28-day) tests that measure survival, growth, or reproduction. Where appropriate, the calculated criteria may be lowered to be protective of commercially or recreationally important species.

Duration for Aquatic Life Criteria

The quality of an ambient water typically varies in response to variations of effluent quality, stream flow, and other factors. Organisms in the receiving water are not experiencing constant, steady exposure but rather are experiencing fluctuating exposures, including periods of high concentrations, which may have adverse effects. Thus, EPA's criteria indicate a time period over which exposure is to be averaged, as well as an upper limit on the average concentration, thereby limiting the duration of exposure to elevated concentrations. For acute criteria, EPA recommends an averaging period of 1 hour. That is, to protect against acute effects, the 1-hour average exposure should not exceed the CMC. For chronic criteria, EPA recommends an averaging period of 4 days. That is, the 4-day average exposure should not exceed the CCC.

Frequency for Aquatic Life Criteria

To predict or ascertain the attainment of criteria, it is necessary to specify the allowable frequency for exceeding the criteria. This is because it is statistically impossible to project that criteria will never be exceeded. As ecological communities are naturally subjected to a series of stresses, the allowable frequency of pollutant stress may be set at a value that does not significantly increase the frequency or severity of all stresses combined.

EPA recommends an average frequency for excursions of both acute and chronic criteria not to exceed once in 3 years. In all cases, the recommended frequency applies to actual ambient concentrations, and excludes the influence of measurement imprecision. EPA established its recommended frequency as part of its guidelines for deriving criteria (Appendix H). EPA selected the 3-year average frequency of criteria exceedence with the intent of providing for ecological recovery from a variety of severe stresses. This return interval is roughly equivalent to a 7Q10 design flow condition. Because of the nature of the ecological recovery studies available, the severity of criteria excursions could not be rigorously related to the resulting ecological impacts. Nevertheless, EPA derives its criteria intending that a single marginal criteria excursion (i.e., a slight excursion over a 1-hour period for acute or over a 4-day period for chronic) would require little or no time for recovery. If the frequency of marginal criteria excursions is not high, it can be shown that the frequency of severe stresses, requiring measurable recovery periods, would be extremely small. EPA thus expects the 3-year return interval to provide a very high degree of protection.

3.1.3 Criteria for Human Health Protection

This section reviews EPA's procedures used to develop assessments of human health effects in developing water quality criteria and reference ambient concentrations. A more complete human health effects discussion is included in the *Guidelines and Methodology Used in the Preparation of Health Effects Assessment Chapters of the Consent Decree Water Documents* (Appendix J). The procedures contained in this document are used in the development and updating of EPA water quality criteria and may be used in updating State criteria and in developing State criteria for those pollutants lacking EPA human health criteria. The procedures may also be applied as site-specific interpretations of narrative standards and as a basis for permit limits under 40 CFR 122.44 (d)(1)(vi).

Magnitude and Duration

Water quality criteria for human health contain only a single expression of allowable magnitude; a criterion concentration generally to protect against long-term (chronic) human health effects. Currently, national policy and prevailing opinion in the expert community establish that the duration for human health criteria for carcinogens should be derived assuming lifetime exposure, taken to be a 70-year time period. The duration of exposure assumed in deriving criteria for noncarcinogens is more complicated owing to a wide variety of endpoints: some developmental (and thus age-specific and perhaps gender-specific), some lifetime, and some, such as organoleptic effects, not duration-related at all. Thus, appropriate durations depend on the individual noncarcinogenic pollutants and the endpoints or adverse effects being considered.

Human Exposure Considerations

A complete human exposure evaluation for toxic pollutants of concern for bioaccumulation would encompass not only estimates of exposures due to fish consumption but also exposure from background concentrations and other exposure routes, The more important of these include recreational and occupational contact, dietary intake from other than fish, intake from air inhalation, and drinking water consumption. For section 304(a) criteria development, EPA typically considers only exposures to a pollutant that occur through the ingestion of water and contaminated fish and shellfish. This is the exposure default assumption, although the human health guidelines provide for considering other sources where data are available (see 45 F.R. 79354). Thus the criteria are based on an assessment of risks related to the surface water exposure route only (57 F.R. 60862-3).

The consumption of contaminated fish tissue is of serious concern because the presence of even extremely low ambient concentrations of bioaccumulative pollutants (sublethal to aquatic life) in surface waters can result in residue concentrations in fish tissue that can pose a human health risk. Other exposure route information should be considered and incorporated in human exposure evaluations to the extent available.

Levels of actual human exposures from consuming contaminated fish vary depending upon a number of case-specific consumption factors. These factors include type of fish species consumed, type of fish tissue consumed, tissue lipid content, consumption rate and pattern, and food preparation practices. In addition, depending on the spatial variability in the fishery area, the behavior of the fish species, and the point of application of the criterion, the average exposure of fish may be only a small fraction of the expected exposure at the point of application of the criterion. If an effluent attracts fish, the average exposure might be greater than the expected exposure.

With shellfish, such as oysters, snails, and mussels, whole-body tissue consumption commonly occurs, whereas with fish, muscle tissue and roe are most commonly eaten. This difference in the types of tissues consumed has implications for the amount of available bioaccumulative contaminants likely to be ingested. Whole-body shellfish consumption presumably means ingestion of the entire burden of bioaccumulative contaminants. However, with most fish, selective cleaning and removal of internal organs, and sometimes body fat as well, from edible tissues, may result in removal of much of the lipid material in which bioaccumulative contaminants tend to concentrate.

Fish Consumption Values

EPA's human health criteria have assumed a human body weight of 70 kg and the consumption of 6.5 g of fish and shellfish per day. Based on data collected in 1973-74, the national per capita consumption of freshwater and estuarine fish was estimated to average 6.5 g/day. Per capita consumption of all seafood (including marine species) was estimated to average 14.3 g/day. The 95th percentile for consumption of all seafood by individuals over a period of 1 month was estimated to be 42 g/day. The mean lipid content of fish and shellfish tissue consumed in this study was estimated to be 3.0 percent (USEPA, 1980c).

Currently, four levels of fish and shellfish consumption are provided in EPA guidance (USEPA, 1991a):

- 6.5 g/day to represent an estimate of average consumption of fish and shellfish from estuarine and freshwaters by the entire U.S. population. This consumption level is based on the average of both consumers and nonconsumers of.
- 20 g/day to represent an estimate of the average consumption of fish and shellfish from marine, estuarine, and freshwaters by the U.S. population. This average consumption level also includes both consumers and nonconsumers of.
- 165 g/day to represent consumption of fish and shellfish from marine, estuarine, and freshwaters by the 99.9th percentile of the U.S. population consuming the most fish or seafood.
- 180 g/day to represent a "reasonable worst case" based on the assumption that some individuals would consume fishand shellfish at a rate equal to the combined consumption of red meat, poultry, fish, and shellfish in the United States.

EPA is currently updating the national estuarine and freshwater fish and shellfish consumption default values and will provide a range of recommended national consumption values. This range will include:

- mean values appropriate to the population at large; and
- values appropriate for those individuals who consume a relatively large proportion of fish and shellfish in their diets (maximally exposed individuals).

Many States use EPA's 6.5 g/day consumption value. However, some States use the above-mentioned 20 g/day value and, for saltwaters, 37 g/day. In general, EPA recommends that the consumption values used in deriving criteria from the formulas in this chapter reflect the most current, relevant, and/or site-specific information available.

Bioaccumulation Considerations

The ratio of the contaminant concentrations in fish tissue versus that in water is termed either the bioconcentration factor (BCF) or the bioaccumulation factor (BAF). Bioconcentration is defined as involving contaminant uptake from water only (not from food). The bioaccumulation factor (BAF) is defined similarly to the BCF except that it includes contaminant uptake from both water and food. Under laboratory conditions, measurements of tissue/water partitioning are generally considered to involve uptake from water only. On the other hand, both processes are likely to apply in the field since the entire food chain is exposed.
The BAF/BCF ratio ranges from 1 to 100, with the highest ratios applying to organisms in higher trophic levels, and to chemicals with logarithm of the octanol-water partitioning coefficient (log P) close to 6.5.

Bioaccumulation considerations are integrated into the criteria equations by using food chain multipliers (FMs) in conjunction with the BCF. The bioaccumulation and bioconcentration factors for a chemical are related as follows:

BAF = FM x BCF

By incorporating the FM and BCF terms into the criteria equations, bioaccumulation can be addressed.

*These recommended FMs are conservative estimates; FMs for log P values greater than 6.5 may range from the values given to as low as 0.1 for contaminants with very low bioavailability.
In Table 3-1, FM values derived from the work of Thomann (1987, 1989) are listed according to log P value and trophic level of the organism. For chemicals with log P values greater than about 7, there is additional uncertainty regarding the degree of bioaccumulation, but generally, trophic level effects appear to decrease due to slow transport kinetics of these chemicals in fish, the growth rate of the fish, and the chemical's relatively low bioavailability. Trophic level 4 organisms are typically the most desirable species for sport fishing and, therefore, FMs for trophic level 4 should generally be used in the equations for calculating criteria. In those <u>very rare</u> situations where only lower trophic level organisms are found, e.g., possibly oyster beds, an FM for a lower trophic level might be considered.

Measured BAFs (especially for those chemicals with log P values above 6.5) reported in the literature should be used when available. To use experimentally measured BAFs in calculating the criterion, the (FM x BCF) term is replaced by the BAF in the equations in the following section. Relatively few BAFs have been measured <u>accurately</u> and reported, and their application to sites other than the specific ecosystem where they were developed is problematic and subject to uncertainty. The option is also available to develop BAFs experimentally, but this will be extremely resource intensive if done on a site-specific basis with all the necessary experimental and quality controls.

Table 3-1. Estimated Food Chain Multipliers (FMs)

Trophic Levels			
Log P	2	3	4
3.5	1.0	1.0	1.0
3.6	1.0	1.0	1.0
3.7	1.0	1.0	1.0
3.8	1.0	1.0	1.0
3.9	1.0	1.0	1.0
4.0	1.1	1.0	1.0
4.1	1.1	1.1	1.1
4.2	1.1	1.1	1.1
4.3	1.1	1.1	1.1
4.4	1.2	1.1	1.1
4.5	1.2	1.2	1.2
4.6	1.2	1.3	1.3
4.7	1.3	1.4	1.4
4.8	1.4	1.5	1.6
4.9	1.5	1.8	2.0
5.0	1.6	2.1	2.6
5.1	1.7	2.5	3.2
5.2	1.9	3.0	4.3
5.3	2.2	3.7	5.8
5.4	2.4	4.6	8.0
5.5	2.8	5.9	11
5.6	3.3	7.5	16
5.7	3.9	9.8	23
5.8	4.6	13	33
5.9	5.6	17	47
6.0	6.8	21	67
6.1	8.2	25	75
6.2	10	29	84
6.3	13	34	92
6.4	15	39	98
6.5	19	45	100
≥6.5	19.2*	45*	100*

Updating Human Health Criteria Using IRIS

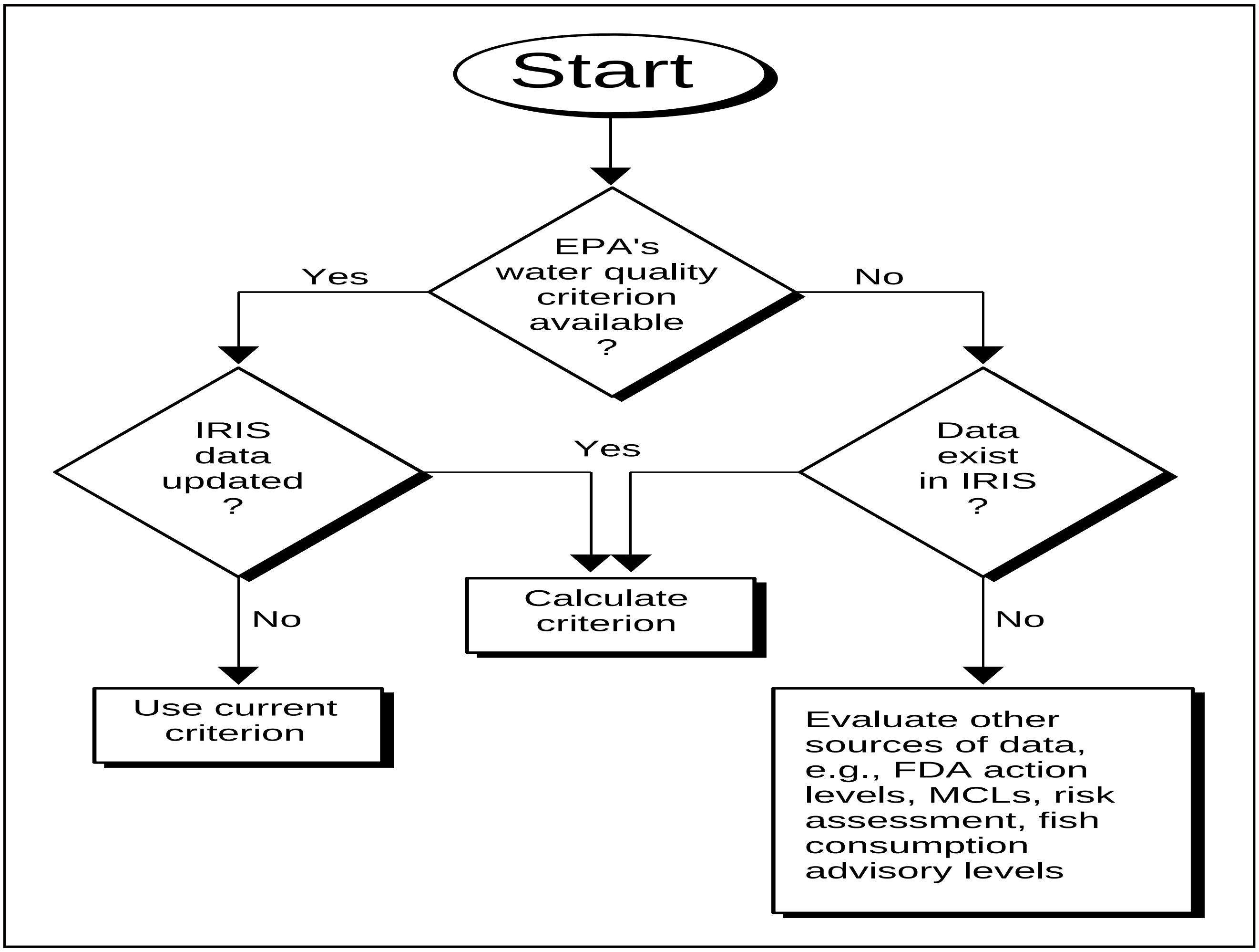
EPA recommends that States use the most current risk information in the process of updating human health criteria. The Integrated Risk Information System (IRIS) (Barns and Dourson, 1988; Appendix N) is an electronic data base of the USEPA that provides chemical-specific risk information on the relationship between chemical exposure and estimated human health effects. Risk assessment information contained in IRIS, except as specifically noted, has been reviewed and agreed upon by an interdisciplinary group of scientists representing various Program Offices within the Agency and represent an Agency-wide consensus. Risk assessment information and values are updated on a monthly basis and are approved for Agency-wide use. IRIS is intended to make risk assessment information readily available to those individuals who must perform risk assessments and also to increase consistency among risk assessment/risk management decisions.

IRIS contains two types of quantitative risks values: the oral Reference Dose (RfD) and the carcinogenic potency estimate or slope factor. The RfD (formerly known as the acceptable daily intake or ADI) is the human health hazard assessment for noncarcinogenic (target organ) effects. The carcinogenic potency estimate (formerly known as q_1*) represents the upper bound cancer-causing potential resulting from lifetime exposure to a substance. The RfD or the oral carcinogenic potency estimate is used in the derivation of EPA human health criteria.

EPA periodically updates risk assessment information, including RfDs, cancer potency estimates, and related information on contaminant effects, and reports the current information on IRIS. Since IRIS contains the Agency's most recent quantitative risk assessment values, current IRIS values should be used by States in updating or developing new human health criteria. This means that the 1980 human health criteria should be updated with the latest IRIS values. The procedure for deriving an updated human health water quality criterion would require inserting the current Rfd or carcinogenic potency estimate on IRIS into the equations in Exhibit 3.1 or 3.2, as appropriate.

Figure 3-1 shows the procedure for determining an updated criterion using IRIS data. If a chemical has both carcinogenic and non-carcinogenic effects, i.e., both a cancer potency estimate and a RfD, both criteria should be calculated. The most stringent criterion applies

Figure 3-1. Procedure for determining an updated criterion using IRIS data.



Calculating Criteria for Non-carcinogens

The RfD is an estimate of the daily exposure to the human population that is likely to be without appreciable risk of causing deleterious effects during a lifetime. The RfD is expressed in units of mg toxicant per kg human body weight per day.

RfDs are derived from the "no-observed-adverse-effect level" (NOAEL) or the "lowest-observed-adverse-effect level" (LOAEL) identified from chronic or subchronic human epidemiology studies or animal exposure studies. (Note: "LOAEL" and "NOAEL" refer to animal and human toxicology and are therefore distinct from the aquatic toxicity terms "no-observed-effect concentration" (NOEC) and "lowest-observed-effect concentration" (LOEC).) Uncertainty factors are then applied to the NOAEL or LOAEL to account for uncertainties in the data associated with variability among individuals, extrapolation from nonhuman test species to humans, data on other than long-term exposures, and the use of a LOAEL (USEPA, 1988a). An additional uncertainty factor may be applied to account for significant weakness or gaps in the database.

The RfD is a threshold below which systemic toxic effects are unlikely to occur. While exposures above the RfD increase the probability of adverse effects, they do not produce a certainty of adverse effects. Similarly, while exposure at or below the RfD reduces the probability, it does not guarantee the absence of effects in all persons. The RfDs contained in IRIS are values that represent EPA's consensus (and have uncertainty spanning perhaps an order of magnitude). This means an RfD of 1.0 mg/kg/day could range from 0.3 to 3.0 mg/kg/day.

For noncarcinogenic effects, an updated criterion can be derived using the equation in Exhibit 3-1.

Exhibit 3-1. Equation for Deriving Human Health Criteria Based on Noncarcinogenic Effects

$$C\ (mg/l) = \frac{(RfD \times WT) - (DT + IN) \times WT}{WI + [FC \times L \times FM \times BCF]}$$

Where:
C= updated water quality criterion (mg/l)
RfD = oral reference dose (mg toxicant/kg human body weight/day)
WT = weight of an average human adult (70 kg)
DT = dietary exposure (other than fish) (mg toxicant/kg body human weight/day)
IN = inhalation exposure (mg toxicant/kg body human weight/day)
WI = average human adult water intake (2 l/day)
FC = daily fish consumption (kg fish/day)
L = ratio of lipid fraction of fish tissue consumed to 3%
FM = food chain multiplier (from Table 3-1)
BCF = bioconcentration factor (mg toxicant/kg fish divided by mg toxicant/L water) for fish with 3% lipid content

If the receiving water body is not used as a drinking water source, the factor WI can be deleted. Where dietary and/or inhalation exposure values are unknown, these factors may be deleted from the above calculation.

Calculating Criteria for Carcinogens

Any human health criterion for a carcinogen is based on at least three interrelated considerations: cancer potency, exposure, and risk characterization. When developing State criteria, States may make their own judgments on each of these factors within reasonable scientific bounds, but documentation to support their judgments must be clear and in the public record.

Maximum protection of human health from the potential effects of exposure to carcinogens through the consumption of contaminated fish and/or other aquatic life would require a criterion of zero. The zero level is based upon the assumption of non-threshold effects (i.e., no safe level exists below which any increase in exposure does not result in an increased risk of cancer) for carcinogens. However, because a publicly acceptable policy for safety does not require the absence of all risk, a numerical estimate of pollutant concentration (in µg/l) which corresponds to a given level of risk for a population of a specified size is selected instead. A cancer risk level is defined as the number of new cancers that may result in a population of specified size due to an increase in exposure (e.g., 10^{-6} risk level = 1 additional cancer in a population of 1 million). Cancer risk is calculated by multiplying the experimentally derived cancer potency estimate by the concentration of the chemical in the fish and the average daily human consumption of contaminated fish. The risk for a specified population (e.g., 1 million people or 10^{-6}) is then calculated by dividing the risk level by the specific cancer risk. EPA's ambient water quality criteria documents provide risk levels ranging from 10^{-5} to 10^{-7} as examples.

The cancer potency estimate, or slope factor (formerly known as the q_1^*), is derived using animal studies. High-dose exposures are extrapolated to low-dose concentrations and adjusted to a lifetime exposure period through the use of a linearized multistage model. The model calculates the upper 95 percent confidence limit of the slope of a straight line which the model postulates to occur at low doses. When based on human (epidemiological) data, the slope factor is based on the observed increase in cancer risk and is not extrapolated. For deriving criteria for carcinogens, the oral cancer potency estimates or slope factors from IRIS are used.

It is important to note that cancer potency factors may overestimate or underestimate the actual risk. Such potency estimates are subject to great uncertainty because of two primary factors:

- adequacy of the cancer data base (i.e., human vs. animal data); and
- limited information regarding the mechanism of cancer causation.

Risk levels of 10^{-5}, 10^{-6}, and 10^{-7} are often used by States as minimal risk levels in interpreting their standards. EPA considers risks to be additive, i.e., the risk from individual chemicals is not necessarily the overall risk from exposure to water. For example, an individual risk level of 10^{-6} may yield a higher overall risk level if multiple carcinogenic chemicals are present.

For carcinogenic effects, the criterion can be determined by using the equation in Exhibit 3-2.

Exhibit 3-2. Equation for Deriving Human Health Criteria Based on Carcinogenic Effects

$$C\ (\mathrm{mg/l}) = \frac{(RL \times WT)}{q_1^*\ [WI + FC \times L \times (FM \times BCF)]}$$

Where:

C = updated water quality criterion (mg/l)
RL = risk level (10^{-x}) where x is usually in the range of 4 to 6
WT = weight of an average human adult (70 kg)
q_1^* = carcinogenic potency factor (kg day/mg)
WI = average human adult water intake (2 l/day)
FC = daily fish consumption (kg fish/day)

$$C\ (\mathrm{mg/l}) = \frac{(RL \times WT)}{q_1^* \left[WI + FC \times L \times (FM \times BCF)\right]}$$

L = ratio of lipid fraction of fish tissue consumed to 3% assumed by EPA
FM = food chain multiplier (from Table 3-1)
BCF = bioconcentration factor (mg toxicant/kg fish divided by mg toxicant/L water) for fish with 3% lipid content

If the receiving water body is not designated as a drinking water source, the factor WI can be deleted.

Deriving Quantitative Risk Assessments in the Absence of IRIS Values

The RfDs or cancer potency estimates comprise the existing dose-response factors for developing criteria. When IRIS data are unavailable, quantitative risk level information may be developed according to a State's own procedures. Some States have established their own procedures whereby dose-response factors can be developed based upon extrapolation of acute and/or chronic animal data to concentrations of exposure protective of fish consumption by humans.
here owing to the complexity of the subject.

3.2 Section 304(a) Criteria to State Designated Uses

The section 304(a)(1) criteria published by EPA from time to time can be used to support the designated uses found in State standards. The following sections briefly discuss the relationship between certain criteria and individual use classifications. Additional information on this subject also can be found in the "Green Book" (FWPCA, 1968); the "Blue Book" (NAS/NAE, 1973); the "Red Book" USEPA, 1976); the EPA *Water Quality Criteria Documents* (see Appendix I); the"Gold Book" (USEPA, 1986a); and future EPA section 304(a)(1) water quality criteria publications.

Where a water body is designated for more than one use, criteria necessary to protect the most sensitive use must be applied. The following four sections discuss the major types of use categories.

3.2.1 Recreation

Recreational uses of water include activities such as swimming, wading, boating, and fishing. Often insufficient data exist on the human health effects of physical and chemical pollutants, including most toxics, to make a determination of criteria for recreational uses. However, as a general guideline, recreational waters that contain chemicals in concentrations toxic or otherwise harmful to man if ingested, or irritating to the skin or mucous membranes of the human body upon brief immersion, should be avoided. The section 304(a)(1) human health effects criteria based on direct human drinking water intake and fish consumption might provide useful guidance in these circumstances. Also, section 304(a)(1) criteria based on human health effects may be used to support this designated use where fishing is included in the State definition of "recreation." In this latter situation, only the portion of the criterion based on fish consumption should be used. Section 304(a)(1) criteria to protect recreational uses are also available for certain physical, microbiological, and narrative "free from" aesthetic criteria.

Research regarding bacteriological indicators has resulted in EPA recommending that States use *Escherichia coli* or enterococci as indicators of recreational water quality (USEPA, 1986b) rather than fecal coliform because of the better correlation with gastroenteritis in swimmers.

The "Green Book" and "Blue Book" provide additional information on protecting recreational uses such as pH criteria to prevent eye irritation and microbiological criteria based on aesthetic considerations.

3.2.2 Aquatic Life

The section 304(a)(1) criteria for aquatic life should be used directly to support this designated use. If subcategories of this use are adopted (e.g., to differentiate between coldwater and warmwater fisheries), then appropriate criteria should be set to reflect the varying needs of such subcategories.

3.2.3 Agricultural and Industrial Uses

The "Green Book" (FWPCA, 1968) and "Blue Book" (NAS/NAE, 1973) provide some information on protecting agricultural and industrial uses. Section 304(a)(1) criteria for protecting these uses have not been specifically developed for numerous parameters pertaining to these uses, including most toxics.

Where criteria have not been specifically developed for these uses, the criteria developed for human health and aquatic life are usually sufficiently stringent to protect these uses. States may also establish criteria specifically designed to protect these uses.

3.2.4 Public Water Supply

The drinking water exposure component of the section 304(a)(1) criteria based on human health effects can apply directly to this use classification. The criteria also may be appropriately modified depending upon whether the specific water supply system falls within the auspices of the Safe Drinking Water Act's (SDWA) regulatory control and the type and level of treatment imposed upon the supply before delivery to the consumer. The SDWA controls the presence of contaminants in finished ("at-the-tap") drinking water.

A brief description of relevant sections of the SDWA is necessary to explain how the Act will work in conjunction with section 304(a)(1) criteria in protecting human health from the effects of toxics due to consumption of water. Pursuant to section 1412 of the SDWA, EPA has promulgated "National Primary Drinking Water Standards" for certain radionuclide, microbiological, organic, and inorganic substances. These standards establish maximum contaminant levels (MCLs), which specify the maximum permissible level of a contaminant in water that may be delivered to a user of a public water system now defined as serving a minimum of 25 people. MCLs are established based on consideration of a range of factors including not only the health effects of the contaminants but also treatment capability, monitoring availability, and costs. Under section 1401(1)(D)(i) of the SDWA, EPA is also allowed to establish the minimum quality criteria for water that may be taken into a public water supply system.

Section 304(a)(1) criteria provide estimates of pollutant concentrations protective of human health, but do not consider treatment technology, costs, and other feasibility factors. The section 304(a)(1) criteria also include fish bioaccumulation and consumption factors in addition to direct human drinking water intake. These numbers were not developed to serve as "at-the-tap" drinking water standards, and they have no regulatory significance under the SDWA. Drinking water standards are established based on considerations, including technological and economic feasibility, not relevant to section 304(a)(1) criteria. Section 304(a)(1) criteria are more analogous to the maximum contaminant level goals (MCLGs) (previously known as RMCLs) under section 1412(b)(1)(B) of the SDWA in which, based upon a report from the National Academy of Sciences, the Administrator should set target levels for contaminants in drinking water at which "no known or anticipated adverse effects occur and which allow an adequate margin of safety." MCLGs do not take treatment, cost, and other feasibility factors into consideration. Section 304(a)(1) criteria are, in concept, related to the health-based goals specified in the MCLGs.

MCLs of the SDWA, where they exist, control toxic chemicals in finished drinking water. However, because of variations in treatment, ambient water criteria may be used by the States as a supplement to SDWA regulations. When setting water quality criteria for public water supplies, States have the option of applying MCLs, section 304(a)(1) human health effects criteria, modified section 304(a)(1) criteria, or controls more stringent than these three to protect against the effects of contaminants by ingestion from drinking water.

For treated drinking water supplies serving 25 people or greater, States must control contaminants down to levels at least as stringent as MCLs (where they exist for the pollutants of concern) in the finished drinking water. However, States also have the options to control toxics in the ambient water by choosing section 304(a)(1) criteria, adjusted section 304(a)(1) criteria resulting from the reduction of the direct drinking water exposure component in the criteria calculation to the extent that the treatment process reduces the level of pollutants, or a more stringent contaminant level than the former three options.

3.3 State Criteria Requirements

Section 131.11(a)(1) of the Regulation requires States to adopt water quality criteria to protect the designated use(s). The State criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use(s). For waters with multiple use designations, the criteria must support the most sensitive use.

In section 131.11, States are encouraged to adopt both numeric and narrative criteria. Aquatic life criteria should protect against both short-term (acute) and long-term (chronic) effects. Numeric criteria are particularly important where the cause of toxicity is known or for protection against pollutants with potential human health impacts or bioaccumulation potential. Numeric water quality criteria may also be the best way to address nonpoint source pollution problems. Narrative criteria can be the basis for limiting toxicity in waste discharges where a specific pollutant can be identified as causing or contributing to the toxicity but where there are no numeric criteria in the State standards. Narrative criteria also can be used where toxicity cannot be traced to a particular pollutant.

Section 131.11(a)(2) requires States to develop implementation procedures which explain how the State will ensure that narrative toxics criteria are met.

To more fully protect aquatic habitats, it is EPA's policy that States fully integrate chemical-specific, whole-effluent, and biological assessment approaches in State water quality programs (see Appendix R). Specifically, each of these three methods can provide a valid assessment of non-attainment of designated aquatic life uses but can rarely demonstrate use attainment separately. Therefore, EPA supports a policy of independent application of these three water quality assessment approaches. Independent application means that the validity of the results of any one of the approaches does not depend on confirmation by one or both of the other methods. This policy is based on the unique attributes, limitations, and program applications of each of the three approaches. Each method alone can provide valid and independently sufficient evidence of non-attainment of water quality standards, irrespective of any evidence, or lack thereof, derived from the other two approaches. The failure of one method to confirm impacts identified by another method does not negate the results of the initial assessment.

It is also EPA's policy that States should designate aquatic life uses that appropriately address biological integrity and adopt biological criteria necessary to protect those uses (see section 3.5.3 and Appendices C, K, and R).

3.4 Criteria for Toxicants

Applicable requirements for State adoption of water quality criteria for toxicants vary depending upon the toxicant. The reason for this is that the 1983 Water Quality Standards Regulation (Appendix A) and the Water Quality Act of 1987 which amended the Clean Water Act (Public Law 100-4) include more specific requirements for the particular toxicants listed pursuant to CWA section 307(a). For regulatory purposes, EPA has translated the 65 compounds and families of compounds listed pursuant to section 307(a) into 126 more specific substances, which EPA refers to as "priority toxic pollutants." The 126 priority toxic pollutants are listed in the WQS regulation and in Appendix P of this Handbook. Because of the more specific requirements for priority toxic pollutants, it is convenient to organize the requirements applicable to State adoption of criteria for toxicants into three categories:

- requirements applicable to priority toxic pollutants that have been the subject of CWA section 304(a)(1) criteria guidance (see section 3.4.1);
- requirements applicable to priority toxic pollutants that have not been the subject of CWA section 304(a)(1) criteria guidance (see section 3.4.1); and
- requirements applicable to all other toxicants (e.g., non-conventional pollutants like ammonia and chlorine) (see section 3.4.2).

3.4.1 Priority Toxic Pollutant Criteria

The criteria requirements applicable to priority toxic pollutants (i.e., the first two categories above) are specified in CWA section 303(c)(2)(B). Section 303(c)(2)(B), as added by the Water Quality Act of 1987, provides that:

Whenever a State reviews water quality standards pursuant to paragraph (1) of this subsection, or revises or adopts new standards pursuant to this paragraph, such State shall adopt criteria for all toxic pollutants listed pursuant to section 307(a)(1) of this Act for which criteria have been published under section 304(a), the discharge or presence of which in the affected waters could reasonably be expected to interfere with those designated uses adopted by the State, as necessary to support such designated uses. Such criteria shall be specific numerical criteria for such toxic pollutants. Where such numerical criteria are not available, whenever a State reviews water quality standards pursuant to paragraph (1), or revises or adopts new standards pursuant to this paragraph, such State shall adopt criteria based on biological monitoring or assessment methods consistent with information published pursuant to section 304(a)(8). Nothing in this section shall be construed to limit or delay the use of effluent limitations or other permit conditions based on or involving biological monitoring or assessment methods or previously adopted numerical criteria.

EPA, in devising guidance for section 303(c)(2)(B), attempted to provide States with the maximum flexibility that complied with the express statutory language but also with the overriding congressional objective: prompt adoption and implementation of numeric toxics criteria. EPA believed that flexibility was important so that each State could comply with section 303(c)(2)(B) and to the extent possible, accommodate its existing water quality standards regulatory approach.

General Requirements

To carry out the requirements of section 303(c)(2)(B), whenever a State revises its water quality standards, it must review all available information and data to first determine whether the discharge or the presence of a toxic pollutant is interfering with or is likely to interfere with the attainment of the designated uses of any water body segment.

If the data indicate that it is reasonable to expect the toxic pollutant to interfere with the use, or it actually is interfering with the use, then the State must adopt a numeric limit for the specific pollutant. If a State is unsure whether a toxic pollutant is interfering with, or is likely to interfere with, the designated use and therefore is unsure that control of the pollutant is necessary to support the designated use, the State should undertake to develop sufficient information upon which to make such a determination. Presence of facilities that manufacture or use the section 307(a) toxic pollutants or other information indicating that such pollutants are discharged or will be discharged strongly suggests that such pollutants could be interfering with attaining designated uses. If a State expects the pollutant not to interfere with the designated use, then section 303(1)(2)(B) does not require a numeric standard for that pollutant.

Section 303(c)(2)(B) addresses only pollutants listed as "toxic" pursuant to section 307(a) of the Act, which are codified at 40 CFR 131.36(b). The section 307(a) list contains 65 compounds and families of compounds, which potentially include thousands of specific compounds. The Agency has interpreted that list to include 126 "priority" toxic pollutants for regulatory purposes. Reference in this guidance to toxic pollutants or section 307(a) toxic pollutants refers to the 126 priority toxic pollutants unless otherwise noted. Both the list of priority toxic pollutants and recommended criteria levels are subject to change.

The national criteria recommendations published by EPA under section 304(a) (see section 3.1, above) of the Act include values for both acute and chronic aquatic life protection; only chronic criteria recommendations have been established to protect human health. To comply with the statute, a State needs to adopt aquatic life and human health criteria where necessary to support the appropriate designated uses. Criteria for the protection of human health are needed for water bodies designated for public water supply. When fish ingestion is considered an important activity, then the human health-related water quality criteria recommendation developed under section 304(a) of the CWA should be used; that is, the portion of the criteria recommendation based on fish consumption. For those pollutants designated as carcinogens, the recommendation for a human health criterion is generally more stringent than the aquatic life criterion for the same pollutant. In contrast, the aquatic life criteria recommendations for noncarcinogens are generally more stringent than the human health recommendations. When a State adopts a human health criterion for a carcinogen, the State needs to select a risk level. EPA has estimated risk levels of 10^{-5}, 10^{-6}, and 10^{-7} in its criteria documents under one set of exposure assumptions. However, the State is not limited to choosing among the risk levels published in the section 304(a) criteria documents, nor is the State limited to the base case exposure assumptions; it must choose the risk level for its conditions and explain its rationale.

EPA generally regulates pollutants treated as carcinogens in the range of 10^{-6} to 10^{-4} to protect average exposed individuals and more highly exposed populations. However, if a State selects a criterion that represents an upper bound risk level less protective than 1 in 100,000 (e.g., 10^{-5}), the State needs to have substantial support in the record for this level. This support focuses on two distinct issues. First, the record must include documentation that the decision maker considered the public interest of the State in selecting the risk level, including documentation of public participation in the decision making process as required by the Water Quality Standards Regulation at 40 CFR 131.20(b). Second, the record must include an analysis showing that the risk level selected, when combined with other risk assessment variables, is a balanced and reasonable estimate of actual risk posed, based on the best and most representative information available. The importance of the estimated actual risk increases as the degree of conservatism in the selected risk level diminishes. EPA carefully evaluates all assumptions used by a State if the State chose to alter any one of the standard EPA assumption values (57 F.R. 60864, December 22, 1993).

EPA does not intend to propose changes to the current requirements regarding the bases on which a State can adopt numeric criteria (40 CFR 131.11(b)(1)). Under EPA's regulation, in addition to basing numeric criteria on EPA's section 304(a) criteria documents, States may also base numeric criteria on site-specific determinations or other scientifically defensible methods.

EPA expects each State to comply with the new statutory requirements in any section 303(c) water quality standards review initiated after enactment of the Water Quality Act of 1987. The structure of section 303(c) is to require States to review their water quality standards at least once each 3 year period. Section 303(c)(2)(B) instructs States to include reviews for toxics criteria whenever they initiate a triennial review. Therefore, even if a State has complied with section 303(c)(2)(B), the State must review its standards each triennium to ensure that section 303(c)(2)(B) requirements continue to be met, considering that EPA may have published additional section 304(a) criteria documents and that the State will have new information on existing water quality and on pollution sources.

It should be noted that nothing in the Act or in the Water Quality Standards Regulation restricts the right of a State to adopt numeric criteria for any pollutant not listed pursuant to section 307(a)(1), and that such criteria may be expressed as concentration limits for an individual pollutant or for a toxicity parameter itself as measured by whole-effluent toxicity testing. However, neither numeric toxic criteria nor whole-effluent toxicity should be used as a surrogate for, or to supersede the other.

State Options

States may meet the requirements of CWA section 303(c)(2)(B) by choosing one of three scientifically and technically sound options (or some combination thereof):

1. Adopt statewide numeric criteria in State water quality standards for all section 307(a) toxic pollutants for which EPA has developed criteria guidance, regardless of whether the pollutants are known to be present;
2. Adopt specific numeric criteria in State water quality standards for section 307(a) toxic pollutants as necessary to support designated uses where such pollutants are discharged or are present in the affected waters and could reasonably be expected to interfere with designated uses;
3. Adopt a "translator procedure" to be applied to a narrative water quality standard provision that prohibits toxicity in receiving waters. Such a procedure is to be used by the State in calculating derived numeric criteria, which shall be used for all purposes under section 303(c) of the CWA. At a minimum, such criteria need to be developed for section 307(a) toxic pollutants, as necessary to support designated

uses, where these pollutants are discharged or present in the affected waters and could reasonably be expected to interfere with designated uses.

Option 1 is consistent with State authority to establish water quality standards. Option 2 most directly reflects the CWA requirements and is the option recommended by EPA. Option 3, while meeting the requirements of the CWA, is best suited to supplement numeric criteria from option 1 or 2. The three options are discussed in more detail below.

OPTION 1:
Adopt statewide numeric criteria in State water quality standards for all section 307(a) toxic pollutants for which EPA has developed criteria guidance, regardless of whether the pollutants are known to be present.

Pro:

- simple, straightforward implementation
- ensures that States will satisfy statute
- makes maximum uses of EPA recommendations
- gets specific numbers into State water quality standards fast, at first

Con:

- some priority toxic pollutants may not be discharged in State
- may cause unnecessary monitoring by States
- might result in "paper standards"

Option 1 is within a State's legal authority under the CWA to adopt broad water quality standards. This option is the most comprehensive approach to satisfy the statutory requirements because it would include all of the priority toxic pollutants for which EPA has prepared section 304(a) criteria guidance for either or both aquatic life protection and human health protection. In addition to a simple adoption of EPA's section 304(a) guidance as standards, a State must select a risk level for those toxic pollutants which are carcinogens (i.e., that cause or may cause cancer in humans).

Many States find this option attractive because it ensures comprehensive coverage of the priority toxic pollutants with scientifically defensible criteria without the need to conduct a resource-intensive evaluation of the particular segments and pollutants requiring criteria. This option also would not be more costly to dischargers than other options because permit limits would be based only on the regulation of the particular toxic pollutants in their discharges and not on the total listing in the water quality standards. Thus, actual permit limits should be the same under any of the options.

The State may also exercise its authority to use one or more of the techniques for adjusting water quality standards:

- establish or revise designated stream uses based on use attainability analyses (see section 2.9);
- develop site-specific criteria; or
- allow short-term variances (see section 5.3) when appropriate.

All three of these techniques may apply to standards developed under any of the three options discussed in this guidance. It is likely that States electing to use option 1 will rely more on variances because the other two options are implemented with more site-specific data being available. It should be noted, however, that permits issued pursuant to such water quality variances still must comply with any applicable antidegradation and antibacksliding requirements.

OPTION 2:

Adopt specific numeric criteria in State water quality standards for section 307(a) toxic pollutants as necessary to support designated uses where such pollutants are discharged or are present in the affected waters and could reasonably be expected to interfere with designated uses.

Pro:

- directly reflects statutory requirement
- standards based on demonstrated need to control problem pollutants
- State can use EPA's section 304(a) national criteria recommendations or other scientifically acceptable alternative, including site-specific criteria
- State can consider current or potential toxic pollutant problems
- State can go beyond section 307(a) toxics list, as desired

Con:

- may be difficult and time consuming to determine if, and which, pollutants are interfering with the designated use
- adoption of standards can require lengthy debates on correct criteria limit to be included in standards
- successful State toxic control programs based on narrative criteria may be halted or slowed as the State applies its limited resources to developing numeric standards
- difficult to update criteria once adopted as part of standards
- to be absolutely technically defensible, may need site-specific criteria in many situations, leading to a large workload for regulatory agency

EPA recommends that a State use this option to meet the statutory requirement. It directly reflects all the Act's requirements and is flexible, resulting in adoption of numeric water quality standards as needed. To assure that the State is capable of dealing with new problems as they arise, EPA also recommends that States adopt a translator procedure the same as, or similar to, that described in option 3, but applicable to all chemicals causing toxicity and not just priority pollutants as is the case for option 3.

Beginning in 1988, EPA provided States with candidate lists of priority toxic pollutants and water bodies in support of CWA section 304(l) implementation. These lists were developed because States were required to evaluate existing and readily available water-related data to comply with section 304(l), 40 CFR 130.10(d). A similar "strawman" analysis of priority pollutants potentially requiring adoption of numeric criteria under section 303(c)(2)(B) was furnished to most States in September or October of 1990 for their use in ongoing and subsequent triennial reviews. The primary differences between the "strawman" analysis and the section 304(l) candidate lists were that the "strawman" analysis (1) organized the results by chemical rather than by water body, (2) included data for certain STORET monitoring stations that were not used in constructing the candidate lists, (3) included data from the Toxics Release Inventory database, and (4) did not include a number of data sources used in preparing the candidate lists (e.g., those, such as fish kill information, that did not provide chemical-specific information).

EPA intends for States, at a minimum, to use the information gathered in support of section 304(l) requirements as a starting point for identifying (1) water segments that will need new and/or revised water quality standards for section 307(a) toxic pollutants, and (2) which priority toxic pollutants require adoption of numeric criteria. In the longer term, EPA expects similar determinations to occur during each triennial review of water quality standards as required by section 303(c).

In identifying the need for numeric criteria, EPA is encouraging States to use information and data such as:

- presence or potential construction of facilities that manufacture or use priority toxic pollutants;
- ambient water monitoring data, including those for sediment and aquatic life (e.g., fish tissue data);
- NPDES permit applications and permittee self-monitoring reports;
- effluent guideline development documents, many of which contain section 307(a)(1) priority pollutant scans;
- pesticide and herbicide application information and other records of pesticide or herbicide inventories;
- public water supply source monitoring data noting pollutants with Maximum Contaminant Levels (MCLs); and
- any other relevant information on toxic pollutants collected by Federal, State, interstate agencies, academic groups, or scientific organizations.

States are also expected to take into account newer information as it became available, such as information in annual reports from the Toxic Chemical Release Inventory requirements of the Emergency Planning and Community Right-To-Know Act of 1986 (Title III, Public Law 99-499).

Where the State's review indicates a reasonable expectation of a problem from the discharge or presence of toxic pollutants, the State should identify the pollutant(s) and the relevant segment(s). In making these determinations, States should use their own EPA-approved criteria or existing EPA water quality criteria for purposes of segment identification. After the review, the State may use other means to establish the final criterion as it revises its standards.

As with option 1, a State using option 2 must follow all its legal and administrative requirements for adoption of water quality standards. Since the resulting numeric criteria are part of a State's water quality standards, they are required to be submitted by the State to EPA for review and either approval or disapproval.

EPA believes this option offers the State optimum flexibility. For section 307(a) toxic pollutants adversely affecting designated uses, numeric criteria are available for permitting purposes. For other situations, the State has the option of defining site-specific criteria.

OPTION 3:

Adopt a procedure to be applied to the narrative water quality standard provision that prohibits toxicity in receiving waters. Such a procedure would be used by a State in calculating derived numeric criteria to be used for all purposes of water quality criteria under section 303(c) of the CWA. At a minimum such criteria need to be derived for section 307(a) toxic pollutants where the discharge or presence of such pollutants in the affected waters could reasonably be expected to interfere with designated uses, as necessary to support such designated uses.

Pro:

- allows a State flexibility to control priority toxic pollutants
- reduces time and cost required to adopt specific numeric criteria as water quality standards regulations
- allows immediate use of latest scientific information available at the time a State needs to develop derived numeric criteria
- revisions and additions to derived numeric criteria can be made without need to revise State law
- State can deal more easily with a situation where it did not establish water quality standards for the section 307(a) toxic pollutants during the most recent triennial review
- State can address problems from non-section 307(a) toxic pollutants

Con:

- EPA is currently on notice that a derived numeric criterion may invite legal challenge

- once the necessary procedures are adopted to enhance legal defensibility (e.g., appropriate scientific methods and public participation and review), actual savings in time and costs may be less than expected
- public participation in development of derived numeric criteria may be limited when such criteria are not addressed in a hearing on water quality standards

EPA believes that adoption of a narrative standard along with a translator mechanism as part of a State's water quality standard satisfies the substantive requirements of the statute. These criteria are subject to all the State's legal and administrative requirements for adoption of standards plus review and either approval or disapproval by EPA, and result in the development of derived numeric criteria for specific section 307(a) toxic pollutants. They are also subject to an opportunity for public participation. Nevertheless, EPA believes the most appropriate use of option 3 is as a supplement to either option 1 or 2. Thus, a State would have formally adopted numeric criteria for toxic pollutants that occur frequently; that have general applicability statewide for inclusion in NPDES permits, total maximum daily loads, and waste load allocations; and that also would have a sound and predictable method to develop additional numeric criteria as needed. This combination of options provides a complete regulatory scheme.

Although the approach in option 3 is similar to that currently allowed in the Water Quality Standards Regulation (40 CFR 131.11(a)(2)), this guidance discusses several administrative and scientific requirements that EPA believes are necessary to comply with section 303(c)(2)(B).

1. The Option 3 Procedure Must Be Used To Calculate Derived Numeric Water Quality Criteria

States must adopt a specific procedure to be applied to a narrative water quality criterion. To satisfy section 303(c)(2)(B), this procedure shall be used by the State in calculating derived numeric criteria, which shall be used for all purposes under section 303(c) of the CWA. Such criteria need to be developed for section 307(a) toxic pollutants as necessary to support designated uses, where these pollutants are discharged or are present in the affected waters and could reasonably be expected to interfere with the designated uses.

To assure protection from short-term exposures, the State procedure should ensure development of derived numeric water quality criteria based on valid acute aquatic toxicity tests that are lethal to half the affected organisms (LC50) for the species representative of or similar to those found in the State. In addition, the State procedure should ensure development of derived numeric water quality criteria for protection from chronic exposure by using an appropriate safety factor applicable to this acute limit. If there are saltwater components to the State's aquatic resources, the State should establish appropriate derived numeric criteria for saltwater in addition to those for freshwater.

The State's documentation of the tests should include a detailed discussion of its quality control and quality assurance procedures. The State should also include a description (or reference existing technical agreements with EPA) of the procedure it will use to calculate derived acute and chronic numeric criteria from the test data, and how these derived criteria will be used as the basis for deriving appropriate TMDLs, WLAs, and NPDES permit limits.

As discussed above, the procedure for calculating derived numeric criteria needs to protect aquatic life from both acute and chronic exposure to specific chemicals. Chronic aquatic life criteria are to be met at the edge of the mixing zone. The acute criteria are to be met (1) at the end-of-pipe if mixing is not rapid and complete and a high rate diffuser is not present; or (2) after mixing if mixing is rapid and complete or a high rate diffuser is present. (See EPA's *Technical Support Document for Water Quality-based Toxics Control*, USEPA 1991a.)

EPA has not established a national policy specifying the point of application in the receiving water to be used with human health criteria. However, EPA has approved State standards that apply human health criteria for fish consumption at the mixing zone boundary and/or apply the criteria for drinking water consumption, at a minimum, at the point of use. EPA has also proposed more stringent requirements for the application of human health criteria for highly bioaccumulative pollutants in the *Water Quality guidance for the Great Lakes System* (50 F.R. 20931, 21035, April 16, 1993) including elimination of mixing zones.

In addition, the State should also include an indication of potential bioconcentration or bioaccumulation by providing for:

- laboratory tests that measure the steady-state bioconcentration rate achieved by a susceptible organism; and/or
- field data in which ambient concentrations and tissue loads are measured to give an appropriate factor.

In developing a procedure to be used in calculating derived numeric criteria for the protection of aquatic life, the State should consider the potential impact that bioconcentration has on aquatic and terrestrial food chains.

The State should also use the derived bioconcentration factor and food chain multiplier to calculate chronically protective numeric criteria for humans that consume aquatic organisms. In calculating this derived numeric criterion, the State should indicate data requirements to be met when dealing with either threshold (toxic) or non-threshold (carcinogenic) compounds. The State should describe the species and the minimum number of tests, which may generally be met by a single mammalian chronic test if it is of good quality and if the weight of evidence indicates that the results are reasonable. The State should provide the method to calculate a derived numeric criterion from the appropriate test result.

Both the threshold and non-threshold criteria for protecting human health should contain exposure assumptions, and the State procedure should be used to calculate derived numeric criteria that address the consumption of water, consumption of fish, and combined consumption of both water and fish. The State should provide the assumptions regarding the amount of fish and the quantity of water consumed per person per day, as well as the rationale used to select the assumptions. It needs to include the number of tests, the species necessary to establish a dose-response relationship, and the procedure to be used to calculate the derived numeric criteria. For non-threshold contaminants, the State should specify the model used to extrapolate to low dose and the risk level. It should also address incidental exposure from other water sources (e.g., swimming). When calculating derived numeric criteria for multiple exposure to pollutants, the State should consider additive effects, especially for carcinogenic substances, and should factor in the contribution to the daily intake of toxicants from other sources (e.g., food, air) when data are available.

2. The State Must Demonstrate That the Procedure Results in Derived Numeric Criteria Are Protective

The State needs to demonstrate that its procedures for developing criteria, including translator methods, yield fully protective criteria for human health and for aquatic life. EPA's review process will proceed according to EPA's regulation of 40 CFR 131.11, which requires that criteria be based on sound scientific rationale and be protective of all designated uses. EPA will use the expertise and experience it has gained in developing section 304(a) criteria for toxic pollutants by application of its own translator method (USEPA, 1980b; USEPA, 1985b).

Once EPA has approved the State's procedure, the Agency's review of derived numeric criteria, for example, for pollutants other than section 307(a) toxic pollutants resulting from the State's procedure, will focus on the adequacy of the data base rather than the calculation method. EPA also encourages States to apply such a procedure to calculate derived numeric criteria to be used as the basis for deriving permit limitations for nonconventional pollutants that also cause toxicity.

3. The State Must Provide Full Opportunity for Public Participation in Adoption of the Procedure

The Water Quality Standards Regulation requires States to hold public hearings to review and revise water quality standards in accordance with provisions of State law and EPA's Public Participation Regulation (40 CFR 25). Where a State plans to adopt a procedure to be applied to the narrative criterion, it must provide full opportunity for public participation in the development and adoption of the procedure as part of the State's water quality standards.

While it is not necessary for the State to adopt each derived numeric criterion into its water quality standards and submit it to EPA for review and approval, EPA is very concerned that all affected parties have adequate opportunity to participate in the development of a derived numeric criterion even though it is not being adopted directly as a water quality standard.

A State can satisfy the need to provide an opportunity for public participation in the development of derived numeric criteria in several ways, including:

- a specific hearing on the derived numeric criterion;
- the opportunity for a public hearing on an NPDES permits as long as public notice is given that a criterion for a toxic pollutant as part of the permit issuance is being contemplated; or
- a hearing coincidental with any other hearing as long as it is made clear that development of a specific criterion is also being undertaken.

For example, as States develop their lists and individual control strategies (ICSs) under section 304(1), they may seek full public participation. NPDES regulations also specify public participation requirements related to State permit issuance. Finally, States have public participation requirements associated with Water Quality Management Plan updates. States may take advantage of any of these public participation requirements to fulfill the requirement for public review of any resulting derived numeric criteria. In such cases, the State must give prior notice that development of such criteria is under consideration.

4. The Procedure Must Be Formally Adopted and Mandatory

Where a State elects to supplement its narrative criterion with an accompanying implementing procedure, it must formally adopt such a procedure as a part of its water quality standards. The procedure must be used by the State to calculate derived numeric criteria that will be used as the basis for all standards' purposes, including the following: developing TMDLs, WLAs, and limits in NPDES permits; determining whether water use designations are being met; and identifying potential nonpoint source pollution problems.

5. The Procedure Must Be Approved by EPA as Part of the State's Water Quality Standards Regulation

To be consistent with the requirements of the Act, the State's procedure to be applied to the narrative criterion must be submitted to EPA for review and approval, and will become a part of the State's water quality standards. (See 40 CFR 131.21 for further discussion.) This requirement may be satisfied by a reference in the standards to the procedure, which may be contained in another document, which has legal effect and is binding on the State, and all the requirements for public review, State implementation, and EPA review and approval are satisfied.

Criteria Based on Biological Monitoring

For priority toxic pollutants for which EPA has not issued section 304(a)(1) criteria guidance, CWA section 303(c)(2)(B) requires States to adopt criteria based on biological monitoring or assessment methods. The phrase "biological monitoring or assessment methods" includes:

- whole-effluent toxicity control methods;
- biological criteria methods; or
- other methods based on biological monitoring or assessment.

The phrase "biological monitoring or assessment methods" in its broadest sense also includes criteria developed through translator procedures. This broad interpretation of that phrase is consistent with EPA's policy of applying chemical-specific, biological, and whole-effluent toxicity methods independently in an integrated toxics control program. It is also consistent with the intent of Congress to expand State standards programs beyond chemical-specific approaches.

States should also consider developing protocols to derive and adopt numeric criteria for priority toxic pollutants (or other pollutants) where EPA has not issued section 304(a) criteria guidance. The State should consider available laboratory toxicity test data that may be sufficient to support derivation of chemical-specific criteria. Existing data need not be as comprehensive as that required to meet EPA's 1985 guidelines in order for a State to use its own protocols to derive criteria. EPA has described such protocols in the proposed *Water Quality Guidance for the Great Lakes System* (58 F.R. 20892, at 21016, April 16, 1993.) This is particularly important where other components of a State's narrative criterion implementation procedure (e.g., WET controls or biological criteria) may not ensure full protection of designated uses. For some pollutants, a combination of chemical-specific and other approaches is necessary (e.g., pollutants where bioaccumulation in fish tissue or water consumption by humans is a primary concern).

Biologically based monitoring or assessment methods serve as the basis for control where no specific numeric criteria exist or where calculation or application of pollutant-by-pollutant criteria appears infeasible. Also, these methods may serve as a supplemental measurement of attainment of water quality standards in addition to numeric and narrative criteria. The requirement for both numeric criteria and biologically based methods demonstrates that section 303(c)(2)(B) contemplates that States develop a comprehensive toxics control program regardless of the status of EPA's section 304(a) criteria.

The whole-effluent toxicity (WET) testing procedure is the principal biological monitoring guidance developed by EPA to date. The purpose of the WET procedure is to control point source dischargers of toxic pollutants. The procedure is particularly useful for monitoring and controlling the toxicity of complex effluents that may not be well controlled through chemical-specific numeric criteria. As such, biologically based effluent testing procedures are a necessary component of a State's toxics control program under section 303(c)(2)(B) and a principal means for implementing a State's narrative "free from toxics" standard.

Guidance documents EPA considers to serve the purpose of section 304(a)(8) include the *Technical Support Document for Water Quality-based Toxics Control* (USEPA, 1991a; *Guidelines for Deriving National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (Appendix H); *Guidelines and Methodology Used in the Preparation of Health Effect Assessment Chapters of the Consent Decree Water Criteria Documents* (Appendix J); *Methods for Measuring Acute Toxicity of Effluents to Freshwater and Marine Organisms* (USEPA, 1991d); *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms* (USEPA, 1991e); and *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms* (USEPA, 1991f).

3.4.2 Criteria for Nonconventional Pollutants

Criteria requirements applicable to toxicants that are not priority toxic pollutants (e.g., ammonia and chlorine), are specified in the 1983 Water Quality Standards Regulation (see 40 CFR 131.11). Under these requirements, States must adopt criteria based on sound scientific rationale that cover sufficient parameters to protect designated uses. Both numeric and narrative criteria (discussed in sections 3.5.1 and 3.5.2, below) may be applied to meet these requirements.

3.5 Forms of Criteria

States are required to adopt water quality criteria, based on sound scientific rationale, that contain sufficient parameters or constituents to protect the designated use. EPA believes that an effective State water quality standards program should include both parameter-specific (e.g., ambient numeric criteria) and narrative approaches.

3.5.1 Numeric Criteria

Numeric criteria are required where necessary to protect designated uses. Numeric criteria to protect aquatic life should be developed to address both short-term (acute) and long-term (chronic) effects. Saltwater species, as well as freshwater species, must be adequately protected. Adoption of numeric criteria is particularly important for toxicants known to be impairing surface waters and for toxicants with potential human health impacts (e.g., those with high bioaccumulation potential). Human health should be protected from exposure resulting from consumption of water and fish or other aquatic life (e.g., mussels, crayfish). Numeric water quality criteria also are useful in addressing nonpoint source pollution problems.

In evaluating whether chemical-specific numeric criteria for toxicants that are <u>not</u> priority toxic pollutants are required, States should consider whether other approaches (such as whole-effluent toxicity criteria or biological controls) will ensure full protection of designated uses. As mentioned above, a combination of independent approaches may be required in some cases to support the designated uses and comply with the requirements of the Water Quality Standards Regulation (e.g., pollutants where bioaccumulation in fish tissue or water consumption by humans is a primary concern).

3.5.2 Narrative Criteria

To supplement numeric criteria for toxicants, all States have also adopted narrative criteria for toxicants. Such narrative criteria are statements that describe the desired water quality goal, such as the following:

All waters, including those within mixing zone, shall be free from substances attributable to wastewater discharge or other pollutant sources that:

1. Settle to form objectionable deposits;
2. Float as debris, scum, oil, or other matter forming nuisances;
3. Produce objectionable color, odor, taste, or turbidity;
4. Cause injury to or are toxic to, or produce adverse physiological responses in humans, animals, or plants; or
5. Produce undesirable or nuisance aquatic life (54 F.R.28627, July 6, 1989).

EPA considers that the narrative criteria apply to all designated uses at all flows and are necessary to meet the statutory requirements of section 303(c)(2)(A) of the CWA.

Narrative toxic criteria (No. 4, above) can be the basis for establishing chemical-specific limits for waste discharges where a specific pollutant can be identified as causing or contributing to the toxicity and the State has not adopted chemical-specific numeric criteria. Narrative toxic criteria are cited as a basis for establishing whole-effluent toxicity controls in EPA permitting regulations at 40 CFR 122.44(d)(1)(v).

To ensure that narrative criteria for toxicants are attained, the Water Quality Standards Regulation requires States to develop implementation procedures (see 40 CFR 131.11(a)(2)). Such implementation procedures.

Exhibit 3-3. Components of a State Implementation Procedure for Narrative Toxics Criteria

State implementation procedures for narrative toxics criteria should describe the following:

- Specific, scientifically defensible methods by which the State will implement its narrative toxics standard for all toxicants, including:
    - methods for chemical-specific criteria, including methods for applying chemical-specific criteria in permits, developing or modifying chemical-specific criteria via a "translator procedure" (defined and discussed below),

    and calculating site-specific criteria based on local water chemistry or biology);
  - methods for developing and implementing whole-effluent toxicity criteria and/or controls; and
  - methods for developing and implementing biological criteria.

- How these methods will be integrated in the State's toxics control program (i.e., how the State will proceed when the specified methods produce conflicting or inconsistent results).
- Application criteria and information needed to apply numerical criteria, for example:
  - methods the State will use to identify those pollutants to be regulated in a specific discharge;
  - an incremental cancer risk level for carcinogens;
  - methods for identifying compliance thresholds in permits where calculated limits are below detection;
  - methods for selecting appropriate hardness, pH, and temperature variables for criteria expressed as functions;
  - methods or policies controlling the size and in-zone quality of mixing zones
  - design flows to be used in translating chemical-specific numeric criteria for aquatic life and human health into permit limits; and
  - other methods and information needed to apply standards on a case-by-case basis.

(Exhibit 3-3) should address all mechanisms to be used by the State to ensure that narrative criteria are attained. Because implementation of chemical-specific numeric criteria is a key component of State toxics control programs, narrative criteria implementation procedures must describe or reference the State's procedures to implement such chemical-specific numeric criteria (e.g., procedures for establishing chemical-specific permit limits under the NPDES permitting program). Implementation procedures must also address State programs to control whole-effluent toxicity (WET) and may address programs to implement biological criteria, where such programs have been developed by the State. Implementation procedures therefore serve as umbrella documents that describe how the State's various toxics control programs are integrated to ensure adequate protection for aquatic life and human health and attainment of the narrative toxics criterion. In essence, the procedure should apply the "independent application" principle, which provides for independent evaluations of attainment of a designated use based on chemical-specific, whole-effluent toxicity, and biological criteria methods (see section 3.5.3 and Appendices C, K, and R).

EPA encourages, and may ultimately require, State implementation procedures to provide for implementation of biological criteria. However, the regulatory basis for requiring whole-effluent toxicity (WET) controls is clear. EPA regulations at 40 CFR 122.44(d)(1)(v) require NPDES permits to contain WET limits where a permittee has been shown to cause, have the reasonable potential to cause, or contribute to an in-stream excursion of a narrative criterion. Implementation of chemical-specific controls is also required by EPA regulations at 40 CFR 122.44(d)(1). State implementation procedures should, at a minimum, specify or reference methods to be used in implementing chemical-specific and whole-effluent toxicity-based controls, explain how these methods are integrated, and specify needed application criteria.

In addition to EPA's regulation at 40 CFR 131, EPA has regulations at 40 CFR 122.44 that cover the National Surface Water Toxics Control Program. These regulations are intrinsically linked to the requirements to achieve water quality standards, and specifically address the control of pollutants both with and without numeric criteria. For example, section 122.44(d)(1)(vi) provides the permitting authority with several options for establishing effluent limits when a State does not have a chemical-specific numeric criterion for a pollutant present in an effluent at a concentration that causes or contributes to a violation of the State's narrative criteria.

3.5.3 Biological Criteria

The Clean Water Act of 1972 directs EPA to develop programs that will evaluate, restore, and maintain the chemical, physical, and biological integrity of the Nation's waters. In response to this directive, States and EPA have implemented chemically based water quality programs that address significant water pollution problems. However, over the past 20 years, it has become apparent that these programs alone cannot identify and address all surface water pollution problems. To help create a more comprehensive program, EPA is setting a priority for the development of biological criteria as part of State water quality standards. This effort will help States and EPA (1) achieve the biological integrity objective of the CWA set forth in section 101, and (2) comply with the statutory requirements under sections 303 and 304 of the Act (see Appendices C and K).

Regulatory Bases for Biocriteria

The primary statutory basis for EPA's policy that States should develop biocriteria is found in sections 101(a) and 303(c)(2)(B) of the Clean Water Act. Section 101(a) of the CWA gives the general goal of biological criteria. It establishes as the objective of the Act the restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters. To meet this objective, water quality criteria should address biological integrity. Section 101(a) includes the interim water quality goal for the protection and propagation of fish, shellfish, and wildlife.

Section 304(a) of the Act provides the legal basis for the development of informational criteria, including biological criteria. Specific directives for the development of regulatory biocriteria can be found in section 303(c), which requires EPA to develop criteria based on biological assessment methods when numerical criteria are not established.

Section 304(a) directs EPA to develop and publish water quality criteria and information on methods for measuring water quality and establishing water quality criteria for toxic pollutants on bases other than pollutant-by-pollutant, including biological monitoring and assessment methods that assess:

- the effects of pollutants on aquatic community components (". . . plankton, fish, shellfish, wildlife, plant life . . .") and community attributes (". . . biological community diversity, productivity, and stability . . .") in any body of water; and
- factors necessary " . . . to restore and maintain the chemical, physical, and biological integrity of all navigable waters . . ." for " . . . the protection of shellfish, fish, and wildlife for classes and categories of receiving waters …"

Once biocriteria are formally adopted into State standards, biocriteria and aquatic life use designations serve as direct, legal endpoints for determining aquatic life use attainment/non-attainment. CWA section 303(c)(2)(B) provides that when numeric criteria are not available, States shall adopt criteria for toxics based on biological monitoring or assessment methods; biocriteria can be used to meet this requirement.

Development and Implementation of Biocriteria

Biocriteria are numerical values or narrative expressions that describe the expected reference biological integrity of aquatic communities inhabiting waters of a designated aquatic life use. In the most desirable scenario, these would be waters that are either in pristine condition or minimally impaired. However, in some areas these conditions no longer exist and may not be attainable. In these situations, the reference biological communities represent the best attainable conditions. In either case, the reference conditions then become the basis for developing biocriteria for major surface water types (streams, rivers, lakes, wetlands, estuaries, or marine waters).

Biological criteria support designated aquatic life use classifications for application in State standards (see chapter 2). Each State develops its own designated use classification system based on the generic uses cited in the Act (e.g., protection and propagation of fish, shellfish, and wildlife). Designated uses are intentionally general. However, States may develop subcategories within use designations to refine and clarify the use class. Clarification of the use class is particularly helpful when a variety of surface waters with distinct characteristics fit within the same use class, or do not fit well into any category.

For example, subcategories of aquatic life uses may be on the basis of attainable habitat (e.g., coldwater versus warmwater stream systems as represented by distinctive trout or bass fish communities, respectively). Special uses may also be designated to protect particularly unique, sensitive, or valuable aquatic species, communities, or habitats.

Resident biota integrate multiple impacts over time and can detect impairment from known and unknown causes. Biological criteria can be used to verify improvement in water quality in response to regulatory and other improvement efforts and to detect new or continuing degradation of waters. Biological criteria also provide a framework for developing improved best management practices and management measures for nonpoint source impacts. Numeric biological criteria can provide effective monitoring criteria for more definitive evaluation of the health of an aquatic ecosystem.

The assessment of the biological integrity of a water body should include measures of the structure and function of the aquatic community within a specified habitat. Expert knowledge of the system is required for the selection of appropriate biological components and measurement indices. The development and implementation of biological criteria requires:

- selection of surface waters to use in developing reference conditions for each designated use;
- measurement of the structure and function of aquatic communities in reference surface waters to establish biological criteria;
- measurement of the physical habitat and other environmental characteristics of the water resource; and
- establishment of a protocol to compare the biological criteria to biota in comparable test waters to determine whether impairment has occurred.

These elements serve as an interactive network that is particularly important during early development of biological criteria where rapid accumulation of information is effective for refining both designated uses and developing biological criteria values and the supporting biological monitoring and assessment techniques.

3.5.4 Sediment Criteria

While ambient water quality criteria are playing an important role in assuring a healthy aquatic environment, they alone have not been sufficient to ensure appropriate levels of environmental protection. Sediment contamination, which can involve deposition of toxicants over long periods of time, is responsible for water quality impacts in some areas.

EPA has authority to pursue the development of sediment criteria in streams, lakes and other waters of the United States under sections 104 and 304(a)(1) and (2) of the CWA as follows:

- section 104(n)(1) authorizes the Administrator to establish national programs that study the effects of pollution, including sedimentation, in estuaries on aquatic life;
- section 304(a)(1) directs the Administrator to develop and publish criteria for water quality, including information on the factors affecting rates of organic and inorganic sedimentation for varying types of receiving waters;
- section 304(a)(2) directs the Administrator to develop and publish information on, among other issues, "the factors necessary for the protection and propagation of shellfish, fish, and wildlife for classes and categories of receiving waters. . . ."

To the extent that sediment criteria could be developed that address the concerns of the section 404(b)(1) Guidelines for discharges of dredged or fill material under the CWA or the Marine Protection, Research, and Sanctuaries Act, they could also be incorporated into those regulations.

EPA's current sediment criteria development effort, as described below, focuses on criteria for the protection of aquatic life. EPA anticipates potential future expansion of this effort to include sediment criteria for the protection of human health.

Chemical Approach to Sediment Criteria Development

Over the past several years, sediment criteria development activities have centered on evaluating and developing the Equilibrium Partitioning Approach for generating sediment criteria. The Equilibrium Partitioning Approach focuses on predicting the chemical interaction between sediments and contaminants. Developing an understanding of the principal factors that influence the sediment/contaminant interactions will allow predictions to be made regarding the level of contaminant concentration that benthic and other organisms may be exposed to. Chronic water quality criteria, or possibly other toxicological endpoints, can then be used to predict potential biological effects. In addition to the development of sediment criteria, EPA is also working to develop a standardized sediment toxicity test that could be used with or independently of sediment criteria to assess chronic effects in fresh and marine waters.

Equilibrium Partitioning (EqP) Sediment Quality Criteria (SQC) are the U.S. Environmental Protection Agency's best recommendation of the concentration of a substance in sediment that will not unacceptably affect benthic organisms or their uses.

Methodologies for deriving effects-based SQC vary for different classes of compounds. For non-ionic organic chemicals, the methodology requires normalization to organic carbon. A methodology for deriving effects-based sediment criteria for metal contaminants is under development and is expected to require normalization to acid volatile sulfide. EqP SQC values can be derived for varying degrees of uncertainty and levels of protection, thus permitting use for ecosystem protection and remedial programs.

Application of Sediment Criteria

SQC would provide a basis for making more informed decisions on the environmental impacts of contaminated sediments. Existing sediment assessment methodologies are limited in their ability to identify chemicals of concern, responsible parties, degree of contamination, and zones of impact. To make the most informed decisions, EPA believes that a comprehensive approach using SQC and biological test methods is preferred.

Sediment criteria will be particularly valuable in site-monitoring applications where sediment contaminant concentrations are gradually approaching a criterion over time or as a preventive tool to ensure that point and nonpoint sources of contamination are controlled and that uncontaminated sediments remain uncontaminated. Also comparison of field measurements to sediment criteria will be a reliable method for providing early warning of a potential problem. An early warning would provide an opportunity to take corrective action before adverse impacts occur. For the reasons mentioned above, it has been identified that SQC are essential to resolving key contaminated sediment and source control issues in the Great Lakes.

Specific Applications

Specific applications of sediment criteria are under development. The primary use of EqP-based sediment criteria will be to assess risks associated with contaminants in sediments. The various offices and programs concerned with contaminated sediment have different regulatory mandates and, thus, have different needs and areas for potential application of sediment criteria. Because each regulatory need is different, EqP-based sediment quality criteria designed specifically to meet the needs of one office or program may have to be implemented in different ways to meet the needs of another office or program.

One mode of application of EqP-based numerical sediment quality criteria would be in a tiered approach. In such an application, when contaminants in sediments exceed the sediment quality criteria the sediments would be considered as causing unacceptable impacts. Further testing may or may not be required depending on site-specific conditions and the degree in which a criterion has been violated. (In locations where contamination significantly exceeds a criterion, no additional testing would be required. Where sediment contaminant levels are close to a criterion, additional testing might be necessary.) Contaminants in a sediment at concentrations less than the sediment criterion would not be of concern. However, in some cases the sediment could not be considered safe because it might contain other contaminants above safe levels for which no sediment criteria exist. In addition, the synergistic, antagonistic, or additive effects of several contaminants in the sediments may be of concern.

Additional testing in other tiers of an evaluation approach, such astoxicity tests, could be required to determine if the sediment is safe. It is likely that such testing would incorporate site-specific considerations. Examples of specific applications of sediment criteria after they are developed include the following:

- Establish permit limits for point sources to ensure that uncontaminated sediments remain uncontaminated or sediments already contaminated have an opportunity to cleanse themselves. Of course, this would occur only after criteria and the means to tie point sources to sediment contamination are developed.
- Establish target levels for nonpoint sources of sediment contamination.
- For remediation activities, SQC would be valuable in identifying:
    - need for remediation,
    - spatial extent of remediation area,
    - benefits derived from remediation activities,
    - responsible parties,
    - impacts of depositing contaminated sediments in water environments, and
    - success of remediation activities.

In tiered testing sediment evaluation processes, sediment criteria and biological testing procedures work very well together.

Sediment Criteria Status

Science Advisory Board Review

The Science Advisory Board has completed a second review of the EqP approach to deriving sediment quality criteria for non-ionic contaminants. The November 1992 report (USEPA, 1992c) endorses the EqP approach to deriving criteria as ". . . sufficiently valid to be used in the regulatory process if the uncertainty associated with the method is considered, described, and incorporated," and that "EPA should establish criteria on the basis of present knowledge within the bounds of uncertainty"

The Science Advisory Board also identified the need for ". . . a better understanding of the uncertainty around the assumptions inherent in the approach, including assumptions of equilibrium, bioavailability, and kinetics, all critical to the application of the EqP."

Sediment Criteria Documents and Application Guidance

EPA efforts at producing sediment criteria documents are being directed first toward phenanthrene, fluoranthene, dieldrin, acenaphthene, and endrin. Efforts are also being directed towards producing a guidance document on the derivation and interpretation of sediment quality criteria. The criteria documents were announced in the *Federal Register* in January 1994; the public comment period ended June 1994. Final documents and implementation guidance should be available in early 1996.

Methodology for Developing Sediment Criteria for Metal Contaminants

EPA is proceeding to develop a methodology for calculating sediment criteria for benthic toxicity to metal contaminants, with key work focused on identifying and understanding the role of acid volatile sulfides (AVS), and other binding factors, in controlling the bioavailability of metal contaminants. A variety of field and laboratory verification studies are under way to add additional support to the methodology. Standard AVS sampling and analytical procedures are under development. Presentation of the metals methodology to the SAB for review is anticipated for Fall 1994.

Biological Approach to Sediment Criteria Development

Under the Contaminated Sediment Management Strategy, EPA programs have committed to using consistent biological methods to determine if sediments are contaminated. In the water program, these biological methods will be used as a complement to the sediment-chemical criteria under development. The biological methods consist of both toxicity and bioaccumulation tests. Freshwater and saltwater benthic species, selected to represent the sensitive range of species' responses to toxicity, are used in toxicity tests to measure sediment toxicity. Insensitive freshwater and saltwater benthic species that form the base of the food chain are used in toxicity tests to measure the bioaccumulation potential of sediment. In FY 1994, acute toxicity tests and bioaccumulation tests selected by all the Agency programs should be standardized and available for use. Training for States and EPA Regions on these methods is expected to begin in FY1995.

In the next few years, research will be conducted to develop standardized chronic toxicity tests for sediment as well as toxicity identification evaluation (TIE) methods. The TIE approach will be used to identify the specific chemicals in a sediment causing acute or chronic toxicity in the test organisms. Under the Contaminated Sediment Management Strategy, EPA's programs have also agreed to incorporate these chronic toxicity and TIE methods into their sediment testing when they are available.

3.5.5 Wildlife Criteria

Terrestrial and avian species are useful as sentinels for the health of the ecosystem as a whole. In many cases, damage to wildlife indicates that the ecosystem itself is damaged. Many wildlife species that are heavily dependent on the aquatic food web reflect the health of aquatic systems. In the case of toxic chemicals, terminal predators such as otter, mink, gulls, terns, eagles, ospreys, and turtles are useful as integrative indicators of the status or health of the ecosystem.

Statutory and Regulatory Authority

Section 101(a)(2) of the CWA sets, as an interim goal of,

> …wherever attainable…water quality which provides for the protection and propagation of fish, shellfish, and wildlife…(emphasis added).

Section 304(a)(1) of the Act also requires EPA to:

> …develop and publish… criteria for water quality accurately reflecting…the kind and extent of all identifiable effects on health and welfare including…wildlife.

The Water Quality Standards Regulation reflect the statutory goals and requirements by requiring States to adopt, where attainable, the CWA section 101(a)(2) goal uses of protection and propagation of fish, shellfish, and wildlife (40 CFR 131.10), and to adopt water quality criteria sufficient to protect the designated use (40 CFR 131.11).

Wildlife Protection in Current Aquatic Criteria

Current water quality criteria methodology is designed to protect fish, benthic invertebrates, and zooplankton; however, there is a provision in the current aquatic life criteria guidelines (Appendix H) that is intended to protect wildlife that consume aquatic organisms from the bioaccumulative potential of a compound. The final residue value can be based on either the FDA Action Level or a wildlife feeding study. However, if maximum permissible tissue concentration is not available from a wildlife feeding study, a final residue value cannot be derived and the criteria quantification procedure continues without further consideration of wildlife impacts. Historically, wildlife have been considered only after detrimental effects on wildlife populations have been observed in the environment (this occurred with relationship to DDT, selenium, and PCBs).

Wildlife Criteria Development

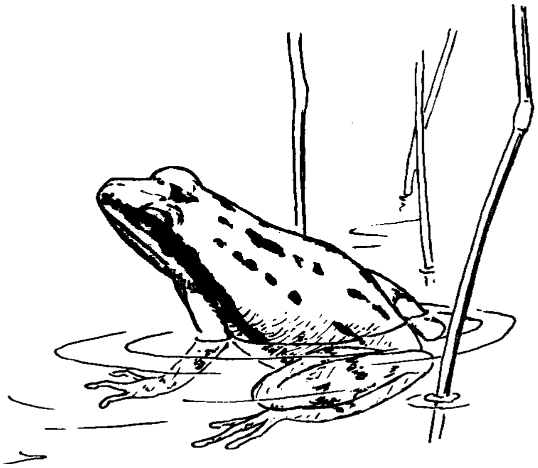
EPA's national wildlife criteria effort began following release of a 1987 Government Accounting Office study entitled *Wildlife Management - National Refuge Contamination Is Difficult To Confirm and Clean Up* (GAO, 1987). After waterfowl deformities observed at Kesterson Wildlife Refuge were linked to selenium contamination in the water, Congress requested this study and recommended that "the Administrator of EPA, in close coordination with the Secretary of the Interior, develop water quality criteria for protecting wildlife and their refuge habitat."

In November of 1988, EPA's Environmental Research Laboratory in Corvallis sponsored a workshop entitled *Water Quality Criteria To Protect Wildlife Resources*, (USEPA, 1989g) which was co-chaired by EPA and the Fish and Wildlife Service (FWS). The workshop brought together 26 professionals from a variety of institutions, including EPA, FWS, State governments, academia, and consultants who had expertise in wildlife toxicity, aquatic toxicity, ecology, environmental risk assessment, and conservation. Efforts at the workshop focused on evaluating the need for, and developing a strategy for production of wildlife criteria. Two recommendations came out of that workshop:

1. The process by which ambient water quality criteria are established should be modified to consider effects on wildlife; and
2. chemicals should be prioritized based on their potential to adversely impact wildlife species.

Based on the workshop recommendations, screening level wildlife criteria (SLWC) were calculated for priority pollutants and chemicals of concern submitted by the FWS to gauge the extent of the problem by:

1. evaluating whether existing water quality criteria for aquatic life are protective of wildlife, and
2. prioritizing chemicals for their potential to adversely impact wildlife species.



There were 82 chemicals for which EPA had the necessary toxicity information as well as ambient water quality criteria, advisories, or lowest-observed-adverse-effect levels (LOAELs) to compare with the SLWC values.

As would be expected, the majority of chemicals had SLWC larger than existing water quality criteria, advisories, or LOAELs for aquatic life. However, the screen identified classes of compounds for which current ambient water quality criteria may not be adequately protective of wildlife: chlorinated alkanes, benzenes, phenols, metals, DDT, and dioxins. Many of these compounds are produced in very large amounts and have a variety of uses (e.g., solvents, flame retardants, organic syntheses of fungicides and herbicides, and manufacture of plastics and textiles. The manufacture and use of these materials produce waste byproduct). Also, 5 of the 21 are among the top 25 pollutants identified at Superfund sites in 1985 (3 metals, 2 organics).

Following this initial effort, EPA held a national meeting in April 1992 to constructively discuss and evaluate proposed methodologies for deriving wildlife criteria to build consensus among the scientific community as to the most defensible scientifically approach(es) to be pursued by EPA in developing useful and effective wildlife criteria.

The conclusions of this national meeting were as follows:

- wildlife criteria should have a tissue-residue component when appropriate;
- peer-review of wildlife criteria and data sets should be used in their derivation
- wildlife criteria should incorporate methods to establish site-specific wildlife criteria;
- additional amphibian and reptile toxicity data are needed;
- further development of inter-species toxicological sensitivity factors are needed; and
- criteria methods should measure biomarkers in conjunction with other studies.

On April 16, 1993, EPA proposed wildlife criteria in the *Water Quality Guidance for the Great Lakes System* (58 F.R. 20802). The proposed wildlife criteria are based on the current EPA noncancer human health criteria approach. In this proposal, in addition to requesting comments on the proposed Great Lakes criteria and methods, EPA also requested comments on possible modifications of the proposed Great Lakes approach for consideration in the development of national wildlife criteria.

3.5.6 Numeric Criteria for Wetlands

Extension of the EPA national 304(a) numeric aquatic life criteria to wetlands is recommended as part of a program to develop standards and criteria for wetlands. Appendices D and E provide an overview of the need for standards and criteria for wetlands. The 304(a) numeric aquatic life criteria are designed to be protective of aquatic life for surface waters and are generally applicable to most wetland types. Appendix E provides a possible approach, based on the site-specific guidelines, for detecting wetland types that might not be protected by direct application of national 304(a) criteria. The evaluation can be simple and inexpensive for those wetland types for which sufficient water chemistry and species assemblage data are available, but will be less useful for wetland types for which these data are not readily available. In Appendix E, the site-specific approach is described and recommended for wetlands for which modification of the 304(a) numeric criteria are considered necessary. The results of this type of evaluation, combined with information on local or regional environmental threats, can be used to prioritize wetland types (and individual criteria) for further site-specific evaluations and/or additional data collection. Close coordination among regulatory agencies, wetland scientists, and criteria experts will be required.

3.6 Policy on Aquatic Life Criteria for Metals

It is the policy of the Office of Water that the use of dissolved metal to set and measure compliance with water quality standards is the recommended approach, because dissolved metal more closely approximates the bioavailable fraction of metal in the water column than does total recoverable metal. This conclusion regarding metals bioavailability is supported by a majority of the scientific community within and outside EPA. One reason is that a primary mechanism for water column toxicity is adsorption at the gill surface which requires metals to be in the dissolved form.

Until the scientific uncertainties are better resolved, a range of different risk management decisions can be justified by a State. EPA recommends that State water quality standards be based on dissolved metal--a conversion factor must be used in order to express the EPA criteria articulated as total recoverable as dissolved. (See the paragraph below for technical details on developing dissolved criteria.) EPA will also approve a State risk management decision to adopt standards based on total recoverable metal, if those standards are otherwise approvable as a matter of law. (*Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria* USEPA, 1993f)

3.6.1 Background

The implementation of metals criteria is complex due to the site-specific nature of metals toxicity. This issue covers a number of areas including the expression of aquatic life criteria; total maximum daily loads (TMDLs), permits, effluent monitoring, and compliance; and ambient monitoring. The following Sections, based on the policy memorandum referenced above, provide additional guidance in each of these areas. Included in this Handbook as Appendix J are three guidance documents issued along with the Office of Water policy memorandum with additional technical details. They are: *Guidance Document on Expression of Aquatic Life Criteria as Dissolved Criteria* (Attachment #2), *Guidance Document on Dynamic Modeling and Translators* (Attachment #3), and *Guidance Document on Monitoring* (Attachment #4). These will be supplemented as additional information becomes available.

Since metals toxicity is significantly affected by site-specific factors, it presents a number of programmatic challenges. Factors that must be considered in the management of metals in the aquatic environment include: toxicity specific to effluent chemistry; toxicity specific to ambient water chemistry; different patterns of toxicity for different metals; evolution of the state of the science of metals toxicity, fate, and transport; resource limitations for monitoring, analysis, implementation, and research functions; concerns regarding some of the analytical data currently on record due to possible sampling and analytical contamination; and lack of standardized protocols for clean and ultraclean metals analysis. The States have the key role in the risk management process of balancing these factors in the management of water programs. The site-specific nature of this issue could be perceived as requiring a permit-by-permit approach to implementation. However, EPA believes that this guidance can be effectively implemented on a broader level, across any waters with roughly the same physical and chemical characteristics, and recommends that States work with the EPA with that perspective in mind.

3.6.2 Expression of Aquatic Life Criteria

Dissolved vs. Total Recoverable Metal

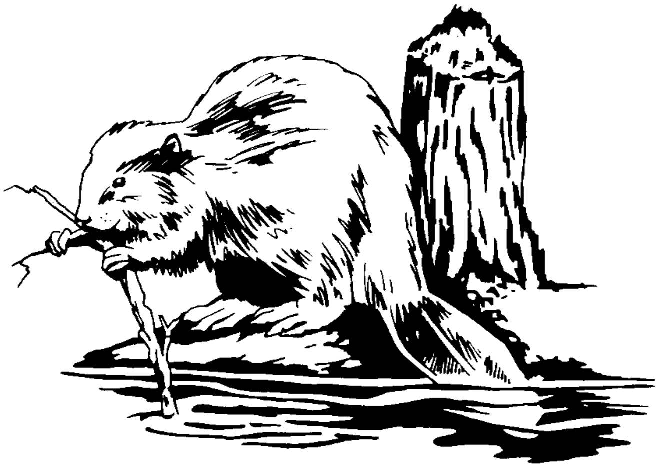
A major issue is whether, and how, to use dissolved metal concentrations ("dissolved metal") or total recoverable metal concentrations ("total recoverable metal") in setting State water quality standards. In the past, States have used both approaches when applying the same EPA Section 304(a) criteria guidance. Some older criteria documents may have facilitated these different approaches to interpretation of the criteria because the documents were somewhat equivocal with regards to analytical methods. The May 1992 interim guidance continued the policy that either approach was acceptable.

The position that the dissolved metals approach is more accurate has been questioned because it neglects the possible toxicity of particulate metal. It is true that some studies have indicated that particulate metals appear to contribute to the toxicity of metals, perhaps because of factors such as desorption of metals at the gill surface, but these same studies indicate the toxicity of particulate metal is substantially less than that of dissolved metal.

Furthermore, any error incurred from excluding the contribution of particulate metal will generally be compensated by other factors which make criteria conservative. For example, metals in toxicity tests are added as simple salts to relatively clean water. Due to the likely presence of a significant concentration of metals binding agents in many discharges and ambient waters, metals in toxicity tests would generally be expected to be more bioavailable than metals in discharges or in ambient waters.

If total recoverable metal is used for the purpose of specifying water quality standards, the lower bioavailability of particulate metal and lower bioavailability of sorbed metals as they are discharged may result in an overly conservative water quality standard. The use of dissolved metal in water quality standards gives a more accurate result in the water column. However, total recoverable measurements in ambient water have value, in that exceedences of criteria on a total recoverable basis are an indication that metal loadings could be a stress to the ecosystem, particularly in locations other than the water column (*e.g.*, in the sediments).

The reasons for the potential consideration of total recoverable measurements include risk management considerations not covered by evaluation of water column toxicity alone. The ambient water quality criteria are neither designed nor intended to protect sediments, or to prevent effects in the food webs containing sediment dwelling organisms. A risk manager, however, may consider sediments and food chain effects and may decide to take a conservative approach for metals, considering that metals are very persistent chemicals. This conservative approach could include the use of total recoverable metal in water quality standards. However, since consideration of sediment impacts is not incorporated into the criteria methodology, the degree of conservatism inherent in the total recoverable approach is unknown. The uncertainty of metal impacts in sediments stem from the lack of sediment criteria and an imprecise understanding of the fate and transport of metals. EPA will continue to pursue research and other activities to close these knowledge gaps.



Dissolved Criteria

In the toxicity tests used to develop EPA metals criteria for aquatic life, some fraction of the metal is dissolved while some fraction is bound to particulate matter. The present criteria were developed using total recoverable metal measurements or measures expected to give equivalent results in toxicity tests, and are articulated as total recoverable. Therefore, in order to express the EPA criteria as dissolved, a total recoverable to dissolved conversion factor must be used. Attachment #2 in Appendix J provides guidance for calculating EPA dissolved criteria from the published total recoverable criteria. The data expressed as percentage metal dissolved are presented as recommended values and ranges. However, the choice within ranges is a State risk management decision. EPA has recently supplemented the data for copper and is proceeding to further supplement the data for copper and other metals. As testing is completed, EPA will make this information available and this is expected to reduce the magnitude of the ranges for some of the conversion factors provided. EPA also strongly encourages the application of dissolved criteria across a watershed or waterbody, as technically sound and the best use of resources.

Site-Specific Criteria Modifications

While the above methods will correct some site-specific factors affecting metals toxicity, further refinements are possible. EPA has issued guidance for three site-specific criteria development methodologies: recalculation procedure, water-effect ratio (WER) procedure (called the indicator species procedure in previous guidance) and resident species procedure. (See Section 3.7 of this Chapter.)

In the National Toxics Rule (57 FR 60848, December 22, 1992), EPA recommended the WER as an optional method for site-specific criteria development for certain metals. EPA committed in the NTR preamble to provide additional guidance on determining the WERs. The *Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals* was issued by EPA on February 22, 1994 and is intended to fulfill that commitment. This interim guidance supersedes all guidance concerning water-effect ratios and the recalculation procedure previously issued by EPA. This guidance is included as Appendix L to this Handbook.

In order to meet current needs, but allow for changes suggested by protocol users, EPA issued the guidance as "interim." EPA will accept WERs developed using this guidance, as well as by using other scientifically defensible protocols.

3.6.3 Total Maximum Daily Loads (TMDLs) and National Pollutant Discharge Elimination System (NPDES) Permits

Dynamic Water Quality Modeling

Although not specifically part of the reassessment of water quality criteria for metals, dynamic or probabilistic models are another useful tool for implementing water quality criteria, especially for those criteria protecting aquatic life. These models provide another way to incorporate site-specific data. The *Technical Support Document for Water Quality-based Toxics Control* (TSD) (USEPA, 1991a) describes dynamic, as well as static (steady-state) models. Dynamic models make the best use of the specified magnitude, duration, and frequency of water quality criteria and, therefore, provide a more accurate representation of the probability that a water quality standard exceedence will occur. In contrast, steady-state models frequently apply a number of simplifying, worst case assumptions which makes them less complex but also less accurate than dynamic models.

Dynamic models have received increased attention over the last few years as a result of the widespread belief that steady-state modeling is over-conservative due to environmentally conservative dilution assumptions. This belief has led to the misconception that dynamic models will always lead to less stringent regulatory controls (e.g., NPDES effluent limits) than steady-state models, which is not true in every application of dynamic models. EPA considers dynamic models to be a more accurate approach to implementing water quality criteria and continues to recommend their use. Dynamic modeling does require a commitment of resources to develop appropriate data. (See Appendix J, Attachment #3 and the USEPA, 1991a for details on the use of dynamic models.)

Dissolved-Total Metal Translators

Expressing ambient water quality criteria for metals as the dissolved form of a metal poses a need to be able to translate from dissolved metal to total recoverable metal for TMDLs and NPDES permits. TMDLs for metals must be able to calculate: (1) dissolved metal in order to ascertain attainment of water quality standards, and (2) total recoverable metal in order to achieve mass balance necessary for permitting purposes.

EPA's NPDES regulations require that limits of metals in permits be stated as total recoverable in most cases (see 40 CFR §122.45(c)) except when an effluent guideline specifies the limitation in another form of the metal, the approved analytical methods measure only dissolved metal, or the permit writer expresses a metals limit in another form (e.g., dissolved, valent specific, or total) when required to carry out provisions of the Clean Water Act. This is because the chemical conditions in ambient waters frequently differ substantially from those in the effluent, and there is no assurance that effluent particulate metal would not dissolve after discharge. The NPDES rule does not require that State water quality standards be expressed as total recoverable; rather, the rule requires permit writers to translate between different metal forms in the calculation of the permit limit so that a total recoverable limit can be established. Both the TMDL and NPDES uses of water quality criteria require the ability to translate between dissolved metal and total recoverable metal. Appendix J, Attachment #3 provides guidance on this translation.

3.6.4 Guidance on Monitoring

Use of Clean Sampling and Analytical Techniques

In assessing waterbodies to determine the potential for toxicity problems due to metals, the quality of the data used is an important issue. Metals data are used to determine attainment status for water quality standards, discern trends in water quality, estimate background loads for TMDLs, calibrate fate and transport models, estimate effluent concentrations (including effluent variability), assess permit compliance, and conduct research. The quality of trace level metal data, especially below 1 ppb, may be compromised due to contamination of samples during collection, preparation, storage, and analysis. Depending on the level of metal present, the use of "clean" and "ultraclean" techniques for sampling and analysis may be critical to accurate data for implementation of aquatic life criteria for metals.

The significance of the sampling and analysis contamination problem increases as the ambient and effluent metal concentration decreases and, therefore, problems are more likely in ambient measurements. "Clean" techniques refer to those requirements (or practices for sample collection and handling) necessary to produce reliable analytical data in the part per billion (ppb) range. "Ultraclean" techniques refer to those requirements or practices necessary to produce reliable analytical data in the part per trillion (ppt) range. Because typical concentrations of metals in surface waters and effluents vary from one metal to another, the effect of contamination on the quality of metals monitoring data varies appreciably.

EPA plans to develop protocols on the use of clean and ultra-clean techniques and is coordinating with the United States Geological Survey (USGS) on this project, because USGS has been doing work on these techniques for some time, especially the sampling procedures. Draft protocols for clean techniques were presented at the Norfolk, VA analytical methods conference in the Spring of 1994 and final protocols are expected to be available in early 1995. The development of comparable protocols for ultra-clean techniques is underway and are expected to be available in late 1995. In developing these protocols, we will consider the costs of these techniques and will give guidance as to the situations where their use is necessary. Appendix L, pp. 98-108 provide some general guidance on the use of clean analytical techniques. We recommend that this guidance be used by States and Regions as an interim step, while the clean and ultra-clean protocols are being developed.

Use of Historical Data

The concerns about metals sampling and analysis discussed above raise corresponding concerns about the validity of historical data. Data on effluent and ambient metal concentrations are collected by a variety of organizations including Federal agencies (e.g., EPA, USGS), State pollution control agencies and health departments, local government agencies, municipalities, industrial dischargers, researchers, and others. The data are collected for a variety of purposes as discussed above.

Concern about the reliability of the sample collection and analysis procedures is greatest where they have been used to monitor very low level metal concentrations. Specifically, studies have shown data sets with contamination problems during sample collection and laboratory analysis, that have resulted in inaccurate measurements. For example, in developing a TMDL for New York Harbor, some historical ambient data showed extensive metals problems in the harbor, while other historical ambient data showed only limited metals problems. Careful resampling and analysis in 1992/1993 showed the latter view was correct. The key to producing accurate data is appropriate quality assurance (QA) and quality control (QC) procedures. EPA believes that most historical data for metals, collected and analyzed with appropriate QA and QC at levels of 1 ppb or higher, are reliable. The data used in development of EPA criteria are also considered reliable, both because they meet the above test and because the toxicity test solutions are created by adding known amounts of metals.

With respect to effluent monitoring reported by an NPDES permittee, the permittee is responsible for collecting and reporting quality data on a Discharge Monitoring Report (DMR). Permitting authorities should continue to consider the information reported to be true, accurate, and complete as certified by the permittee. Where the permittee becomes aware of new information specific to the effluent discharge that questions the quality of previously submitted DMR data, the permittee must promptly submit that information to the permitting authority. The permitting authority will consider all information submitted by the permittee in determining appropriate enforcement responses to monitoring/reporting and effluent violations. (See Appendix J, Attachment #4 for additional details.)

3.7 Site-Specific Aquatic Life Criteria

The purpose of this section is to provide guidance for the development of site-specific water quality criteria which reflect local environmental conditions. Site-specific criteria are allowed by regulation and are subject to EPA review and approval. The Federal water quality standards regulation at section 131.11(b)(1)(ii) provides States with the opportunity to adopt water quality criteria that are "...modified to reflect site-specific conditions." Site-specific criteria, as with all water quality criteria, must be based on a sound scientific rationale in order to protect the designated use. Existing guidance and practice are that EPA will approve site-specific criteria developed using appropriate procedures.

A site-specific criterion is intended to come closer than the national criterion to providing the intended level of protection to the aquatic life at the site, usually by taking into account the biological and/or chemical conditions (i.e., the species composition and/or water quality characteristics) at the site. The fact that the U.S. EPA has made these procedures available should not be interpreted as implying that the agency advocates that states derive site-specific criteria before setting state standards. Also, derivation of a site-specific criterion does not change the intended level of protection of the aquatic life at the site.

3.7.1 History of Site-Specific Criteria Guidance

National water quality criteria for aquatic life may be under- or over-protective if:

1. the species at the site are more or less sensitive than those included in the national criteria data set (*e.g.*, the national criteria data set contains data for trout, salmon, penaeid shrimp, and other aquatic species that have been shown to be especially sensitive to some materials), or
2. physical and/or chemical characteristics of the site alter the biological availability and/or toxicity of the chemical (*e.g.*, alkalinity, hardness, pH, suspended solids and salinity influence the concentration(s) of the toxic form(s) of some heavy metals, ammonia and other chemicals).

Therefore, it is appropriate that site-specific procedures address each of these conditions separately as well as the combination of the two. In the early 1980's, EPA recognized that laboratory-derived water quality criteria might not accurately reflect site-specific conditions and, in response, created three procedures to derive site-specific criteria. This Handbook contains the details of these procedures, referenced below.

1. The Recalculation Procedure is intended to take into account relevant differences between the sensitivities of the aquatic organisms in the national dataset and the sensitivities of organisms that occur at the site (see Appendix L, pp. 90-97).
2. The Water-Effect Ratio Procedure (called the Indicator Species Procedure in USEPA, 1983a; 1984f) provided for the use of a water-effect ratio (WER) that is intended to take into account relevant differences between the toxicities of the chemical in laboratory dilution water and in site water (see Appendix L).
3. The Resident Species Procedure intended to take into account both kinds of differences simultaneously (see Section 3.7.6).

These procedures were first published in the 1983 *Water Quality Standards Handbook* (USEPA, 1983a) and expanded upon in the *Guidelines for Deriving Numerical Aquatic Site-Specific Water Quality Criteria by Modifying National Criteria* (USEPA, 1984f). Interest has increased in recent years as states have devoted more attention to chemical-specific water quality criteria for aquatic life. In addition, interest in water-effect ratios increased when they were integrated into some of the aquatic life criteria for metals that were promulgated for several states in the National Toxics Rule (57 FR 60848, December 22, 1992). The *Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Criteria for Metals* (USEPA, 1993f) (see Section 3.6 of this Handbook) provided further guidance on site-specific criteria for metals by recommending the use of dissolved metals for setting and measuring compliance with water quality standards.

The early guidance concerning WERs (USEPA, 1983a; 1984f) contained few details and needed revision, especially to take into account newer guidance concerning metals. To meet this need, EPA issued *Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals* in 1994 (Appendix L). Metals are specifically addressed in Appendix L because of the National Toxics Rule and because of current interest in aquatic life criteria for metals; although most of this guidance also applies to other pollutants, some obviously applies only to metals. Appendix L supersedes all guidance concerning water-effect ratios and the Indicator Species Procedure given in Chapter 4 of the *Water Quality Standards Handbook* (USEPA, 1983a) and in *Guidelines for Deriving Numerical Aquatic Site-Specific Water Quality Criteria by Modifying National Criteria* (USEPA, 1984f). Appendix L (p. 90-98) also supersedes the guidance in these earlier documents for the Recalculation Procedure for performing site-specific criteria modifications. The Resident Species Procedure remains essentially unchanged since 1983 (except for changes in the averaging periods to conform to the 1985 aquatic life criteria guidelines (USEPA, 1985b) and is presented in Section 3.7.6, below.

The previous guidance concerning site-specific procedures did not allow the Recalculation Procedure and the WER procedure to be used together in the derivation of a site-specific aquatic life criterion; the only way to take into account both species composition and water quality characteristics in the determination of a site-specific criterion was to use the Resident Species Procedure. A specific change contained Appendix L is that, except in jurisdictions that are subject to the National Toxics Rule, the Recalculation Procedure and the WER Procedure may now be used together provided that the recalculation procedure is performed first. Both the Recalculation Procedure and the WER Procedure are based directly on the guidelines for deriving national aquatic life criteria (USEPA 1985) and, when the two are used together, use of the Recalculation Procedure must be performed first because the Recalculation Procedure has specific implications concerning the determination of the WER.

3.7.2 Preparing to Calculate Site-Specific Criteria

Adopting site-specific criteria in water quality standards is a State option--not a requirement. Moreover, EPA is not advocating that States use site-specific criteria development procedures for setting all aquatic life criteria as opposed to using the National Section 304(a) criteria recommendations. Site-specific criteria are not needed in all situations. When a State considers the possibility of developing site-specific criteria, it is essential to involve the appropriate EPA Regional office at the start of the project.

This early planning is also essential if it appears that data generation and testing may be conducted by a party other than the State or EPA. The State and EPA need to apply the procedures judiciously and must consider the complexity of the problem and the extent of knowledge available concerning the fate and effect of the pollutant under consideration. If site-specific criteria are developed without early EPA involvement in the planning and design of the task, the State may expect EPA to take additional time to closely scrutinize the results before granting any approval to the formally adopted standards.

The following sequence of decisions need to be made before any of the procedures are initiated:

- verify that site-specific criteria are actually needed (*e.g.*, that the use of clean sampling and/or analytical techniques, especially for metals, do not result in attainment of standards.)
- Define the site boundaries.
- Determine from the national criterion document and other sources if physical and/or chemical characteristics are known to affect the biological availability and/or toxicity of a material of interest.
- If data in the national criterion document and/or from other sources indicate that the range of sensitivity of the selected resident species to the material of interest is different from the range for the species in the national criterion document, and variation in physical and/or chemical characteristics of the site water is not expected to be a factor, use the *Recalculation Procedure* (Section 3.7.4).
- If data in the national criterion document and/or from other sources indicate that physical and/or chemical characteristics of the site water may affect the biological availability and/or toxicity of the material of interest, and the selected resident species range of sensitivity is similar to that for the species in the national criterion document, use the *Water-Effect Ratio Procedure* (Section 3.7.5).
- If data in the national criterion document and/or from other sources indicated that physical and/or chemical characteristics of the site water may affect the biological availability and/or toxicity of the material of interest, and the selected resident species range of sensitivity is different from that for the species in the national criterion document, and if both these differences are to be taken into account, use the *Recalculation Procedure in conjunction with the Water-Effect Ratio Procedure* or use the *Resident Species Procedure* (Section 3.7.6).

3.7.3 Definition of a Site

Since the rationales for site-specific criteria are usually based on potential differences in species sensitivity, physical and chemical characteristics of the water, or a combination of the two, the concept of site must be consistent with this rationale.

In the general context of site-specific criteria, a "site" may be a state, region, watershed, waterbody, or segment of a waterbody. The site-specific criterion is to be derived to provide adequate protection for the entire site, however the site is defined.

If water quality effects on toxicity are not a consideration, the site can be as large as a generally consistent biogeographic zone permits. For example, large portions of the Chesapeake Bay, Lake Michigan, or the Ohio River may be considered as one site if their respective aquatic communities do not vary substantially. However, when a site-specific criterion is derived using the Recalculation Procedure, all species that "occur at the site" need to be taken into account when deciding what species, if any, are to be deleted from the dataset. Unique populations or less sensitive uses within sites may justify a designation as a distinct site.

If the species of a site are toxicologically comparable to those in the national criteria data set for a material of interest, and physical and/or chemical water characteristics are the only factors supporting modification of the national criteria, then the site can be defined on the basis of expected changes in the material's biological availability and/or toxicity due to physical and chemical variability of the site water. However, when a site-specific criterion is derived using a WER, the WER is to be adequately protective of the entire site. If, for example, a site-specific criterion is being derived for an estuary, WERs could be determined using samples of the surface water obtained from various sampling stations, which, to avoid confusion, should not be called "sites". If all the WERs were sufficiently similar, one site-specific criterion could be derived to apply to the whole estuary. If the WERs were sufficiently different, either the lowest WER could be used to derive a site-specific criterion for the whole estuary, or the data might indicate that the estuary should be divided into two or more sites, each with its own criterion.

3.7.4 The Recalculation Procedure

The Recalculation Procedure is intended to cause a site-specific criterion to appropriately differ from a national aquatic life criterion if justified by demonstrated pertinent toxicological differences between the aquatic species that occur at the site and those that were used in the derivation of the national criterion. There are at least three reasons why such differences might exist between the two sets of species.

- First, the national dataset contains aquatic species that are sensitive to many pollutants, but these and comparably sensitive species might not occur at the site.
- Second, a species that is critical at the site might be sensitive to the pollutant and require a lower criterion. (A critical species is a species that is commercially or recreationally important at the site, a species that exists at the site and is listed as threatened or endangered under section 4 of the Endangered Species Act, or a

species for which there is evidence that the loss of the species from the site is likely to cause an unacceptable impact on a commercially or recreationally important species, a threatened or endangered species, the abundances of a variety of other species, or the structure or function of the community.)

- Third, the species that occur at the site might represent a narrower mix of species than those in the national dataset due to a limited range of natural environmental conditions.

The procedure presented in Appendix L, pp. 90-98 is structured so that corrections and additions can be made to the national dataset without the deletion process being used to take into account taxa that do not occur at the site; in effect, this procedure makes it possible to update the national aquatic life criterion. All corrections and additions that have been approved by EPA are required, whereas use of the deletion process is optional. The deletion process may not be used to remove species from the criterion calculation that are not currently present at a site due to degraded conditions.

The Recalculation Procedure is more likely to result in lowering a criterion if the net result of addition and deletion is to decrease the number of genera in the dataset, whereas the procedure is more likely to result in raising a criterion if the net result of addition and deletion is to increase the number of genera in the dataset.

For the lipid soluble chemicals whose national Final Residue Values are based on Food and Drug Administration (FDA) action levels, adjustments in those values based on the percent lipid content of resident aquatic species is appropriate for the derivation of site-specific Final Residue Values. For lipid-soluble materials, the national Final Residue Value is based on an average 11 percent lipid content for edible portions for the freshwater chinook salmon and lake trout and an average of 10 percent lipids for the edible portion for saltwater Atlantic herring. Resident species of concern may have higher (e.g., Lake Superior siscowet, a race of lake trout) or lower (e.g., many sport fish) percent lipid content than used for the national Final Residue Value.

For some lipid-soluble materials such as polychlorinated biphenyls (PCB) and DDT, the national Final Residue Value is based on wildlife consumers of fish and aquatic invertebrate species rather than an FDA action level because the former provides a more stringent residue level. See the National Guidelines (USEPA, 1985b) for details.

For the lipid-soluble materials whose national Final Residue Values are based on wildlife effects, the limiting wildlife species (mink for PCB and brown pelican for DDT) are considered acceptable surrogates for resident avian and mammalian species (e.g., herons, gulls, terns, otter, etc.) Conservatism is appropriate for those two chemicals, and no less restrictive modification of the national Final Residue Value is appropriate. The site-specific Final Residue Value would be the same as the national value.

3.7.5 The Water-Effect Ratio (WER) Procedure

The guidance on the Water-Effect Ratio Procedure presented in Appendix L is intended to produce WERs that may be used to derive site-specific aquatic life criteria from most national and state aquatic life criteria that were derived from laboratory toxicity data.

As indicated in Appendix L, the determination of a water-effect ratio may require substantial resources. A discharger should consider cost-effective, preliminary measures described in this Appendix L (e.g., use of "clean" sampling and chemical analytical techniques especially for metals, or in non-NTR States, a recalculated criterion) to determine if an indicator species site-specific criterion is really needed. In many instances, use of these other measures may eliminate the need for deriving water-effect ratios. The methods described in the 1994 interim guidance (Appendix L) should be sufficient to develop site-specific criteria that resolve concerns of dischargers when there appears to be no instream toxicity but, where (a) a discharge appears to exceed existing or proposed water quality-based permit limits, or (b) an instream concentration appears to exceed an existing or proposed water quality criterion.

WERs obtained using the methods described in Appendix L should only be used to adjust aquatic life criteria that were derived using laboratory toxicity tests. WERs determined using the methods described herein cannot be used to adjust the residue-based mercury Criterion Continuous Concentration (CCC) or the field-based selenium freshwater criterion.

Except in jurisdictions that are subject to the NTR, the WERs may also be used with site-specific aquatic life criteria that are derived using the Recalculation Procedure described in Appendix L (p.90).

Water-Effect Ratios in the Derivation of Site-Specific Criteria

A central question concerning WERs is whether their use by a State results in a site-specific criterion subject to EPA review and approval under Section 303(c) of the Clean Water Act?

Derivation of a water-effect ratio by a State is a site-specific criterion adjustment subject to EPA review and approval/disapproval under Section 303(c). There are two options by which this review can be accomplished.

Option 1:

A State may derive and submit each individual water-effect ratio determination to EPA for review and approval. This would be accomplished through the normal review and revision process used by a State.

Option 2:

A State can amend its water quality standards to provide a formal procedure which includes derivation of water-effect ratios, appropriate definition of sites, and enforceable monitoring provisions to assure that designated uses are protected. Both this procedure and the resulting criteria would be subject to full public participation requirements. EPA would review and approve/disapprove this protocol as a revised standard as part of the State's triennial review/revision. After adoption of the procedure, public review of a site-specific criterion could be accomplished in conjunction with the public review required for permit issuance. For public information, EPA recommends that once a year the State publish a list of site-specific criteria.

An exception to this policy applies to the waters of the jurisdictions included in the National Toxics Rule. The EPA review is not required for the jurisdictions included in the National Toxics Rule where EPA established the procedure for the State for application to the criteria promulgated. The National Toxics Rule was a formal rulemaking process (with notice and comment) in which EPA pre-authorized the use of a correctly applied water-effect ratio. That same process has not yet taken place in States not included in the National Toxics Rule.

However, the National Toxics Rule does not affect State authority to establish scientifically defensible procedures to determine Federally authorized WERs, to certify those WERs in NPDES permit proceedings, or to deny their application based on the State's risk management analysis.

As described in Section 131.36(b)(iii) of the water quality standards regulation (the official regulatory reference to the National Toxics Rule), the water-effect ratio is a site-specific calculation. As indicated on page 60866 of the preamble to the National Toxics Rule, the rule was constructed as a rebuttable presumption. The water-effect ratio is assigned a value of 1.0 until a different water-effect ratio is derived from suitable tests representative of conditions in the affected waterbody. It is the responsibility of the State to determine whether to rebut the assumed value of 1.0 in the National Toxics Rule and apply another value of the water-effect ratio in order to establish a site-specific criterion. The site-specific criterion is then used to develop appropriate NPDES permit limits. The rule thus provides a State with the flexibility to derive an appropriate site-specific criterion for specific waterbodies.

As a point of emphasis, although a water-effect ratio affects permit limits for individual dischargers, it is the State in all cases that determines if derivation of a site-specific criterion based on the water-effect ratio is allowed and it is the State that ensures that the calculations and data analysis are done completely and correctly.

3.7.6 The Resident Species Procedure

The resident Species Procedure for the derivation of a site-specific criterion accounts for differences in resident species sensitivity and differences in biological availability and/or toxicity of a material due to variability in physical and chemical characteristics of a site water. Derivation of the site-specific criterion maximum concentration (CMC) and site-specific criterion continuous concentration (CCC) are accomplished after the complete acute toxicity minimum data set requirements have been met by conducting tests with resident species in site water. Chronic tests may also be necessary. This procedure is designed to compensate concurrently for any real differences between the sensitivity range of species represented in the national data set and for site water which may markedly affect the biological availability and/or toxicity of the material of interest.

Certain families of organisms have been specified in the National Guidelines acute toxicity minimum data set (e.g., Salmonidae in fresh water and Penaeidae or Mysidae in salt water); if this or any other requirement cannot be met because the family or other group (e.g., insect or benthic crustacean) in fresh water is not represented by resident species, select a substitute(s) from a sensitive family represented by one or more resident species and meet the 8 family minimum data set requirement. If all the families at the site have been tested and the minimum data set requirements have not been met, use the most sensitive resident family mean acute value as the site-specific Final Acute Value.

To derive the criterion maximum concentration divide the site-specific Final Acute Value by two. The site-specific Final Chronic Value can be obtained as described in the Appendix L. The lower of the site-specific Final Chronic Value (as described in the recalculation procedure - Appendix L, p. 90) and the recalculated site-specific Final Residue Value becomes the site-specific criterion continuous concentration unless plant or other data (including data obtained from the site-specific tests) indicates a lower value is appropriate. If a problem is identified, judgment should be used in establishing the site-specific criterion.

The frequency of testing (e.g., the need for seasonal testing) will be related to the variability of the physical and chemical characteristics of site water as it is expected to affect the biological availability and/or toxicity of the material of interest. As the variability increases, the frequency of testing will increase. Many of the limitations discussed for the previous two procedures would also apply to this procedure.

Endnotes

1. Proceedings in production.

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Seattle, Washington 98101

Authorization to Discharge under the National Pollutant Discharge Elimination System (NPDES)

In compliance with the provisions of the Clean Water Act, 33 U.S.C. §1251 *et seq*., as amended by the Water Quality Act of 1987, P.L. 100-4, the "Act",

Federal Aquaculture Facilities and Aquaculture Facilities Located in Indian Country

Within the boundaries of the State of Washington

which are described in Part I of this general NPDES permit are authorized to discharge to Waters of the United States, in accordance with discharge points, effluent limitations, monitoring requirements and other conditions set forth herein.

A copy of this General Permit must be kept at all times at the facility where discharges occur, if feasible. Otherwise, it must be in the possession of staff whenever working at the facility.

This General Permit will become effective: **insert date.**

This General Permit and the authorization to discharge will expire: **insert date.**

Each Permittee must apply for reauthorization to discharge on or before **insert date.**
if it intends to continue operations and discharge from the facility beyond the term of this permit.

Signed this ______day of ___________, 2015

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Daniel D. Opalski, Director
Office of Water and Watersheds

Preliminary Draft Permit – Not an authorization to discharge

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I. SCHEDULE OF SUBMISSIONS

The following is a summary of some of the items the Permittee must complete and/or submit to EPA during the term of this permit:

Item	**Due Date**
1. Initial Notice of Intent (NOI)	Existing dischargers: no additional NOI submittal necessary at this time. New dischargers: at least 180 days before initiation of discharge. (§II.A.2) Authorization to discharge must be obtained from the EPA prior to commencement of a discharge.
2. Discharge Monitoring Reports (DMRs)	Facilities must submit DMRs monthly by the 20th day of the month. See §V for instructions on submitting DMRs.
3. Surface Water Monitoring Report	Due with the DMR for the month in which the monitoring is conducted. (§III.B.6.)
4. Monitoring Records	Monitoring records must be retained for a period of at least five years. (§V.)
5. Quality Assurance Plan (QA Plan)	New dischargers: Provide written notification to the EPA and to the Lummi or Spokane Tribes (as appropriate) that the QA Plan has been developed and implemented within 90 days after receiving authorization to discharge under this Permit (§III.B.7). Existing dischargers: Modify the QA Plan as necessary and submit written notice to the EPA and to the Lummi or Spokane Tribes (as appropriate) that the Plan has been modified and implemented within 90 days of the effective date of this General Permit. The QA Plan must be kept on-site and made available to the EPA upon request.

Item	Due Date
6. Best Management Practices (BMP) Plan	New dischargers: Provide written notification to the EPA and to the Lummi or Spokane Tribes (as appropriate) that the BMP Plan has been developed and implemented within 90 days after authorization to discharge under this Permit (§III.C.3). Existing dischargers: Modify the Plan as necessary and submit written notice to the EPA and to the Lummi or Spokane Tribes (as appropriate) that the Plan has been modified and implemented within 90 days of the effective date of this General Permit. The Plan must be kept on-site and made available to the EPA upon request.
7. Anticipated INAD Study Participation or Extralabel Drug Use	Written notification to the EPA within 7 days of signing up for an INAD study or receiving a prescription for extralabel drug use if the drug was not previously listed on an NOI or if the drug is being used at a higher dosage than previously approved by Food and Drug Administration (FDA) for this or a different species or disease. (§IV.A.2.a)
8. INAD Use, Extralabel Drug Use, or First Use of Low Regulatory Priority Drugs or Potassium Permanganate	Oral notification to the EPA within 7 days of beginning use and written notification to the EPA within 30 days of beginning use if the drug was not previously listed on an NOI or if the drug is being used at a higher dosage than previously approved by Food and Drug Administration (FDA) for this or a different species or disease. (§IV.A.2.a & b)
9. Structural failure or damage notification	Oral notification to the EPA within 24 hours of becoming aware of structural damage or failure that caused a release of pollutants to waters of the U.S. Written notification to the EPA within 5 days of becoming aware of such damage or failure. (§IV.B)
10. Notification of spills of feed, drugs, pesticides, or other chemicals notification	Oral notification to the EPA within 24 hours of becoming aware of a spill that caused a release of pollutants to waters of the U.S. Written notification to the EPA within 5 days of becoming aware of such a spill. (§IV.C.1)
11. Oil or hazardous materials	The Permittee must report immediately to the EPA at 1-800-424-8802 any spills of oil or hazardous materials to waters of the U.S. The Permittee must report any spills of oil or hazardous materials to waters of the State of Washington to Ecology at 1-800-258-5990 or 1-800-OILS-911 and to the appropriate Ecology regional office. (§IV.C.2)

Item	**Due Date**
12. Annual Report	By January 20 each year. (§IV.E)
13. Non-Compliance Report	Oral notification to the EPA within 24 hours of becoming aware of an unanticipated bypass of treatment facilities or an upset that result in exceedance of effluent limits, or any exceedance of an applicable maximum daily limit for total residual chlorine. Written notification to the EPA within 5 days. (§V.G.)
14. Submittal of subsequent NOI	The NOI to be covered under a subsequent General Permit must be submitted to the EPA at least 180 days before the expiration date of this permit. (§VII.B)
15. Notice of Termination of Discharge	Facilities must request permit termination from the EPA in writing. The EPA will respond with a written determination on the request, in accordance with 40 CFR 122.64. (§II.D.)

II. Permit Coverage

A. EPA Authorization Required

1. ***Authorization to discharge under this General Permit requires written notification from the U.S. Environmental Protection Agency (EPA) that coverage has been granted and that a specific permit number has been assigned to the facility.***

2. The EPA may notify a discharger that it is covered under the General Permit even if the discharger has not submitted a Notice of Intent (NOI) to be covered.

B. Eligible Facilities

1. Facilities eligible for coverage under this permit include the following, within the boundaries of the State of Washington:

a) Federally owned or operated fish hatcheries, fish farms, or other such facilities;

b) Fish hatcheries, fish farms, or other such facilities, regardless of type of ownership, that are located in Indian country, as defined in 18 U.S.C. 1151.

2. To be eligible for coverage under this General Permit, a fish hatchery, fish farm, or other such facility must contain, grow, or hold cold water species of fin-fish in ponds, raceways, or similar structures, which discharge to fresh or marine waters within the State of Washington from a federal facility or from such a facility located in Indian country.

3. The General Permit applies only to those upland facilities that discharge for at least 30 days per year except facilities which produce less than 9,000 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding. The EPA may designate a smaller facility as a significant contributor of pollution to Waters of the United States based on the considerations, such as those listed below [40 CFR §122.24(c)]. Under such circumstances, the designated facility is subject to the limitations and conditions of this permit. Considerations include:

a. The location and quality of the receiving waters;

b. The holding, feeding, and production capacities of the facility;

c. The quantity and nature of the pollutants reaching waters of the United States; and

d. Any other relevant factors.

C. New Sources

Aquaculture facilities that produce 100,000 pounds or more of aquatic animals per year in flow-through or recirculating systems that are constructed after September 22, 2004, are *new sources*, as defined in 40 CFR §§122.2, and 122.29. A facility is a *new source* if (1) the facility is constructed at a site where no other facility is located, (2) the facility totally replaces the process or production equipment that causes the discharge of pollutants at the existing facility, or (3) the facility processes are substantially independent of an existing facility at the same site. See 40 CFR §122.29(b) and (c). A facility smaller than 100,000 pounds of annual production is not a *new source* for these purposes and is not subject to these *new source* requirements.

Pursuant to Section 511(c) of the Clean Water Act, 33 U.S.C. 1371(c), National Environmental Policy Act (NEPA) compliance is required for NPDES permits for the discharge of any pollutant by a "new source."

In accordance with 40 CFR §§ 6.300 and 6.301, the *new source* facility must prepare and submit to the EPA, along with its NOI, an Environmental Information Document or a draft Environmental Assessment (EA) and supporting documents.

New sources may be required to apply for an individual permit.

D. Authorized Discharges

The General Permit authorizes discharges to Waters of the United States as described in Section I.B, above. During the effective period of the permit, authorized discharges are subject to the requirements and conditions set forth in this permit. The General Permit does not authorize the discharge of any waste streams, including spills and other unintentional or non-routine discharges of pollutants, that are not part of the normal operation of the facility, as disclosed in the Permittee's NOI, or any pollutants that are not ordinarily present in such waste streams.

E. Discharges Not Authorized

1. The General Permit does not automatically apply to discharges from aquaculture facilities which produce less than 9,000 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year or to facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding. Facilities below the thresholds for permit coverage may voluntarily submit the information required in a Notice of Intent with a request in a cover letter to be included or excluded from coverage.

2. The General Permit does not apply to net pens.

3. The General Permit does not automatically apply to discharges from facilities where an individual NPDES permit has been terminated or denied for cause nor where coverage has been denied under this or any other General Permit. The EPA will review such facilities for coverage on a case by case basis.

4. The General Permit does not apply to discharges that may contribute to a violation of an applicable water quality standard.

5. The General Permit does not apply to discharges to (a) *impaired waters*, designated pursuant to Section 303(d) of the Clean Water Act (CWA), which are water-quality limited for a pollutant of concern evaluated in the development of this permit (BOD_5, total suspended solids, settleable solids, nutrients, ammonia, chlorine), unless a wasteload allocation has been assigned to the discharge and is applied in this permit, or to (b) receiving waters that are one mile or less upstream from an impaired water that is designated as such pursuant to Section 303(d) of the CWA, unless a specific effluent limit based on a WLA has been applied in this permit.

If a waterbody to which an existing Permittee discharges becomes impaired during the next permit cycle, the Permittee may submit information to the EPA that demonstrates that the discharge is not expected to cause or contribute to an exceedance of water quality standards. Then, the EPA will determine 1) whether the discharge would cause or contribute to an exceedance or impairment, and 2) whether the facility may remain covered under this General Permit in future permit cycles or if an individual permit is needed. New dischargers to impaired waterbodies are not eligible under this General Permit, and must seek permit coverage under an individual permit.

6. The General Permit does not apply to any discharges that include copper or copper compounds.

7. The General Permit does not apply to discharges from processes not associated with fish hatcheries or farms nor to discharges from fish hatchery or farm processes where the EPA determines at the time a discharger seeks coverage that the General Permit does not adequately address the environmental concerns associated with the discharge.

8. The General Permit does not apply to discharges to land or to publicly owned treatment works.

9. The General Permit does not apply to facilities that discharge one mile or less upstream from waters that constitute an outstanding national resource.[1]

10. The General Permit does not apply to facilities that discharge to waters that constitute special resource tribal waters.

F. Permit Expiration

This General Permit will expire five years after its effective date, as specified on the cover page of the permit. In accordance with 40 CFR §122.6, if the permit is not reissued by the expiration date, the conditions of the General Permit will continue in force and effect until a

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[1] As part of an antidegradation policy, Tier 3 maintains and protects water quality in outstanding national resource waters. Except for certain temporary changes, water quality cannot be lowered in such waters. States and authorized Indian Tribes decide which water bodies qualify for this type of protection. As of the date of this permit, no outstanding national resource waters have been designated within the boundaries of Washington State.

new General Permit is issued. Only those facilities authorized to discharge under the expiring General Permit and who submit an NOI at least 180 days prior to the expiration date of the General Permit will remain authorized to discharge under the administratively continued permit conditions.

III. Obtaining Authorization to Discharge under this General Permit

A. Submitting a Notice of Intent

Owners or operators seeking coverage under this General Permit must submit to the EPA Region 10 a timely and complete Notice of Intent (NOI) to be covered by the General Permit. The owner/operator must submit the information indicated in Appendix A (Notice of Intent Contents) of this General Permit. ***A copy of the NOI must be retained on-site***.

1. Submittal Address

a. To the EPA

The NOI must be submitted to the EPA at the following address:

USEPA Region 10
Washington Hatchery NOI, OWW-130
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

b. To the Lummi Nation

As per the Tribe's CWA Section 401 certification, the NOI for dischargers to waters of the Lummi Nation must also be submitted to the Lummi Nation at the following address:

Lummi Natural Resources Department
Water Resources Manager
Lummi Natural Resources Department
2665 Kwina Road
Bellingham, WA 98226-9298

c. To the Spokane Tribe

As per the Tribe's CWA Section 401 certification, the NOI for dischargers to waters of the Spokane Tribe must also be submitted to the Spokane Tribe Water Control Board at the following address:

Spokane Tribe
Brian Crossley
Water & Fish Program
PO Box 480
Wellpinit WA 99040

2. A Permittee authorized to discharge under this General Permit must submit to the EPA an updated and/or amended NOI when there is any material change in the information submitted within its original NOI. A material change may include, but is not limited to, changes in the operator/owner of the facility, a modification in the treatment train, the introduction of new pollutants not identified in the original NOI, or increases in pollutants above the presently authorized levels.

3. When an aquaculture facility is owned by one person or company, and is operated by another person or company, it is the operator's responsibility to apply for and obtain permit coverage. For owners/operators of multiple facilities, a separate NOI must be completed for each site or facility.

4. Deadlines for Submittal

a. Existing facilities with coverage under this permit are ***not*** required to reapply to be covered by this General Permit upon reissuance. In order to remain covered by the General Permit after this permit expires (i.e., five years from issuance), existing dischargers must submit an NOI at least 180 days before the expiration of this permit. See Appendix A of this General Permit for NOI requirements.

b. Existing facilities without permit coverage that increase their production levels and/or feed levels to exceed both the thresholds in §I.B.3, above, must submit an NOI within 30 days of knowing they will exceed or have exceeded both thresholds.

c. New dischargers must submit NOIs at least 180 days prior to initiation of new discharges.

5. Signatory Requirement

The NOI must be signed and certified in accordance with 40 CFR §122.22, as required by Section VII.E (Signatory Requirements) of this permit.

B. When the Permittee is Authorized to Discharge

A discharger will be authorized to discharge beginning on the date it receives written notification from the EPA that grants coverage under the General Permit and assigns an individual number under this General Permit.

C. Individual Permit Alternative

1. EPA Requirement for Individual Permit.

The Director may require any discharger requesting coverage under this General Permit to apply for and obtain an individual NPDES permit in accordance with 40 CFR 122.28(b)(3)(i). In this case, the Permittee will be notified in writing that an individual permit is required and be given a brief explanation of the reasons for the decision. Individual permits may be appropriate if:

a. Whenever the Permittee is not in compliance with the conditions of this General Permit;

b. Whenever a change has occurred in the availability of demonstrated technology or practices for the control or abatement of pollutants applicable to the point source, therefore causing limitations of the General Permit to not be appropriate for the control or abatement of pollutants from the point source(s);

c. If a water quality management plan, including a Total Maximum Daily Load (TMDL), containing requirements applicable to the point source is approved after the effective date of the General Permit;

d. If the discharge(s) is a significant contributor of pollution;

e. If circumstances have changed since the time of NOI submittal, so that the Permittee is no longer appropriately controlled under the General Permit, or either a temporary or permanent reduction or elimination of the discharge is necessary.

D. Permittee’s Request to be Excluded from Coverage under the General Permit

Applying for an Individual Permit.

Any owner or operator authorized by this General Permit may request to be excluded from the coverage under the General Permit by applying for an individual permit. The Permittee must submit an individual permit application with reasons supporting the request to the Director no later than 90 days after the publication by EPA of the General Permit in the Federal Register. The request shall be granted by issuing of any individual permit if the reasons cited by the owner or operator are adequate to support the request. Coverage under this General Permit will be automatically terminated on the effective date of the individual permit. 40 CFR 122.28(b)(3)(ii-iii).

E. Notice of Termination of Discharge

The Permittee must notify the EPA and any affected tribe within 30 days of discharge termination. The Permittee is required to submit DMRs until the effective date of Permit termination.

1. Requests to terminate coverage under this Permit must be in writing and submitted to EPA at the following address:

United States Environmental Protection Agency, Region 10
Unit Manager, NPDES Permits Unit
1200 Sixth Avenue, Suite 900 OWW-130
Seattle, WA 98101

2. Coverage under this Permit may be terminated in accordance with 40 CFR 122.64 if the EPA determines in writing that the entire discharge is permanently terminated, either by elimination of the flow or by connection to a publicly owned treatment works (POTW). Termination of coverage will become effective 30 days after the written determination is sent to the Permittee by the EPA, unless the Permittee objects within that time.

3. Any Permittee whose production and/or feed levels drop below and are expected to remain below the thresholds in §I.B.3, above, may request termination of coverage under this permit in accordance with this Part. The Permittee must include information on projected levels of production and feed for the following five years.

4. Under all circumstances, a Permittee must be covered under this Permit until it has properly disposed of wastewater or solids that were generated at the facility or collected in a raceway or settling basin or held in storage, and until the facility is no longer discharging to waters of the U.S.

IV. Effluent Limitations and Monitoring Requirements

A. Effluent Limitations

1. Prohibited Discharges

a. The Permittee must not discharge to waters of the U.S. from the hatchery complex:

(1) Atlantic salmon *(Salmo salar).*

(2) Solids, including sludge and grit that accumulate in raceways or ponds, in off-line or full-flow settling basins, or in other components of the production facility in excess of the applicable limits in this permit.

(3) Hazardous substances, unless authorized by this permit.

(4) Untreated cleaning wastewater (e.g., obtained from a vacuum or standpipe bottom drain system or rearing/holding unit disinfection).

(5) Visible foam or floating, suspended or submerged matter, including fish mortalities, kill spawning, processing wastes, and leachate from these materials, in amounts causing, or contributing to, a nuisance or objectionable condition in the receiving water or that may impair designated beneficial uses in the receiving water.

(6) Disease control chemicals and drugs except those approved by the Food and Drug Administration and/or the EPA for hatchery use or those reported to the EPA in accordance with Section IV (Aquaculture specific reporting requirements).

(7) Toxic substances, including drugs, pesticides, or other chemicals, in toxic amounts that may impair designated uses or violate water quality standards of the receiving water.

2. Prohibited Practices

The Permittee is prohibited from engaging in any of the following practices or otherwise facilitating prohibited discharges described in §III.A.1, above:

a. Practices that allow accumulated solids in excess of the limits to be discharged to waters of the United States from the permitted facility (*e.g.*, the removal of dam boards in raceways or ponds, the cleaning of settling basins, etc.);

b. Sweeping, raking, or otherwise intentionally discharging accumulated solids from raceways, ponds, or settling basins to waters of the United States; and/or

c. Containing, growing or holding fish within an off-line or in-line settling basin.

3. Discharge Limits

a. Permitted Discharges. During the effective period of the Permittee's authorization to discharge, the Permittee is authorized to discharge pollutants from the outfall(s) specified in its NOI within the limits and subject to the conditions set forth in this permit. This permit authorizes the discharge of only those pollutants resulting from facility processes, waste streams, and operations that have been clearly identified in the NOI, including non-production facilities, such as incubators, laboratories, tagging operations, etc. It does not authorize the discharge of any waste streams, including spills and other unintentional or non-routine discharges of pollutants, that are not part of the normal operation of the facility as disclosed in the Permittee's NOI nor does it authorize the discharge of any pollutants that are not ordinarily present in such waste streams.

b. Discharge Limits. The Permittee must limit discharges from all outfalls authorized under this permit as specified in Tables 1 and 2, below, as applicable. The limits in Table 1 apply to all hatchery discharges except those from separate off-line settling basin outfalls and rearing pond discharges during drawdown, limits for which are listed in Table 2. All limits represent maximum effluent limits, unless otherwise indicated. The Permittee must comply with the applicable effluent limits in the tables at all times, unless otherwise indicated, regardless of the frequency of monitoring or reporting.

Table 1
Effluent Limitations for Hatchery Discharges[1]

Pollutant	Average Monthly Limit	Maximum Daily Limit	Instantaneous Maximum
Net **Total Suspended Solids**[2]	5 mg/L	---	15 mg/L
Net **Settleable Solids**[2]	0.1 ml/L	---	---
Total Residual Chlorine[3] – into fresh water	9.0 µg/L	18.0 µg/L	---
Total Residual Chlorine[3] – into marine water	6.1 µg/L	12.3 µg/L	---

[1] Excluding discharges from separate off-line settling basins (OLSBs) and from raceways or pond systems during drawdown; see Table 2 for limits on those discharges.

[2] Net concentration = effluent concentration – influent concentration. Net TSS and settleable solids determinations will require influent analysis in addition to effluent analysis unless the permittee chooses to assume that the pollutant concentration in the influent is zero. Influent samples must be collected prior to collection of effluent samples; and net TSS and settleable solids will be determined by subtracting the influent concentrations from the effluent concentrations: see Appendix B. The EPA may require additional sampling to prove substantial similarity between influent and effluent solids, where indicated. All influent and effluent samples and flow measurements must be taken on the same day.

[3] Chlorine limits only apply when chlorine or Chloramine-T is being used. The Permittee will be in compliance with the effluent limits for total residual chlorine, provided the total residual chlorine residual levels are at or below the compliance evaluation level of 50 µg/L. Chlorine monitoring is not required if chlorine is allowed to dry at the location of use.

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c. Discharge Limits for Off-Line Settling Basins (OLSBs) and for Raceways or Rearing Ponds during drawdown for fish release. These limits apply to any discharge to waters of the U.S. from an OLSB in addition to limitations listed in Table 1, above, for the total hatchery flow. These limits apply to raceways or pond systems during drawdown for fish release in lieu of the TSS and settleable solids limits in Table 1, above. See Table 2, below. The total residual chlorine limits set forth in Table 1, above, still apply to raceways or pond systems during drawdown for fish release.

Table 2

Effluent Limits for Discharges from Off-line Settling Basins[1] and from Raceways or Rearing Ponds during Drawdown for Fish Release

Pollutant	Maximum Daily Limit
Total Suspended Solids	100 mg/L
Settleable Solids	1.0 ml/L

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[1] These limits apply to only those OLSB effluents that discharge directly to waters of the U.S.

4. Rearing Vessel Disinfection Water

When rearing vessels are disinfected with chlorine, the total residual chlorine effluent limits in Table 1, above, apply.

B. Effluent Monitoring Requirements

1. Hatchery Monitoring

Discharges authorized by this permit from fish hatcheries must be monitored at each outfall described in the NOI. Monitoring in Table 3, below, must be performed before the effluent is discharged to the receiving water. Monitoring results must be submitted to the EPA as directed in §V.B.

Table 3
Hatchery Effluent Monitoring Requirements

Parameter	Units	Sample Type	Sample Frequency	Sample Location
Effluent Flow[1]	Gallons per day	Flow meter, calibrated weir, or other approved method	Monthly[2]	Effluent[3,4]
Net Total Suspended Solids[5]	mg/L	Composite[6]	Monthly[2]	Influent[5] & Effluent[6]
Net Settleable Solids[5]	ml/L	Grab	Monthly[2]	Influent[5] & Effluent[6]
Total Residual Chlorine (including when Chloramine-T is in use)[7]	µg/L	Grab	Monthly[2]	Effluent[6]
Formaldehyde (when Formalin is in use)[7]	mg/L	Grab	Quarterly[2, 8]	Effluent[6]
Temperature (facilities that discharge to waters impaired for temperature)	ºC	Meter	Continuous	Upstream & Effluent[6]

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[1] All influent and effluent samples and flow measurements must be taken on the same day.

[2] Monthly monitoring must begin in the first full calendar month of permit coverage; quarterly monitoring must begin in the first full calendar quarter of permit coverage.

[3] Effluent samples must be collected from the effluent stream after the last unit prior to discharge into the receiving waters or to subsequent mixing with other water flows. If off-line settling basin effluent combines with raceway flows, at least one quarter of the grab samples that go into a composite sample must be collected when the OLSB is discharging.

[4] If the facility is operating in a steady state (no drawdown nor filling up), the flow may be monitored at the influent or the effluent.

[5] Net concentration = effluent concentration – influent concentration. Net TSS and settleable solids determinations will require influent analysis in addition to effluent analysis unless the permittee chooses to assume that the pollutant concentration in the influent is zero. Influent samples must be collected prior to collection of effluent samples; and net TSS and settleable solids will be determined by subtracting the influent concentrations from the effluent concentrations: see Appendix B. The EPA may require additional sampling to prove substantial similarity between influent and effluent solids, where indicated.

[6] Composite samples must consist of four or more discrete samples taken at one-half hour intervals or greater over a 24-hour period; for facilities that clean raceways periodically, at least one fourth of the samples must be taken during quiescent zone or raceway cleaning. Facilities with multiple effluent discharge points and/or influent points must composite samples from all points proportionally to their respective flows. Only the composite sample must be analyzed.

[7] Total residual chlorine and formaldehyde must be monitored only when being used, giving consideration to retention times in the facility. Monitoring for must be conducted during each calendar quarter if the chemical used at any time during the quarter but sampling does not need to occur more than once a quarter.

[8] Formaldehyde monitoring may cease after the first four quarters in which formalin is used if all monitoring results are below 10 mg/L formaldehyde.

Temperature

The following facilities covered by this General Permit discharge to water bodies impaired for temperature and are required to monitor for temperature:

1. Makah National Fish Hatchery (USFWS)
2. Quilcene National Fish Hatchery (USFWS)
3. House of Salmon (Lower Elwha Klallam Tribe)
4. Chief Joseph Hatchery on the Columbia (Confederated Tribes of the Colville Reservation).

Continuous temperature monitoring must begin within one year of the effective date of this Permit. Permittees must monitor for two (not necessarily consecutive) calendar years. Permittees must monitor their effluent, as well as the receiving water immediately upstream of the facility. Upstream and effluent temperature monitoring must occur simultaneously. If a facility has more than one outfall, the Permittee must perform temperature monitoring on the outfall that is most representative of the facility's flow.

Temperature data must be recorded using a micro-recording temperature devices known as a thermistor. Set the recording device to record at one-hour intervals. Collect the following data: monthly instantaneous maximum, maximum daily average, and a seven-day running average of the daily instantaneous maximum.

Use the temperature device manufacturer's software to generate (export) an Excel text or electronic ASCII text file. The text file and placement log must be submitted to the EPA with the annual report for the 2020 calendar year. The placement logs should include the following information for both thermistor deployment and retrieval: date, time, temperature device manufacturer ID, location, depth, whether it measured air or water temperature, and any other details that may explain data anomalies.

Formaldehyde

Sampling for formaldehyde must be conducted only during formalin use. Formaldehyde monitoring may cease after the first four quarters in which formalin is used if all monitoring results are below 10 mg/L formaldehyde. Sampling is not required if formalin is not used and "No Discharge" must be reported on the Discharge Monitoring Reports for that month. In order to capture the maximum concentration of formaldehyde, sampling for formaldehyde must occur as soon as possible after any application of formalin to the hatchery's culture water, after accounting for its detention time through the raceways, tanks and piping networks to the outfall. The detention time calculation must take into account dosage, injection point, facility flow (both velocity and volume), etc. where possible. See Section IV.C.5.c of the General Permit).

Formaldehyde must be tested using EPA Method 8315A. The ML for formaldehyde is 50 µg/l. Alternate analytical method(s) must be approved by the EPA at the Permittee's written request as long as the permittee utilizes method(s) that obtain MLs that are equal to or less than 50 µg/l. Such a request, if granted, will be considered a minor modification to the permit. Permittees should note that the holding time for formaldehyde is three days (i.e., laboratory analysis must begin within three days of taking the sample). See Method 8315A and/or consult with a qualified laboratory for details on logistical considerations.

2. Off-line Settling Basin Effluent Monitoring

Discharges to waters of the U.S. from OLSBs must be monitored as required in Table 4, below.

Table 4

Off-Line Settling Basin Effluent Monitoring Requirements[1]

Parameter	Units	Sample Type	Sample Frequency	Sample Location
Effluent Flow[2]	Gallons per day	Flow meter, calibrated weir, or other approved method	Monthly[3]	Effluent[4]
Total Suspended Solids	mg/L	Grab[5]	Monthly[3]	Effluent[4]
Settleable Solids	ml/L	Grab[5]	Monthly[3]	Effluent[4]
Ammonia[6]	mg/L	Grab[5]	Quarterly[3]	Effluent[4]
Temperature[7]	º C.	Meter	Weekly when OLSB is discharging	Effluent[4]
pH[8]	Standard Units	Meter	Quarterly[3]	Effluent[4]

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[1] Only direct discharges to waters of the U.S. need to be monitored; if the discharge combines with other process wastewaters, these additional OLSB monitoring requirements do not apply.

[2] All effluent samples and flow measurements must be taken on the same day.

[3] Monthly monitoring must begin in the first full calendar month of permit coverage; quarterly monitoring must begin in the first full calendar quarter of permit coverage.

[4] Effluent samples must be collected from the effluent stream after the last unit prior to discharge into the receiving waters or to subsequent mixing with other water flows.

[5] Facilities with multiple effluent discharge points must composite grab samples from all points proportionally to their respective flows. Only the composite sample must be analyzed.

[6] Ammonia monitoring is required only for those facilities with OLSBs discharging directly to receiving waters.

[7] Temperature monitoring must be taken concurrently with each grab sample for the composite ammonia sample and the results averaged and reported on the discharge monitoring report (DMR).

[8] pH monitoring must be taken concurrently with each grab sample for the composite ammonia sample and the range of results reported on the discharge monitoring report (DMR).

3. Monitoring Discharges of Rearing Pond and Raceway Drawdowns for Fish Release

Samples for rearing pond and raceway drawdowns for fish release must be collected regardless of amount of fish in the facility. See Table 5, below.

Table 5

Monitoring Requirements for Discharges from Rearing Pond or Raceway Drawdowns for Fish Release

Parameter	Sample Point	Sampling Frequency	Type of Sample
Settleable Solids (mL/L)	Effluent	1/Drawdown[1]	Grab
Total Suspended Solids (mg/L)	Effluent	1/Drawdown[1]	Grab

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[1] Drawdown samples must be collected during the last quarter of each drawdown event. If the drawdown is a continuous event that involves more than one rearing pond or raceway discharging directly to waters of the US, the Permittee may composite grab samples from each rearing pond or raceway proportionally to their respective flows, each taken in the last quarter of its drawdown; the combined sample may be analyzed instead of separately analyzing grab samples from each of the rearing ponds or raceways. If the discharge is to a settling pond, the facility must estimate when the final ¼ of the discharge is being released to the settling pond, delay the monitoring by the residence time calculated for the pond, and then monitor as the effluent discharges from the pond to the receiving water. If multiple drawdown events are sequential or on different days, a separate grab sample must be analyzed for each event.

4. Monitoring Discharges of Rearing Vessel Disinfection Water

Rearing vessel disinfection water that has been treated with chlorine must be tested before it is allowed to be discharged to waters of the United States; see Table 6, below. Chlorine monitoring is not required if rearing vessels are allowed to dry completely and there is no discharge of chlorine.

Table 6

Monitoring Requirement for Discharges of Rearing Vessel Disinfection Water

Parameter	Sample Point	Sampling Frequency	Type of Sample
Total Residual Chlorine (mg/L)	Effluent	1/Discharge	Grab

C. Surface Water Monitoring

a. Ammonia, Temperature, and pH Monitoring. All Permittees that have off-line settling basins that discharge **directly** to surface waters must conduct surface water monitoring quarterly for ammonia, pH, and temperature immediately upstream, outside the influence of the discharge.

b. Sample Collection. All surface water samples must be grab samples and must be collected at approximately the same time as the effluent samples.

c. Minimum Levels. All samples must be analyzed for the parameters listed in Table 7 to achieve minimum levels (MLs) that are equivalent to or less than those listed in Table 8. The Permittee may request different MLs if its results have consistently been above the required MLs. Such a request must be in writing and must be approved by the EPA before the Permittee may use the revised MLs.

d. Reporting Surface Water Monitoring Results. All surface water monitoring results must be submitted to the EPA with the DMRs for the month when the monitoring is conducted. The report must include all information required in §V.E, below, and a summary and evaluation of the analytical results.

Table 7

Surface Water Monitoring Requirements

Parameter	Units
Ammonia Nitrogen as N[1]	mg/L
pH[21]	standard units
Temperature[1]	° C

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[1] Surface water monitoring is only required for Permittees that have off-line settling basins that discharge **directly** to surface waters.

D. PCB Monitoring for Facilities in the Spokane Watershed

All facilities that discharge to waters in WRIA 54 (Lower Spokane) and WRIA 57 (Middle Spokane) must monitor their effluent for PCB congeners. As of the date of permit issuance, these permit provision applies to two facilities that discharge within these WRIAs: Ford State Fish Hatchery and Spokane Tribal Hatchery.

The EPA is requiring the use of EPA Method 1668C. Permittees must report the total concentration of "dioxin-like" PCB congeners (see Table 8). A complete congener analysis must also be submitted as an attachment to the DMR. PCB monitoring must take place annually, during the calendar quarter of maximum feeding. For any analysis of PCB congeners using EPA Method 1668, the permittee must target MDLs no greater than the MDLs listed in Table 2 of EPA Method 1668 Revision C (EPA-820-R-10-005) and must analyze for each of the 209 individual congeners.

Permittees must follow the Spokane River Regional Toxics Task Force Quality Assurance Project Plan with respect to data validation and blank censoring. The Task Force QAPP addresses this issue in Section 4.2.2, on Pages 40 and 41. Analytes found in samples at concentrations less than 3 times the associated blank concentration will be flagged with a "B" qualifier. The Task Force QAPP states that "all qualified data will be reported with validation qualifiers, however B flagged data will not be used in congener summations for total PCB" (Page 41). See http://srrttf.org/wp-content/uploads/2013/05/QAPP_FINAL_081114.pdf.

Table 8. Dioxin-Like PCB Congeners

Dioxin-Like PCBs IUPAC #	Homolog Group	Substitution Group	IUPAC Name
non-*ortho* substituted PCBs			
77	tetra-CB	non-ortho	3,3',4,4'-tetra-CB
81	tetra-CB	non-ortho	3,4,4',5-tetra-CB
126	penta-CB	non-ortho	3,3',4,4',5-penta-CB
169	hexa-CB	non-ortho	3,3',4,4',5,5'-hexa-CB
mono-*ortho* substituted PCBs			
105	penta-CB	mono-ortho	2,3,3',4,4'-penta-CB
114	penta-CB	mono-ortho	2,3,4,4',5-penta-CB
118	penta-CB	mono-ortho	2,3',4,4',5-penta-CB
123	penta-CB	mono-ortho	2,3',4,4',5-penta-CB
156	hexa-CB	mono-ortho	2,3,3',4,4',5-hexa-CB
157	hexa-CB	mono-ortho	2,3,3',4,4',5'-hexa-CB
167	hexa-CB	mono-ortho	2,3',4,4',5,5'-hexa-CB
189	hepta-CB	mono-ortho	2,3,3',4,4',5,5'-hepta-

In addition to the BMP requirements at section IV.C.5.e.(12) of the General Permit, Permittees in WRIAs 54 and 57 must use any available product testing data to preferentially purchase paint and caulk with the lowest practicable total PCB concentrations.

E. Minimum Levels (MLs)

For all effluent monitoring, the Permittee must use a sufficiently sensitive analytical method which meets the following:

a) Parameters with an effluent limit: The method must achieve a minimum level (ML) less than the effluent limitation unless otherwise specified in Table 1 Effluent Limitations and Monitoring Requirements.
b) Parameters that do not have effluent limitations: The Permittee must use a method that detects and quantifies the level of the pollutant, or the Permittee must use a method that can achieve a maximum ML less than or equal to those specified in Table 8.
c) Minimum Levels: For parameters that do not have an effluent limit, the Permittee may request different MLs. The request must be in writing and must be approved by the EPA. See also Part VI.B. Monitoring Procedures.

For purposes of reporting on the DMR for a single sample, if a value is less than the Method Detection Limit (MDL), the Permittee must report “less than {numeric value of the MDL}” and if a value is less than the ML, the Permittee must report “less than {numeric value of the ML}.”

For purposes of calculating monthly averages, zero may be assigned for values less than the MDL, and the {numeric value of the MDL} may be assigned for values between the MDL and the ML. If the average value is less than the MDL, the Permittee must report “less than {numeric value of the MDL}” and if the average value is less than the ML, the Permittee must report “less than {numeric value of the ML}.” If a value is equal to or greater than the ML, the Permittee must report and use the actual value. The resulting average value must be compared to the compliance level, the ML, in assessing compliance.

Table 9
Minimum Levels

Parameter	**Minimum Level (ML)**
Total Suspended Solids	5 mg/L
Ammonia Nitrogen as N	50 µg/L
pH	NA
Temperature	0.2° C
Total Residual Chlorine	50 µg/L
Formaldehyde	50 µg/L

F. Quality Assurance (QA) Plan

a. Plan Development.

The Permittee must develop a quality assurance plan (QA Plan) for all monitoring required by this permit to assist in planning for the collection and analysis of effluent and receiving water samples in support of the permit and in explaining data anomalies when they occur. The plan must be developed and implemented within 60 days after receiving authorization to discharge under this permit. Any existing QA Plans may be modified to meet this requirement.

Existing Permittees must review and update their QA Plans within 60 days of the reissuance of this General Permit.

b. Required Submittal

(1) To the EPA

A Permittee must certify that a QA Plan has been developed and is being implemented and must submit the certification, which includes the information specified in Appendix C, to EPA within 90 days after receiving authorization to discharge under this permit. The submittal address for the EPA is set forth in §II.A.1, above. A new Permittee must submit the certification with the NOI to be covered under this permit.

(2) To the Lummi Nation

As a requirement of the Tribe’s 401 Certification, any Permittee that discharges to waters of the Lummi Nation must submit its QA Plan to the Lummi Nation address listed in § V.B, below, for review and approval prior to submitting certification to the EPA that the QA Plan has been developed and implemented. It also must submit that certification to the same Lummi Nation address within 90 days after receiving authorization to discharge under this permit.

(3) To the Spokane Tribe

As a requirement of the Tribe’s 401 Certification, any Permittee that discharges to waters of the Spokane Tribe must submit its QA Plan to the Spokane Tribe address listed in § V.B, below, within 90 days after receiving authorization to discharge under this permit.

c. Conformity with EPA procedures

Throughout all sample collection and analysis activities, the Permittee must use the EPA-approved quality assurance and quality control (QA/QC) and chain-of-custody procedures described in Requirements for Quality Assurance Project Plans

(EPA/QA/R-5)[2] and Guidance for Quality Assurance Project Plans (EPA/QA/G-5)[3]. The QA Plan must be prepared in the format that is specified in these documents.

d. Plan contents

At a minimum, the QA Plan must include the following:

(1) Details on the number of samples, type of sample containers, preservation of samples, holding times, analytical methods, analytical detection and quantification limits for each parameter, type and number of quality assurance field samples, precision and accuracy requirements, sample preparation requirements, and sample shipping methods. See § V.A.-F for additional requirements regarding monitoring.

(2) Description of flow measuring devices used to measure influent and/or effluent flow at each point, calibration procedures, and calculations used to convert to flow units. Facilities with multiple effluent discharge points and/or influent points must describe their method of compositing samples from all points proportionally to their respective flows;

(3) Maps indicating the location of each sampling point;

(4) Qualification and training of personnel; and

(5) Name, address and telephone number of the laboratory used by or proposed to be used by the Permittee.

e. Modifications required

The Permittee must amend the QA Plan whenever there is a modification in sample collection, sample analysis, or other procedure addressed by the QA Plan and must update it whenever there is a change in ownership or operator.

f. Copies required on-site

Copies of the QA Plan must be kept on site and made available to the EPA upon request. If lack of suitable storage area makes on-site storage impossible, the QA Plan must be in the possession of staff whenever they are working on-site.

G. Best Management Practices Plan

1. Purpose

Through implementation of the best management practices (BMP) plan, the Permittee must prevent or minimize the generation and discharge of wastes and pollutants from the facility to waters of the United States to meet water quality standards and permit requirements; the Permittee must also ensure that disposal or land application of wastes is carried out in such a way as to minimize negative environmental impact and, if applicable, to comply with Washington State solid waste disposal regulations.

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[2] http://www.epa.gov/quality/qs-docs/r5-final.pdf
[3] http://www.epa.gov/quality/qs-docs/g5-final.pdf

2. Development and Implementation Deadline

The Permittee must develop and implement a BMP Plan that meets the specific requirements listed in Part III.C.5, below. An existing BMP Plan may be modified for use under this section. The Permittee must implement the provisions of the BMP Plan as conditions of this permit within 90 days of receiving authorization to discharge under this permit.

Existing Permittees must review and update their BMP Plans within 90 days of the reissuance of this General Permit.

3. Required Submittal

a. To the EPA:

A Permittee must certify that a BMP Plan has been developed and is being implemented. The certification must be submitted to the EPA and must include the information specified in Appendix C. An existing discharger must submit the certification within 90 days after receiving the authorization to discharge under this permit. A new Permittee must submit the certification with the written NOI to be covered under this permit.

b. To the Lummi Nation

As a requirement of the Tribe's 401 Certification, any Permittee that discharges to waters of the Lummi Nation must submit its BMP Plan to the Lummi Nation address listed in § V.B, below, for review and approval prior to submitting certification to the EPA that the BMP Plan has been developed and implemented. It also must submit that certification to the same Lummi Nation address by 90 days after it receives authorization to discharge.

c. To the Spokane Tribe

As a requirement of the Tribe's 401 Certification, any Permittee that discharges to waters of the Spokane Tribe must submit its BMP Plan to the Spokane Tribe address listed in § V.B, below, within 90 days after receiving authorization to discharge under this permit.

4. Annual Review

a. The Permittee must review the BMP Plan annually.

b. A certified statement that the annual review has been completed and that the BMP Plan fulfills the requirements set forth in this permit must be submitted to the EPA in the Annual Report of Operations, due by January 20 each year. See Appendix E.

5. Requirements of the BMP Plan

The BMP Plan must include, at a minimum, the following BMPs. Where a particular practice below is infeasible, the Permittee will substitute another practice to achieve the same end.

a. Materials Storage

(1) Ensure proper storage of drugs and other chemicals to prevent spills that may result in the discharge to waters of the United States.

(2) Implement procedures for properly containing, cleaning, and disposing of any spilled materials.

b. Structural Maintenance

(1) Routinely inspect rearing and holding units and waste collection and containment systems to identify and promptly repair damage.

(2) Regularly conduct maintenance of rearing and holding units and waste collection and containment systems to ensure their proper function.

c. Record keeping

(1) Document feed amounts and numbers and weights of aquatic animals to calculate feed conversion ratios.

(2) Document the frequency of cleanings, inspections, maintenance, and repairs.

(3) Maintain records of all medicinal and therapeutic chemical usage for each treatment at the facility. Include the information required in the Chemical Log Sheet in Appendix D and in the Annual Reports in Appendix E.

(4) A copy of the label (with treatment application requirements) and the Material Safety Data Sheet (MSDS) must be maintained in the facility's records for each drug or chemical used at the facility.

(5) In order to show how the maximum concentrations of chlorine and formalin were derived (see Table 3 for monitoring requirements), facilities must maintain records by chemical and by outfall of the approach/analyses used to determine the elapsed time from its application to its maximum (peak) effluent concentration, giving consideration to retention times within the facility.

(6) Permittees must keep the records necessary to provide the water-borne treatment/calculations information required on page 7 of the revised Annual Report (see Appendix E).

d. Training Requirements

(1) Train all relevant personnel in spill prevention and how to respond in the event of a spill to ensure proper clean-up and disposal of spilled materials.

(2) Train personnel on proper structural inspection and maintenance of rearing and holding units and waste collection and containment systems.

e. Operational Requirements

(1) Raceways and ponds must be cleaned at such a frequency and in such a manner that minimizes accumulated solids discharged to waters of the U.S.

(2) Fish feeding must be conducted in such a manner as to minimize the discharge of unconsumed food.

(3) Fish grading, harvesting and other activities within ponds or raceways must be conducted in such a way as to minimize the discharge of accumulated solids and blood wastes.

(4) Animal mortalities must be removed and disposed of on a regular basis to the greatest extent feasible.

(5) Water used in the rearing and holding units or hauling trucks that is disinfected with chlorine or other chemicals must be treated before it is discharged to waters of the U.S.

(6) Treatment equipment used to control the discharge of floating, suspended or submerged matter must be cleaned and maintained at a frequency sufficient to minimize overflow or bypass of the treatment unit by floating, suspended, or submerged matter; turbulent flow must be minimized to avoid entrainment of solids.

(7) Procedures must be implemented to prevent fish from entering quiescent zones, full-flow, and off-line settling basins. Fish that have entered quiescent zones or basins must be removed as soon as practicable.

(8) Procedures must be implemented to minimize the release of diseased fish from the facility.

(9) All drugs and pesticides must be used in accordance with applicable label directions (FIFRA or FDA), except under the following conditions, both of which must be reported to the EPA in accordance with § V.A, below:

(a) Participation in Investigational New Animal Drug (INAD) studies, using established protocols; or

(b) Extralabel drug use, as prescribed by a veterinarian.

(10) Procedures must be identified and implemented to collect, store, and dispose of wastes, such as biological wastes. Such wastes include fish mortalities and other processing solid wastes from aquaculture operations.

(11) Facilities must dispose of excess/unused disinfectants in a way that does not allow them to enter waters of the U.S.

(12) Facilities must implement procedures to eliminate the release of Polychlorinated Biphenyls (PCBs) from any known sources in the facility-including paint, caulk, or feed. If removing paint or caulk that was applied prior

to 1980, refer to the EPA guidance (abatement steps 1-4) at http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/caulk/guide/guide-sect4a.htm. Any future application of paint or caulk must be below the allowable TSCA level of 50 ppm. Facilities must implement purchasing procedures that give preference for fish food that contains the lowest amount of PCBs that is economically and practically feasible.

6. Documentation

The Permittee must maintain a copy of the BMP Plan at the facility and make it available to the EPA or an authorized representative upon request. If lack of a suitable storage area makes on-site storage impossible, the BMP Plan must be in the possession of staff whenever they are working on-site.

7. BMP Plan Modification

The Permittee must amend the BMP Plan whenever there is a change in the facility or in the operation of the facility which materially increases the generation of pollutants or their release or potential release to surface waters. With any change in operator, the BMP Plan must be reviewed and modified, if necessary. The new operator must submit a certification in accordance with Part III.C.3, above.

V. Aquaculture Specific Reporting Requirements

A. Drug and Other Chemical Use and Reporting Requirements

The following requirements apply to chemicals that are used in such a way that they will be or may be discharged to waters of the United States, regardless of whether or not they were listed in the NOI.

B. Use of Drugs, Pesticides, and Other Chemicals

a. Only disease control chemicals and drugs approved for hatchery use by the U.S. Food and Drug Administration or by the EPA may be used, except

(1) Investigational New Animal Drugs (INADs) and extralabel drug use, as provided in §IV.A.2, below.

(2) Low Regulatory Priority (LRP) compounds in accordance with conditions included on the list in the FDA policy 1240.4200: *Enforcement Priorities for Drug Use in Aquaculture* (08/09/2002; 4/26/07 minor revisions)[4] p.13--15. (See Appendix F of this permit.) These compounds must be reported in the Notice of Intent and in annual reports. If they have not previously been reported on an NOI, the Permittee must report its first use in accordance with the requirements in § IV.A.2.b, below.

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[4] http://www.fda.gov/cvm/Policy_Procedures/4200.pdf

(3) Potassium permanganate, a deferred regulatory priority drug, also needs to be reported on the NOI, the annual report, and upon first use in accordance with the requirements in § IV.A.2.b, below.

b. All drugs, pesticides and other chemicals must be applied in accordance with label directions.

c. Records required

Records of all applications of drugs, pesticides, and other chemicals must be maintained and must, at a minimum, include information specified in Appendix D. This information must also be summarized in the annual report as required in Part IV.D, below.

C. Reporting Drug Usage

a. <u>INADs and Extralabel Drug Use</u>

The following written and oral reports must be provided to the EPA when an INAD or extralabel drug is used for the first time at a facility (not previously listed on a Notice of Intent) and when an INAD or extralabel drug is used at a higher dosage than previously approved by the FDA for this or a different animal species or disease:

(1) Anticipated INAD Study Participation and Extralabel Drug Usage

Written Report: A Permittee must provide a written report to the EPA within seven days of agreeing or signing up to participate in an INAD drug study or receiving a prescription for extralabel drug use. The report must include the information specified in Appendix D.

(2) Actual Use of INADs or Extralabel Drug Use

(a) **Oral Report:**

For INAD and extralabel drug uses, the Permittee must provide an oral report to the EPA (206-553-1846) as soon as possible during business hours, preferably in advance of use, but no later than 7 days after initiating use of the drug. The report must include the information specified in Appendix D.

(b) **Written Report:**

For INADs and extralabel drug uses, the Permittee must provide to the EPA a written report within 30 days after initiating use of the drug. The report must include the information specified in Appendix D.

b. <u>First Use of Low Regulatory Priority (LRP) Drugs or Potassium Permanganate</u>

(1) Oral Report:

For first use of an LRP drug or potassium permanganate if it was not listed in the NOI, the Permittee must provide an oral report to the EPA (206-553-1846) as soon as possible during business hours, preferably in advance of use, but no later than 7 days after initiating use of the drug. The report must include the information specified in Appendix D.

(2) Written Report:

For first use of an LRP drug or potassium permanganate if it was not listed in the NOI, the Permittee must provide to the EPA a written report within 30 days after initiating use of the drug. The report must include the information specified in Appendix D.

D. Structural Failure or Damage to the Facility

Structural failure or damage to the facility must be reported to the EPA orally within 24 hours and in writing within five days when there is a resulting discharge of pollutants to waters of the U.S. Reports must include the identity and quantity of pollutants released. (See Representative Sampling and Noncompliance Reporting in § VI.A. and § VI. H-I.)

E. Spills of Drugs, Pesticides or Other Chemicals

1. Drugs, Pesticides or Other Chemicals

The Permittee must monitor and report to the EPA any spills of drugs, pesticides, or other chemicals that result in a discharge to waters of the United States; these must be reported orally within 24 hours and in writing within five days. Reports must include the identity and quantity of pollutants released. (See Representative Sampling and Noncompliance Reporting in § VI.A. and § VI. H-I.).

2. Oil or Hazardous Materials

a. To the EPA

The Permittee must report immediately to the EPA at 1-800-424-8802 any spills of oil or hazardous materials to waters of the U.S.

b. To Washington Department of Ecology

The Permittee must report any spills of oil or hazardous materials to waters of the State of Washington to Ecology at 1-800-258-5990 or 1-800-OILS-911 and to the appropriate Ecology regional office:

Northwest Region	Island, King, Kitsap, San Juan, Skagit, Snohomish, & Whatcom counties	425-649-7000
Southwest Region	Clallum, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, & Wahkiakum counties	360-407-6300

Central Region	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, & Yakima counties	509-575-2490
Eastern Region	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, & Whitman counties	509-329-3400

c. To the Lummi Nation

As a requirement of the Tribe's 401 Certification, any operator of a facility must report immediately any spills of oil or hazardous materials to waters of the Lummi Nation to the Lummi Natural Resources Department Director at 360-410-1706.

d. To the Spokane Tribe

As a requirement of the Tribe's 401 Certification, any operator of a facility must report immediately any spills of hazardous materials to waters of the Spokane Tribe to the Spokane Tribe Water Control Board at 509-626-4409.

F. Records of Fish Mortalities

1. **Maintenance of Records.** Records of routine and mass mortalities must be maintained on site for at least three years.

2. **Annual Reporting.** Summaries of mortality data must be included in annual reports.

G. Annual Report of Operations

During the term of this permit, the Permittee must prepare and submit an annual report of the previous year's operations by January 20th of each year. A copy of the annual report and the data used to compile it must be available to the EPA upon request and during inspections. The report must include the information specified in Appendix E.

1. To the EPA:

A Permittee must submit the annual report to the EPA at the address in § V.B.1.a, below.

2. To the Lummi Nation:

A Permittee that discharges to waters of the Lummi Nation must submit the annual report to the Lummi Nation at the address in § V.B, below.

3. To the Spokane Tribe:

A Permittee that discharges to waters of the Spokane Tribe must submit the annual report to the Spokane Tribe at the address in § V.B, below.

VI. Standard Monitoring, Recordkeeping, and Reporting Requirements

A. Representative Sampling (Routine and Non-Routine Discharges)

Samples and measurements must be representative of the volume and nature of the monitored discharge or source water.

In order to ensure that the effluent limits set forth in this permit are not violated at times other than when routine samples are taken, the Permittee must collect additional samples at the appropriate outfall whenever any discharge occurs that may reasonably be expected to cause or contribute to a violation that is unlikely to be detected by a routine sample. The Permittee must analyze the additional samples for those parameters limited in §III.A.3 (“Effluent Limitations”) that are likely to be affected by the discharge.

The Permittee must collect such additional samples as soon as the spill, discharge, or bypassed effluent reaches the outfall. The samples must be analyzed in accordance with §VI.B (“Monitoring Procedures”). The Permittee must report all additional monitoring in accordance with §V.D (“Additional Monitoring by Permittee”).

B. Monitoring Procedures

The Permittee must conduct monitoring according to test procedures approved under 40 CFR 136, unless another method is required under 40 CFR subchapters N or O, or other test procedures have been specified in this Permit or approved by the EPA as an alternative test procedure under 40 CFR 136.5.

C. Reporting of Monitoring Results

The Permittee must summarize monthly monitoring results on the DMR. Monitoring data must be submitted electronically using NetDMR. NetDMR is described in more detail below. If additional monitoring of any pollutant is performed more frequently than required by the permit, the results must be included in the DMR.

The Permittee is not required to monitor when the facility is not discharging. However, the DMR must indicate the facility is not discharging and must be submitted as described below. The Permittee must submit a monthly DMR even if a discharge has not occurred, unless permit coverage has been terminated in accordance with Section II. D. of this permit.

An annual report of raw monitoring data in a spreadsheet or text-format electronic file must be submitted to the EPA and to the Lummi or Spokane Tribes (as appropriate) with the January DMR each year.

During the period between the effective date of the Permit and six months from the effective date, the Permittee must either submit monitoring data and other reports in paper form, or must report electronically using NetDMR.

1. Paper Copy Submissions

Prior to switching to NetDMR, all required monitoring data must be submitted using the DMR form (EPA No. 3320-1) or the equivalent and must be postmarked by the 20th day of the month following the end of the reporting period.

The Permittee must submit the legible originals of required documents as follows:

a. To the EPA:

The Permittee must submit the legible originals of these documents to the EPA Region 10 Director, Office of Compliance and Enforcement, at the address below:

USEPA Region 10
Attn: ICIS Data Entry Team
1200 Sixth Avenue, Suite 900, OCE-133
Seattle, Washington 98101-3140

b. To the Lummi Nation:

As a requirement of the Tribe's 401 Certification, any operator of a facility that discharges to Lummi Nation Waters must submit copies of DMRs, surface water monitoring reports, annual reports, notices of intent, BMP and QA Plans and certifications, spill reports, and any Non-compliance reports to the address below:

Lummi Natural Resources Department
ATTN: Water Resources Manager
2616 Kwina Road
Bellingham, WA 98226

c. To the Spokane Tribe

As a requirement of the Tribe's 401 Certification, any Permittee that discharges to Spokane Tribe waters must submit copies of DMRs, surface water monitoring reports, annual reports, notices of intent, BMP and QA Plans and certifications, spill reports, and any Non-compliance reports to the address below:

Water Control Board

c/o Brian Crossley
PO Box 480
Wellpinit, WA 99040

2. Electronic submissions

All required monitoring data must be submitted electronically to EPA no later than the 20th day of the month following the end of the reporting period.

All reports required under this Permit must be submitted to EPA as a legible electronic attachment to the DMR.

Once a Permittee begins submitting reports using NetDMR, it will no longer be required to submit paper copies of DMRs to EPA and to the Lummi and/or Spokane Tribes, as appropriate.

1. After the first six (6) months of the effective date of the Permit, the Permittee must submit monitoring data and other reports electronically using NetDMR. The Permittee may use NetDMR after requesting and receiving permission from U.S. EPA Region 10. NetDMR is accessed from http://www.epa.gov/netdmr.

D. Additional Monitoring by the Permittee

If the Permittee monitors any pollutant more frequently than required by this permit, using test procedures approved under 40 CFR §136 or as specified in this permit or approved by the Regional Administrator, the results of this monitoring must be included in the calculation and reporting of the data submitted in DMRs.

Upon request by the EPA, the Permittee must submit results of any other sampling, regardless of the test method used.

E. Records Contents

Records of monitoring information must include:

1. The date, exact place, and time of sampling or measurements,
2. Names of the individual(s) who performed the sampling or measurements,
3. The date(s) analyses were performed,
4. Name of the individual(s) who performed the analyses**,**
5. The analytical techniques or methods used, and
6. The results of such analyses.

F. Retention of Records

The Permittee must retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this Permit, and records of all data used to complete the NOI to become authorized to discharge under this permit, for a period of at least five years from the date of the sample, measurement, report, or NOI. This period may be extended by request of the EPA at any time. Data collected on-site, copies of DMRs and Annual Reports, and a copy of this NPDES permit and the NOI must be maintained on site during the duration of activity at the permitted location or in the possession of staff when working on-site.

G. Twenty-four Hour Notice of Noncompliance Reporting

1. The Permittee must report the following occurrences of noncompliance by telephone to the EPA (206-553-1846). For Lummi Nation dischargers, Permittees must also report to the Lummi Natural Resources Department Director (360-410-1706), and, for Spokane Tribe dischargers, to the Water Control Board (509-626-4409), as soon as possible, but no later than 24 hours from the time the Permittee becomes aware of the circumstances:

a. Any unanticipated bypass that exceeds an effluent limitation in the Permit;

b. Any upset that exceeds an effluent limitation in the permit;

c. Violation of an applicable maximum daily discharge limitation for total residual chlorine.

2. A written report must also be submitted within 5 days after the Permittee becomes aware of the circumstances. The written submission must contain:

a. Description of the noncompliance and its cause;

b. The period of noncompliance, including exact dates and times;

c. If the noncompliance has not been corrected, the anticipated time it is expected to continue; and

d. Steps taken or planned to reduce, eliminate, and prevent recurrence of the noncompliance.

3. The written report must be submitted, as follows:

a. to the EPA at the address in §V.B.1.a, above;

b. for Lummi Nation dischargers, the report must also be submitted to the address in §V.B.1.b, above.

c. for Spokane Tribe dischargers, the report must also be submitted to the address in §V.B.1.c, above.

4. The EPA may waive the requirement for a written report of non-compliance on a case-by-case basis, if an oral report has been received within 24 hours by telephone at 206-553-1846.

H. Other Noncompliance Reporting

The Permittee must report all instances of noncompliance, not required to be reported within 24 hours, at the time that monitoring reports for §V.B (“Reporting of Monitoring Results”) are submitted. The report must contain the information listed in §V.G.3 of this permit (“Twenty-four Hour Notice of Noncompliance Reporting”).

VII. Compliance Responsibilities

A. Duty to Comply

The Permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Clean Water Act (the Act) and is grounds for enforcement action, for termination of the authorization to discharge, or for denial of coverage after submittal of a Notice of Intent.

B. Penalties for Violations of Permit Conditions

1. **Civil Penalties.** Pursuant to 40 CFR §19 and the Act, any person who violates section 301, 302, 306, 307, 308, 318 or 405 of the Act, or any permit condition or limitation implementing any such sections in a permit issued under section 402, or any requirement imposed in a pretreatment program approved under sections 402(a)(3) or 402(b)(8) of the Act, is subject to a civil penalty not to exceed the maximum amounts authorized by Section 309(d) of the Act and the Federal Civil Penalties Inflation Adjustment Act (28 U.S.C. §2461 note) as amended by the Debt Collection Improvement Act (31 U.S.C. §3701 note) (currently $37,500 per day for each violation).

2. **Administrative Penalties.** Any person may be assessed an administrative penalty by the Administrator for violating section 301, 302, 306, 307, 308, 318 or 405 of this Act, or any permit condition or limitation implementing any of such sections in a permit issued under section 402 of this Act. Pursuant to 40 CFR §19 and the Act, administrative penalties for Class I violations are not to exceed the maximum amounts authorized by Section 309(g)(2)(A) of the Act and the Federal Civil Penalties Inflation Adjustment Act (28 U.S.C. §2461 note) as amended by the Debt Collection Improvement Act (31 U.S.C. §3701 note) (currently $16,000 per violation, with the maximum amount of any Class I penalty assessed not to exceed $37,500). Pursuant to 40 CFR §19 and the Act, penalties for Class II violations are not to exceed the maximum amounts authorized by Section 309(g)(2)(B) of the Act and the Federal Civil Penalties Inflation Adjustment Act (28 U.S.C. §2461 note) as amended by the Debt Collection Improvement Act (31 U.S.C. §3701 note) (currently $16,000 per day for each day during which the violation continues, with the maximum amount of any Class II penalty not to exceed $177,500).

1. Criminal Penalties:

a. Negligent Violations. The Act provides that any person who negligently violates sections 301, 302, 306, 307, 308, 318, or 405 of the Act, or any condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, or any requirement imposed in a pretreatment program approved under section 402(a)(3) or 402(b)(8) of the Act, is subject to criminal penalties of $2,500 to $25,000 per day of violation, or imprisonment of not more than 1 year, or both. In the case of a second or subsequent conviction for a negligent violation, a person shall be subject to criminal penalties of not more than $50,000 per day of violation, or by imprisonment of not more than 2 years, or both.

b. Knowing Violations. Any person who knowingly violates such sections, or such conditions or limitations is subject to criminal penalties of $5,000 to $50,000 per day of violation, or imprisonment for not more than 3 years, or both. In the case of a second or subsequent conviction for a knowing violation, a person shall be subject to criminal penalties of not more than $100,000 per day of violation, or imprisonment of not more than 6 years, or both.

c. Knowing Endangerment. Any person who knowingly violates section 301, 302, 303, 306, 307, 308, 318 or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, and who knows at that time that he thereby places another person in imminent danger of death or serious bodily injury, shall, upon conviction, be subject to a fine of not more than $250,000 or imprisonment of not more than 15 years, or both. In the case of a second or subsequent conviction for a knowing endangerment violation, a person shall be subject to a fine of not more than $500,000 or by imprisonment of not more than 30 years, or both. An organization, as defined in section 309(c)(3)(B)(iii) of the Act, shall, upon conviction of violating the imminent danger provision, be subject to a fine of not more than $1,000,000 and can be fined up to $2,000,000 for second or subsequent convictions.

d. False Statements. The Act provides that any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000, or by imprisonment for not more than 2 years, or both. If a conviction of a person is for a violation committed after a first conviction of such person under this paragraph, punishment is a fine of not more than $20,000 per day of violation, or by imprisonment of not more than 4 years, or both. The Act further provides that any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or non-compliance shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.

C. Need to Halt or Reduce Activity Not a Defense

It shall not be a defense for the Permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

D. Duty to Mitigate

The Permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit which has a reasonable likelihood of adversely affecting human health or the environment.

E. Proper Operation and Maintenance

The Permittee must at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the Permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems only when the operation is necessary to achieve compliance with the conditions of this permit.

F. Bypass of Treatment Facilities

2. **Bypass not exceeding limitations.** The Permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of paragraphs b and c of this section.

   Notice:

   a. Anticipated bypass. If the Permittee knows in advance of the need for a bypass, it shall submit prior notice, if possible at least 10 days before the date of the bypass.

   b. Unanticipated bypass. The Permittee shall submit notice of an unanticipated bypass as required under permit §V.G (Twenty-four Hour Notice of Noncompliance Reporting).

3. **Prohibition of bypass.** Bypass is prohibited and the EPA may take enforcement action against the Permittee for a bypass, unless:

   a. The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

   b. There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and

   c. The Permittee submitted notices as required under §VI.F.2, above.

4. The Director of the Office of Compliance and Enforcement may approve an anticipated bypass, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above in §VI.F.3.

G. Upset Conditions

1. **Effect of an upset.** An upset constitutes an affirmative defense to an action brought for noncompliance with technology based permit effluent limitations, if the requirements of §VI.G.2, below, are met. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review.

2. **Conditions necessary to demonstrate an upset.** To establish the affirmative defense of upset, the Permittee shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence, that:

   a. An upset occurred and that the Permittee can identify the cause(s) of the upset;

   b. The permitted facility was at the time being properly operated;

   c. The Permittee submitted notice of the upset as required under §V.G (Twenty-four Hour Notice of Noncompliance Reporting); and

   d. The Permittee complied with any remedial measures required under §VI.D (Duty to Mitigate).

3. **Burden of proof.** In any enforcement proceeding, the Permittee seeking to establish the occurrence of an upset has the burden of proof.

H. Toxic Pollutants

The Permittee must comply with effluent standards or prohibitions established under Section 307(a) of the Act for toxic pollutants within the time provided in the regulations that establish those standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

I. Planned Changes

The Permittee must give notice to the EPA as soon as possible of any planned physical alterations or additions to the permitted facility whenever:

1. The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source as determined in 40 CFR §122.29 (b); or

2. The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged. This notification applies to pollutants that are not subject to effluent limitations in the permit.

J. Anticipated Noncompliance

The Permittee must give advance notice to the EPA of any planned changes in the permitted facility or activity that may result in noncompliance with this permit.

VIII. General Provisions

A. Permit Actions.

This permit or coverage under this permit may be modified, revoked and reissued, or terminated for cause as specified in 40 CFR §§ 122.62, 122.64, or 124.5. The filing of a request by the Permittee for a permit modification, revocation and reissuance, termination, or a notification of planned changes or anticipated noncompliance does not stay any permit condition.

B. Duty to Reapply

If the Permittee intends to continue an activity regulated by this permit after the expiration date of this permit, the Permittee must submit a Notice of Intent. In accordance with 40 CFR §122.28(b)(2)(iii), the Permittee must submit a new Notice of Intent at least 180 days before the expiration date of this permit, unless the Regional Administrator has granted permission to submit the Notice of Intent at a later date in accordance with 40 CFR §122.21(d). If the NOI is received by the applicable deadline, even if the permit is not reissued before the expiration date, the conditions of the permit will continue in force until the effective date of the subsequently reissued permit. If the facility is no longer operating but still has a potential to discharge when the permit is due to expire, the Permittee must reapply for coverage.

C. Duty to Provide Information

The Permittee must furnish to the EPA and, within the time specified in the request, any information that the EPA may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The Permittee must also furnish to the EPA, upon request, copies of records required to be kept by this permit.

D. Other Information

When the Permittee becomes aware that it failed to submit any relevant facts in a permit application, or that it submitted incorrect information in a notice of intent or any report to the EPA, it must promptly submit the omitted facts or corrected information.

E. Signatory Requirements

All Notices of Intent, reports, or information submitted to the EPA must be signed and certified as follows.

1. All Notices of Intent must be signed as follows:

    a. For a corporation: by a responsible corporate officer.

    b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively.

    c. For a municipality, state, federal, Indian tribe, or other public agency: by either a principal executive officer or ranking elected official.

2. All reports required by the permit and other information requested by the EPA must be signed by a person described above or by a duly authorized representative of that person. A person is a duly authorized representative only if:

    a. The authorization is made in writing by a person described above;

    b. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of plant manager, operator of a well or a well field, superintendent, position of equivalent responsibility, or an individual or position having overall responsibility for environmental matters for the company; and

    c. The written authorization is submitted to the EPA.

3. **Changes to authorization.** If an authorization under §VII.E.2 is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of §VII.E.2 must be submitted to the EPA prior to or together with any reports, information, or applications to be signed by an authorized representative.

4. **Certification.** Any person signing a document under this Part must make the following certification:

> *"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."*

F. Availability of Reports

In accordance with 40 CFR §2, information submitted to the EPA pursuant to this permit may be claimed as confidential by the Permittee. In accordance with the Act, permit applications, permits and effluent data are not considered confidential. Any confidentiality claim must be asserted at the time of submission by stamping the words "confidential business information" on each page containing such information. If no claim is made at the time of submission, the EPA may make the information available to the public without further notice to the Permittee. If a claim is asserted, the information will be treated in accordance with the procedures in 40 CFR §2, Subpart B (Public Information) and 41 Fed. Reg. 36902 through 36924 (September 1, 1976), as amended.

G. Inspection and Entry

The Permittee must allow the EPA, an authorized EPA representative (including an authorized contractor acting as a representative of the Administrator), and, in the case of Permittees discharging to waters of the Spokane Tribe, an authorized representative of the Tribal Water Control Board or its designee, upon the presentation of credentials and other documents as may be required by law, to:

1. Enter upon the Permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this permit;

2. Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;

3. Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and

4. Sample or monitor at reasonable times, for the purpose of assuring permit compliance or as otherwise authorized by the Act, any substances or parameters at any location.

H. Property Rights

The issuance of this permit does not convey any property rights of any sort, or any exclusive privileges, nor does it authorize any injury to persons or property or invasion of other private rights, nor any infringement of federal, tribal, state or local laws or regulations.

I. Transfer

Authorization to discharge under this permit may be automatically transferred to a new Permittee on the date specified in the agreement only if:

1. The current Permittee notifies the Director of the Office of Water and Watersheds at least 30 days in advance of the proposed transfer date;

2. The notice includes a written agreement between the existing and new Permittees containing a specific date for transfer of permit responsibility and liability between them; and

3. The Director does not notify the existing and new permittees of the intent to revoke and reissue the authorization to discharge.

J. State Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the Permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable state law or regulation under authority preserved by Section 510 of the Act.

IX. Definitions and Acronyms

the Act ... the Clean Water Act, codified at 33 U.S.C. §1251 et seq.

Aquaculture facility … a hatchery, fish farm, or other facility which contains, grows, or holds fish for later harvest (or process) and sale or for release.

Background ... the biological, physical, or chemical condition of waters measured at a point immediately upstream of the influence of the discharge.

Best Management Practices (BMPs) ... schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of Waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage. (40 CFR §122.2)

Bypass ... the intentional diversion of waste streams from any portion of a treatment facility. (40 CFR §122.41 (m))

CAAP … concentrated aquatic animal production; At 40 CFR §122.24, the EPA defines concentrated aquatic animal production (CAAP) facilities as point sources subject to the National Pollutant Discharge Elimination System (NPDES) permit program including those upland facilities that discharge for at least 30 days per year and contain, grow, or hold cold water fish species or other cold water aquatic animals except in facilities which produce less than 9,0000 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding.

CFR ... Code of Federal Regulations, the body of federal regulations. Title 40 of the Code of Federal Regulations, Parts 1 - 1499 contains regulations of the Environmental Protection Agency.

Chemical ... any substance that is added to the facility to maintain or restore water quality for aquatic animal production and that may be discharged to Waters of the United States.

Clean Water Act ... formerly referred to as the Federal Water Pollution Control Act of 1972, codified at 33 U.S.C. §1251 et seq.

Cold water species … Cold water aquatic animals include, but are not limited to, the Salmonidae family of fish, e.g. trout and salmon.

*Composite …*a combination of four or more discrete samples taken at on-half hour intervals or greater over a 24-hour period; at least one fourth of the samples must be taken while cleaning. Facilities with multiple effluent discharge points and/or influent points must composite samples from all points proportionally to their respective flows.

Critical Habitat ...the geographical area occupied by a threatened or endangered species. See 16 U.S.C. §1532 (the Endangered Species Act of 1973) for a complete definition.

CWA ... the Clean Water Act.

DMR ... discharge monitoring report

Discharge . . . any addition of any pollutant or combination of pollutants from any point source to waters of the U.S. (40 CFR §122.2)

Ecology … the Washington Department of Ecology.

Effluent Limitations Guidelines ... regulations published by EPA pursuant to CWA Section 304 (b).

EPA ... the United States Environmental Protection Agency. The State of Washington is located in Region 10 of the EPA.

Extralabel Drug Use . . . a drug approved under the Federal Food, Drug, and Cosmetic Act that is not used in accordance with the approved label directions; see 21 CFR 530. (40 CFR §451.2(f))

Flow-through System ... a system designed for continuous water flow to waters of the United States through chambers used to produce aquatic animals. Flow-through systems typically use either raceways or tank systems. Water is transported from nearby rivers or springs to raceways which are typically long, rectangular chambers at or below grade, constructed of earth, concrete, plastic, or metal. Tanks systems are similarly supplied with water and concentrate aquatic animals in circular or rectangular tanks above grade. The term “flow through system” does not include net pens.

General Permit ... an NPDES permit issued in accordance with 40 CFR §122.28, authorizing a category of discharges under the CWA within a geographical area. (40 CFR §122.2)

Grab Samples ... a discrete volume of water collected, by hand or machine, during one short sampling period (less than 15 minutes).

*Hatchery …*culture or rearing unit such as a raceway, pond, tank, net or other structure used to contain, hold or produce aquatic animals. The containment system includes structures designed to hold sediments and other materials that are part of a wastewater treatment system.(40 CFR §451.2 (c))

Hazardous Substance … any substance designated under 40 CFR part 116, pursuant to Section 311 of the CWA.

Impaired Waters ... waters identified by Ecology pursuant to Section 303(d) of the Clean Water Act for which effluent limitations guidelines are not stringent enough to implement all applicable water quality standards.

INAD . . . Investigational New Animal Drug, a drug for which there is a valid exemption in effect under section 512(j) of the Federal Food, Drug, and Cosmetic Act, 21 U.S.C.360b(j), to conduct experiments. (40 CFR §451.2(h))

Indian Country . . . "all land within the limits of any Indian reservation under the jurisdiction of the United States Government, notwithstanding the issuance of any patent, and, including rights-of-way running through the reservation, (b) all dependent Indian communities within the borders of the United States whether within the original or subsequently acquired territory thereof, and whether within or without the limits of a state, and (c) all Indian allotments, the Indian titles to which have not been extinguished, including rights-of-way running through the same." (18 USC §1151)

Listed Endangered or Threatened Species ... species that are in danger of extinction throughout all or a significant portion of their range or that are likely to become endangered species within the foreseeable future. See 16 U.S.C. §1532 (the Endangered Species Act of 1973) for a complete definition.

Minimum level (ML) means the concentration at which the entire analytical system must give a recognizable signal and an acceptable calibration point. The ML is the concentration in a sample that is equivalent to the concentration of the lowest calibration standard analyzed by a specific analytical procedure, assuming that all the method-specified sample weights, volumes and processing steps have been followed (40 CFR §136).

Net Pen ... a stationary, suspended, or floating system of nets or screens in open marine, lake, or estuarine waters of the United States. Net pen systems are typically located along a shore or pier or may be anchored and floating offshore. Net pens and cages rely on tides or currents to provide a continual supply of high quality water.

New Source ... any building, structure, facility, or installation from which there is or may be a discharge of pollutants, the construction of which commenced:

> (a) After promulgation of standards of performance under Section 306 of the CWA, which are applicable to such source, or
>
> (b) After proposal of standards of performance in accordance with Section 306 of the CWA, which are applicable to such source, but only if the standards are promulgated in accordance with Section 306 within 120 days of their proposal. (40 CFR §122.2)

NOI (Notice of Intent) ... a written application form submitted to the permitting authority (i.e. EPA) seeking authorization to discharge under a General Permit.

NPDES ... the National Pollutant Discharge Elimination System, the national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing [wastewater discharge] permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318, and 405 of the CWA. (40 CFR §122.2)

Off-line Settling Basin ... a constructed retention basin that receives wastewater from cleaning of aquaculture facility rearing or holding units and/or quiescent zones for the retention and treatment of the wastewater through settling of solids.

Outfall ... a discrete point or outlet where the discharge is released to the receiving water.

Outstanding National Resource … a state park, game sanctuary or refuge; a national park, preserve, or monument; a national wildlife refuge; a national wilderness area; or a river designated as *wild* or *scenic* under the Wild and Scenic Rivers Act.

Permittee ... an individual, association, partnership, corporation, municipality, Indian Tribe or authorized Indian tribal organization, State or Federal agency, or an agent or employee thereof, who is authorized by the EPA to discharge in accordance with the requirements of the General Permit.

Point Source ... any discernible, confined, and discrete conveyance from which pollutants are or may be discharged.

Pollutant . . . chemical wastes, biological materials, … industrial waste discharge into water. (40 CFR §122.2)

Production … the act of harvesting, processing or releasing fish, or the harvest weight of fish contained, grown, or held in a CAAP facility. (40 CFR §122, Appx. C)

Publicly Owned Treatment Works (POTW) ... devices and systems, owned by a state or municipality, used in storage, treatment, recycling, and reclamation of municipal sewage or liquid industrial wastes, including sewers that convey wastewater to a POTW treatment plant. (40 CFR §403.3)

QA ... quality assurance, an integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed to meet the performance criteria.

Recirculating System ... a system that filters and reuses water in which the aquatic animals are produced prior to discharge; recirculating systems typically use tanks, biological or mechanical filtration, and mechanical support equipment to maintain high quality water to produce aquatic animals.

Regional Administrator ... the Administrator of Region 10 of the United States Environmental Protection Agency, or an authorized representative.

Severe property damage ... substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production. (40 CFR § 122.41(m)(ii))

Special Resource Tribal Waters ... waters that comprise a special and/or a unique resource to the Tribe, as determined by the appropriate tribal authority at the time a discharger seeks coverage under this General Permit

TSS ... Total Suspended Solids

Tier II water ... waters of a higher quality than the criteria assigned that may not be degraded unless such lowering of water quality is necessary and in the overriding public interest.

Toxic pollutants ... those pollutants, or combinations of pollutants, including disease-causing agents, which, after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the Administrator, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction) or physical deformation in such organisms or their offspring. (CWA §502(13))

Toxic substances ... substances that when discharged above natural background levels in waters of the state have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the Department of Ecology.

Upland hatchery ... a hatchery not located within the waters of the State (or, by extension, the U.S.) where fish are hatched, fed, nurtured, held, maintained, or reared to reach the size of release or for market sale. (WAC 173-221A-030)

Upset ... an exceptional incident in which there is unintentional and temporary noncompliance with technology-based permit effluent limitations because of factors beyond the reasonable control of the Permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventative maintenance, or careless or improper operation. (40 CFR §122.41(n)(1)).

Waters of the United States ... (40 CFR §122.2)

(a) All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;
(b) All interstate waters, including interstate wetlands;
(c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters:
    (1) Which are or could be used by interstate or foreign travelers for recreational or other purposes;
    (2) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or
    (3) Which are or could be used for industrial purposes by industries in interstate commerce;
(d) All impoundments of waters otherwise defined as Waters of the United States under this definition;
(e) Tributaries of waters identified in paragraphs (a) through (d) of this definition;
(f) The territorial sea; and
(g) Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (a) through (f) of this definition

Appendix A

Notice of Intent Contents

A Notice of Intent (NOI) to discharge under the General Permit,
supplying the information indicated in this appendix,
and must be submitted to the EPA Region 10
in order to obtain authorization for the discharge(s).
See §II.A of this permit.

NOI

Notice of Intent to be Covered Under EPA's NPDES Permit for Federal Aquaculture Facilities and Aquaculture Facilities Located in Indian Country within the Boundaries of the State of Washington

General Permit WAG130000

In addition to the requirements in the following pages, a complete application must also include the following:

☐ 1) An area map showing regional context

☐ 2) A sketch, aerial photograph, or map of the existing or proposed facility with the following clearly marked (include scale):

- ☐ Approximate overall dimensions of the facility
- ☐ All raceways and rearing ponds
- ☐ All water sources and water flow rates
- ☐ Any settling ponds, including dimensions and volume
- ☐ All discharge points and receiving waters
- ☐ All water flow paths
- ☐ Sludge disposal areas
- ☐ Water conditioning units
- ☐ Water treatment units (such as off-line settling basins)
- ☐ Holding tanks
- ☐ Locations where flows are measured
- ☐ Points of chemical and therapeutic drug addition
- ☐ Points of feed addition
- ☐ Painted or caulked surfaces in contact with water

☐ 3) A sketch, aerial photograph, or map of all satellite facilities that are part of your hatchery program, in relation to the facility for which you are seeking NPDES permit coverage

☐ 4) A map to accompany driving directions to the facility (if address is not posted or visible on-site)

☐ 5) A completed signature page

Notice of Intent

To comply with NPDES General Permit No. WAG130000 for Federal Aquaculture Facilities and Aquaculture Facilities Located in Indian Country within the Boundaries of the State of Washington

Permit Number for your facility (if already enrolled in this permit):

Other permit number(s), date, and issuing agency:

Section 1. Owner/Operator Information

Owner Name:	Title:
Phone:	Fax:
Email:	

Owner Mailing Address

Line 1:		
Line 2:		
City:	State:	Zip:

Operator Information

Owner Name:	Title:
Phone:	Fax:
Email:	

Operator Mailing Address

Line 1:		
Line 2:		
City:	State:	Zip:

Section 2. Facility Information

Facility Name:

Tribal or Federal Facility? ☐ Tribal ☐ Federal ☐ Other ________________

Is the facility located in Indian Country? ☐ Yes ☐ No

Notes:

Facility Mailing Address

Line 1:

Line 2:

City: State: Zip:

Facility Physical Address

Line 1:

Line 2:

City: State: Zip:

County/Reservation:

Please provide driving directions to the facility from the nearest town or city. Attach a separate page if needed. Include a map to accompany these directions if the address is not posted or visible on-site.

Is there a locked gate or barrier that prevents access via car to the facility? ☐ Yes ☐ No

Notes:

Section 2. Facility Information (cont'd)

Is this an existing facility? ☐ Yes ☐ No	Date of first discharge:
Is this a planned/proposed facility? ☐ Yes ☐ No	
If yes, estimated construction start date:	Estimated construction end date:
Date(s) facility remodeled, expanded, or upgraded (MM/DD/YYYY):	
Have there been any changes or additions to the facility that will increase it to more than 100,000 lbs of annual production since the last permit application? ☐ Yes ☐ No Describe:	
Are there any planned remodels, additions, or expansions that will increase annual production to over 100,000 lbs during the next 5 years? ☐ Yes ☐ No Describe:	

Section 2. Facility Information (cont'd) Satellite Facilities

Please describe any satellite facilities that operate in tandem with the NPDES-permitted facility as part of the hatchery program. This may include off-site acclimation ponds, net pens, other hatcheries that fish are transported to or from, facilities from which eggs are delivered, etc.

Attach a sketch, aerial photograph, or map to show where any satellite facilities are located in relation to the facility for which you are seeking NPDES coverage in this application.

Submit additional pages as necessary to cover all additional facilities.
Label additional pages: Satellite Facilities/Hatchery Program

Name of facility:
Describe the function of satellite facility and how it relates to the facility for which this NOI is requesting NPDES coverage. Include the species raised and life stage for each facility that is part of the hatchery program.

Satellite Facility Physical Address

Line 1:		
Line 2:		
City:	State:	Zip:
County/Reservation:		

Satellite Facility Operator Information

Agency/Tribe/Entity:	Name of Facility Manager:
Phone:	
Email:	

Satellite Facility Operator Mailing Address

Line 1:		
Line 2:		
City:	State:	Zip:

Section 3. Operations and Production

Is the production system best described as:

☐ Flow through ☐ Recirculating ☐ Pond system ☐ Other____

Does the facility operate year-round? ☐ Yes ☐ No
If not, please indicate which months the facility holds fish or eggs:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

List the species grown or held at your facility and estimate the annual production of each in gross harvestable weight. If fish are released rather than harvested, list the estimated weight at time of release. The estimate can be a range over the next 5 years, if appropriate.

Species	Fish Produced (lbs)	Receiving Water to which Fish are Released	Month Released/ Spawned

Fill in the table below with the highest production numbers expected for the next 5 years. List the maximum amount of fish on-site and the maximum amount of food **per month** for the year of maximum production. For **new facilities**, provide information for the year of highest anticipated production within the next 5 years.

Month	Total Fish (lbs)	Fish Feed (lbs)	Month	Total Fish (lbs)	Fish Feed (lbs)
January			July		
February			August		
March			September		
April			October		
May			November		
June			December		

From what year are these data? _________________________

Note: If you operate for 30 or more days per year and exceed the production (20,000 lbs) and feed thresholds (5,000 lbs of food during the month of maximum feeding) for even a brief period of time, your facility is required to apply for NPDES permit coverage.

Section 3. Operations and Production (cont'd)

Does this facility process fish for market at this location? ☐ Yes ☐ No

Are fish spawned on-site? ☐ Yes ☐ No During which months are fish spawned on-site?

Describe wastes generated as a result of on-site spawning (e.g., blood, anesthetics, disinfectants, carcasses):

Describe how spawning wastes are disposed of and to which outfall (if any):

Provide the percentage of fish released from the facility directly to a lake, river, or other location.		
☐ Lake _____ % Approximate lbs fish: Location/Receiving water name:	☐ River _____ % Approximate lbs fish: Location/Receiving water name:	☐ Other _____ % Approximate lbs fish: Location/Receiving water name:
Provide the percentage of fish hauled off-site to a lake, river, or other location.		
☐ Lake _____ % Approximate lbs fish: Location/Receiving water name:	☐ River _____ % Approximate lbs fish: Location/Receiving water name:	☐ Other _____ % Approximate lbs fish: Location/Receiving water name:

Are fish held on-site for broodstock? ☐ Yes ☐ No

Describe the species, where obtained, quantity, and where held (i.e., raceway or pond):

Section 4. Source Waters (Intakes)

Describe the facility’s water sources. Attach additional pages as necessary.

Source No. 1	Source Water Name:	Max Flow	Min Flow	Avg Flow	Units (cfs or gpm)
Source Water Treatment:					
Are solids removed from influent water? ☐ Yes ☐ No Describe:					

Source No. 2	Source Water Name:	Max Flow	Min Flow	Avg Flow	Units (cfs or gpm)
Source Water Treatment:					
Are solids removed from influent water? ☐ Yes ☐ No Describe:					

Source No. 3	Source Water Name:	Max Flow	Min Flow	Avg Flow	Units (cfs or gpm)
Source Water Treatment:					
Are solids removed from influent water? ☐ Yes ☐ No Describe:					

Source No. 4	Source Water Name:	Max Flow	Min Flow	Avg Flow	Units (cfs or gpm)
Source Water Treatment:					
Are solids removed from influent water? ☐ Yes ☐ No Describe:					

Source No. 5	Source Water Name:	Max Flow	Min Flow	Avg Flow	Units (cfs or gpm)
Source Water Treatment:					
Are solids removed from influent water? ☐ Yes ☐ No Describe:					

Section 5. Receiving Waters

Do the receiving waters primarily consist of: ☐ Fresh water ☐ Salt/Brackish water ☐ Other (Describe below)
Notes:

- Indicate if a receiving water is listed as impaired, in accordance with Section 303(d) of the Clean Water Act.
- Indicate the pollutants for which the water body is impaired and any wasteload allocations that have been assigned to the facility.
- Indicate if the discharge is to waters in Indian Country located within one mile upstream of a waterbody listed as impaired.
- Refer to the 303(d) list of impaired waters at http://www.ecy.wa.gov/programs/Wq/303d/index.html.
- If there is an applicable Total Maximum Daily Load (TMDL) with a Wasteload Allocation assigned to the facility, include that information here.

Receiving Water			
Receiving Water	Pollutant for which impaired	Wasteload Allocations	TMDL document the WLA
Additional Notes:			

Section 6. Wastewater

Wastewater Discharges						
Outfall	Location of Outfall				Notes: Include source (where in the facility the wastewater is generated), frequency, duration & volume (cfs or gpm) of discharge)	Name of Receiving Water
		Degrees	Minutes	Seconds		
001	Latitude					
	Longitude					
002	Latitude					
	Longitude					
003	Latitude					
	Longitude					
004	Latitude					
	Longitude					
005	Latitude					
	Longitude					
006	Latitude					
	Longitude					
007	Latitude					
	Longitude					
008	Latitude					
	Longitude					
009	Latitude					
	Longitude					
010	Latitude					
	Longitude					

Section 6. Wastewater (cont'd)

Indicate the type(s) of wastewater treatment provided at this facility.

In-line Settling Basin

Do any rearing units discharge through an in-line settling basin? ☐ Yes ☐ No

Describe in-line settling basin (length, volume, retention time, etc.):

Which rearing units discharge to the in-line settling basin, and when?

Off-line Settling Basin

Does the facility use an off-line settling basin? ☐ Yes ☐ No Number of off-line settling basins:	
Which rearing units discharge to the off-line settling basin, and when/under what circumstances?	
Does the off-line settling basin discharge directly to surface water? ☐ Yes ☐ No Describe:	
Basin size:	Retention time:
Water volume of off-line settling basin:	
Estimate the number of discharges from the off-line settling basin per year:	
How often is the off-line settling basin cleaned/excavated?	
If an off-line settling basin is used for cleaning wastes, is there a quiescent zone at the end of the last raceway or rearing pond in each series? ☐ Yes ☐ No Describe:	
Is there a mechanism to block discharges of floating material? ☐ Yes ☐ No Describe:	
Does the facility discharge to the ground? ☐ Yes ☐ No Describe:	
Does the facility have unlined structures? ☐ Yes ☐ No	
Material:	Quantity:
Describe:	

Section 6. Wastewater (cont'd)

Construction of Off-line Settling Basin (if known)	
Liner Material	Thickness
Concrete	Inches
Asphalt	Inches
Clay or earthen	Inches
Plastic PVC/HDPE/other Describe:	mils

Pond and Raceway Cleaning
How frequently are the ponds and/or raceways cleaned (specify which)? Notes:
Methods of cleaning: ☐ Vacuum ☐ Manually ☐ Other ____
What is done with the removed solids?
Are ponds cleaned prior to fish release? ☐ Yes ☐ No
Are any liquid or solid wastes discharged to the ground? ☐ Yes ☐ No If yes, describe:
Are any wastes (other than domestic sewage) discharged to a septic system? ☐ Yes ☐ No If yes, describe:
Are any solids or wastes (other than domestic waste) discharged to a publicly owned treatment works? ☐ Yes ☐ No If yes, name of facility: Describe waste:
Are wastes discharged to any other waste treatment system? ☐ Yes ☐ No If yes, describe:

Section 7. Solid Waste Disposal

Describe annual quantities of solids (including fish mortalities) disposed and location of disposal.

Type of Solid Disposed	Quantity Disposed	Date Disposed	Location Disposed

Notes:

Section 8. Aquaculture Drugs and Chemicals

Please indicate which drugs or chemicals you plan to use at the facility during the next 5 years.

Plan to use in the next 5 years?	Investigational New Animal Drug (INAD)?	Drug or Chemical
☐ Yes ☐ No	☐ Yes ☐ No	Azithromyicin
☐ Yes ☐ No	☐ Yes ☐ No	Chloramine-T
☐ Yes ☐ No	☐ Yes ☐ No	Chlorine
☐ Yes ☐ No	☐ Yes ☐ No	Draxxin
☐ Yes ☐ No	☐ Yes ☐ No	Erythromycin - injectable
☐ Yes ☐ No	☐ Yes ☐ No	Erythromycin - medicated feed
☐ Yes ☐ No	☐ Yes ☐ No	Florfenicol (Aquaflor)
☐ Yes ☐ No	☐ Yes ☐ No	Formalin - 37% formaldehyde
☐ Yes ☐ No	☐ Yes ☐ No	Herbicide - describe:
☐ Yes ☐ No	☐ Yes ☐ No	Hormone - describe:
☐ Yes ☐ No	☐ Yes ☐ No	Hydrogen Peroxide
☐ Yes ☐ No	☐ Yes ☐ No	Iodine
☐ Yes ☐ No	☐ Yes ☐ No	Oxytetracycline
☐ Yes ☐ No	☐ Yes ☐ No	Potassium Permanganate
☐ Yes ☐ No	☐ Yes ☐ No	Romet
☐ Yes ☐ No	☐ Yes ☐ No	SLICE (emamectin benzoate)
☐ Yes ☐ No	☐ Yes ☐ No	Sodium Chloride - salt
☐ Yes ☐ No	☐ Yes ☐ No	Vibrio vaccine
☐ Yes ☐ No	☐ Yes ☐ No	Other:
☐ Yes ☐ No	☐ Yes ☐ No	Other:
☐ Yes ☐ No	☐ Yes ☐ No	Other:

Section 9. Painted or Caulked Surfaces

Describe all painted and caulked surfaces that are in regular contact with water that is discharged to waters of the U.S.

Location of such surfaces should appear in the drawing required as part of the checklist on page 1.

Type of Paint/Caulk	Where applied (including area)	Amount applied	Date applied	Reason for application
Notes:				

Section 10. Other Information/Changes

Describe any changes to the facility or operations since the last permit application. Disregard this section if this is a new or proposed facility.

Section 11. Signature and Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly evaluate and gather the information submitted. Based on my inquiry of the person or persons, who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Printed name of person signing	Title
Applicant Signature	Date Signed

All permit applications must be signed as follows:

a. For a corporation: by a responsible corporate officer.

b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively.

c. For a municipality, state, federal, Indian tribe, or other public agency: by either a principal executive officer or ranking elected official.

Section 12. Submittal Information

Send the complete, signed information, along with required attachments, to the following address:

U.S. EPA Region 10, OWW-130

Washington Hatchery NOI

1200 Sixth Avenue, Suite 900

Seattle, WA 98101-3140

Appendix B

Effluent Calculations

Guidance on Calculating Effluent Values

Calculating "Net" Effluent Values

Pollutant Concentrations for Total Suspended Solids and Settleable Solids are measured at both influent and effluent monitoring locations. The net concentration is the difference between the two measurements and can either be positive or negative since the pollutant concentration may either increase or decrease as the water passes through the facility. It is calculated as follows:

Effluent concentration (mg/L) -- influent concentration (mg/L) =

Net concentration (mg/L)

Appendix C

Quality Assurance Plan & Best Management Practices Plan Certification

Quality Assurance Plan
(QA Plan)
Certification

Facility Name:____

NPDES Permit Number:______________________

The QA Plan is complete and is available upon request to the EPA.

The QA Plan is being implemented by trained employees.

The QA Plan has been reviewed and endorsed by the facility manager.

The individuals responsible for implementation of the QA Plan have been properly trained.

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Signature:	**Title/Company:**
Print Name:	**Date:**

An existing discharger must submit this certification within 90 days of the effective date of this permit. For a new Permittee, this certification must be submitted no later than the written Notice of Intent to be covered under this permit. The certification must be submitted to the EPA (§III.B.7 of the permit).

Best Management Practices Plan
(BMP Plan)
Certification

Facility Name:____

NPDES Permit Number:_______________________

The BMP Plan is complete and is available upon request to the EPA.

The BMP Plan is being implemented by trained employees.

The BMP Plan has been reviewed and endorsed by the facility manager.

The individuals responsible for implementation of the BMP Plan have been properly trained.

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Signature:	**Title/Company:**
Print Name:	**Date:**

An existing discharger must submit this certification within 90 days of the effective date of this permit. For a new Permittee, this certification must be submitted no later than the written Notice of Intent to be covered under this permit. The certification must be submitted to the EPA (§III.C.3 of the permit).

Appendix D

Drug and Chemical Use
Report Contents

CHECKLIST FOR ORAL REPORT FOR INVESTIGATIONAL NEW ANIMAL DRUG (INAD) USE, EXTRALABEL DRUG USE, AND FIRST USE OF LOW REGULATORY PRIORITY DRUGS AND POTASSIUM PERMANGANATE

(Provide an oral report to the EPA: 206-553-1846 and to Ecology (where applicable) within 7 days after initiating use of the drug)

(First row is an example.)

Name of Drug (INAD & Extralabel) Used & Reason for Use	Method of Application	First Date of Drug Use	Date Oral Report to EPA	Person reporting
Extralabel: Erythromycin *Treat bacterial infections*	*Injection*	*09/09/04*	*09/10/04*	*MJ*

WRITTEN REPORT FOR AGREEING TO PARTICIPATE IN AN INAD STUDY

(Submit a written report to the EPA and Ecology within 7 days of agreeing or signing up to participate in an INAD study)

Facility Name:______________________NPDES Permit Number:_____________

Name of person submitting this report:_________________________________

Date of agreement to participate in INAD study: ___________________________

Date this written report will be submitted:__________________________________

The first row is an example.

Expected Dates of Use	Name of INAD Used	Disease or Condition Intended to Treat	Method of Application	Dosage
09/09/04	*Oxytetracycline*	*For controlling columnaris in trout*	☑ *Medicated feed* ☐ *Injection* ☐ *Bath treatment* ☐ *Other:* ____________	
			☐ Medicated feed ☐ Injection ☐ Bath treatment ☐ Other: ____________	
			☐ Medicated feed ☐ Injection ☐ Bath treatment ☐ Other: ____________	
			☐ Medicated feed ☐ Injection ☐ Bath treatment ☐ Other: ____________	

Written Report for INAD and Extralabel Drug Use and First Use of Low Regulatory Priority Drugs and Potassium Permanganate

(Submit a written report to the EPA and Ecology within 30 days after initiating use of the drug)

Facility Name:____________________NPDES Permit Number:_________________

Name of person submitting this report:____

Date this written report will be submitted to the EPA:__________________

For Extralabel Drug Use, include the **name of the prescribing veterinarian** and **date of the prescription** in a footnote.

<u>The first row is an example.</u>

Name of Drug & Reason for Use	Date and Time of Application (start & end)	Duration	Method of Application	Total Amount of Active Ingredient Added	Total Amount of Medicated Feed Added*
Oxytetracycline *For control of columnaris in walleye*	*09/09/04 10:00 AM* *09/13/04 10:00 AM*	*5 consecutive days*	☑ *Medicated feed* ☐ *Injection* ☐ *Bath treatment* ☐ *Other:* ____________________ ______________________________	*1 g/lb as sole ration*	*50 lbs*
			☐ Medicated feed ☐ Injection ☐ Bath treatment ☐ Other: ____________________ ______________________________		
			☐ Medicated feed ☐ Injection ☐ Bath treatment ☐ Other: ____________________ ______________________________		
			☐ Medicated feed ☐ Injection ☐ Bath treatment ☐ Other: ____________________ ______________________________		

* Applies only to drugs applied through medicated feed.

CHEMICAL LOG SHEET

(SEE ALSO THE REQUIREMENTS IN THE ANNUAL REPORT)

Facility Name:________________________________ NPDES Permit Number:__________________

Date	Raceway Treated	Chemical Name[1]	Active Ingredient	Amount Applied	Units	Duration of Treatment	Treatment Type[2]	Flow Treated (cfs)	Total Effluent Flow (cfs)	Effluent Conc. (ppb)	Person reporting

---

[1] Both a copy of the label with application requirements and the Material Safety Data Sheet (MSDS) must be kept in your records.

[2] Treatment type means, for example, static or flush bath, injection or feed.

Appendix E

Annual Report Contents

Annual Report of Operations for Year ________________

To comply with NPDES General Permit No. WAG130000 for Federal Aquaculture Facilities and Aquaculture Facilities Located in Indian Country within the Boundaries of the State of Washington

NPDES # for your Facility:

Facility & Owner Information

Facility Name:	
Operator Name (Permittee):	
Address:	
Email:	Phone:
Owner Name (if different from operator):	
Email:	Phone:

Best Management Practices (BMP) Plan

Has the BMP Plan been reviewed this year? ☐ Yes ☐ No

Does the BMP Plan fulfill the requirements of the General Permit? ☐ Yes ☐ No

Summarize any changes to the BMP Plan since the last annual report. Attach additional pages if necessary.

Operations and Production

Total harvestable weight produced in the past calendar year in pounds (lbs):

Pounds of food fed to fish during the maximum month:

List the species grown or held at your facility and the annual production of each in gross harvestable weight. If fish were released rather than harvested, list the weight at time of release.

Species	Fish Produced	Receiving Water(s) to which Fish were Released	Month Released/ Spawned

Fill in the table below with production numbers from the past year. List the **maximum** amount of fish on-site and the maximum amount of food fed **per month**.

Month	Total Fish (lbs)	Fish Feed (lbs)	Month	Total Fish (lbs)	Fish Feed (lbs)
January			July		
February			August		
March			September		
April			October		
May			November		
June			December		

Additional Comments:

Solid Waste Disposal

Describe annual quantities of solids (including fish mortalities) disposed and location of disposal.

Type of Solid Disposed	Quantity Disposed	Date Disposed	Location Disposed
Additional Comments:			

Fish Mortalities

Include a description and the dates of mass mortalities in the past year (more than 5% per week). Attach additional pages, if necessary. Include total mortalities from all causes.

Date	Cause of Deaths	Steps Taken to Correct Problem	Pounds of Fish
Additional Comments:			

Noncompliance Summary

Include a description and the dates of noncompliance events (including spills), the reasons for the incidents, and the steps taken to correct the problems. Attach additional pages, if necessary.

Inspections & Repairs for Production & Wastewater Treatment Systems

Date Inspected	Date Repaired	Description of System Inspected and/or Repaired

Aquaculture Drugs and Chemicals

Please indicate whether you used each drug/chemical **during the past calendar year**.
Describe the use of each drug/chemical in more detail on the following pages.

Used in the past year?	**Drug or Chemical**
☐ Yes ☐ No	Azithromycin
☐ Yes ☐ No	Chloramine-T: ***See additional reporting requirements on page 7***
☐ Yes ☐ No	Chlorine
☐ Yes ☐ No	Draxxin
☐ Yes ☐ No	Erythromycin - injectable
☐ Yes ☐ No	Erythromycin - medicated feed
☐ Yes ☐ No	Florfenicol (Aquaflor)
☐ Yes ☐ No	Formalin - 37% formaldehyde: ***See additional reporting requirements on page 7***
☐ Yes ☐ No	Herbicide - describe:
☐ Yes ☐ No	Hormone - describe:
☐ Yes ☐ No	Hydrogen Peroxide: ***See additional reporting requirements on page 7***
☐ Yes ☐ No	Iodine: ***See additional reporting requirements on page 7***
☐ Yes ☐ No	Oxytetracycline
☐ Yes ☐ No	Potassium Permanganate: ***See additional reporting requirements on page 7***
☐ Yes ☐ No	Romet
☐ Yes ☐ No	SLICE (emamectin benzoate)
☐ Yes ☐ No	Sodium Chloride - salt
☐ Yes ☐ No	Vibrio vaccine
☐ Yes ☐ No	Other:
☐ Yes ☐ No	Other:

Aquaculture Drugs and Chemicals (cont'd)

Describe all drug and/or chemical treatments that occurred during the year. Fill out the information below for each drug or chemical, plus page 7 for water-borne treatments. Attach additional pages as necessary.

Brand Name:		Generic Name:	
Reason for use:			
☐ Preventative/Prophylactic ☐ As-needed	Total quantity of formulated product per treatment:	Total quantity of formulated product used in past year (specify units):	
Date(s) of treatment:			Total number of treatments in past year:
Maximum daily volume of treated water:	Treatment concentration (specify units):	Duration and frequency of treatment(s):	
Method of application:	☐ Static Bath ☐ Flow-through	☐ Medicated Feed ☐ Other (describe):	
Location in facility chemical was used (check all that apply):	☐ Raceways ☐ Incubation building	☐ Ponds ☐ Off-line settling basin	☐ Other (describe):
Where did water treated with this chemical go? (check all that apply):	☐ Discharged w/o treatment ☐ Settling basin	☐ Septic System ☐ Publicly owned treatment works	☐ Other (describe):
Provide any additional information about how this chemical was used and/or special pollution prevention practices during use:			

Brand Name:		Generic Name:	
Reason for use:			
☐ Preventative/Prophylactic ☐ As-needed	Total quantity of formulated product per treatment:	Total quantity of formulated product used in past year (specify units):	
Date(s) of treatment:			Total number of treatments in past year:
Maximum daily volume of treated water:	Treatment concentration (specify units):	Duration and frequency of treatment(s):	
Method of application:	☐ Static Bath ☐ Flow-through	☐ Medicated Feed ☐ Other (describe):	
Location in facility chemical was used (check all that apply):	☐ Raceways ☐ Incubation building	☐ Ponds ☐ Off-line settling basin	☐ Other (describe):
Where did water treated with this chemical go? (check all that apply):	☐ Discharged w/o treatment ☐ Settling basin	☐ Septic System ☐ Publicly owned treatment works	☐ Other (describe):
Provide any additional information about how this chemical was used and/or special pollution prevention practices during use:			

Aquaculture Drugs and Chemicals (cont'd)
Additional Reporting Requirements for Water-Borne Treatments

- **If a water-borne treatment was used during the calendar year, Permittees must include detailed records/calculations as an attachment to this Annual Report in order to demonstrate how the maximum effluent concentrations of solution and active ingredient were calculated.**
- At a minimum, Permittees must include the information listed in the following tables - either for each treatment, or for a reasonable worst case (i.e., maximum effluent concentration) scenario. See also Appendix D for the Chemical Log Sheet.
- Specify whether static bath or flow-through treatment.
- For assistance with these calculations, Permittees may refer to the USFWS treatment calculator tool at:
  http://www.fws.gov/fisheries/aadap/AFS-FCS%20documents/GUIDE_TRT_CALC_FEB_2011.xlsx

Static Bath Treatments	
Tank Volume	Liters
Desired Static Bath Treatment Concentration	µg/L
Volume of Product Needed	Liters Product
Maximum Effluent Concentration of: **1) Solution and 2) Active Ingredient**	Solution: Active Ingredient: Specify Units
Maximum % of Facility Discharge Treated	% of Total Discharge

Flow-Through Treatments	
Tank Volume	Liters
Calculated Flow Rate	Liters/Minute
Duration of Treatment	Minutes
Desired Flow-Through Treatment Concentration of Product	µg/L
Amount of Product to Add Initially	Liters Product
Amount of Product to Add During Treatment	mL/Minute
Total Volume of Product Needed	Liters Product
Maximum Effluent Concentration of: **1) Solution and 2) Active Ingredient**	Solution: Active Ingredient: Specify Units
Maximum % of Facility Discharge Treated	% of Total Discharge

Changes to the Facility or Operations

Describe any changes to the facility or operations since the last annual report.

Signature and Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly evaluate and gather the information submitted. Based on my inquiry of the person or persons, who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Printed name of person signing	Title
Applicant Signature	Date Signed

Submittal Information

Send the complete, signed information, along with any attachments, to the following address:

U.S. EPA Region 10, OWW-130

Washington Hatchery Annual Report

1200 Sixth Avenue, Suite 900

Seattle, WA 98101-3140

Appendix F

Food and Drug Administration Policy:

Enforcement Priorities for Drug Use in Aquaculture

SUPPLEMENTAL POLICIES

ENFORCEMENT PRIORITIES FOR DRUG USE IN AQUACULTURE

PART A

ENFORCEMENT PRIORITIES FOR DRUG USE IN NON-FOOD FISH

I. Purpose

This document describes enforcement priorities that apply to drugs for use in aquaculture nonfood species/populations.

II. Definitions

Non-food fish - An aquaculture species is presumed to be a non-food species if it is reasonably likely that a) no significant percentage of the species population will be consumed directly or indirectly by humans for food, or b) the fish species is not known to be consumed by an identifiable human population. The following definitions are provided for categories of non-food fish.

Ornamental and aquarium fish - In general, ornamental and aquarium species are nonfood species. Ornamental and aquarium fish are defined as: fish that are produced and maintained solely for exhibit purposes in home or public aquaria, or in ornamental garden ponds. (Policy and Procedures (P&P) PPM 1240.4260).

Baitfish – Fish commercially raised to be used as bait in sport or commercial fishing e.g., fathead minnows, golden shiners and goldfish. A baitfish species will be considered a food fish if humans will consume any significant part of the species directly or indirectly.

Home aquarium - An aquarium in a private residence or exhibited in a business for hobby or decorative purposes.

Ornamental garden pond - Pond on the property of a private residence or for display in a business for hobby or decorative purposes.

Commercial pond – Pond/ raceway where the fish are grown ultimately to be sold to individuals at pet stores or for some other commercial use.

III. Regulation of Drug Use in Non-Food Species

When CVM personnel in Division of Compliance are asked questions or receive inquiries regarding the use of compounds in non-food fish they need to:

A. Determine which Agency or Food and Drug Administration (FDA) Center has jurisdiction for the regulation of the product based on the following categories:

1. The compound is intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease in man or other animal; and intended to affect the structure or any function of the body of man or other animals. The compound is a drug and is under the jurisdiction of FDA, Center for Veterinary Medicine (CVM). [Federal Food, Drug and Cosmetic Act (FFDCA), 201(g).] [Go to Section III B]. If the compound is determined to be a drug under FFDCA it is a drug even if it has pesticide, biologic, food or color additive properties or claims.

2. The compound is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, or any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant. [Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)] The compound is a **pesticide** and is under the jurisdiction of the Environmental Protection Agency (EPA). Contact EPA, Office of Pesticides.
3. The compound is a virus, serum, toxin (excluding substances that are selectively toxic to microorganisms, e.g., antibiotics), or analogous product at any stage of production, shipment, distribution, or sale, which is intended for use in the treatment of animals and which acts primarily through the direct stimulation, supplementation, enhancement, or modulation of the immune system or immune response. (9 CFR 101.2) The compound is a **biologic** and is under the jurisdiction of USDA, Animal and Plant Health Inspection Service (APHIS), Center for Veterinary Biologics (CVB). Contact USDA APHIS CVB.
4. The compound is a substance with the intended use of which results or may reasonably be expected to result, directly or indirectly, in its becoming a component of, or otherwise affecting the characteristics of any food for man or animals. (FFDCA 201 (s)) The compound is a **food additive** and is under the jurisdiction of the FDA CVM. Contact FDA, CVM, Division of Animal Feeds.
5. The compound is a substance which is capable of coloring food, and its use or intended use is not for a purpose other than coloring. (FFDCA

201 (t)) The compound is a **color additive** and is under the jurisdiction of the FDA Center for Food Safety and Applied Nutrition (CFSAN). Contact FDA CFSAN.

B. Decide the regulatory status. CVM will use the following categories to determine the regulatory status of a drug:

1. **Approved new animal drug** - An approved New Animal Drug Application (NADA) exists for this indication. Refer to 21 Code of Federal Regulations (CFR) Part 514. Product is used according to label directions.
2. **Investigational New Animal Drug (INAD)** - A potential sponsor may request an INAD exemption for collecting data to support a new animal drug approval. Contact the CVM Aquaculture Drugs Team, HFV-131.
3. **Extra-label use drug - Use of an FDA** - approved drug under the provisions of Animal Medicinal Drug Use Clarification Act (AMDUCA). See 21 CFR 530.
4. **Extra-label use of medicated feeds** -Provisions for the use of approved medicated feeds for minor species are explained in the Compliance Policy Guide (CPG) for Extra-label Use of Medicated Feeds for Minor Species. Compliance Policy Guide, Chapter 6, Section 615.115.
5. **Regulatory discretion** - Drugs that have been evaluated for regulatory discretion as low priority for enforcement action (INADs/NADAs will not be required). See Low Regulatory Priority (LRP) list in Part C of this document. For others not on the list go to Part A, Section IV of this document.

IV. Factors to Consider for Regulatory Discretion

Division of Compliance evaluates the potential for regulatory discretion. Drugs will be categorized at CVM's initiative or on request of an interested party. In the latter case, the requestor will be asked to provide available data and information that the Center can use to determine enforcement priority. The criteria used in this determination are as follows:

A. The safety status of the compound including:

1. User safety – Contact the Division of Human Food Safety, HFV-150.

High priorities are:

a. known or suspected carcinogens;

b. known serious toxicological hazards;

c. and suspected serious toxicological hazards believed to have substantial use in aquaculture.

2. Environmental safety – Contact the Environmental Assessment Team, HFV-145. Considerations include:

a. potential public or ecological safety issues including:

(1) potential for surface or groundwater contamination;
(2) known serious human toxicological hazard; and
(3) known serious toxicological hazard to aquatic organisms including fish, insects, and birds.

b. compliance with applicable Federal, State, and local environmental laws.

B. Extent of data available for enforcement priority determinations

In general, only published peer-reviewed studies or literature will be reviewed for the purpose of making enforcement priority determinations. However, unpublished data may be reviewed for enforcement priority determinations on a case-by-case basis. Areas to be reviewed include:

1. Human Food Safety;
2. Target animal safety and effectiveness;
3. Environmental safety; and
4. Human user and occupational safety.

V. Factors to Consider for Enforcement Priorities

A. In general, regulatory action may be considered in any case where a high enforcement priority drug (see section V.C.) is found. In addition, high enforcement priority drugs may be the subjects of special assignments to the Field. Other drugs will be subject to regulatory action on a case-by-case basis, based on the factors listed below.

1. Jurisdiction – (see Part A, Section III A of this document)

2. Approval status of the active ingredient

a. If FDA has withdrawn the approval of the active ingredient for reasons other than human food safety, priority will be determined on a case-by-case basis.

b. If an approved animal drug product containing the same active ingredient is available, the drug will ordinarily not be considered a low enforcement priority to protect the marketing of the approved product.

3. Approval or LRP status of drugs with different active ingredients but similar uses

   a. If an approved animal drug product containing a different active ingredient but for a similar use is available, then the drug will ordinarily not be considered a low enforcement priority to protect the marketing of the approved product.

   b. If an animal drug product containing a different active ingredient but for a similar use as a drug is included on the LRP list (see Part C of this guide), then the drug under consideration will ordinarily not be considered a low enforcement priority.

4. The presence or absence of any significant safety or effectiveness concern as established by the available data will determine the enforcement priority. These data will include information about the active ingredient, formulation, and proposed conditions of use.

5. Products with a known potential for diversion, either directly to humans (e.g., anabolic steroids) or to food-producing species should be considered for high priority.

6. Regulatory considerations include:

   a. potential effect on public health;
   b. availability of expert support for a court case;
   c. availability of agency resources to support a regulatory action;
   d. egregiousness of the violative action; and
   e. availability of the required evidence.

B. Enforcement Priorities by Segment of Industry

II. <u>Priorities for Regulation of Drug Use in Food Species/Populations</u>:

A. Enforcement Priorities by Segment of Industry.

1. Drug Manufacturers:

   a Primary focus among drug manufacturers and distributors will be on firms that specialize in manufacturing for, and distributing to, the aquaculture industry. Special attention should be given to:

      (1) distribution of high priority drugs;

(2) possible diversion and abuse situations, e.g., promotion for food species use of drugs labeled for nonfood species; and packaging of "nonfood fish" drugs in commercial pond-size containers.

b. If intended drug use of a multi-purpose chemical is not established by labeling, or by overt acts by the vendor (e.g., promotion), enforcement actions against the vendor would have to be based on case-by-case analysis. See 21 CFR 201.128.

c. All products granted low enforcement priority must:

(1) be labeled “For Non-food Fish Only” in a prominent place on the label;
(2) have adequate directions for use: and
(3) be drug listed per 21 CFR 207.

d. Manufacturers must:

(1) be registered: and
(2) follow Current Good Manufacturing Practices (CGMPs) per 21 CFR 210 & 211.

2. Feed Manufacturers:

Priorities will be determined on a case-by-case basis. For firms required to be licensed to manufacture medicated feeds and veterinary feed directive drugs, inspections and enforcement actions will be handled according to relevant compliance guidelines.

Extra-label use of medicated feeds is prohibited under the Animal Medicinal Drug Use Clarification Act. See 21 CFR 530. However, regulatory discretion is allowed for extra-label use of medicated feeds in minor species, including fish, under a Compliance Policy Guide. See CPG 615-115. Note that for extra-label use in aquatic species, the medicated feed must already be approved for use in another aquatic species and may not be reformulated.

3. Producers:

Primary objective with producers will be on education with emphasis on proper drug usage, e.g., which drugs are permitted and under what conditions. There will be no routine inspections for enforcement purposes. This will not preclude "for-cause" inspections or surveys to determine usage patterns for drugs, sources of the drugs, etc.

"For cause" inspection assignments will encompass either individual producers, or could be more broadly based. Such inspections might include, for example, a situation in which there is reason to believe that producers might be holding significant quantities of a drug of high enforcement priority (such as malachite green) and regulation at the manufacturer/distributor level is not feasible.

PART B

ENFORCEMENT PRIORITIES FOR DRUG USE IN FOOD, FISH AND SHELFISH

I. Purpose

This part of this document describes enforcement priorities that apply to drugs for use in aquaculture food species, fin fish or shellfish.

II. Definitions

Food fish and shellfish for human consumption - An aquaculture species is presumed to be a food species if it is reasonably likely that a) a significant percentage of the species population will be consumed directly or indirectly by humans for food, or b) the species is consumed by an identifiable human population.

Food fish and shellfish for animal feed - fish used in whole or in part as a component of any animal feed will be considered a food fish species.

III. Regulation of Drug Use in Food Species, both fin fish and shellfish

When CVM personnel in Division of Compliance are faced with inquiries regarding the use of compounds in food fish (fin fish and shellfish) they need to:

A. Determine which Agency or Food and Drug Administration (FDA) Center has jurisdiction for the regulation of the product based on the following categories:

1. The compound is intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease in man or other animal; and intended to affect the structure or any function of the body of man or other animals. The compound is a **drug** and is under the jurisdiction of FDA, CVM. [Federal Food, Drug and Cosmetic Act (FFDCA), 201(g).] [Go to Section III B]. If the compound is determined to be a drug under FFDCA it is a drug even if it has pesticide, biologic, food or color additive properties or claims.

2. The compound is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, or any substance or mixture of substances intended for use as a plant regulator, defoliant, or

3. Desiccant. [Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)] The compound is a **pesticide** and is under the jurisdiction of the Environmental Protection Agency (EPA). Contact EPA, Office of Pesticides.

4. The compound is a virus, serum, toxin (excluding substances that are selectively toxic to microorganisms, e.g., antibiotics), or analogous product at any stage of production, shipment, distribution, or sale, which is intended for use in the treatment of animals and which acts primarily through the direct stimulation, supplementation, enhancement, or modulation of the immune system or immune response. (9 CFR 101.2) The compound is a **biologic** and is under the jurisdiction of USDA, Animal and Plant Health Inspection Service (APHIS), Center for Veterinary Biologics (CVB). Contact USDA APHIS CVB.

5. The compound is a substance with the intended use of which results or may reasonably be expected to result, directly or indirectly, in its becoming a component of, or otherwise affecting the characteristics of any food for humans or animals. (FFDCA 201 (s)) The compound is a **food additive** and is under the jurisdiction of the FDA, CVM. Contact FDA CVM, Division of Animal Feeds.

6. The compound is a substance which is capable of coloring food, and its use or intended use is not for a purpose other than coloring. (FFDCA 201 (t)) The compound is a **color additive** and is under the jurisdiction of the FDA Center for Food Safety and Applied Nutrition (CFSAN). Contact FDA CFSAN.

B. Decide the regulatory status. CVM will use the following categories to determine the regulatory status of a drug:

1. **Approved new animal drug** - An approved New Animal Drug Application (NADA) exists for this indication. Refer to 21 Code of Federal Regulations (CFR) Part 514. Product is used according to label directions.

2. **Investigational New Animal Drug (INAD)** - A potential sponsor may request an INAD exemption for collecting data to support a new animal drug approval. Contact the CVM Aquaculture Drugs Team, HFV-131.

3. **Extra-label use drug -**Use of an FDA-approved drug under the provisions of Animal Medicinal Drug Use Clarification Act (AMDUCA). See 21 CFR 530.

4. **Extra-label use of medicated feeds** - Provisions for the use of

approved medicated feeds for minor species are explained in the Compliance Policy Guide (CPG) for Extra-label Use of Medicated Feeds for Minor Species. Compliance Policy Guide, Chapter 6, Section 615.115.

5. **Regulatory discretion** - Drugs that have been evaluated for regulatory discretion as low priority for enforcement action (INADs/NADAs will not be required). See Low Regulatory Priority (LRP) list in Part C of this document. For others not on the list, go to Part A, Section IV of this document.

IV. Factors to Consider for Regulatory Discretion

Division of Compliance evaluates the potential for regulatory discretion. Drugs will be categorized at CVM's initiative or on request of an interested party. In the latter case, the requestor will be asked to provide available data and information that the Center can use to determine enforcement priority. The criteria used in this determination are as follows:

A. The safety status of the compound including:

1. Human Food Safety – Contact the Division of Human Food Safety, HFV-150. High priority are:
    a. known or suspected carcinogens;
    b. known serious toxicological hazards;
    c. suspected serious toxicological hazards believed to have substantial use in aquaculture; and
    d. antimicrobials likely to confer bacterial resistance to drugs used in human medicine.

2. User safety – Contact the Division of Human Food Safety, HFV-150. High priority are:
    a. known or suspected carcinogens;
    b. known serious toxicological hazards; and
    c. suspected serious toxicological hazards believed to have substantial use in aquaculture.

3. Environmental safety – Contact the Environmental Assessment Team, HFV-145. Considerations include:
    a. potential public or ecological safety issues including:
        (1) potential for surface or groundwater contamination;
        (2) known serious human toxicological hazard; and
        (3) known serious toxicological hazard to aquatic organisms

including fish, insects, and birds.

   b. compliance with applicable Federal, State, and local environmental laws.

B. Extent of data available for enforcement priority determinations

In general, only published peer-reviewed studies or literature will be reviewed for the purpose of making enforcement priority determinations. However, unpublished data may be reviewed for enforcement priority determinations on a case-by-case basis. Areas to be reviewed include:

1. Human food safety;
2. Target animal safety and effectiveness;
3. Environmental safety; and
4. Human user and occupational safety.

V. Factors to Consider for Enforcement Priorities

A. In general, regulatory action may be considered in any case where a high enforcement priority drug (see section V.C.) is found. In addition, high enforcement priority drugs may be the subjects of special assignments to the Field. Other drugs will be subject to regulatory action on a case-by-case basis, based on the factors listed below.

1. Jurisdiction – (see Part A, Section III A of this document)
2. Approval status of the active ingredient -
   a. If FDA has withdrawn the approval of the active ingredient for human food safety reasons regulatory discretion will not normally be granted.

   b. If FDA has withdrawn the approval of the active ingredient for reasons other than food safety reasons regulatory discretion will be determined on a case-by-case basis.

   c. If an approved animal drug product containing the same active ingredient is available, the drug will ordinarily not be considered a low enforcement priority to protect the marketing of the approved product.

3. Approval or LRP status of drugs with different active ingredients but similar uses

   a. If an approved animal drug product containing a different active ingredient but for a similar use is available, then the drug will ordinarily not be considered a low enforcement priority to protect the marketing of the approved product.

b. If an animal drug product containing a different active ingredient but for a similar use as a drug is included on the LRP list (see Part C of this document), then the drug under consideration will ordinarily not be considered a low enforcement priority.

4. If the treated fish are intended for use in animal feed, then there is a higher concern if the feed is to be used for food-producing animals. The method of feed preparation should also be considered, e.g., rendering vs. fish or fish parts.

5. The presence or absence of any significant safety or effectiveness concern as established by the available data will determine the enforcement priority. These data will include information about the active ingredient, formulation, and proposed conditions of use.

6. Regulatory considerations include:

   a. potential effect on public health;
   b. availability of expert support for a court case;
   c. availability of agency resources to support a regulatory action;
   d. egregiousness of the violative action; and
   e. availability of the required evidence.

B. Enforcement Priorities by Segment of Industry

1. Drug Manufacturers

a. Primary focus among drug manufacturers and distributors will be on firms that specialize in manufacturing for, and distributing to, the aquaculture industry. Special attention should be given to:
   (1) distribution of high priority drugs; and
   (2) abuse situations, e.g., promotion for food species use of drugs labeled for nonfood species and packaging of "non-food fish" drugs in commercial pond-size containers.

b. If intended drug use of a multi-purpose chemical is not established by labeling, or by overt acts by the vendor (e.g., promotion), enforcement actions against the vendor should be based on case-by-case analysis. See 21 CFR 201.128.

c. All products granted low enforcement priority must:

   (1) have adequate directions for use; and
   (2) be drug listed per 21 CFR 207.

d. Manufacturers must:

(1) be registered;
(2) be drug listed per 21 CFR 207; and
(3) follow Current Good Manufacturing Practices (CGMPs) per 21 CFR 210 & 211.

2. Feed Manufacturers

For firms required to be licensed to manufacture medicated feeds and veterinary feed directive drugs, inspections and enforcement actions will be handled according to relevant compliance guides.

Extra-label use of medicated feeds is prohibited under the Animal Medicinal Drug Use Clarification Act. See 21 CFR 530. However, regulatory discretion is allowed for extra-label use of medicated feeds in minor species, including fish, under a Compliance Policy Guide. See CPG 615-115. Note that for extra-label use in an aquatic species, the medicated feed must already be approved for use in another aquatic species and may not be reformulated.

3. Producers

Primary emphasis with producers will be on education with emphasis on proper drug usage, e.g., which drugs are permitted and under what conditions. There will be no routine inspections for enforcement purposes. This will not preclude "for-cause" inspections or surveys to determine usage patterns for drugs, sources of the drugs, etc.

"For cause" inspection assignments will encompass either individual producers, or could be more broadly based. Such inspections might include, for example, a situation in which there is reason to believe that producers might be holding significant quantities of a drug of high enforcement priority (such as malachite green) and regulation at the manufacturer/distributor level is not feasible.

PART C

ENFORCEMENT PRIORITIES

I. LOW REGULATORY PRIORITY AQUACULTURE DRUGS

The following compounds have undergone review by the Food and Drug Administration and have been determined to be new animal drugs of low regulatory priority.

ACETIC ACID - 1000 to 2000 ppm dip for 1 to 10 minutes as a parasiticide for fish.

CALCIUM CHLORIDE - Used to increase water calcium concentration to ensure proper egg hardening. Dosages used would be those necessary to raise calcium concentration to 10-20 ppm $CaC0_3$.

- Used up to 150 ppm indefinitely to increase the hardness of water for holding and transporting fish in order to enable fish to maintain osmotic balance.

CALCIUM OXIDE - Used as an external protozoacide for fingerlings to adult fish at a concentration of 2000 mg/L for 5 seconds.

CARBON DIOXIDE GAS - For anesthetic purposes in cold, cool, and warm water fish.

FULLER'S EARTH - Used to reduce the adhesiveness of fish eggs to improve hatchability.

GARLIC (Whole Form) - Used for control of helminth and sea lice infestations of marine salmonids at all life stages.

ICE - Used to reduce metabolic rate of fish during transport.

MAGNESIUM SULFATE - Used to treat external monogenic trematode infestations and external crustacean infestations in fish at all life stages. Used in all freshwater species. Fish are immersed in a 30,000 mg $MgS0_4$/L and 7000 mg NaCl/L solutions for 5 to 10 minutes.

ONION (Whole Form) - Used to treat external crustacean parasites, and to deter sea lice from infesting external surface of salmonids at all life stages.

PAPAIN - Use of a 0.2% solution in removing the gelatinous matrix of fish egg masses in order to improve hatchability and decrease the incidence of disease.

POTASSIUM CHLORIDE - Used as an aid in osmoregulation; relieves stress and prevents shock. Dosages used would be those necessary to increase chloride ion concentration to 10-2000 mg/L.

POVIDONE IODINE - 100 ppm solution for 10 minutes as an egg surface disinfectant during and after water hardening.

SODIUM BICARBONATE - 142-642 ppm for 5 minutes as a means of introducing carbon dioxide into the water to anesthetize fish.

SODIUM CHLORIDE - 0.5% to 1.0% solution for an indefinite period as an osmoregulatory aid for the relief of stress and prevention of shock; and 3% solution for 10 to 30 minutes as a parasiticide.

SODIUM SULFITE – 1.5% solution for 5 to 8 minutes to treat eggs in order to improve their hatchability.

THIAMINE HYDROCHLORIDE - Used to prevent or treat thiamine deficiency in salmonids. Eggs are immersed in an aqueous solution of up to 100 ppm for up to four hours during water hardening. Sac fry are immersed in an aqueous solution of up to 1,000 ppm for up to one hour.

UREA and TANNIC ACID - Used to denature the adhesive component of fish eggs at concentrations of 15g urea and 20g NaCl/5 liters of water for approximately 6 minutes, followed by a separate solution of 0.75g tannic acid/5 liters of water for an additional 6 minutes. These amounts will treat approximately 400,000 eggs.

The Agency is unlikely to object to the use of these substances if the following conditions are met:

(1) The substances are used for these indications;
(2) The substances are used at the prescribed levels;
(3) The substances are used according to good management practices;
(4) The product is of an appropriate grade for use in food animals, and
(5) There is not likely to be an adverse effect on the environment.

The Agency's enforcement position on the use of these substances should not be considered an approval nor an affirmation of their safety and effectiveness. Based on the information available at some time in the future, the Agency may take a different position on the use of any or all of these substances.

Classification of these substances as new animal drugs of low regulatory priority does not exempt facilities from complying with other Federal, State, and local environmental requirements. For example, facilities using these substances would still be required to comply with National Pollutant Discharge Elimination System (NPDES) requirements.

NOTE: The primary long range goals in enforcement prioritization will be to protect public health and encourage submission of INADs and NADAs with a view toward obtaining approvals to meet therapeutic and production needs in aquaculture.

(6) Labeling and GMPs for Low Priority Drugs.

a. Labeling for low priority use will not be required for a chemical that is commonly used for nondrug purposes even if the manufacturer or distributor promotes the chemical for the permitted low priority use.

b. However, a chemical that has significant animal or human drug uses in addition to the low priority aquaculture use will be required to be labeled for the low priority uses if the manufacturer or distributor establishes the intended low priority use for its product by promotion or other means.

c. Where labeling is required, all other provisions of the Act pertaining to drugs except the approval requirement will apply. This includes registration, drug listing and Current Good Manufacturing Practices (CGMPs), etc.

d. Low regulatory priority compounds may be marketed for aquaculture use with drug claims (the claims permitted for such compounds) but must be of an appropriate quality for use in food animals.

e. If drug claims appear on the product label, in product catalogs, or in promotional material, the following conditions must be met:

The product must have been manufactured according to CGMPs as defined in 21 CFR 210 & 211;

The product manufacturer must be registered with the FDA; and

The product must be drug-listed with FDA.

Material deviations in labeling or promotion from the permitted low priority claims might cause a particular product to be removed from the low priority category.

II. SPECIAL CATEGORY

Products found not to be low regulatory priority but regulatory action deferred pending further study:

Copper sulfate

Potassium permanganate

III. EXAMPLES OF DRUGS WITH HIGH ENFORCEMENT PRIORITY

Chloramphenicol Nitrofurans Fluoroquinolones and Quinolones Malachite Green Steroid Hormones

HISTORY

July 26, 2011 – Typo was found on page 15, under compounds - SODIUM SULFITE. Changed from 15% to 1.5% solution

EPA's Plan for Addressing PCBs in the Spokane River

July 14, 2015

This document sets out EPA's schedule, detailed more fully below, in response to the Order issued on March 16, 2015, by the U.S. District Court in Sierra Club, et al. v. McLerran, No. 11-CV-1759-BJR (March 16, 2015). In its Order, the Court directed EPA to:

> [C]onsult with Ecology and file herein, within 120 days of the date of this order, a complete and duly adopted reasonable schedule for the measuring and completion of the work of the Task Force, including quantifiable benchmarks, plans for acquiring missing scientific information, deadlines for completed scientific studies, concrete permitting recommendations for the interim, specific standards upon which to judge the Task Force's effectiveness, and a definite endpoint at which time Ecology must pursue and finalize its TMDL.

EPA sets out its schedule below, following a more general presentation of the variety of regulatory and non-regulatory considerations informing EPA's plan for addressing PCBs in the Spokane River.

SUMMARY

The goal of this plan is the attainment of applicable water quality standards for PCBs in the Spokane River. The plan describes significant ongoing regulatory and non-regulatory actions to identify and address sources of PCB pollution in the river. The plan provides that if the Spokane River remains impaired[1] for PCBs, the Washington Department of Ecology (Ecology) will initiate a TMDL to address the impairments by no later than July 15, 2028, and will finalize that TMDL by no later than July 1, 2030. Such a TMDL would establish PCB loads for point sources and nonpoint sources that would achieve the applicable water quality standards for PCBs. For the time period leading up to July 15, 2028, EPA's plan provides "benchmarks"—specified instream concentrations of PCBs that decrease incrementally over time. If the quantifiable benchmarks are not attained by specified dates certain (identified in the schedule in this document), then the trigger to initiate development of a TMDL would be accelerated. Under this schedule, a TMDL could be completed as early as July 2019 or as late as July 2030.

As described in greater detail below, all individually permitted dischargers to the Spokane River will be installing advanced treatment technologies that will significantly reduce their discharge of PCBs. As a result of those reductions and others, as well as uncertain but likely advances in analytical technologies to measure PCBs, a PCB TMDL developed pursuant to EPA's schedule will be more scientifically and technically defensible than any TMDL for PCBs that could be developed in the interim. This schedule reflects EPA's judgment that the actions being taken now to reduce PCBs are critical to the development of a TMDL in the future and are intended to maximize the

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[1] For purposes of this document, "impaired" means that segments of the Spokane River and/or its tributaries remain listed by the State of Washington as impaired for non-attainment of applicable water quality standards for PCBs as of the relevant benchmark date.

resources that Ecology and the Task Force can devote to the ongoing efforts to reduce PCBs in the Spokane River.

CONTEXT REGARDING PCBs CONTAMINATION IN THE SPOKANE RIVER

By letter to Plaintiff's counsel dated April 2013, EPA determined that a constructive submission regarding a TMDL for PCBs in the Spokane River had not occurred and that an alleged non-discretionary duty under the CWA was not triggered. That determination was upheld by the Court in its March 2015 decision. In describing factors and circumstances EPA considered in the course of reaching that determination, EPA noted that work by the Task Force was ongoing. Neither EPA nor Ecology has previously described the Task Force and its ongoing work in detail in the briefing. Accordingly, EPA, in explaining the reasons for its schedule, also provides additional context regarding PCBs, water quality standards for PCBs, anticipated reductions in PCBs due to ongoing activities, as well as the ongoing work of the Task Force.

1. PCBs: Historic Uses and Health Effects

A polychlorinated biphenyl (PCB) is a synthetic organic chemical compound with one or more chlorine molecules attached to biphenyl, which is a molecule composed of two benzene rings. A congener is any single, unique well-defined chemical compound in the PCB category. There are 209 individual PCB congeners, and they differ from one another in the number and placement of the chlorine atoms. Most commercial PCBs are mixtures of different congeners and are generally known in the United States by their industrial trade names. The most common trade name is Aroclor. PCBs are human-made; there are no known natural sources.

PCBs were produced in large quantities within the United States from 1929 to 1979. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics, and rubber products; in pigments, dyes, and carbonless copy paper; and many other industrial applications.

As a result of this widespread use for 50 years and because they do not break down readily after they are released, PCBs are ubiquitous, found throughout the natural environment in air, water, soils, and sediments. PCBs are found in plants and animals throughout the food chain. PCBs bioaccumulate in plants and animals and can reach levels in fish tissue that are hundreds of thousands of times higher than the levels in water. PCBs are also transported readily through the air, and have been found in remote locations, far from where they were initially released (ATSDR, 2000).

PCBs have a limited solubility in water. Because PCBs are hydrophobic compounds, they tend to bind to sediments and organic particulate matter, which in turn may enter the food chain rather than remain in the water column. Although background levels for water column measurements can be in the parts per quadrillion range[2], the sediments in which PCBs tend to accumulate can often have levels two to three orders of magnitude higher.

PCBs have been shown to cause cancer in animals and are a probable human carcinogen. PCBs also cause a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, and endocrine system (ATSDR, 2000). Concerns about the toxicity of PCBs are largely based on twelve of the more highly chlorinated PCB congeners that share a structural similarity to, and toxic mode of action with, dioxin (van den Berg et. al, 2006).

Because of these adverse health effects, the Toxics Substances Control Act (TSCA) in 1976 prohibited the majority of manufacturing, processing, and distribution of PCBs. 15 U.S.C. § 2605(e)(3). Regulations implementing TSCA exclude from the prohibition products containing PCBs in concentrations less than 50 ppm, as well as manufacturing processes that inadvertently generate and release PCBs to products, air, and water in excess of specific regulatory thresholds.[3] EPA has identified 70 chemical processes with high potential to inadvertently generate PCBs (Fed. Register, 1983) and estimates an annual production of 100,000 pounds of inadvertently generated PCBs. Examples of products included in this calculation include some pigments and dyes that are commonly used in consumer products. Ecology has identified non-point releases, such as those from consumer products, as being increasingly important to control in order to reduce overall PCB delivery to humans and the environment (Ecology and Health, 2015). In a recent study, the City of Spokane detected PCBs in all but two of almost 50 consumer product samples, including yellow pigmented road paint, hydroseed and laundry soap (City of Spokane, 2015). A recent Ecology analysis identified the congener PCB-11 in 49 consumer products, including food packaging and yellow spray paint (Ecology 2014). Because these PCBs are found legally in new consumer products, this may make it more difficult to attain water quality standards for PCBs.

2. Water Quality Standards for PCBs in the Spokane River

Standards for PCBs in surface water are set at levels to protect human health. Because the primary way by which people are exposed to PCBs is through the consumption of contaminated fish and/or shellfish (in which PCBs may have

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[2] In 2015, background water column measurements at the outlet of Lake Coeur d'Alene were largely below 50 pg/L (or 50 parts per quadrillion) (LimnoTech, 2014).

[3] The concentration of inadvertently generated PCBs in products leaving any manufacturing site or imported into the United States must have an annual average of less than 25 ppm, with a 50 ppm maximum. The concentration of inadvertently generated PCBs in the components of detergent bars leaving the manufacturing site or imported into the United States must be less than 5 ppm. The release of inadvertently generated PCBs at the point at which emissions are vented to ambient air must be less than 10 ppm. The amount of inadvertently generated PCBs added to water discharged from a manufacturing site must be less than 100 micrograms per resolvable gas chromatographic peak per liter of water discharged. 40 C.F.R. 761.3 (definition of excluded manufacturing process).

bioaccumulated in tissue), assumptions about average fish consumption rates affect the derivation of concentrations in water quality standards. In Washington, the water quality criterion for total PCBs is 170 picograms per liter (pg/L). 40 C.F.R. 131.36(b)(1) & (d)(14). Washington's criterion, which was promulgated by EPA as part of the National Toxics Rule, was based on an assumed daily fish consumption rate of 6.5 grams per day.[4] In 1996, Ecology began listing the various segments of the Spokane River and adjacent water bodies (see map in Appendix A) as impaired due to PCBs based on levels of PCBs in edible fish tissue[5] (specifically, fish tissue levels projected to represent an exceedance of the water column concentrations in the water quality standards). The listings were not directly based on non-attainment of the numeric water criteria, which are water column concentrations.

In January of 2015, Ecology proposed revisions to its water quality criteria established to protect human health. Specifically, Ecology proposed to adopt a numeric water quality criterion in its standards to incorporate the 170 pg/L value for total PCBs as State regulations.[6] Ecology also proposed a generally-applicable narrative water quality criterion that "[a]ll waters shall maintain a level of water quality when entering downstream waters that provides for the attainment and maintenance of the water quality standards of those downstream waters, including the waters of another state." Ecology completed the public process on the draft rule on March 23, 2015, and is proceeding to take final action on its proposed revisions. Depending on the scope of Ecology's final action, EPA anticipates that the revised water quality criteria will (after EPA approval) provide for greater protections for downstream waters, including the Spokane Tribe tribal waters.

The waters of the Spokane Tribe are downstream from the segments of the Spokane River and adjacent water bodies that Ecology listed as impaired. On December 19, 2013, EPA approved water quality criteria for PCBs established by the Spokane Tribe. The Tribe's water quality criteria for PCBs are based on a fish consumption rate that is protective of human health and designed to support traditional subsistence practices. In the absence of site-specific fish consumption data, EPA's recommended criteria for PCBs are based on an assumed national fish consumption rate of 17.5 grams per day for the general population, and/or 142 g/day for high fish consumers; the EPA-approved Tribal standards are based on an assumed fish consumption rate of 865 grams per day. The Tribe's water quality criterion for total PCBs is 1.3 pg/L. This criterion is more than two orders of magnitude lower than the current Washington criterion and is probably the lowest PCB criterion in the country.

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[4] Since then, EPA updated the fish consumption rate assumption to 17.5 grams per day for PCBs. Based on the revised fish consumption rate, EPA now recommends water quality criteria for total PCBs at 64 picograms per liter for PCBs.

[5] Sampled fish include rainbow trout, brown trout, mountain whitefish, white crappie, walleye, yellow perch, smallmouth bass, largemouth bass, and kokanee and, for more recent listings, also largescale sucker.

[6] The proposed criterion of 170 pg/L, while identical to the current criterion, was derived differently, using a higher fish consumption rate but also a higher cancer risk level. In public comments provided to Ecology, EPA expressed concern about the cancer risk level used.

PCB levels this low pose analytic difficulties. The method approved by EPA for detecting total PCBs for Clean Water Act permits can quantify PCBs at concentrations of about 500,000 pg/L or greater, which is about 3,000 times Washington's PCB criterion and about 385,000 times the Spokane Tribe's PCB criterion. The most sensitive method currently available, which has not been approved by EPA for use with Clean Water Act permits, can quantify PCBs at 10 to 30 pg/L or higher, which is still approximately 10 times the Spokane Tribe criterion.

3. Sources of PCBs in the Spokane Watershed and PCB Control Measures

The PCB sources in the Spokane Watershed are numerous and diffuse, and therefore difficult to identify in their entirety. PCB sources include legacy contamination of soil and groundwater; some building caulks and paints; and inadvertently generated PCBs that remain in today's consumer products. The PCBs in these diffuse sources are mobilized by a variety of mechanisms that include volatilization into the air (e.g. from building materials); and transport of PCBs that adhere to surface particulate matter by rainwater, stormwater, sanitary sewage, and groundwater. When PCBs have mobilized, they enter the Spokane River through a variety of pathways that include air deposition, stormwater, groundwater and municipal and industrial wastewater discharges.

Numerous commercial and industrial sources discharge effluent containing PCBs (both legacy PCBs and those found in modern consumer products) to the Spokane River and its tributaries in Idaho and Washington and from Spokane Tribal lands. The largest of these types of discharges include municipal wastewater treatment facilities (three in Idaho, three in Washington); industrial facilities (Kaiser Aluminum and Inland Empire Paper) and three fish hatcheries (in Washington and on the Spokane Tribal lands). Municipal separate storm sewer systems and other sources of stormwater discharges in Washington and Idaho also contribute to PCB loadings in the Spokane River. Nonpoint sources of pollution that contribute PCB loads include groundwater and air deposition. Other potential sources of PCB loading include unregulated stormwater discharges, and point and nonpoint source discharges in tributaries to the Spokane River.

A. Advanced Solids Removal Will Reduce PCB Loading to the Spokane River

Point-source dischargers to the Spokane River[7] will be responsible for the most significant expected reductions in PCB loading to the river. All of these facilities are subject to NPDES permit requirements to install advanced solids-removal treatment technology that will remove substantial quantities of PCBs. The permit requirements are the result of an EPA-approved Ecology TMDL to restore dissolved oxygen (DO) levels in the Spokane River and adjacent water bodies. DO levels are dependent, in part, on phosphorous levels, and the permits therefore require phosphorous removal. Upstream

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[7] These dischargers include municipal wastewater treatment plants for the cities of Spokane, Liberty Lake, Coeur d'Alene, Post Falls, and Hayden, as well as the industrial discharges from Inland Empire Paper Company and Kaiser Aluminum Fabricated Products.

facilities in Idaho discharging to the Spokane River are also required to install this advanced treatment technology to meet the downstream state water quality standard for DO as required under NPDES regulations.[8] In order to achieve the lower phosphorus limits in the permits, advanced solids-removal technology is required; this technology will also remove PCBs, which are generally found adhering to solids. With the exception of the permit for the municipal wastewater treatment plant serving Spokane County (which was constructed using this technology), each of the permits includes a compliance schedule ranging between eight to ten years. The compliance schedules in the permits are based on the need for time to provide for capitalization (funding), installation, and optimization. By the end of 2024, all permittees must be in compliance with the new permit requirements.

The advanced treatment technology to meet the phosphorus limits is projected to result in significant reductions of PCBs entering the Spokane River. Installation and optimization of the advanced treatment necessary to restore dissolved oxygen levels may result in very significant PCB load reductions from each source. The Task Force reports that membrane filters in use at the Spokane County facility have demonstrated the capability to remove “up to 99% of PCBs from municipal wastewater facilities.” (Task Force, 2015). Until the treatment is installed and optimized, however, the achievable concentrations remain uncertain.

In addition to the PCB reductions expected based on solids removal, the individual permits for discharges to the Spokane River in both Washington and Idaho include requirements specifically intended to reduce PCBs through further “upsource” controls on PCBs in solids. All of the permits for municipal sewage treatment plants include requirements that the permittee develop and implement toxics management plans addressing source control of PCBs from the following: contaminated soils and sediments; storm water entering the wastewater collection system; industrial and commercial sources, including paint, caulking, soaps and cleaners. The permits also require public education regarding the difference between products that are demonstrably “free” of PCBs and those products that are labeled “non-PCB,” but which likely contain PCBs at concentrations below the federal regulatory thresholds. The permit for Kaiser Aluminum includes a requirement to continue PCB source identification and cleanup actions initiated under the State’s Model Toxics Control Act (MTCA) cleanup order, including a “scope of work for additional source identification efforts.”

In response to the Court’s Order of March 2015, EPA has prepared detailed permitting recommendations that provide guidance for the issuance of new permits for the Spokane River municipal wastewater treatment plants, the industrial facilities, three fish hatcheries in the watershed, and all municipal and general stormwater permits associated with the Spokane River and its adjacent waters. EPA issues some of the relevant hatchery and stormwater permits, as well as the Idaho municipal wastewater treatment plant permits. The recommendations have been transmitted to Ecology for

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[8] Ecology’s TMDL to restore dissolved oxygen could not set wasteload allocations for Idaho dischargers, but the TMDL assumed that Idaho dischargers would also be required to reduce their phosphorous loads. EPA subsequently used these assumptions in developing the permits for the Idaho dischargers.

their use in municipal, industrial, hatchery, and stormwater permits, and are attached to this document in Appendix B.

In a real and meaningful way, the requirements of the municipal and industrial wastewater permits for discharges to the Spokane River are already poised to make significant reductions to discharges of PCBs. Implementation of the existing permit requirements and EPA's new permitting recommendations may well achieve all the PCB reductions possible using current technologies and toxics reduction strategies. EPA's schedule is intended to provide adequate time for those measures to be implemented, for water column concentrations to come into equilibrium, and for the impacts of these reductions on fish tissue to be assessed.

B. Remediation at Kaiser Aluminum Facility

In the past, the Kaiser Aluminum Fabricated Products facility used hydraulic oils containing high concentrations of PCBs for aluminum casting operations. Kaiser's long-term use and storage of PCB-contaminated oils have contaminated the soil and underlying groundwater with PCBs. Since 2005, Kaiser has conducted a series of investigation and cleanup activities for soil and groundwater under the authority and requirements of Ecology's cleanup regulations, the state's MTCA. The investigation and cleanup required by MTCA is separate from Kaiser's participation on the Task Force.

In 2012, Ecology issued an Amended Agreed Order requiring soil excavation and capping of deeper soil to address PCB contamination; these actions have been completed, resulting in the removal of 540 tons of soil that contained elevated levels of PCBs. The 2012 order also requires Kaiser to initiate a PCB groundwater treatment pilot study by October 30, 2015. The contamination of groundwater underlying the Kaiser facility is widespread, with PCB levels exceeding 500,000 pg/L (Hart Crowser 2012). After completion of this pilot study, Ecology will issue a cleanup action plan that will specify the actions that Kaiser must take to remediate the PCB-contaminated groundwater. Ecology estimates that this groundwater treatment system will be operational by 2020. Groundwater from the Kaiser facility discharges to the Spokane River, but the extent to which the contaminated groundwater affects the PCB concentrations in the Spokane River is unknown.

C. Local Electric Utility Is Removing PCB-Containing Transformers

Avista Utilities, the company that provides electric service to large parts of eastern Washington, including the Spokane area and northern Idaho, initiated a three-year program to remove all of its overhead electrical distribution transformers containing PCBs. Although transformers with higher PCB concentrations were removed years ago, thousands of transformers containing PCBs at concentrations less than 50 ppm remained in service. As of 2015, Avista has retired most of the remaining PCB-containing transformers and plans to eliminate all PCB-containing transformers by 2018. Electric transformers represent significant and historically high sources of intentionally manufactured PCBs, including the dioxin-like congeners. Removal of these PCB sources will ensure that these pollutants do not end up in the Spokane River.

D. NPDES Permits for Discharges from Municipal Separate Storm Sewers

A comparatively recent expansion of the NPDES permitting program to apply to discharges from municipal separate storm sewer systems (commonly referred to as “MS4s”) will reduce the discharge of particulate solids from diffuse sources that contaminate stormwater runoff, which in turn will further reduce the loading of PCBs into the Spokane River and adjacent waterbodies. Contaminated stormwater runoff is commonly transported and discharged through MS4s to nearby waterbodies through hundreds, if not thousands of outfalls within the MS4. Under federal rules, the MS4s discharging to the Spokane River watershed[9] were required to apply for discharge authorization under the NPDES permitting program.

Discharges from the Washington MS4s are authorized under an Ecology general permit issued in 2012 and expiring in 2019. Discharges from the Idaho MS4s are currently regulated by individual NPDES permits[10]; EPA is preparing to propose issuance of a state-wide MS4 general permit (during the current calendar year) that would replace the individual MS4 permits in Idaho. Under MS4 stormwater permits, each regulated MS4 is required to develop and implement a comprehensive stormwater program as defined by federal regulations at 40 CFR §122.34.

The current MS4 permits are reducing the loads of particulate solids to the Spokane River and are therefore reducing PCB loads. Reissuance of these permits provides opportunities for more targeted reductions. EPA’s permitting recommendations, discussed above and included in Appendix B, contain several specific recommendations for MS4 permits, as well as recommendations for other types of stormwater general permits.

E. The Spokane River Regional Toxics Task Force

In recognition that nonpoint sources of PCBs in the Spokane watershed present a persistent and diffuse problem that cannot be easily addressed by direct regulatory authority, in 2011 Ecology made a significant change in reissued NPDES permits for facilities discharging into the Spokane River. The new permits required permittees to participate in the Task Force (Task Force, 2012).[11] Although participation is required by Ecology, the Task Force exists independent of and therefore is not legally required to account to Ecology. The Task Force includes voting members (representing NPDES permittees, state and local agencies other than Ecology, environmental groups and

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[9] Regulated MS4s discharging to the Spokane River watershed are located in the Washington cities of Spokane and Spokane Valley; Spokane County, Washington; Washington State University, Spokane campus; the Washington State Department of Transportation (areas located within the Spokane urbanized area); the Idaho cities of Coeur d’Alene and Post Falls; the Post Falls (Idaho) Highway District; Lakes (Idaho) Highway District; and the Idaho Transportation Department District 1.

[10] The EPA-issued individual permits for MS4s in the Spokane River watershed in Idaho expired in 2014.

[11] NPDES permittees who discharge to the Spokane River and are located in Idaho agreed to participate in the Task Force as well, and participation is similarly required in their NPDES permits, which EPA issued in September 2014.

other stakeholders) and advisory members (Ecology, tribal sovereigns, and EPA) (Task Force, 2014). The proceedings of the Task Force are facilitated by the William D. Ruckelshaus Center at Washington State University. The Task Force has convened approximately monthly since September 2011.[12] The goal of the Task Force is to "develop a comprehensive plan to bring the Spokane River into compliance with applicable water quality standards for PCBs" (Task Force, 2012, p. 7). This is to be accomplished through actions funded[13], designed, and implemented by members of the Task Force to identify and eliminate diffuse nonpoint sources of PCBs. Although the Task Force's work will be used if development of a TMDL is necessary, the Task Force was not convened for that purpose.

i. Task Force Accomplishments to Date

The Task Force has undertaken several projects and activities designed to identify sources and reduce PCBs in the Spokane River since it was created in 2011. In its June, 2015 "Coordinated Response," the Task Force describes its operations, accomplishments, and future plans. A major project, currently underway, is the Task Force's efforts to consolidate existing data about sources, fate, and transport of PCBs in the Spokane River and to address significant data gaps and inconsistencies. In November of 2013, a Task Force report identified the primary data gaps (in their decreasing order of importance): (1) determining magnitude of sources contributing to stormwater loads; (2) determining PCB sources upstream of the Idaho/Washington border; and (3) determining the significance of loading from atmospheric and groundwater sources. (LimnoTech, 2013). In August of 2014, the Task Force initiated a comprehensive, simultaneous data collection effort in Washington and Idaho. This data, collected during dry weather,[14] provided the first contemporaneous "snapshot" of PCBs in the Spokane River from Lake Coeur d'Alene to Nine Mile Dam. The Task Force will continue to collect additional data to complete the source characterization and quantification throughout 2015 and 2016 (Task Force, 2015).

In addition to data collection and analysis, the Task Force and its members individually have taken actions to identify and reduce diffuse sources of PCBs that impact stormwater. They are currently engaged in product testing to identify current consumer products with high levels of PCBs that have the potential to be released to the river. Task Force-sponsored analysis demonstrated that specific "hydroseed" products, used to manage stormwater erosion for many types of construction activities, contain elevated levels of PCBs. Because hydroseed is used to manage stormwater,

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[12] The Memorandum of Agreement that governs the formation and activities of the Task Force provides that the Task Force shall continue in effect for the duration of the Ecology 2011 through 2016 NPDES wastewater permit cycle. The Task Force is expected to continue thereafter if future NPDES wastewater permits require participation in the Task Force (Task Force, 2012, p. 1). Organizational documents, meeting notes, meeting schedules, and an annual reports of Task Force activities are maintained at a website. See www.srrttf.org.

[13] Task Force funding comes from NPDES permittee Task Force members and from Ecology. To date, the Task Force has spent approximately $1 million. Recently the Washington legislature appropriated $310K over two years to support continuation of the Task Force's work.

[14] The Task Force intends to conduct a similar data collection effort for wet weather conditions, but the high water necessary to collect such data did not occur in the 2014-2015 winter.

any PCBs in hydroseed will end up in the river. The Task Force is working collaboratively with manufacturers and State agencies to define construction specifications for hydroseed products and to inform the State purchasing process (Ecology, 2015). Hatchery fish food has also been identified as a potential source that readily enters the river. The Task Force's product testing efforts will continue to investigate this, as well as other potential sources of PCBs.

The Task Force has been active in political and policy arenas to encourage PCB restrictions, to address and reduce inadvertently generated PCBs, and to encourage preferential purchase of low- and no-PCB products for public use. The Task Force has also collaborated on public outreach activities to educate and engage the Spokane community on the risks of PCBs and the need to avoid activities that may release PCBs.

Washington enacted State legislation in 2014 that directed the Washington Department of Enterprise Services to "establish purchasing and procurement policies that provide a preference for products and products in packaging that does not contain polychlorinated biphenyls." RCW 39.26.280. The legislation also precluded other State agencies from knowingly purchasing "products or products in packaging containing polychlorinated biphenyls above the practical quantification limit except when it is not cost-effective or technically feasible to do so." Id. This legislation was adopted, in part, as a result of Task Force efforts to discourage use of products containing PCBs.

In June of 2014, the City of Spokane enacted a similar municipal ordinance providing a preference in City purchases for products and products in packaging that do not contain PCBs.[15] Implementation of the municipal ordinance should not only reduce the introduction materials containing PCBs, but also facilitate the development of an economic market with reduced amounts of PCBs.

ii. Further Work of the Task Force

The Task Force is into its third year of a phased five-year workplan (Task Force, 2013). Under the work plan, Phase 3 (analysis of data and characterization / quantification of PCB sources) and Phase 4 (assessment of potential BMPs) are scheduled for completion by December 2016. The Task Force anticipates a delay in completion of Phase 3 because this past winter wasn't wet enough to allow it to complete wet weather sampling. Completion of Phase 3, including the identification of locations with the highest PCB concentrations, should enable closure of one of the data gaps previously identified as the highest priority--source identification.

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[15] The ordinance provides as follows: Specifically, the ordinance provides that:

> No department may knowingly purchase products or products in packaging containing polychlorinated biphenyls above the practical quantification limit except when it is not cost-effective or technically feasible to do so. "Practical quantification limit" means the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, or using EPA Method 1668. "Not cost effective" means compliance with this requirement would increase the purchase price of the product by at least twenty-five percent.

Remaining phases under the workplan will address developing an inventory of sources and sinks of PCBs and developing a comprehensive plan for reducing PCBs.

SCHEDULE

In response to the Court's March 16, 2015 Order, and following consultation with Ecology, EPA sets out below its schedule for achievement of benchmarks and triggers for TMDL initiation and completion. In submitting this schedule, EPA clarifies that it does not interpret its regulations at 40 C.F.R. 130.7(d)(1), which are referenced in the Court's order, to give EPA the authority to establish a legally enforceable schedule for either the Task Force or the State. EPA's regulation states in relevant part that "[s]chedules for submission of TMDLs shall be determined by the Regional Administrator and the State." The regulation speaks to the collaborative nature of the development of such schedules. However, it does not authorize EPA to establish a legally enforceable schedule for State submissions of TMDLs or for work by an independent task force. This interpretation is consistent with past EPA guidance that "EPA *will not take any action* on the [State] schedule …," and that "the schedule is intended *to help* the public and EPA to understand the state's priorities and *assist* in work planning."(EPA, 2005, p. 63 (emphasis added)). EPA has not relied on the referenced regulation as the basis for this schedule, but rather has developed this schedule for the State's initiation and completion of a PCB TMDL in response to the Court's remand instructions.

1. December 31, 2016: The Task Force completes a Comprehensive Plan to bring the Spokane River into compliance with applicable water quality standards for PCBs. The comprehensive plan should include the following:

    a. A summary of the available data for PCBs in Spokane River water, fish tissue, and sediments.
    b. A list of the identified sources of PCBs in the Spokane River with estimates of current loadings.
    c. A range of BMPs expected to reduce or eliminate PCBs for each source or category of sources.
    d. Recommendations for BMP implementation.
    e. Recommendations for future studies to address remaining data gaps.

    If the Task Force does not submit a final Comprehensive Plan or if in EPA's determination the Comprehensive Plan does not adequately address the items listed above, then Ecology would immediately initiate development of a PCB TMDL for impaired segments of the Spokane River, and such TMDL would be submitted for EPA's approval by July 15, 2019.

2. December 15, 2020: Instream concentration of PCBs meets 200 pg/L based on the annual central tendency of the preceding year. EPA issues a determination by July 15, 2021, after conferring with Ecology and the Spokane Tribe, whether the instream concentration of PCBs meets 200 pg/L. If EPA determines that instream concentrations exceed 200 pg/L, then Ecology would immediately initiate development of a PCB TMDL for impaired

segments of the Spokane River, and such TMDL would be submitted for EPA's approval by July 15, 2023.

3. December 15, 2024: Instream concentration of PCBs meets 170 pg/L based on the annual central tendency of the preceding year. EPA issues a determination by July 15, 2025, after conferring with Ecology and the Spokane Tribe, whether the instream concentration of PCBs meets 170 pg/L. If EPA determines that instream concentrations exceed 170 pg/L, then Ecology would immediately initiate development of a PCB TMDL for impaired segments of the Spokane River, and such TMDL would be submitted for EPA's approval by July 15, 2027.

4. December 15, 2027: The applicable water quality standards for PCBs are met and the Spokane River and adjacent segments are no longer included on Washington's 303(d) list of impaired waters. EPA issues a determination by July 15, 2028, after conferring with Ecology and the Spokane Tribe, whether the waters meet the applicable water quality standards. If EPA determines that applicable water quality standards are not met or if the Spokane River and adjacent segments remain on Washington's 303(d) list of impaired waters, then Ecology would immediately initiate development of a PCB TMDL for impaired segments of the Spokane River, and such TMDL would be submitted for EPA's approval by July 15, 2030.

Under this schedule, a TMDL could be completed as early as July 2019 or as late as July 2030. Initiation of a TMDL can only be delayed as long as successive reductions of instream concentrations of PCBs are occurring consistent with the schedule.

In this Plan for Addressing PCBs in the Spokane River, EPA has described a complex array of factors that will affect PCB concentrations. The schedule does not contemplate immediate initiation of a TMDL because, in EPA's judgment, developing the TMDL at a later date is justified by the reductions that will occur and the data that will be gathered, as well as the likely changes to relevant water quality standards.

Perhaps most importantly, this schedule allows time to implement the advanced solids removal that is already required of the municipal wastewater treatment plants and the industrial dischargers to the Spokane. This treatment technology will reduce both phosphorus and PCBs discharged to the river. The permits contain compliance schedules, and all the facilities must be in compliance with their permit limits by the end of 2024. However, it takes time for instream and fish tissue concentrations to respond to decreases in loading, and it takes time for Ecology and the Task Force to conduct and analyze the monitoring data that is expected to describe the new share of the load attributable to point sources. Because this data is extremely relevant to the development of a TMDL, EPA has allowed three additional years beyond the conclusion of the last of the compliance schedules before making a determination about attainment of applicable standards. This will ensure that the water quality data reflect the dischargers' use of the new treatment technology.

In addition to providing time for the benefits of advanced treatment to be realized, the schedule also recognizes that it is very likely that applicable water quality standards will change. Although changes are expected, at this juncture it is very difficult to predict what the new standards will be or when they will be adopted. Washington has not proposed to modify its PCB criterion, but it has proposed to adopt a narrative water quality standard that would require that water quality in Washington will not contribute to violations of downstream water quality standards. Should this proposal be adopted, the Spokane tribal standard is a downstream standard that Washington would be required to protect. Such a change in standards would have significant implications for any TMDL that would be developed for PCBs in the Spokane watershed. The uncertainty about the relevant future standards, especially since they may be more protective than the current standards, provides another reason for not initiating a TMDL immediately.

EPA is also mindful that the work currently being performed by the Task Force provides immediate significant benefits that would not be realized should the Task Force cease functioning. Participation in the Task Force is required by current NPDES permits, but neither EPA nor Ecology can require particular work products. The Task Force, on its own initiative, is providing extensive data collection and analysis, conducting product testing, pushing for progress on preferential purchasing and reduction of inadvertently generated PCBs, and identifying and addressing nonpoint sources. This last element is especially important because this is work that will likely not be done by any other party, public or private, if not done by the Task Force. The benefits from voluntary Task Force activities are worth preserving.

Not only would deferring the initiation of a PCB TMDL according to EPA's schedule ensure a better and more defensible TMDL that provides greater environment benefit, requiring such a PCB TMDL now will likely disrupt important progress now underway. Once a TMDL is completed, each affected point source will be responsible for achieving its own individual wasteload allocation. This will likely eliminate the incentive for Task Force members to continue to work together to address sources for which they are not responsible. Prior to TMDL development, however, the Task Force is making progress to seek out and remove diffuse sources of PCBs. The Task Force is also collecting and analyzing data that will be crucial to the development of a TMDL, such as the dry weather synoptic sampling that occurred in August 2014. It is unlikely that Ecology would have the resources to conduct similar data collection projects. This data is useful to the Task Force now, and it will be useful to Ecology should development of a TMDL be necessary.

In EPA's judgment, there are substantial benefits to be gained from postponing development of the TMDL as long as sufficient progress is being made during the interim. EPA believes that its schedule strikes an appropriate balance between achieving instream reductions in the short-term and providing time to allow a number of ongoing activities to conclude.

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EPA’s Plan for Addressing PCBs in the Spokane River

July 14, 2015

Appendix A

Map of the Spokane River Watershed from Lake Coeur d’Alene to the Nine Mile Dam

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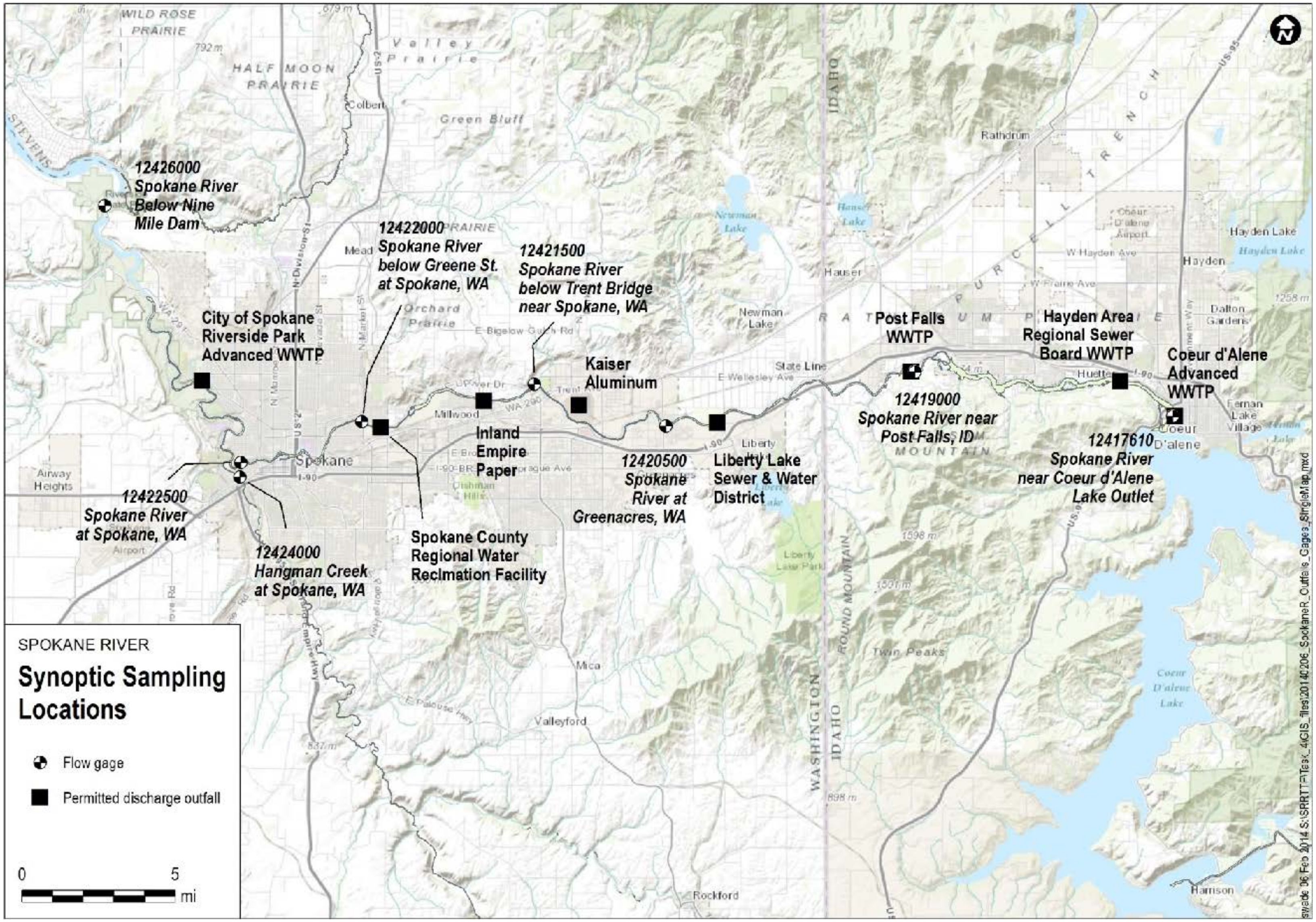
SPOKANE RIVER
Synoptic Sampling Locations
● Flow gage
■ Permitted discharge outfall
0
5
mi
12426000 Spokane River Below Nine Mile Dam
12422000 Spokane River below Greene St. at Spokane, WA
12421500 Spokane River below Trent Bridge near Spokane, WA
City of Spokane Riverside Park Advanced WWTP
Kaiser Aluminum
Inland Empire Paper
12420500 Spokane River at Greenacres, WA
Liberty Lake Sewer & Water District
Post Falls WWTP
12419000 Spokane River near Post Falls, ID
Hayden Area Regional Sewer Board WWTP
Coeur d'Alene Advanced WWTP
12417610 Spokane River near Coeur d'Alene Lake Outlet
12422500 Spokane River at Spokane, WA
12424000 Hangman Creek at Spokane, WA
Spokane County Regional Water Reclmation Facility
Spokane
Rathdrum
Hayden
Coeur d'Alene
Mica
Valleyford
Rockford
Harrison
WASHINGTON
IDAHO
Coeur d'Alene Lake
Hayden Lake
Newman Lake
Liberty Lake
Green Bluff
HALF MOON PRAIRIE
WILD ROSE PRAIRIE
Valley Prairie
Orchard Prairie
Airway Heights
Colbert
Mead
Millwood
Hauser
Twin Peaks
RATHDRUM PRAIRIE
PURCELL TRENCH
ROUND MOUNTAIN
Fernan Lake Village
Dalton Gardens
State Line
N

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EPA’s Plan for Addressing PCBs in the Spokane River

July 14, 2015

Appendix B

July 13, 2015, Letter from EPA to Ecology, re: NPDES Permitting Recommendations for the Spokane River

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF
WATER AND
WATERSHEDS

JUL 13 2015

Reply to
Attn of: OWW-191

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. Jim Bellatty
Washington State Department of Ecology
4601 North Monroe Street
Spokane, WA 99205-1295

Re: NPDES Permitting Recommendations for the Spokane River Watershed

Dear Mr. Bellatty:

In response to the U.S. District Court order in *Sierra Club et al. v. McLerran*, No. 11-CV-1759-BJR, the EPA is making the enclosed permitting recommendations to the Washington State Department of Ecology (Ecology). These recommendations are specific to National Pollutant Discharge Elimination System (NPDES) permits for point sources discharging to the Spokane River in Washington (water resource inventory areas—WRIAs—54 and 57), the Little Spokane River (WRIA 55). Except for recommendations specific to certain dischargers in the State of Washington, these recommendations are also applicable to EPA Region 10's direct implementation NPDES permitting for discharges to the Spokane River in Idaho (hydrologic unit code 17010305) and on the Spokane Indian Reservation.

Although the EPA encourages Ecology to consider and as appropriate accept the enclosed recommendations, they are not binding. The goal of these recommendations is to help Ecology establish enforceable and defensible permit conditions that can reasonably be expected to result in reductions in polychlorinated biphenyl (PCB) loading to the Spokane River and the Little Spokane River from regulated point sources. The EPA encourages Ecology to establish permit conditions to further that goal, even if they are different from the enclosed recommendations.

If you have any questions about the enclosed recommendations, please contact Brian Nickel of my staff at 206-553-6251 or Nickel.Brian@epa.gov.

Sincerely,

Michael J. Lidgard
Manager, NPDES Permits Unit

cc: Mr. Daniel Redline, Regional Administrator, Idaho Department of Environmental Quality Coeur d'Alene Regional Office

July 13, 2015

Permitting Recommendations for the Spokane River Watershed

Introduction

In response to the U.S. District Court order in Sierra Club et al. v. McLerran, No. 11-CV-1759-BJR, the EPA is making the following permitting recommendations. These recommendations are specific to National Pollutant Discharge Elimination System (NPDES) permits for point sources discharging to the Spokane River in Idaho (hydrologic unit code 17010305) and Washington (water resource inventory areas—WRIAs—54 and 57, including waters of the Spokane Tribe of Indians) and the Little Spokane River in Washington (WRIA 55).

Although the EPA encourages Ecology and the permitting authority for Idaho and the Spokane Tribe of Indians (currently EPA Region 10) to consider and as appropriate accept these recommendations, these recommendations are not binding. The goal of these recommendations is to help the permitting authorities establish enforceable and defensible permit conditions that can reasonably be expected to result in reductions in polychlorinated biphenyl (PCB) loading to the Spokane River and the Little Spokane River from regulated point sources. The EPA encourages permitting authorities to establish permit conditions to further that goal, even if they are different from the conditions recommended herein. This document is not legally enforceable; it does not confer rights or impose obligations on any party, including EPA, States or the regulated community.

Rationale for Recommending a BMP Approach to PCB Control

In general, the EPA is currently recommending a best management practices (BMP) approach to controlling and abating discharges of PCBs from point sources in the Spokane watershed. As explained below, the EPA believes this approach will be more effective in reducing discharges of PCBs than numeric effluent limits. The authority to establish BMP conditions in NPDES permits is provided in 40 CFR 122.44(k).

Limitations of Approved Analytical Methods for PCBs

Federal regulations require NPDES permits to include requirements to monitor discharges according to procedures approved under 40 CFR Part 136, unless another method is required by 40 CFR subchapters N or O (i.e. pretreatment requirements, effluent limit guidelines, or sewage sludge requirements).[1] For pollutants without approved analytical methods, the permitting authority shall specify in the permits the test procedure(s) to be used.[2]

The PCB water quality criteria for the States of Idaho and Washington and the Spokane Tribe of Indians are expressed as total PCBs, which is the sum of all congener, isomer, homolog, or aroclor analyses.[3]

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[1] 40 CFR 122.41(j)(4), 122.44(i)(1)(iv)

[2] 40 CFR 122.44(i)(1)(iv)

[3] See footnote q to 40 CFR 131.36(b)(1) and footnote o to IDAPA 58.01.02.210.01. See also: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#hhtable

Thus, any water quality-based effluent limit (WQBEL) for PCBs must also be expressed as total PCBs.[4] The approved analytical methods for PCBs can only measure PCB aroclors (i.e., the mixtures of PCBs that were sold commercially[5]). Because total PCBs may be measured as the sum of aroclor analyses, the approved methods can be used for total PCBs and therefore must be used to determine compliance with WQBELs for total PCBs.[6]

Of the methods approved for national use under 40 CFR 136, the most sensitive (EPA Method 608) can quantify PCB aroclors at concentrations of about 0.5 µg/L (500,000 pg/L) or greater, which is about 3,000 times Washington's PCB criterion (170 pg/L) and about 385,000 times the Spokane Tribe's PCB criterion (1.3 pg/L). Thus, any numeric WQBEL for PCBs for a point source to the Spokane River is likely to be orders of magnitude lower than the concentrations quantifiable by approved analytical methods.

If a WQBEL is below the detection limit, EPA guidance recommends that the permit include the actual limit and a requirement for the specific method to be used for monitoring. The permit should also state that any sample analyzed using the specified method and found to be below the minimum level will be deemed compliant with the limit.[7,8] Thus, WQBELs for total PCBs, which would need to be enforced using the approved methods, would, in effect, allow discharges of total PCBs many thousands of times greater than criteria. Because actual discharges from Spokane River point sources have been orders of magnitude below the quantification limits of the approved methods, such methods would provide no quantitative data on the actual loading of PCBs from point sources, no incentive for point sources to reduce discharges, nor any means to determine whether the discharges are increasing or decreasing.

Basis for Requirements to Analyze PCB Congeners in Support of BMPs

When establishing monitoring requirements for PCBs in order to assess the effectiveness of BMPs, EPA recommends that the permit authority require analysis of PCB congeners, because this aids in source identification, which will, in turn, aid in source control.[9] There are no approved methods for PCB congeners (as distinct from aroclors). As explained above, for pollutants without approved methods, such as PCB congeners, the permitting authority shall specify the test procedure(s) to be used; thus, permitting authorities have the flexibility to require the use of EPA Method 1668C for monitoring of PCB congeners.

Monitoring requirements for PCB congeners using Method 1668C can provide quantitative data about the actual PCB loading from point sources. This represents a significant advantage over numeric WQBELs for total PCBs, which, as explained above, currently must be enforced using the far less sensitive approved analytical methods. Therefore, the EPA is recommending that the permits continue to use a BMP approach to PCB control and require the use of EPA method 1668C for monitoring of final effluents for PCB congeners, instead of establishing numeric WQBELs enforced using methods approved under 40 CFR Part 136.

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[4] 40 CFR 122.44(d)(1)(iii)

[5] http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/aroclor.htm

[6] 40 CFR 122.44(i)(1)(iv)

[7] *Technical Support Document for Water Quality-based Toxics Control* (EPA/505/2-90-001, March 1991) Section 5.7.3.

[8] 40 CFR 136 Appendix A

[9] http://srrttf.org/wp-content/uploads/2014/10/2015-Spokane-PCBs-1.pdf

Even if the permitting authority determines that it is appropriate to include numeric WQBELs for PCBs to be enforced using methods approved under 40 CFR 136 in one or more of the subject permits, the EPA nonetheless recommends that the permitting authority include the following BMP requirements and monitoring for PCB congeners using EPA method 1668C in addition to any such numeric WQBELs.

1 General Recommendations for All POTWs Discharging to the Spokane River in Idaho and Washington, Kaiser Aluminum (permit #WA0000892), and Inland Empire Paper (permit #WA0000825)

The EPA recommends that:

- The permits should require monitoring of final effluents for PCB congeners using EPA Method 1668C at least quarterly.
- When establishing requirements for toxics management plans (TMP) or best management practices (BMP) plans, the permitting authority should consider the assessment by the Spokane River Regional Toxics Task Force ("Task Force") of the optimal mix of BMPs applicable to the permitted source.[10]
- The permits should require an annual report of PCB monitoring results and activities that have been completed or that have been ongoing in the past twelve months, pursuant to the TMP or BMP plan. The annual report should include:
    - A summary of effluent PCB data and any other PCB data relevant to the discharge (e.g., raw sewage, biosolids, pretreatment, or internal monitoring locations) collected over the previous twelve months.
    - A comparison of effluent PCB data collected over the previous twelve months to older effluent data.
    - An estimate of the reduction in PCB loading or concentration achieved through TMP or BMP plan activities during the previous twelve months.
    - Additional TMP or BMP plan activities planned for the following twelve months.
- The permits should require an update to the TMP or BMP plan if the permitting authority determines, based on the annual reports and other available information, that the TMP or BMP plan will not likely reduce PCB discharges to the maximum extent practicable.
- The permits should require reporting of total concentration of "dioxin-like" PCB congeners on DMRs.[11]
- The permits should require the complete congener analyses to be submitted as attachments to the DMRs.
- The permits should require receiving water monitoring for PCB congeners upstream and downstream of the outfalls using EPA Method 1668C at a frequency adequate to assess both high and low river flow conditions.

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[10] The assessment of BMPs is Task 2 of Phase 4 of the Task Force's Technical Consultant Work Plan and is scheduled to be completed by September 2016.

[11] The dioxin-like PCB congeners are IUPAC numbers 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189.

1.1 Specific Recommendations for POTWs

1.1.1 All POTWs

The EPA recommends that:

- The permits should require operation of tertiary filtration (once completed) year-round.[12]
- Prior to completion and optimization of tertiary filtration, the permits should include BMP requirement(s) to minimize discharges of TSS.[13]
- The permits should prohibit the POTW from authorizing discharges of PCBs to the treatment works unless the PCB concentration is <3 µg/L or unless the discharge is in accordance with a PCB discharge limit included in a pretreatment permit issued under §307(b) of the Clean Water Act.[14]

1.1.2 Pretreatment POTWs Only

The EPA recommends that:

- The permits should require sampling of all significant industrial users' (SIU) discharges for PCB aroclors using the most sensitive method approved under 40 CFR Part 136. All PCB aroclor results above the method detection limit (MDL) should be reported to the POTW and to the approval authority.
  - For any SIU where PCB aroclors are detected using approved methods, follow-up monitoring for PCB congeners using EPA Method 1668C should be performed at least once.
  - The POTW should use the results of the required monitoring of SIUs and any other available information to estimate the combined loading of total PCBs to the POTW from all SIUs.
  - If the POTW estimates that the combined loading of total PCBs to the POTW from all SIUs is at least ten percent of the influent total PCB loading to the POTW, the POTW should either develop numeric local limits for total PCBs or require SIUs to implement BMPs[15] to reduce discharges of total PCBs to the POTW.

1.2 Specific Recommendations for Industrial Individual Permits (Kaiser Aluminum and Inland Empire Paper)

The EPA recommends that:

- Ecology should analyze available effluent TSS and PCB data to determine if effluent TSS and PCB concentrations are positively correlated.

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[12] Phosphorus limits necessary to meet dissolved oxygen criteria will require operation of tertiary filtration (i.e., advanced solids removal) to meet effluent limits for phosphorus for eight to nine months of the year. This will reduce total suspended solids (TSS) loading, and, in turn, PCBs. Operating this kind of treatment year-round (even when not necessary to meet phosphorus limits) will further reduce TSS and PCBs on an annual basis. BMPs can include "treatment requirements" (40 CFR 122.2).

[13] PCB removal in POTWs is correlated with TSS removal. BMPs may be required when "the practices are reasonably necessary…to carry out the purposes and intent of the CWA" (40 CFR 122.44(k)(4).

[14] 40 CFR 761.50(a)(3)

[15] Local limits may be BMPs instead of numeric limits (40 CFR 403.5(c)(4)).

- If effluent TSS and PCB concentrations are determined to be positively correlated, Ecology should establish all known, available and reasonable treatment (AKART) or performance-based effluent limits for TSS. AKART or performance-based TSS limits should be re-evaluated following completion and optimization of tertiary filtration.
- The permits should require the permittee to address water conservation in its BMP plan.

1.2.1 Specific Recommendations Kaiser Aluminum

- The permit should require separate monitoring of the groundwater remediation discharge (if any) and the effluent from the black walnut shell filters for PCB congeners using EPA Method 1668C.

2 Recommendations for Fish Hatcheries in WRIAs 54, 55, and 57

The EPA recommends that:

- The permits should require monitoring of effluents for PCB congeners using EPA Method 1668C at a frequency adequate to assess sources of PCBs within the facility.
- The permits should require reporting of the total concentration of "dioxin-like" PCB congeners on DMRs.
- The permits should require the complete congener analysis to be submitted as an attachment to the DMR.
- The permits should require that the facilities' pollution prevention plans or BMP plans address PCBs from caulk, paint, and feed.
    - The permits should require removal of paint or caulk that contacts process water and that was applied prior to January 1, 1980.
        - During removal, permittees should implement PCB abatement and disposal consistent with EPA guidance.[16]
        - Permits should require BMPs to prevent removed PCB-containing paint or caulk from reaching waters of the United States and to ensure that disposal of such materials is performed in compliance with applicable state, federal, and local laws.
    - The permits should require the permittee to use any available product testing data to preferentially purchase paint and caulk with the lowest practicable total PCB concentrations.
- Recommendations for general NPDES permits may be incorporated into the permits themselves or into administrative orders, as appropriate.

3 General Recommendations for Stormwater Permits

The EPA recommends that:

- The permits, except construction stormwater permits, should require monitoring for PCBs at frequencies and locations adequate to assess and identify sources of PCBs to stormwater.
    - In general, for water sampling, the permits should require monitoring for PCB congeners using EPA Method 1668C. For monitoring of locations or waste streams that the

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[16] http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/caulk/guide/guide-sect4.htm

permitting authority determines can be adequately characterized using less sensitive methods (e.g., EPA Method 608 or 8082), such methods may be used at such locations.

- For any monitoring of PCB congeners in final effluent, the permits should require reporting of the total concentration of "dioxin-like" PCB congeners on DMRs.
- For any monitoring of PCB congeners in final effluent, the permits should require the complete congener analysis to be submitted as an attachment to the DMR.
- When updating stormwater pollution prevention plan or stormwater management plan (SWPPP or SWMP) requirements in permits, the permitting authority should consider the Task Force's assessment of the optimal mix of BMPs applicable to the permitted sources.
- Recommendations for general NPDES permits may be incorporated into the permits themselves or into administrative orders, as appropriate.

3.1 Specific Recommendations for Areas of Permitted MS4s Contributing to Surface Water Discharges to the Spokane River or the Little Spokane River'

The EPA recommends that:

- In addition to the general stormwater monitoring recommendations above, the permits should require monitoring for PCBs in sediment traps, catch basins, and in stormwater suspended particulate matter (SSPM) at frequencies and locations adequate to assess and identify sources of PCBs to municipal stormwater.
  - For monitoring of PCBs in solids, the permits should require a quantitation level for total PCBs no greater than 10 µg/kg dry weight.
- The permits should require all BMPs related to reducing or eliminating PCBs in stormwater to be prioritized in areas of the MS4 more likely to contribute PCBs to surface waters, based on any available information, including but not limited to the following:
  - Previous and ongoing PCB monitoring.
  - Nearby toxics cleanup sites with PCBs as a known contaminant.
  - Business inspections and compliance records.
- The permits should require removal of accumulated solids from drain lines (including inlets, catch basins, sumps, conveyance lines, and oil/water separators) in priority areas of the MS4 at least once during the permit cycle, unless the permittee can demonstrate that such removal is not necessary to reduce discharges of PCBs from stormwater.
- The permits should require removal of any identified legacy PCB sources within the MS4 (e.g., PCB-containing sealant) as soon as practicable.
- The permits should require preferential purchasing by the permittee of products with the lowest practicable PCB concentrations for products likely to contain inadvertently generated PCBs and to contact municipal stormwater, including but not limited to the following:
  - Hydroseed
  - Dust suppressants
  - Traffic marking paint
  - Deicer
- The permits should allow permittees to comply with PCB source control requirements through a collaborative effort.

- The permits should include the following requirements for new development and redevelopment disturbing one acre or more:
    - Site design to minimize impervious areas, preserve vegetation, and preserve natural drainage systems.
    - On-site stormwater management.

3.1.1 Specific Recommendations for Cities and Counties with MS4 Permits

The EPA recommends that:

- The permits should require the following, for construction projects requiring a building permit from the permittee that do **not** require an NPDES permit for construction stormwater:
    - During demolition of any structure with at least 10,000 square feet of floor space and built before January 1, 1980, the permittee should require the building permit applicant to implement BMPs to achieve the following:
        - Prevent removed PCB-containing building materials, including paint, caulk, and pre-1980 fluorescent lighting fixtures,[17] from contacting municipal stormwater or otherwise reaching waters of the United States; and
        - Ensure that disposal of such materials is performed in compliance with applicable state, federal, and local laws.
- The permits should address possible contributions of PCBs to the MS4 from businesses within the areas served by the MS4 as follows:
    - The permits should require the establishment and maintenance of a database of inspections and status of compliance with applicable State and federal laws and local ordinance related to PCBs in stormwater, for businesses within the area served by the MS4.
    - Based on the information in the database and other available information, the permits should require the permittees to identify businesses that are likely to contribute PCBs to the MS4 and to follow up with such businesses and appropriate regulatory agencies to develop and implement BMPs to reduce contributions of PCBs to the MS4 from such businesses.

3.1.2 Specific Recommendations for Idaho MS4 Permits

The EPA recommends that:

- The permitting authority should issue a Clean Water Act §308 letter requiring monitoring for PCBs at frequencies and locations adequate to assess and identify sources of PCBs to stormwater, unless final permits including such monitoring requirements are issued by July 1, 2016.
    - In general, the permits should require monitoring for PCB congeners using EPA Method 1668C. For monitoring of locations or waste streams that the permitting authority determines can be adequately characterized using less sensitive methods (e.g., EPA Method 608 or 8082), such methods may be used at such locations.

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[17] http://www.epa.gov/solidwaste/hazard/tsd/pcbs/pubs/ballasts.htm

3.2 Specific Recommendations for Industrial Stormwater Permits

The EPA recommends that:

- The permits should require removal of accumulated solids from storm drain lines (including inlets, catch basins, sumps, conveyance lines, and oil/water separators) within the facility at least once during the permit cycle, unless the permittee can demonstrate that such removal is not necessary to reduce discharges of PCBs from stormwater.
- The permits should require removal of any identified legacy PCB sources within the facility's storm drain lines (e.g. PCB-containing sealant) as soon as practicable.
- If hydroseed is used for erosion and sediment control, the permittee should use any available product testing data to preferentially purchase hydroseed with the lowest practicable total PCB concentration.[18]
- If dust suppressants other than water are used (e.g., on unimproved roads), the permittee should use any available product testing data to preferentially purchase dust suppressants with the lowest practicable total PCB concentration.[19]

3.3 Specific Recommendations for Construction Stormwater Permits

The EPA recommends that:

- During demolition of any structure with at least 10,000 square feet of floor space and built before January 1, 1980, the permits should require the permittee to implement BMPs to achieve the following:
  - Prevent PCB-containing building materials, including paint, caulk, and pre-1980 fluorescent lighting fixtures, from contacting stormwater or otherwise reaching waters of the United States; and
  - Ensure that disposal of such materials is performed in compliance with applicable state, federal and local laws.
- If dust suppressants other than water are used, the permittee should use any available product testing data to preferentially purchase dust suppressants with the lowest practicable total PCB concentration.
- If hydroseed is used, the permittee should use any available product testing data to preferentially purchase hydroseed with the lowest practicable total PCB concentration.

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[18] The Task Force is investigating PCBs in hydroseed. Product testing by the City of Spokane showed PCB concentrations of about 2.5 ppm in hydroseed.

[19] The City of Spokane's product testing found concentrations ranging from 0.09 – 3.6 ppb (i.e., a two-order-of-magnitude range).

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
1985

FEDERAL REGISTER

Vol. 77 Monday,
No. 93 May 14, 2012

Part V

The President

Executive Order 13610—Identifying and Reducing Regulatory Burdens

Federal Register
Vol. 77, No. 93
Monday, May 14, 2012

Presidential Documents

Title 3—

The President

Executive Order 13610 of May 10, 2012

Identifying and Reducing Regulatory Burdens

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to modernize our regulatory system and to reduce unjustified regulatory burdens and costs, it is hereby ordered as follows:

Section 1. *Policy.* Regulations play an indispensable role in protecting public health, welfare, safety, and our environment, but they can also impose significant burdens and costs. During challenging economic times, we should be especially careful not to impose unjustified regulatory requirements. For this reason, it is particularly important for agencies to conduct retrospective analyses of existing rules to examine whether they remain justified and whether they should be modified or streamlined in light of changed circumstances, including the rise of new technologies.

Executive Order 13563 of January 18, 2011 (Improving Regulation and Regulatory Review), states that our regulatory system ‘‘must measure, and seek to improve, the actual results of regulatory requirements.’’ To promote this goal, that Executive Order requires agencies not merely to conduct a single exercise, but to engage in ‘‘periodic review of existing significant regulations.’’ Pursuant to section 6(b) of that Executive Order, agencies are required to develop retrospective review plans to review existing significant regulations in order to ‘‘determine whether any such regulations should be modified, streamlined, expanded, or repealed.’’ The purpose of this requirement is to ‘‘make the agency's regulatory program more effective or less burdensome in achieving the regulatory objectives.’’

In response to Executive Order 13563, agencies have developed and made available for public comment retrospective review plans that identify over five hundred initiatives. A small fraction of those initiatives, already finalized or formally proposed to the public, are anticipated to eliminate billions of dollars in regulatory costs and tens of millions of hours in annual paperwork burdens. Significantly larger savings are anticipated as the plans are implemented and as action is taken on additional initiatives.

As a matter of longstanding practice and to satisfy statutory obligations, many agencies engaged in periodic review of existing regulations prior to the issuance of Executive Order 13563. But further steps should be taken, consistent with law, agency resources, and regulatory priorities, to promote public participation in retrospective review, to modernize our regulatory system, and to institutionalize regular assessment of significant regulations.

Sec. 2. *Public Participation in Retrospective Review.* Members of the public, including those directly and indirectly affected by regulations, as well as State, local, and tribal governments, have important information about the actual effects of existing regulations. For this reason, and consistent with Executive Order 13563, agencies shall invite, on a regular basis (to be determined by the agency head in consultation with the Office of Information and Regulatory Affairs (OIRA)), public suggestions about regulations in need of retrospective review and about appropriate modifications to such regulations. To promote an open exchange of information, retrospective analyses of regulations, including supporting data, shall be released to the public online wherever practicable.

Sec. 3. *Setting Priorities.* In implementing and improving their retrospective review plans, and in considering retrospective review suggestions from the public, agencies shall give priority, consistent with law, to those initiatives that will produce significant quantifiable monetary savings or significant quantifiable reductions in paperwork burdens while protecting public health, welfare, safety, and our environment. To the extent practicable and permitted by law, agencies shall also give special consideration to initiatives that would reduce unjustified regulatory burdens or simplify or harmonize regulatory requirements imposed on small businesses. Consistent with Executive Order 13563 and Executive Order 12866 of September 30, 1993 (Regulatory Planning and Review), agencies shall give consideration to the cumulative effects of their own regulations, including cumulative burdens, and shall to the extent practicable and consistent with law give priority to reforms that would make significant progress in reducing those burdens while protecting public health, welfare, safety, and our environment.

Sec. 4. *Accountability.* Agencies shall regularly report on the status of their retrospective review efforts to OIRA. Agency reports should describe progress, anticipated accomplishments, and proposed timelines for relevant actions, with an emphasis on the priorities described in section 3 of this order. Agencies shall submit draft reports to OIRA on September 10, 2012, and on the second Monday of January and July for each year thereafter, unless directed otherwise through subsequent guidance from OIRA. Agencies shall make final reports available to the public within a reasonable period (not to exceed three weeks from the date of submission of draft reports to OIRA).

Sec. 5. *General Provisions.* (a) For purposes of this order, ‘‘agency’’ means any authority of the United States that is an ‘‘agency’’ under 44 U.S.C. 3502(1), other than those considered to be independent regulatory agencies, as defined in 44 U.S.C. 3502(5).

(b) Nothing in this order shall be construed to impair or otherwise affect:

(i) the authority granted by law to a department or agency, or the head thereof; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(c) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(d) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

THE WHITE HOUSE,
May 10, 2012.

[FR Doc. 2012–11798
Filed 5–11–12; 11:15 am]
Billing code 3295–F2–P

Regulatory Toxicology and Pharmacology **35**, 209–216 (2002)
doi:10.1006/rtph.2002.1534, available online at http://www.idealibrary.com on IDEAL®

Extending the Threshold of Regulation Concept: *De Minimis* Limits for Carcinogens and Mutagens

Janice M. Fiori and Roger D. Meyerhoff

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Received June 8, 2001; published online March 28, 2002

Risk assessment processes for carcinogens are highly developed but risk assessment processes for mutagens are not well established. In the pharmaceutical industry, risk associated with exposure to carcinogens is tightly controlled. It is desirable to control risk associated with exposure to mutagens also, in spite of the greater uncertainty associated with the risk. In this paper, a published cancer potency database is used to frame the risk and to support risk management decisions. A *de minimis* exposure for mutagens is proposed and a decision matrix is presented to align available data with risk assessment approaches for carcinogens and mutagens.

***Key Words*: safety evaluation; mutagens; *de minimis*; carcinogens; risk assessment.**

INTRODUCTION

In the pharmaceutical industry, solvents, raw materials, intermediates, and contaminants in a synthetic route process are occasionally found to be carcinogens and/or mutagens. Risk assessments are conducted to ensure worker and product safety following guidelines from FDA, ICH, OSHA, and other regulatory groups.

From a regulatory perspective, carcinogens have historically been characterized using a linearized multistaged model. Inherent in this model is the notion that there is no threshold for cancer incidence. Therefore, it is impossible using the model to determine a dose without some calculated risk. The challenge for risk assessors is to determine a *de minimis* or threshold limit below which risk of cancer is negligible. This determination can be quite simple for a chemical with a wealth of carcinogenicity data, but can be complex for a chemical with a limited carcinogenicity dataset or for a chemical only found to be a mutagen. A quantitative risk assessment process has been developed to allow risk assessors to set limits for carcinogens and mutagens. This comprehensive approach is based on the practice supporting the threshold of regulation for indirect food additives, is consistent with methods used for drinking water standards, and incorporates a hierarchy of approaches. The result of this risk assessment process is a numerical value that can be translated into a *de minimis* daily exposure, an analytical detection level, or a cleaning limit for manufacturing equipment at which risk of cancer is negligible.

RISK ASSESSMENT PROCESSES FOR CARCINOGENS

Methods for assessing the potency of carcinogens and risk assessment tools to determine risk have been developed and the pros and cons of each have been debated. The linearized multistage model (LMS) has become the standard among regulatory groups to calculate the cancer slope factor as a measure of potency. In 1980, EPA began using the linearized multistage model to extrapolate from the dose–response curve to estimate upper-bound risks for very low doses used in setting drinking water standards (Anderson, 1983). FDA does not restrict analysis to a specific model, as long as the goal of an adequate fit to the data is achieved (Gaylor *et al.*, 1997). WHO predominantly used the linearized multistage model in calculating carcinogenic risk when developing guidelines for drinking water quality. For carcinogens for which there is convincing evidence to suggest a nongenotoxic mechanism, guideline values were calculated using a tolerable daily intake approach assuming a threshold (WHO, 1996). Recent draft guidelines for carcinogen risk assessment proposed by EPA (1996) discuss the use of a nonlinear model if the mechanism of carcinogenicity has a threshold mode of action that can be defined. This would allow for an approach using the NOEL/safety factor or benchmark-dose/safety factor method in determining an allowable exposure. Extensive study is required for an evaluation of mode of action. However, mode of action data, if available, allow matching of mathematical assumptions with the biological behavior and avoid overly conservative limits. The data requirement to conduct a linear multistage model analysis is also high.

Mathematical analyses have led to a characterization of carcinogens as a group. Correlations have been reported which allow for an estimation of potency when the data set is not optimal. Correlations using the TD_{50} and maximum tolerated dose (MTD) have been described. We have assembled these approaches into a continuum and extrapolated the process to apply not only to carcinogens, but also to mutagens, using concepts underlying threshold of regulation. By assembling all the available methods into a continuum, the method that matches the available data set is easily identified. The resulting decision matrix is a flexible tool to calculate a numerical exposure limit.

Currently, there is no quantitative method to incorporate mutagenicity data into a risk assessment. Rather, discussion of the mutagenicity data is part of the qualitative risk assessment. The EPA guideline for mutagenicity risk assessment (EPA, 1984) focuses on germ cells and heritable genetic risk. It does not discuss somatic cell mutation and cancer risk. Although very conservative, mutagens can be evaluated in the same risk paradigm as carcinogens by assuming mutagens have the potential to be carcinogens. This allows for control of mutagens by a quantitative process.

REGULATORY PRECEDENTS FOR NEGLIGIBLE CARCINOGENIC RISK

Acceptable risk is a concept that is required because of the adoption of the no threshold theory of carcinogenicity. Setting the acceptable risk level is a risk management decision. Several regulatory agencies have set precedents for *de minimis* carcinogenic risk. When EPA sets an acceptable risk for the general population (as for drinking water standards), the upper bound risk level of one excess cancer per 1 million people (i.e., 10^{-6}) is used (EPA, 1991), that is, a lifetime risk over background of one excess cancer death per 1 million people exposed to an agent daily for 70 years. WHO uses 10^{-5} for drinking water standards (WHO, 1993). FDA, first acting under the DES proviso, set a policy of "essentially zero" risk at one excess cancer in 1 million (FDA, 1982). Additionally, the U.S. Supreme Court has affirmed the *de minimis* principle that "safe" does not mean zero risk (U.S. Supreme Court, 1980).

Numerous factors play a role in the determination of a *de minimis* risk including the characterization of the exposed population. The population EPA is protecting through drinking water standards can be characterized as a large general population unaware of the risks. A patient population taking pharmaceuticals is comparable to the population the EPA is protecting in the drinking water standards. A policy for residuals consistent with the regulatory precedents of a *de minimis* risk of 10^{-6} for carcinogens has been adopted for patient safety.

The Occupational Safety and Health Administration (OSHA) sets standards for safety in the workplace in the United States. Airborne workplace exposure limits for carcinogens are typically set at about a risk level of 1/1000 which has been affirmed in a court ruling. The population OSHA is protecting is smaller and more homogeneous than the general population. Additionally, workers generally are aware of occupational hazards. A *de minimis* risk for workplace exposure at no more than 1 in 1000 has been adopted for worker safety.

With these two values, namely, cancer potency slope factor (CPS) and *de minimis* risk, an exposure limit can be calculated. Using the reported slope factor value, the exposure associated with a risk can be calculated directly using the equation: *de minimis* risk level/slope factor = *de minimis* exposure level.

RISK ASSESSMENT PROCESS—CONCEPTUAL BASIS OF MODEL

Chemical exposures can occur from raw materials, manufactured intermediates, final products, or contaminants. The data set available for each of these chemicals is quite variable and may affect the process for the hazard evaluation. Purchased materials range from commodity chemicals which have been thoroughly studied to specialty chemicals with limited toxicity data. Similarly, the data for contaminants can vary substantially. Intermediates are typically novel chemicals with no published toxicity data and a small internal dataset. Final pharmaceuticals typically have a large toxicity database. The completeness of the data set often dictates the process used for the risk assessment. A flow chart has been developed which links the available carcinogenic data or mutagenic data to a hazard evaluation method (Fig. 1).

Carcinogen with a published or calculated slope factor. Many high-volume chemicals have been well characterized, and fully reported 2-year bioassays with highly analyzed data sets are available. For example, the EPA has evaluated chemicals with public exposure impact and has calculated cancer potency values based upon the linearized multistage model. EPA reports its cancer potency calculations in the IRIS database. Another source of such data is the California EPA, which also evaluates chemicals for carcinogenic potency and reports the results. Using the reported slope factor value, the exposure associated with a risk can be calculated directly using the equation: *de minimis* risk level/slope factor = *de minimis* exposure level. Alternatively, software is available to conduct the LMS if the data set is available.

Carcinogen with published or calculated TD_{50}. If a slope factor value is not available, methods are available for estimating the cancer potency value from published data tables. Gold *et al.* (1984) devised a statistic termed the TD_{50} as a method for comparing carcinogens. The TD_{50} is defined as the average daily dose estimated to halve the probability of remaining tumor-free at a specified tissue site throughout a 2-year study.

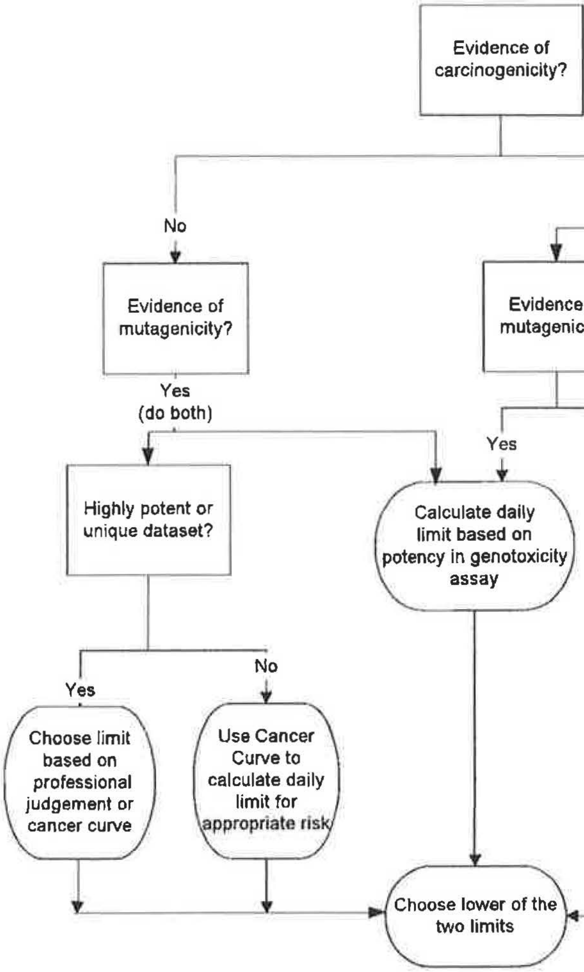

FIG. 1. Process flow diagram for risk assessment of carcinogens and mutagens.

A compilation of bioassays with a TD_{50} analysis has been published (Gold and Zeiger, 1997). Alternatively, if a complete bioassay data set is available for a given chemical, the TD_{50} can be calculated as outlined by Peto *et al.* (1984). From the TD_{50}, an estimate of the slope factor can be calculated based on the correlation reported by Gaylor and Gold (1995). Using summary data from 191 carcinogens, the relationship between the slope factor and the TD_{50} was derived. Mathematically, the slope factor $= 0.87/TD_{50}$.

Carcinogen with incomplete data (use MTD to estimate slope). Occasionally, there is no acceptable 2-year study for a chemical demonstrated to be a carcinogen. For example, the occurrence of tumors may have been reported, but tumor incidence data were incompletely or inadequately reported (e.g., lack of control data, inadequate numbers for valid statistical evaluation) to allow a conclusive analysis. Frequently, older studies do not meet current protocol standards, and the data do not fit the established models so that a slope factor cannot be calculated. In these cases, a slope factor can be estimated from a MTD based on the results of a 90-day study. The correlation is due in part to the convention of running bioassays at dose levels equal to the MTD and 1/2 MTD. Gaylor and Gold (1995) reported that the virtually safe dose (VSD), the dose associated with an excess cancer risk of 1 in 1 million, can be estimated by the relationship VSD = MTD/740,000. The result of this equation is estimated to be within a factor of 10 of the VSD that would be obtained from a rodent carcinogen based on a 2-year NCI/NTP chronic bioassay. The authors suggest that since cancer potency estimates from different experiments with the same chemical can also vary up to a factor of 10 from their geometric mean, there may be little loss in precision by estimating potency from a MTD.

Carcinogen with inadequate data to estimate slope factor from MTD. If there is evidence of carcinogenicity but the data are inadequate to calculate an estimated cancer potency value and there is no 90-day study from which to estimate a MTD, there is currently no accepted way to develop a chemical-specific potency.

In lieu of chemical-specific potency, methods based on carcinogens as a class can be used.

Rulis (1986) used this strategy to support the threshold of regulation concept for indirect food additives. The threshold of regulation established a *de minimis* level, an exposure considered to have negligible risk. To support a *de minimis* level, Rulis collected TD_{50} values and determined the risk-specific dose (RSD, the dose associated with a chosen level of risk, e.g., 10^{-6}) at a risk of 10^{-6} for a large group ($N = 343$) of animal carcinogens. He found, for example, that the RSD for 85% of the evaluated chemicals was an exposure of 0.15 μg/day.

A similar process is used here to develop a limit for carcinogens with unknown potency and for mutagens. The data set supporting threshold of regulation consisted of TD_{50} values for animal carcinogens chosen from the Gold and Zeiger database. The potency database was updated using the available summary table on the Carcinogenic Potency Project Web site. The summary table reports the most potent TD_{50} value for each species from a positive test or the harmonic mean of the lowest TD_{50} values from multiple tests on a single chemical. The lowest TD_{50} value for each of the 705 chemicals reported as positive by the study author was used in our assessment. If a TD_{50} was available for both rats and mice, the lower of the two was used. For each TD_{50}, the RSD associated with a 10^{-6} risk was calculated (see Appendix). A logistic curve was fit to the RSD values (Fig. 2) and is referred to as the cancer curve. From the model, a risk-specific dose associated with any chosen percentile can be calculated.

This process closely parallels that of Rulis. The final rule for indirect food additives (FDA, 1995) was based on a data set limited to 477 chemicals tested by the oral route only. For a broader application, our data set was not limited to oral carcinogens and includes data collected by the inhalation and parenteral routes. As predicted by Munro (1999), the distribution of potency in experimental animals is not significantly altered by addition of more chemicals. Nonetheless, the approximately 40% increase in the number of chemicals reported herein adds data points to the tails of the curve, thus increasing the confidence in the 90th and 95th percentiles. As in the Rulis approach, a linear extrapolation was used to derive risk-based doses from the TD_{50} values. The impact of the use of TD_{50} values and linear extrapolation methodology was evaluated in a workshop on the threshold of regulation value (Munro, 1990). It was again reviewed at the incorporation of the process into Joint Expert Committee on Food Additives's (JECFA) processes to evaluate flavoring substances (Munro, 1999). The results of the curve compared to previously examined datasets are presented in the appendix.

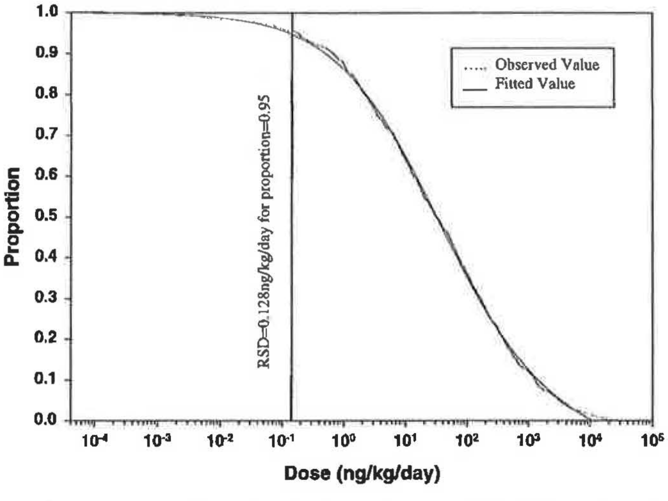

FIG. 2. Proportion of animal carcinogens ($N = 705$) with risk-specific (10^{-6}) daily dose. At the 95th percentile, the RSD is 0.128 ng/kg/day. Exposure at this level provides for 1 in 1 million excess cancer risk for 95% of the known animal carcinogens.

In the development of the threshold of regulation, Rulis originally proposed that the 85th percentile combined with a 20% probability of an untested chemical to be a carcinogen provided a *de minimis* risk of 95% probability of 1 in 1 million risk. In targeting the 95th percentile in the current strategy, no modifiers have been incorporated; 100% exposure and 100% probability of carcinogenicity are assumed. By choosing to limit exposure of a carcinogen to 95% on the cancer potency curve, the exposure will be protective at an established level of risk for 95% of the known carcinogens. At the 95th percentile, the RSD was 0.128 ng/kg/day or 9 ng/day for a 70-kg person (Fig. 2). At the RSD of 9 ng/day, there is a 95% probability of not exceeding a risk of 1 excess cancer in 1 million. The resulting exposure guideline, therefore, provides for negligible risk for all but the very most potent carcinogens with no slope factor or MTD.

No data for carcinogenicity; some data for mutagenicity. If there are no carcinogenicity data for a chemical, but results are positive in one or more primary mutagenicity tests (i.e., Ames, mouse lymphoma, mouse micronucleus test, *in vitro* or *in vivo* chromosome aberration assay, CHO/HGPRT, sister chromatid exchange assay, and unscheduled DNA synthesis assay), it may be assumed that the chemical has potential to be a carcinogen. A weight of evidence assessment is typically not used. Attempts to demonstrate an overall correlation between mutagenic potency and carcinogenic potency have yielded weak results (Fettermann *et al.*, 1997; McCann *et al.*, 1988; Piegorsch and Hoel, 1988; Hatch *et al.*, 1992). Without a measure of carcinogenic potency for a given chemical, the *de minimis* approach utilizing the cancer potency curve can be used to set a *de minimis* exposure for a mutagen.

In considering an appropriate risk level for mutagens, EPA guidance for drinking water standards for carcinogens was reviewed. Implementation of EPA standards results in detection limits associated with risk levels ranging from 10^{-6} to 10^{-4} (EPA, 1991). Following this guidance, mutagens of unknown carcinogenic potential can be controlled to a risk level of 10^{-5}, one additional cancer per 100,000 persons exposed. The cancer potency curve (adjusted for a *de minimis* risk level of 10^{-5}) shows that an exposure level of 90 ng/day (2300 μg/lifetime) will maintain a 10^{-5} risk level for 95% of the surveyed carcinogens. This limit was adopted as the *de minimis* limit for mutagens of unknown carcinogenic potency. This exposure is equal to about the 85th percentile at the 10^{-6} risk level.

The process also allows for scientific judgment to be applied in determining an appropriate risk level for mutagens. For example, a review of the genotoxicity data is conducted for unusual results or evidence that mutagenic potency is "high," suggesting that the default assumptions may not be applicable. Internal criteria may be developed to trigger a review of the risk level. On a case-by-case basis, it may be decided to control a specific chemical to a risk level of 10^{-6} ratherthan 10^{-5}.

RISK ASSESSMENT PROCESS—EXAMPLES OF APPLICATION

An illustration of the use of the flow chart and the effect on the allowable exposures is presented in Table 1. As data become available for a chemical, the allowable limit is revised. Once the chemical is identified as a mutagen (data set 1), the exposure is severely restricted, with a lifetime limit of 2300 μg (90 ng/day × 25,550 days in a 70-year lifetime). Evidence of carcinogenicity in animals further limits exposure to 10^{-6} risk with a lifetime limit of 230 μg in lieu of chemical-specific potency data (data set 2). From dose–response data, the cancer potency slope can be estimated/calculated (data set 3 and 4). For chemical A, the actual potency is not within the top 5% of the most potent carcinogens so the default limits are adequate, whereas chemical B is in the top 5% of most potent carcinogens and use of the default limits will overestimate the allowable exposure.

An example of how the process can be used for risk assessment is in setting a cleaning limit following the manufacture of a prototypic mutagenic anticancer drug. The registration package includes a genotoxicity battery and a 6-month rodent study. This compound is not acutely toxic. It is more toxic with daily repeated dosing than with intermittent dosing. Two of the four genotoxicity assays were positive, but no 2-year carcinogenicity study was conducted. Following the decision diagram, the data set can be described as positive mutagenicity with no carcinogenicity data. Therefore, the cleaning limit for the equipment will be set so that exposure to this chemical as a residual in the next drug to be manufactured will be limited to a risk of 10^{-5} at 95% of the curve or a total lifetime exposure of 2300 μg. Assuming that the second drug has a chronic daily dose of 100 mg and the potential of 35 years of therapy, exposure to the residue must be no more than 0.18 μg/day or 1.8 ppm as a residual in the second active ingredient. In this example, the limit is about 50 times lower than a normal default cleaning limit of 100 ppm. The cleaning limit will vary widely depending on dose and duration of the second product. An additional evaluation of the nonmutagenic/noncarcinogenic endpoints is also required in setting this cleaning limit. The lower limit is then adopted.

The daily limits proposed here for mutagens (90 ng/day) and carcinogens (9 ng/day) are lower than the 1.5 μg/day threshold of regulation limit currently used by FDA for indirect food additives. The FDA assumption of a 20% probability of the chemical being a carcinogen may no longer be appropriate once positive mutagenic findings are reported. This assumption is not included in the model presented here resulting in a more conservative limit. The method described here could provide an option for quantitatively framing the risk of a mutagenic indirect food additive.

TABLE 1
Limits of Exposure as a Result of the Application of the Decision Matrix

Chemical A	Data set 1	Data set 2	Data set 3	Data set 4
Mutagenicity	Positive	Positive	Positive	Positive
Carcinogenicity	No data	Unquantifiable evidence of carcinogenicity	$TD_{50} = 6.15$ est. CPS = 0.14	CPS = 4.5
Lifetime limit	2300 μg	230 μg	12.8 mg	0.4 mg
Chemical B	**Data set 1**	**Data set 2**	**Data set 3**	**Data set 4**
Mutagenicity	Positive	Positive	Positive	Positive
Carcinogenicity	No data	Unquantifiable evidence of carcinogenicity	$TD_{50} = 0.00357$ est. CPS = 244	CPS = 220
Lifetime limit	2300 μg	230 μg	7 μg	8 μg

DISTRIBUTION OF EXPOSURE BASED ON CANCER ENDPOINTS AND GENOTOXICITY ENDPOINTS

One of the underlying principles associated with the linear low-dose extrapolation methodology is that risk associated with a short duration of exposure can be distributed across the 70-year life span. That is to say, under the theory of the no-threshold mechanism, risk is associated with the total exposure and not the pattern of exposure. The total lifetime dose is, therefore, the appropriate number to use for *de minimis* exposure. If the anticipated exposure duration is less than lifetime, the lifetime dose can be redistributed over the period of exposure. Theoretically, a single once-in-a-lifetime dose of 2300 μg of a mutagen has an excess cancer risk of 10^{-5}. This methodology is adequate for assessing cancer risk. Another endpoint to consider, however, is mutagenicity itself.

It is necessary to prevent rolling up the lifetime exposure into an excessive dose in order to control risk of mutagenicity as its own endpoint. While a genotoxicity test result does not give information about the potency of the chemical as a carcinogen, it can often provide dose–response data on mutagenicity endpoints. In order to provide a margin of safety on genotoxicity endpoints, daily exposure is restricted to provide at least a 100-fold safety margin on a first effect level in genotoxicity assays.

The lower of the two limits, one based on carcinogenic endpoints using the cancer curve and one on genotoxic endpoints, is selected as the *de minimis* risk level. Additionally, the exposure cannot exceed the safe limits as determined by nongenotoxic endpoints.

OCCUPATIONAL EXPOSURE LIMITS FOR WORKPLACE SAFETY

The same principles can be applied in setting occupational exposure levels for workplace safety. OSHA has used a risk level at about 10^{-3} in setting permissible exposure limits (PEL) for carcinogens such as benzene. For carcinogens of known potency, this same level of risk is adopted. For cases where potency is unknown, risk management decisions can be made based on the cancer potency database curve. For carcinogens of unknown potency, the limit is set at 95% of the 10^{-3} curve, resulting in a maximum daily exposure of 9 μg/day for a 70-year lifetime. OSHA has not articulated a *de minimis* range comparable to the 10^{-6} to 10^{-4} range used by EPA. Instead of accepting a higher level of risk for mutagens, a point lower on the same potency curve was selected. It was noted above that the 95th percentile at 10^{-5} was equivalent to the 85th percentile at 10^{-6} (Table 2). Therefore, a limit equal to the 85th percentile on the 10^{-3} curve is the limit used for mutagens or 90 μg/day for a 70-year lifetime. Assuming an exposure to the same compound in the workforce is limited to 20 years (250 eight-hour workdays/year) and a volume of air breathed at a moderate work level for 8 h is 10 m^3, the airborne limit for a carcinogen is about 5 μg/m^3. A similar calculation yields a default limit of about 50 μg/m^3 for mutagens.

TABLE 2
Daily Lifetime Dose at Selected Points on the Curve across Different Risk Levels

	10^{-6} risk	10^{-5} risk	10^{-3} risk
95th percentile	9 ng/day	90 ng/day	9 μg/day
85th percentile	90 ng/day		90 μg/day

It may be possible to tailor the time parameter of years of exposure by considering whether the plant site is a dedicated or a flexible manufacturing site. Even so, the limits derived by using time parameters between 35 and 5 years are only approximately sevenfold different (viz., 2/26 and 18/183 μg/m^3 for carcinogens/mutagens, at 35 and 5 years, respectively). There is a break in containment technology at about 10 to 25 μg/m^3, so that carcinogens tend to fall into a different containment configuration than mutagens irrespective of the time parameter. Furthermore, no adjustment is required to develop a 12-h limit. The number of hours worked in a year is nearly the same whether worked as 8-h shifts, 5 days a week for 50 weeks (2000 h) or as 12-h shifts, 7 days on, 7 days off for 50 weeks (2100 h).

This strategy provides a consistent approach to defining limits for exposure to carcinogens and mutagens to the public and to workers.

DISCUSSION

There are numerous chemicals involved in a synthesis route for a pharmaceutical product, and some of these chemicals are occasionally found to be carcinogens and/or mutagens. Attempts to completely eliminate the use of carcinogens or mutagens in a manufacturing process are often not feasible because of a lack of alternative solvents or intermediates. Also, with carcinogenicity studies constantly being conducted with common solvents and raw materials, there will always be the possibility of a new positive study being introduced into the literature. Therefore, a means by which a *de minimis* or threshold limit can be determined provides great value in the continued development and manufacture of a product both for product quality control and workplace safety.

Risk assessment strategies for mutagens are not well developed. The potency correlation between mutagenicity and carcinogenicity is weak. The relevance of the results in animal studies where doses are targeted at maximum tolerated doses and extrapolated to very low exposures to humans as trace residuals in food, water, or pharmaceuticals is unknown. The influence of biological repair systems on mutagenic events is not quantified. The risk management system presented here enables reasonable control of exposure to mutagens. The result of this process is a numerical limit that can be translated into a *de minimis* daily exposure, an analytical detection level, or a cleaning limit.

APPENDIX

Statistical Methods and Results

The logistic model (1.1) was selected to fit the proportion of the TD_{50} levels in mg/kg/day on the common logarithm scale (log 10 based). Although the log-normal model was attempted on the data, it resulted in a significant lack of fit with $P = 0.0012$ using the Shapiro–Wilk test (Shapiro and Wilk, 1965). Four parameters were estimated from a five-parameter logistic model with the maximum fixed at 1.0; the minimum, min; the slope parameter, slope; the location parameter, location; and the asymmetry parameter, asym. The fitted logistic curve and the observed data are plotted in Fig. 2. The TD_{50} value, below which a given proportion of the chemicals are less potent, can be calculated using Formula 1.2. The dose corresponding to one-in-a-million risk, risk-specific (10^{-6}) dose, was calculated based on the TD_{50} as in Formula 1.3.

1.1. The Model

$$\text{proportion} = (1-\text{min})/\left(1+10^{\text{slope}(\log_{10}\mathrm{TD}_{50}-\text{location})}\right)^{\text{asym}} + \text{min}, \quad (1)$$

where min $= -0.0936$, slope $= 0.5487$, location $= 0.9016$, asym $= 0.6831$.

1.2. Rearranged to Solve for $\log_{10}\mathrm{TD}_{50}$, with Proportion $= 0.95$

$$\log_{10}\mathrm{TD}_{50} = \left\{\left[\log_{10}\left(\frac{1+0.0936}{0.95+0.0936}\right)^{(1/0.6831)} - 1\right]\Big/(0.5487)\right\} + 0.9016$$

$$= (\log_{10}(1.0709 - 1))/0.5487 + 0.901$$

$$= -1.1930$$

$$\mathrm{TD}_{50} = 10^{-1.1930} = 0.0641.$$

1.3. The Formula for Converting TD_{50} to RSD at 10^{-6} Risk (as Described in Rulis, 1989) is

$$\mathrm{RSD} = \mathrm{TD}_{50}/(0.5/1 \times 10^{-6}).$$

The plot of fitted results for the cancer potency curve is shown in Fig. 2. Table 3 shows the results of the computations for the 10th, 25th, 50th, 75th, 90th, and 95th percentiles using the developed model and the empirical data. Figure 3 compares the RSD values from the inverse of the expanded curve to the four data sets reviewed by Krewski *et al.* (1990). At all points the expanded curve reported herein lies in the range of the other data sets.

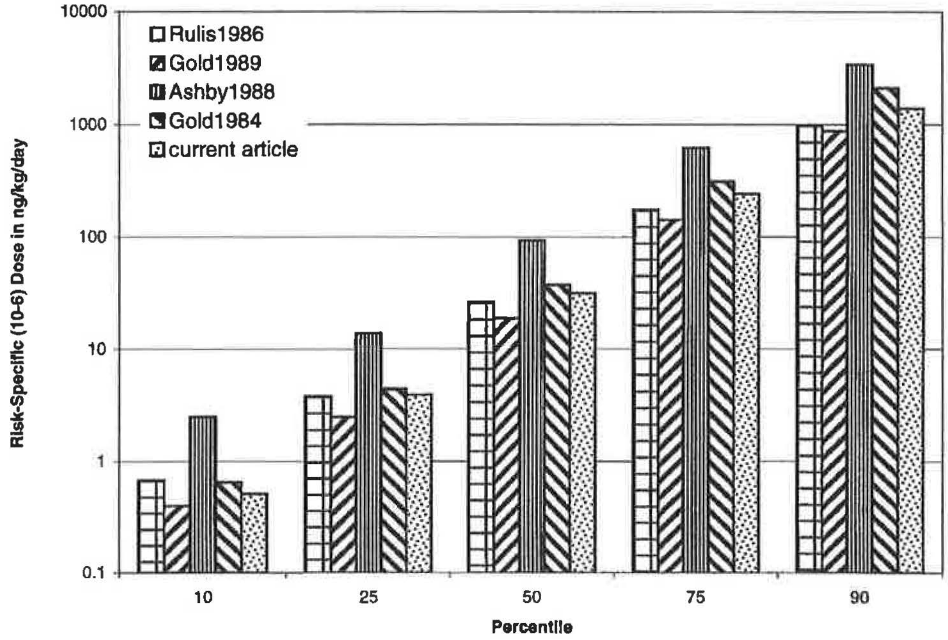

FIG. 3. Risk-specific doses at a risk of 10^{-6} across five data sets of animal carcinogens.

TABLE 3
Percentile Distribution of Virtually Safe Doses for Cancer Potency Curve

Percentile	LogTD_{50}	TD_{50} (mg/kg/day)	Risk specific dose at 10^{-6}, calculated (ng/kg/day)	Risk specific dose at 10^{-6}, empirical (ng/kg/day)
95	−1.19297	0.0641	0.1283	0.18
90	−0.59620	0.2534	0.5068	0.68
75	0.29081	1.9535	3.9069	3.45
50	1.19355	15.6153	31.2306	30.73
25	2.08249	120.9170	241.8339	243.0
10	2.84240	695.6711	1391.3423	1278

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Part III

The President

Executive Order 13579—Regulation and Independent Regulatory Agencies

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Presidential Documents

Title 3—

The President

Executive Order 13579 of July 11, 2011

Regulation and Independent Regulatory Agencies

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to improve regulation and regulatory review, it is hereby ordered as follows:

Section 1. *Policy.* (a) Wise regulatory decisions depend on public participation and on careful analysis of the likely consequences of regulation. Such decisions are informed and improved by allowing interested members of the public to have a meaningful opportunity to participate in rulemaking. To the extent permitted by law, such decisions should be made only after consideration of their costs and benefits (both quantitative and qualitative).

(b) Executive Order 13563 of January 18, 2011, ‘‘Improving Regulation and Regulatory Review,’’ directed to executive agencies, was meant to produce a regulatory system that protects ‘‘public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation.’’ Independent regulatory agencies, no less than executive agencies, should promote that goal.

(c) Executive Order 13563 set out general requirements directed to executive agencies concerning public participation, integration and innovation, flexible approaches, and science. To the extent permitted by law, independent regulatory agencies should comply with these provisions as well.

Sec. 2. *Retrospective Analyses of Existing Rules.* (a) To facilitate the periodic review of existing significant regulations, independent regulatory agencies should consider how best to promote retrospective analysis of rules that may be outmoded, ineffective, insufficient, or excessively burdensome, and to modify, streamline, expand, or repeal them in accordance with what has been learned. Such retrospective analyses, including supporting data and evaluations, should be released online whenever possible.

(b) Within 120 days of the date of this order, each independent regulatory agency should develop and release to the public a plan, consistent with law and reflecting its resources and regulatory priorities and processes, under which the agency will periodically review its existing significant regulations to determine whether any such regulations should be modified, streamlined, expanded, or repealed so as to make the agency’s regulatory program more effective or less burdensome in achieving the regulatory objectives.

Sec. 3. *General Provisions.* (a) For purposes of this order, ‘‘executive agency’’ shall have the meaning set forth for the term ‘‘agency’’ in section 3(b) of Executive Order 12866 of September 30, 1993, and ‘‘independent regulatory agency’’ shall have the meaning set forth in 44 U.S.C. 3502(5).

(b) Nothing in this order shall be construed to impair or otherwise affect:

(i) authority granted by law to a department or agency, or the head thereof; or

(ii) functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(c) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(d) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

THE WHITE HOUSE,
July 11, 2011.

[FR Doc. 2011–17953
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Report on Selected Aspects of EPA’s Draft 2014 Update of Human Health Ambient Water Quality Criteria

Docket Number: EPA–HQ–OW–2014–0135

Prepared for Federal Water Quality Coalition (FWQC)

August 13, 2014

ARCADIS

Report on Selected Aspects of EPA's Draft 2014 Update of Human Health Ambient Water Quality Criteria

Docket Number: EPA–HQ–OW–2014–0135

Prepared for:

Federal Water Quality Coalition (FWQC)

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Report on Selected Aspects of EPA’s Draft 2014 Update of Human Health Ambient Water Quality Criteria

Federal Water Quality
Coalition (FWQC)

Executive Summary

In May 2014, the United States Environmental Protection Agency (EPA) released its draft updated recommended water quality criteria for human health (HHWQC) for 94 chemical substances. According to EPA, the 2014 updates reflect the latest scientific information and also include updated fish consumption rates. ARCADIS has prepared these comments on select aspects of the draft updated HHWQC as they pertain to the overall approach used by EPA for development of the draft updated criteria and specific issues related to EPA’s methodology and documentation on behalf of the Federal Water Quality Coalition (FWQC).

EPA has attempted to update the HHWQC methodology through the application of scientific knowledge in the fields of dietary consumption and bioaccumulation estimation. In particular, the use of a fish consumption rate representative of long-term fish consumption behaviors, instead of relying on the results of short-term surveys, and of use bioaccumulation factors (BAFs) where appropriate instead of bioconcentration factors (BCFs), can lead to HHWQC that have a scientific basis more appropriate than that of current HHWQC and are protective of public health. However, the specific methodology EPA has used for deriving the draft updated HHWQC requires substantial revision. Once such revisions are completed, the draft updated HHWQC can be revised and reissued for additional public comment.

Comments contained in this document are organized into the categories listed below.

- Comments pertaining to certain aspects of EPA’s derivation of usual fish consumption rates (UFCRs) and life-cycle apportionment of marine fish species.
- Comments pertaining to EPA’s assumptions regarding human exposure and toxicity benchmarks.
- Comments on EPA’s selection the BCFBAF™ model for estimating national BAFs.
- EPA’s choice of input parameters for the BCFBAF™ model, including a sensitivity analysis on select input parameters.

However, an overarching comment is that the overall process used by EPA to derive the draft updated HHWQC is not transparent, in large part because many decisions are presented with little or no discussion or justification. This contrasts with EPA’s historical and highly commendable efforts to explain the basis for its decision making regarding development of HHWQC (e.g., EPA 2000, 2003, 2009). This lack of transparency combined with the absence of crucial information prevented us from providing EPA a full and thorough review of the draft HHWQC and the methodology used by EPA to derive the draft updated HHWQC. As a consequence, these comments should not be considered complete until all the information is provided to the public for review.

EPA's draft updated HHWQC are based on a UFCR that includes a contribution from marine fish under the pretext that fish classified as marine but caught in near shore waters (within approximately three miles of the shoreline) represent "local" fish that could be affected by chemicals at a concentration equal to the draft updated HHWQC. The key assumption is that near shore waters have concentrations of chemicals equal to the draft updated HHWQC. However, marine fish, even those caught in near shore waters, are expected to have substantially lower exposures to chemicals discharged to fresh or estuarine waters than true freshwater or estuarine fish species. Because of this, before including marine fish in the UFCR used to derive HHWQC, EPA needs to demonstrate that such exposures make a significant contribution to the chemical-specific body burdens found in marine fish caught in near shore waters. Regardless, if marine fish are to be included in the draft updated HHWQC, EPA needs to provide all the information used to develop the marine fish apportionment enabling the public to understand the contribution of marine fish to the overall UFCR.

The exposure assumptions selected by EPA to derive the draft updated HHWQC are representative of adult lifetime exposure, yet the toxicity benchmarks for some of the chemicals for which HHWQC have been proposed have been adjusted to account for exposures that occur during the pre-adult portions of a person's life (e.g., childhood). EPA should carefully consider whether adjusting toxicity factors to account for the assumed potential increased sensitivity of early lifestages when deriving updated HHWQC is appropriate and address the uncertainties embedded in this adjustment.

The draft updated HHWQC rely on the BCFBAF™ (formerly called BCFWIN™) model contained in EPA's Estimation Program Interface Suite (EPI Suite™) software. The BAF estimation algorithm of this model is based on the screening level bioaccumulation model originally published in Arnot and Gobas (2003), which in the authors' own words was developed "to screen new and existing chemicals for their potential to bioaccumulate" (Arnot and Gobas, 2004). The supporting literature for Arnot and Gobas (2003) also mentions the model as a screening tool (Gobas and Arnot, 2003; Costanza et al., 2012). It is not scientifically appropriate to derive nationwide HHWQC using a model developed primarily as a screening tool. Even if the BCFBAF™ model were not a screening tool, its current application in the derivation of nationwide HHWQC is not appropriate for the reasons listed below.

- BCFBAF™ does not allow users to employ site-specific parameters that affect bioaccumulation. This contradicts general scientific understanding about bioaccumulation and is inconsistent with previous EPA guidance on the use of site-specific BAFs to derive HHWQC.
- Some of the data used by EPA to parameterize/calibrate BCFBAF™ are representative of the Great Lakes and, therefore, the resulting BAFs should not be used to estimate BAFs for all waters of the United States.
- Several of the inputs to BCFBAF™ used by EPA to develop national BAFs appear to overestimate bioaccumulation in many waters of the United States.
- Food web structure and other site-specific parameters are embedded in the food web biomagnification factor, so cannot be modified to reflect site-specific conditions.
- Aquatic invertebrates were not included in the training or validation dataset of the whole-body biotransformation rate constant (kM) model within BCFBAF™ even though they are commonly consumed by humans (e.g., shrimp, clams, crabs, lobster). It is not clear whether BAFs derived using the model are applicable to invertebrates and, therefore, whether the draft updated HHWQC are under or over protective of human populations consuming these species.
- EPA's documentation of the BCFBAF™ model is often not fully transparent and/or is absent for many assumptions and processes used by the model.
- EPA has included the BCFBAF™ model in EPI Suite™ and proposed its use in the methodology for deriving HHWQC. This is contrary to the guidance of EPA's Science Advisory Board (SAB) which questioned whether BCFBAF™ has been sufficiently verified to be used in even screening assessments and requested review before EPA added BCFBAF™ to EPI Suite™.

Each of these points is discussed in detail in the following sections of these comments.

To provide an example of the potential bias associated with EPA's choice of input parameters for the BCFBAF™ model, a sensitivity analysis was conducted for select input parameters built into the model that may vary among surface waters of the United States. The sensitivity analysis demonstrates that BCFBAF™ appears to use values for several, but not all, key parameters that lead to overestimates of BAFs rather than central estimates of BAFs. This results in BAFs that overestimate bioaccumulation of most chemicals and lead to more conservative HHWQC than necessary to protect public health at the levels recommended by EPA.

Based on the information presented in these comments, we recommend that EPA develop and provide to the public for review and comment technical support documents (TSDs) detailing the processes and rationale behind the multiple scientific and policy decisions EPA has made as part of deriving the draft updated HHWQC. The current draft updated HHWQC should not be finalized until these TSDs have been prepared and subjected to review by EPA's SAB. Once the SAB review has been addressed, EPA can revise the draft updated HHWQC and release an updated proposal for review by the public. In particular, the TSDs should include a full presentation of the derivation of the UFCR and guidance on how state regulators and other interested parties can cost-effectively develop state-, region-, or water body-specific BAFs, which is the preferred option under existing EPA guidance. As part of this, EPA should specifically justify selection of the proposed approach to developing BAFs, especially any choice to use a QSAR model over a mechanistic food web model. Given that EPA itself has explored use of the AQUAWEB model (Arnot and Gobas 2004), EPA should, at the very least, provide a detailed justification for adopting BCFBAF™ over AQUAWEB. Ultimately, a simplified version of the AQUAWEB model allowing States and authorized Tribes to use site-specific inputs for highly-sensitive parameters, but established default values for less sensitive parameters, may be more appropriate than the current proposal based on BCFBAF™.

Specific Comments

Comment 1. Marine species should not be included in the fish consumption rate used to develop the draft updated HHWQC.

Summary: Dilution provided by the large volume of water, tides, and ocean currents present in most near shore waters indicates that concentrations of chemicals regulated by HHWQC in near shore waters will be small compared to concentrations present in fresh and estuarine waters. Additionally, marine species caught in such waters may not have been present in such waters for a long enough time to have accumulated tissue concentrations assumed by the HHWQC. As a result, concentrations of chemicals in marine fish caught in near shore waters are likely to be much lower than assumed by the draft updated HHWQC. Regardless, the chemical-specific body burdens in true marine species reflect bioaccumulation in the marine environment, which is outside the jurisdictional control of States and authorized Tribes. This means that including any marine species in the UFCR would result in HHWQC that, almost by definition, can never be achieved based on actions any one state, or any group of states, could take. Based on these observations we recommend that EPA continue its past practice of excluding marine fish from the UFCR used to derive the draft updated HHWQC. If marine fish are to be included we recommend EPA provide data and analyses demonstrating that tissue concentrations in marine fish caught in near shore waters are larger than tissue concentrations of such fish caught in open oceans.

Discussion: The UFCR used to develop the draft updated HHWQC incorporates marine species under the pretext that fish classified as marine but caught in near shore waters represent "local" fish that could be affected by chemicals at a concentration equal to the draft updated HHWQC. The key assumption is that near shore waters (within approximately three miles of the shoreline) have concentrations of chemicals equal to the draft updated HHWQC and that the fraction of marine species harvested from such near shore waters have spent sufficient time in such waters to have their tissue concentrations be in equilibrium with the concentration in the near shore waters, where the equilibrium concentration is defined by the BAF. Neither of these assumptions is likely to be representative of near shore waters and, thus, of marine fish harvested from such waters. In fact, the chemical concentrations in such waters and marine fish caught from such waters are likely to be much lower than assumed by the draft updated HHWQC.

To the extent near shore waters are affected by concentrations of chemicals regulated by HHWQC, those chemicals are present in such waters because they were discharged in a freshwater environment, transported to the near shore waters by way of a river, and then released into the near shore waters at the mouth of the river. Even if one assumes that the concentration of the chemical in the river water at its mouth prior to release to the ocean is equal to the HHWQC, which is a very unrealistic assumption given that most discharges are diluted by river flow, the concentration in the near shore waters will be greatly diluted by the volume of the ocean, tidal exchange, and ocean currents. Therefore, the concentration of chemicals in near shore waters as defined by EPA will be substantially lower than the HHWQC. Indeed, the concentrations may be so much lower as to not to lead to a material increase in exposure.

Moreover, concentrations of many chemicals in mussels and oysters collected from near shore waters have been decreasing over the past two decades or more (O'Conner and Lauenstein 2006). EPA should provide data justifying the need to include potential exposures associated with fish caught from near shore waters in the draft updated HHWQC when such fish were not included when the existing HHWQC were established and concentrations of chemicals in near shore biota were higher.

We recommend that EPA provide an evaluation of the potential contribution of freshwater releases to near shore waters to document the need for inclusion of marine fish. If near shore waters are shown to be affected by freshwater releases approaching the HHWQC, EPA should then document that the marine species caught in those waters have or are expected to have concentrations that are in equilibrium with the water concentrations. This will depend upon assumptions about uptake and depuration and time spent in the near shore waters versus open ocean waters. EPA needs to provide specific examples of species for which this is a concern and why those examples are likely to be representative of other (all) marine species harvested in near shore waters.

We acknowledge that ocean discharges represent a possible special, localized condition. EPA should examine how many such discharges occur and how the volume compares to freshwater discharges. EPA should also document that harvesting of marine fish occurs near such discharges. If such discharges are frequent enough and of a large enough magnitude to warrant consideration when setting HHWQC, we recommend that EPA develop a process that is transparent enough and flexible enough that regulatory agencies responsible for establishing allowable water concentrations can use the approach recommended by EPA to establish more stringent site-specific HHWQC for such situations. The special case of ocean discharges should not be the basis for including marine fish in the UFCR, assuming such discharges require such inclusion in the first place.

The above comments suggest that it is very unlikely that marine fish caught in near shore waters can be considered to have the same potential to accumulate chemicals as fish that reside in and are caught in fresh and estuarine waters. Based on the reduced potential, we recommend that EPA exclude marine fish from the UFCR, and that if marine fish are to be included, EPA provide data and analyses that demonstrate such exposures are material and need to be accounted for by HHWQC.

Comment 2. EPA has not adequately documented its methodology for estimating fish consumption rate and life-cycle apportionment for marine species.

<u>Summary:</u> The apportionment of species to freshwater, estuarine, and marine habitats is not thoroughly documented by EPA. We recommend that EPA make transparent the process by which the apportionment was conducted such that members of the public interested in the process can duplicate EPA's findings and determine the fraction of the overall fish consumption rate that is comprised of freshwater and estuarine fish versus marine fish. To facilitate this we recommend that EPA provide a summary of the commercial landings data, species-specific life history data, and species-specific fish consumption data EPA used to arrive at the apportionments shown in Table 1 of EPA (2014a).

<u>Discussion:</u> In contrast to EPA's existing HHWQC that do not include marine fish when deriving HHWQC, EPA's draft updated HHWQC are based on a fish consumption rate that includes a contribution from marine fish. That contribution is based on apportioning the fraction of marine species that are harvested in estuarine and near shore waters versus open ocean waters. The habitat apportionment process is poorly documented. Furthermore, for anadromous fish (i.e., those that spend part of their lives in marine waters and part of their lives in estuarine and near shore waters), this assumption oversimplifies the process by which the chemical body burdens of fish are accumulated.

EPA (2014a) states that the assignments of species to freshwater, estuarine, and marine habitats were completed by a fisheries biologist. While Appendix A of EPA (2014a) provides the results of this analysis, the methodology that was used to arrive at these assignments is not clear. For select species, EPA (2014a) states that it used NOAA landings data to apportion the species-specific consumption rate to various habitats. However, for a number of species, what appear to be generalized habitat apportionments are assigned without a strong scientific basis. For example, grouper are apportioned 50% estuarine and 50% marine, with the note that there are "150 species", some of which are "marine only, some estuarine and marine." Similarly, rockfish are apportioned 50% estuarine and 50% marine, with a similar note simply indicating that "approximately half are found in estuaries (in addition to marine habitats)." Scallops are assigned as entirely estuarine. However the NMFS landings data referred to by EPA (2014a) indicate that about 99% of scallops are ocean scallops and not bay scallops (57,540,043 pounds of ocean scallops landed in 2010 and 376,827 pounds of bay scallops). Based on the landings data, scallops should be weighted almost entirely marine and not estuarine. Because species specific consumption rates are not provided, the effect of this misclassification on the UFCR used to derive the draft updated HHWQC cannot be determined. In these cases and others, the technical justification for habitat assignments needs to be clearly documented including references to life history information used to make judgments about habitat use.

While EPA (2014a) recognizes that habitat apportionment is complicated by the fact that some species live in multiple habitat types at different life stages, the method used to apportion consumption of anadromous fish to estuarine/near shore and marine habitats is unclear. For example, an apportionment of 15% estuarine and 85% marine is assigned to both chum salmon and coho salmon, with a note simply indicating that "some populations spend many months in estuaries." In the past, EPA has designated Pacific salmon as marine species, effectively excluding them from the UFCR used to derive HHWQC (EPA 2002), as it was commonly accepted that salmon accrue most of their body mass and chemical body burden in marine waters. However, in recent years, the treatment of salmon and other anadromous species in the FCR used to derive WQC has been called into question (e.g., WDOE 2013). Not only are salmon of particular cultural significance in the Pacific Northwest, but their life histories are varied and complex. While all current research supports a conclusion that the majority (i.e., >90%) of the bioaccumulative chemical body burden in adult Pacific salmon is acquired in the marine phase of their life (Cullon et al. 2009, O'Neill and West 2009), this has not necessarily been proven for all anadromous fish. Therefore, there is some debate about the best approach to apportionment for these species. If EPA wishes to include some consumption of anadromous fish in the UFCR it needs to carefully weight apportionment based on residence time (i.e., apportionment of consumption based on relative amount of time each species spends in marine waters) vs. growth patterns (i.e., apportionment of consumption based on where and when each species accrues body mass) vs. catch location (i.e., apportionment of consumption based on where fish are caught). Whichever method is ultimately used, EPA should provide clear justification for it's selection, and the process as executed should be clearly and thoroughly documented so that reviewers can understand and reproduce the results.

EPA needs to provide all necessary information to enable stakeholders to reproduce the apportionment upon which the draft updated HHWQC are based. To that end, we recommend that EPA provide a summary of the landings data used in the habitat apportionment process. We also request that EPA provide the species specific UFCRs that were combined with the habitat apportionment estimates to determine the overall freshwater, estuarine, and near shore consumption rates.

Comment 3. EPA has not consistently applied assumptions related to toxicity and exposure.

Summary: The exposure assumptions selected by EPA to derive the draft updated HHWQC are representative of adult lifetime exposure, yet the toxicity benchmarks for some of the chemicals for which HHWQC have been proposed partially apply to exposures that happen during specific portions of a person's life (e.g., childhood). We recommend that EPA carefully consider whether adjusting toxicity factors to account for potential increased sensitivity of children when deriving the draft updated HHWQC is appropriate. If EPA wishes to retain the early lifestage adjustment, we recommend that EPA discuss the uncertainty associated with this adjustment. EPA also needs to apply this adjustment consistently for all chemicals believed to act through a mutagenic mode of action.

Discussion: All of the exposure assumptions used by EPA to derive the draft updated HHWQC are representative of adults and assume a lifetime of exposure. Body weight, drinking water intake, and fish consumption rate are all derived from data for adults 21 years of age or older. Exposure duration and averaging time are not explicitly included in the equation used to derive EPA's draft updated HHWQC and are, thus, implicit assumptions that combined have the effect of assuming daily exposure for an entire lifetime but using only exposure assumptions representative of adults. Yet the toxicity benchmarks for some of the chemicals for which HHWQC have been proposed partially apply to exposures that happen during specific portions of a person's life (e.g., childhood).

For cancer risk assessments, EPA recommends modifying the carcinogenic toxicity factors [cancer slope factors (CSFs)] for chemicals acting through a mutagenic mode of action using age-dependent adjustment factors (ADAFs) before estimating a cancer risk (EPA, 2005). ADAFs are intended to account for potential early lifestage susceptibilities to the carcinogenic effects of mutagenic chemicals. As the name implies, ADAFs are specific to certain age ranges, or life stages. During the first two years of life, the default ADAF is 10 (i.e., the expected response to a given dose is 10 times greater at this age compared to adults). For ages 2 to 16, the ADAF is 3, and for ages 16 and onward, the ADAF is 1. Without adjusting for early lifestage sensitivity, the cumulative lifetime risk associated with a given dose of a hypothetical chemical received over 70 years is calculated using the equation shown below[1]:

Lifetime risk = CSF x Dose.

If one assumes that the dose received by a given person remains constant throughout his or her lifetime, and that early lifestages demonstrate increased sensitivity to the chemical as described by the default ADAFs, a cumulative lifetime toxicity adjustment factor can be derived as follows:

Age 0 to 2 risk = Duration (2 years/70 years) x ADAF (10) x CSF x Dose
= 0.32 x CSF x Dose;

Age 2 to 16 risk = Duration (14 years/70 years) x ADAF (3) x CSF x Dose
= 0.6 x CSF x Dose;

Age 16 to 70 risk = Duration (54 years/70 years) x ADAF (1) x CSF x Dose
= 0.77 x CSF x Dose;

Lifetime risk = Sum of age-specific risks
= 1.7 x CSF x Dose.

Of the 94 chemicals for which EPA derived updated HHWQC, EPA assumes 11 act through a mutagenic mode of action (EPA, 2014b). EPA modified the carcinogenic

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[1] For simplicity, the linear cancer risk equation is shown in these comments. This equation is a special case of the more general equation: lifetime risk = $1\text{-}e^{-(\text{cancer slope factor x dose})}$. As long as the product of "cancer slope factor x dose" is less than about 1×10^{-2}, as by definition it will be for HHWQC based on an allowable risk level of between 1×10^{-6} or 1×10^{-4}, the linear equation provides an accurate representation of the cancer risk estimated by the more general exponential equation.

toxicity factors for eight of the 11 mutagenic chemicals to account for potential increased sensitivity of children (Table 1). The cumulative lifetime toxicity adjustment factor of 1.7 was applied to all of the chemicals for which this modification was made, with the exception of vinyl chloride, for which the CSF was derived using the linearized multistage method for continuous lifetime exposure from birth. While the adjustment factor of 1.7 is assumed to account for the limited duration of exposure during sensitive lifestages, a critical assumption embedded in the adjustment factor is that the dose remains constant throughout a person's lifetime. In other words, the assumption is that the dose received by an infant is the same as that received by an adolescent or an adult. However, the dose a person receives is determined by the physical and behavioral characteristics of that person (i.e., drinking water intake, fish consumption rate, body weight), which change throughout the stages of a person's lifetime.

Table 1 Mutagenic Chemicals with Updated HHWQC

Mutagenic Chemical	Toxicity Factor Adjusted for Early Lifestage Exposure?
Benzidine	No
Benzo[a]anthracene	Yes
Benzo[a]pyrene	Yes
Benzo[b]fluoranthene	Yes
Benzo[k]fluoranthene	Yes
Chrysene	Yes
Dibenzo[a,h]anthracene	No
Ideno[1,2,3-cd]pyrene	Yes
Methylene chloride	Yes
Trichloroethylene	No*
Vinyl chloride	Yes**

* Adjustment omitted for trichloroethylene because it applies only to the kidney cancer component of the total cancer risk estimate, the impact of which was considered minimal.

** The cancer slope factor for vinyl chloride was derived using the linearized multistage method for continuous lifetime exposure from birth.

To illustrate how dose might change over the course of a lifetime, hypothetical risk estimates were calculated using 50th percentile and 90th percentile age-specific fish consumption rates and drinking water intakes. These hypothetical risk estimates use an age-specific "dose" calculated as ingestion divided by body weight. Each age-specific dose is then normalized to the adult (i.e., age 21 and older) dose and multiplied by the age-specific exposure duration and ADAF to determine hypothetical risk. The results of this analysis demonstrate that the approach used by EPA to account for early lifestage exposures (i.e., applying an adjustment factor of 1.7, which assumes a constant relative dose at each lifestage) might overestimate risk by up to 50% when considering the fish consumption exposure pathway or underestimate risk by up to 20% when considering the drinking water exposure pathway (Tables 2 and 3). The degree to which the total fish consumption risk is over estimated depends on the segment of the population considered, as the relative dose received by children compared to adults appears to be lower for the general population than for upper-end consumers. Whether the total risk is over- or underestimated when the fish consumption and drinking water exposure pathways are combined will ultimately depend on the chemical in question. The fish consumption exposure pathway is the dominant pathway for chemicals that have large BAFs; that is to say, the chemical dose received by consuming fish is considerably higher than the dose received by drinking water for such chemicals. Conversely, the drinking water exposure pathway is the dominant pathway for chemicals that have small BAFs in fish tissue. EPA needs to consider the changes exposure at various lifestages and clarify whether application of ADAFs is ultimately justified.

Table 2 Hypothetical Risk Calculations for Fish Ingestion Exposure Pathway

				Implicit Assumption in EPA's Use of ADAFs		Hypothetical Risk Using 50th Percentile UFCR				Hypothetical Risk Using 90th Percentile UFCR			
Age	Body Weight, kg (EPA 2011)	Duration (Fraction of 70 Years)	ADAF	Ratio to Adult Dose	Risk	50th Percentile UFCR, g/day (EPA 2014)	UFCR/BW	Ratio to Adult Dose	Risk	90th Percentile UFCR, g/day (EPA 2014)	UFCR/BW	Ratio to Adult Dose	Risk
0 - <1	7.83	0.014	10	1	0.1429	0	0	0	0	0	0	0	0
1 - <2	11.4	0.014	10	1	0.1429	0.6	0.053	0.842	0.120	4.7	0.412	1.499	0.214
2 - <3	13.8	0.014	3	1	0.0429	0.6	0.043	0.696	0.030	4.7	0.341	1.238	0.053
3 - <4	18.6	0.014	3	1	0.0429	0.7	0.038	0.602	0.026	5.8	0.312	1.134	0.049
4 - <5	18.6	0.014	3	1	0.0429	0.7	0.038	0.602	0.026	5.8	0.312	1.134	0.049
5 - <6	18.6	0.014	3	1	0.0429	0.7	0.038	0.602	0.026	5.8	0.312	1.134	0.049
6 - <7	31.8	0.014	3	1	0.0429	1.1	0.035	0.553	0.024	7.7	0.242	0.881	0.038
7 - <8	31.8	0.014	3	1	0.0429	1.1	0.035	0.553	0.024	7.7	0.242	0.881	0.038
8 - <9	31.8	0.014	3	1	0.0429	1.1	0.035	0.553	0.024	7.7	0.242	0.881	0.038
9 - <10	31.8	0.014	3	1	0.0429	1.1	0.035	0.553	0.024	7.7	0.242	0.881	0.038
10 - <11	31.8	0.014	3	1	0.0429	1.1	0.035	0.553	0.024	7.7	0.242	0.881	0.038
11 - <12	56.8	0.014	3	1	0.0429	1.1	0.019	0.310	0.013	8.3	0.146	0.531	0.023
12 - <13	56.8	0.014	3	1	0.0429	1.1	0.019	0.310	0.013	8.3	0.146	0.531	0.023
13 - <14	56.8	0.014	3	1	0.0429	1.1	0.019	0.310	0.013	8.3	0.146	0.531	0.023
14 - <15	56.8	0.014	3	1	0.0429	1.1	0.019	0.310	0.013	8.3	0.146	0.531	0.023
15 - <16	56.8	0.014	3	1	0.0429	1.1	0.019	0.310	0.013	8.3	0.146	0.531	0.023
16 - <17	71.6	0.014	1	1	0.0143	1.4	0.020	0.313	0.004	9.5	0.133	0.482	0.007
17 - <18	71.6	0.014	1	1	0.0143	1.4	0.020	0.313	0.004	9.5	0.133	0.482	0.007
18 - <19	71.6	0.014	1	1	0.0143	1.7	0.024	0.380	0.005	11.6	0.162	0.589	0.008
19 - <20	71.6	0.014	1	1	0.0143	1.7	0.024	0.380	0.005	11.6	0.162	0.589	0.008
20 - <21	71.6	0.014	1	1	0.0143	1.7	0.024	0.380	0.005	11.6	0.162	0.589	0.008
21 +	80	0.700	1	1	0.7	5	0.063	1	0.7	22	0.28	1	0.7
				Total Hypothetical Risk:	**1.7**			**Total Hypothetical Risk:**	**1.1**			**Total Hypothetical Risk:**	**1.5**

Notes:

BW = body weight

g/day = grams per day

kg = kilograms

UFCR = usual fish consumption rate

Hypothetical risk calculated as Duration x ADAF x Ratio to Adult Dose

Table 3 Hypothetical Risk Calculations for Drinking Water Exposure Pathway

				Implicit Assumption in EPA's Use of ADAFs		Hypothetical Risk Using 50th Percentile DI				Hypothetical Risk Using 90th Percentile DI			
Age	Body Weight, kg (EPA 2011)	Duration (Fraction of 70 Years)	ADAF	Ratio to Adult Dose	Risk	50th Percentile DI, mL/day (EPA 2011)	DI/BW	Ratio to Adult Dose	Risk	90th Percentile DI, mL/day (EPA 2011)	DI/BW	Ratio to Adult Dose	Risk
0 - <1	7.83	0.014	10	1	0.1429	525	66.957	3.533	0.505	1042	133	3.442	0.492
1 - <2	11.4	0.014	10	1	0.1429	300	26.316	1.389	0.198	772	67.72	1.753	0.250
2 - <3	13.8	0.014	3	1	0.0429	341	24.710	1.304	0.056	920	66.67	1.725	0.074
3 - <4	18.6	0.014	3	1	0.0429	437	23.495	1.240	0.053	933	50.16	1.298	0.056
4 - <5	18.6	0.014	3	1	0.0429	437	23.495	1.240	0.053	933	50.16	1.298	0.056
5 - <6	18.6	0.014	3	1	0.0429	437	23.495	1.240	0.053	933	50.16	1.298	0.056
6 - <7	31.8	0.014	3	1	0.0429	574	18.050	0.953	0.041	1186	37.30	0.965	0.041
7 - <8	31.8	0.014	3	1	0.0429	574	18.050	0.953	0.041	1186	37.30	0.965	0.041
8 - <9	31.8	0.014	3	1	0.0429	574	18.050	0.953	0.041	1186	37.30	0.965	0.041
9 - <10	31.8	0.014	3	1	0.0429	574	18.050	0.953	0.041	1186	37.30	0.965	0.041
10 - <11	31.8	0.014	3	1	0.0429	574	18.050	0.953	0.041	1186	37.30	0.965	0.041
11 - <12	56.8	0.014	3	1	0.0429	689	12.130	0.640	0.027	1829	32.20	0.833	0.036
12 - <13	56.8	0.014	3	1	0.0429	689	12.130	0.640	0.027	1829	32.20	0.833	0.036
13 - <14	56.8	0.014	3	1	0.0429	689	12.130	0.640	0.027	1829	32.20	0.833	0.036
14 - <15	56.8	0.014	3	1	0.0429	689	12.130	0.640	0.027	1829	32.20	0.833	0.036
15 - <16	56.8	0.014	3	1	0.0429	689	12.130	0.640	0.027	1829	32.20	0.833	0.036
16 - <17	71.6	0.014	1	1	0.0143	973	13.589	0.717	0.010	2298	32.09	0.831	0.012
17 - <18	71.6	0.014	1	1	0.0143	973	13.589	0.717	0.010	2298	32.09	0.831	0.012
18 - <19	71.6	0.014	1	1	0.0143	986	13.771	0.727	0.010	2617	36.55	0.946	0.014
19 - <20	71.6	0.014	1	1	0.0143	986	13.771	0.727	0.010	2617	36.55	0.946	0.014
20 - <21	71.6	0.014	1	1	0.0143	986	13.771	0.727	0.010	2617	36.55	0.946	0.014
21 +	80	0.700	1	1	0.7	1516	18.95	1	0.700	3091	38.64	1	0.700
				Total Hypothetical Risk:	**1.7**			**Total Hypothetical Risk:**	**2.0**			**Total Hypothetical Risk:**	**2.1**

Notes:

BW = body weight

DI = drinking water intake

kg = kilograms

mL/day = milliliters per day

Hypothetical risk calculated as Duration x ADAF x Ratio to Adult Dose

Furthermore, EPA should clarify why it used adjusted toxicity factors for some, but not all, of the mutagenic chemicals for which it has proposed draft updated HHWQC. EPA does note that the early lifestage adjustment for trichloroethylene was omitted because it applies only to the kidney cancer component of the total cancer risk estimate, the impact of which was considered minimal. However, no explanation is provided for the lack of early lifestage adjustments for benzidine and dibenzo[a,h]anthracene.

Given that the exposure assumptions selected by EPA are representative of adult lifetime exposure, we recommend that EPA carefully consider whether adjusting carcinogenic toxicity factors to account for potential increased sensitivity of children when deriving draft updated HHWQC is appropriate. If EPA wishes to retain the early lifestage adjustment, we recommend that this adjustment be applied consistently for all chemicals believed to act through a mutagenic mode of action following the lifestage specific methodology presented in EPA (2005) guidance. Furthermore, EPA should discuss the uncertainty associated with this adjustment, in particular the uncertainty associated with assuming that a person will receive the same level of exposure throughout his or her lifetime.

Comment 4. EPA has chosen to use the BCFBAF™ model to estimate BAFs without input from EPA's Science Advisory Board (SAB).

Summary: Despite historic cautions from EPA's Science Advisory Board (SAB) that the addition of any bioaccumulation model to EPI Suite™ should be subject to careful scientific scrutiny, EPA has included the BCFBAF™ model in EPI Suite™ and is proposing to use it for estimating national BAFs to derive HHWQC. Prior to use of BAFs derived using BCFBAF™ EPA should seek SAB input on the broad question of how to incorporate BAFs into the HHWQC paradigm, as well as the specific question of which is the best model to use for estimating BAFs. EPA should not adopt national BAFs without the input of the SAB on these questions.

Discussion: EPA has proposed development of national default BAFs (and/or BSAFs) in the past, and has published a technical guidance document (TSD) outlining, in detail, an approach for developing these BAFs (EPA, 2003) independent of the BCFBAF™ model currently being proposed for this purpose. Subsequently, EPA built on this first TSD in a second TSD (EPA, 2009), addressing development of site-specific BAFs. None of these documents address use of BCFBAF™ for developing national BAFs, and in this respect the current proposal is inconsistent with previous guidance.

When the Office of Pollution and Prevention and Toxics (OPPT) requested an SAB review of the EPI Suite™ software, EPI Suite™ did not include a model for estimating bioaccumulation (or BAFs) so the SAB provided comments (EPA, 2007) on BCFWIN only. However, the SAB recommended that a model for predicting bioaccumulation be added to EPI Suite™, and that this should be considered a priority. Of note, in their discussion of bioaccumulation models, the SAB cited the mechanistic food web model of Arnot and Gobas (2004) (AQUAWEB) as a candidate model, albeit with some concern over the ability of this model to deal with metabolism, but did not discuss nor mention the QSAR model of Arnot and Gobas (2003) that EPA has now added to EPI Suite™ as BCFBAF™. In addition, the SAB cautioned the following regarding the use of any BAF module for screening assessments (EPA, 2007):

In light of the widespread application of EPI Suite™, before the decision to add a new module, such as the BAF module, the Agency should assess to the extent practical, whether there is a consensus in the scientific community that the model has been or can be appropriately parameterized and has been sufficiently verified to be applicable in screening assessments.

In the proposed approach, EPA is using BCFBAF™ for the development of regulatory criteria, which implies a higher level of scrutiny than for application in screening assessments. Despite this caution, EPA has added the BCFBAF™ model to the EPI Suite™ package and is now using it to derive HHWQC apparently without requesting input from scientific community as to whether BCFBAF™ can be appropriately parameterized or from the SAB. Given that the incorporation of BAFs will result in significant shifts in numeric HHWQC, the input of the SAB seems a valuable prerequisite to use of any model for estimating BAFs. As a consequence, EPA should heed the guidance given by the SAB and request SAB input on the broad question of how to incorporate BAFs into the HHWQC paradigm, as well as the specific question of which is the best model to use for estimating BAFs. EPA should not adopt national BAFs without the input of the SAB on these questions.

Comment 5. The current approach is inconsistent with previous EPA guidance for the derivation of national BAFs.

Comment 5.01 The current approach for estimating the national BAF does not follow previous EPA guidance for the inclusion of site-specific information

Summary: Previous EPA guidance on deriving recommended HHWQC (EPA, 2000, 2003, 2009) has focused on the inclusion of site-specific inputs when estimating BAFs. In fact, the 2009 TSD (EPA, 2009) was specifically developed to provide guidance to States and authorized Tribes on how to develop their own site-specific BAFs for use in deriving HHWQC. Despite this, under EPA's current proposal users are unable to utilize critical site-specific information as part of developing site-specific BAFs (using BCFBAF™). This is contrary to existing guidance that provides using site-specific data as the preferred option for deriving BAFs. Rather, the national BAFs are entirely based on default values, including for parameters EPA has acknowledged have significant influence on BAFs for piscivorous fish. Thus, if adopted, the current approach will effectively limit the ability of States and authorized Tribes to develop site-specific BAFs. Further, EPA has provided no guidance on how to implement such modifications or whether such modifications are even permitted. Some of the inflexibility apparent in the current proposal results from EPA's decision to use BCFBAF™ as opposed to a mechanistic food web model to estimate BAFs, yet EPA has not provided any justification for the selection of BCFBAF™ over one of these alternatives. Because some mechanistic food web models allow use of site-specific values for a wider range of inputs than BCFBAF™, most specifically inputs reflecting site-specific food web structure, we urge EPA to consider adoption of one of these alternatives to BCFBAF™. AQUAWEB is an example of such a model, though it is likely more data intensive than necessary (see *Comment 12 Development of an alternative model or methodology to predict state-, region- and water body specific BAFs* for further discussion of key aspects of the ideal bioaccumulation model).

Discussion: As noted, EPA has historically (EPA 2000, 2003) stressed the importance of including site-specific input parameters (e.g., lipid content of organisms and the fraction of freely dissolved chemical in water (or dissolved organic carbon [DOC] and particulate organic carbon [POC] by proxy)) when developing BAFs, and EPA's methodology for deriving HHWQC (EPA, 2000) encourages States and authorized Tribes to make adjustments to national BAFs to reflect local conditions. Thus, EPA provided a stand-alone TSD (EPA, 2009) intended to assist States and authorized

Tribes in selecting site-specific information for use in estimating BAFs as part of deriving HHWQC.

Under EPA's proposed approach for deriving HHWQC, EPA has selected the BCFBAF™ model for estimation of the national BAFs. This model is based on a QSAR model originally published by Arnot and Gobas (2003), and requires as input a number of parameters that are likely to vary between sites, including:

- mean water temperature;
- dissolved organic carbon (DOC) and particulate organic carbon (POC), which relate to the fraction of freely dissolved (i.e., bioavailable) chemical in water (ϕ);
- lipid content of lowest trophic organisms; and
- lipid content of TL 2, 3 and 4 fishes.

Therefore, at first glance, it appears that the proposed approach follows EPA guidance (EPA, 2000, 2003, 2009) by using a model that allows accounting for site-specific input parameters. However, as applied by EPA, default assumptions are made for these key parameters and applied across all surface waters of the U.S. Two important examples are the site-specific lipid content of TL 2, 3 and 4 fishes and the amount of freely dissolved (i.e., bioavailable) chemical in water, the importance of which is stressed in EPA (2003) (emphasis added):

…These two factors are important in affecting the bioaccumulation of nonionic organic chemicals. However, baseline BAFs are not directly used to determine national human health AWQC, <u>because they do not reflect the lipid content of target aquatic organisms and the fraction of chemical that is freely dissolved in water for the sites to which the AWQC applies</u>.

In EPA (2003), baseline BAFs are derived from BAFs measured in the field, or total BAFs (i.e., based on the total concentration of the chemical in tissue compared to the total concentration of chemical in the water), to specifically-account for these two key site-specific parameters. The following equation is presented in EPA (2003) to convert from total BAF to baseline BAF:

$$Baseline\ BAF = \left[\frac{BAF_T^t}{f_{fd}} - 1\right] \times \frac{1}{f_{R}}.$$

Where: BAF_T^t is the total BAF, f_{fd} is the fraction of the total chemical that is freely dissolved in the study water, and f_R is the lipid fraction of the fish in the study.

Essentially, the baseline BAF normalizes the total BAF based on lipid fraction and bioavailability of the chemical. EPA (2003) also includes the calculation method for the national BAFs, which are estimated from baseline BAFs using site-specific values for lipid fraction (f_R) and bioavailability (f_{fd}). The approach currently proposed by EPA fails to take these key site-specific parameters into account despite EPA having previously provided extensive guidance on how to take them into consideration.

Moreover, lipid fraction and bioavailability are not the only parameters that are likely to make site-specific BAFs different than the national defaults, et al. Additional site-specific factors expected to affect BAFs include, but are not limited to, the degree of sediment-water disequilibrium and the overall food-web structure (i.e., effective trophic level(s), benthic/pelagic character of the food web, etc.). In the BCFBAF™ model, no food-web structure-specific parameters can be modified by the user with site-specific information. Instead, these parameters are collectively subsumed in the β value obtained via calibration of the BCFBAF™ model. Thus, even though EPA (2003) stresses that the feeding preference of forage fish for pelagic (e.g., zooplankton) vs. benthic (e.g., benthic invertebrates) food items is perhaps the most important ecological factor affecting ultimate BAFs for TL 4 piscivores, there is no means of accounting for site-specific differences in feeding preferences under EPA's currently proposed approach. Furthermore, EPA has not provided any information on how the TL-specific β values are expected to vary among various types of surface waters in the U.S., nor has it provided any justification for t use of a single β value for each tropic level to describe biomagnification for all fishes across all waters of the United States.

For the current draft updated HHWQC, EPA is effectively using a methodology that precludes the ability to modify the default BAFs for critical site-specific conditions. No guidance is provided on how a user should modify BCFBAF™ for this purpose even assuming the user has extensive site-specific data (e.g., tissue concentrations in multiple species, POC and DOC concentrations, sediment concentrations, water column concentrations, etc.). This suggests that, once adopted, it will be essentially impossible to modify the national default.

As discussed in Comment 12, we urge EPA to consider adopting a mechanistic food web model for estimating BAFs in place of the BCFBAF™ QSAR as these models generally allow for use of a wider range of site-specific input: a simplified version of the mechanistic food web model originally published in Arnot and Gobas (2004) (i.e., the

AQUAWEB model) is one example of such a mechanistic food web model. If EPA decides to follow through and use BCFBAF™ to develop national BAFs it should provide a thorough justification showing why use of BCFBAF™ is preferred over the use of a model such as AQUAWEB, including a direct comparison between the models demonstrating the utility each for derivation of national BAFs. This comparison should also explore how amenable each modeling approach might be to adjust for regional, state or water body-specific conditions.

Comment 5.02 EPA has failed to provide explanation of why the least preferred method for estimating national BAFs is used

Summary: EPA (2003) describes four methods of deriving baseline BAFs, or BAFs corrected for the fraction of freely dissolved chemical (i.e., fraction of chemical that is bioavailable) and the lipid fraction of the organism. EPA ranked these 4 methods in order of preference. In the current approach, EPA uses a single method for estimating BAFs, which closely aligns with the least-preferred method (estimation of BAFs via the K_{OW}), without providing any explanation of why the least preferred method) was chosen and why that specific single method was chosen over other, apparently more preferred methods. EPA needs to provide justification for the selection of a single method of estimating national BAFs (EPA, 2003) and how the currently proposed BCFBAF™ model is an improvement over historic EPA guidance on developing BAFs.

Discussion: In EPA (2003), a two-step process is described for the derivation of national BAFs. The first step involves the derivation of a baseline BAF for a particular compound, corrected for the lipid fraction (L_B) of the experimental organism (if using method 1 below, which requires experimental BAF data) and the fraction of freely dissolved chemical in water (ϕ). In the second step, trophic-level-specific national BAFs (i.e., TLs 2, 3 and 4) are calculated in each of three different food web structures (water, sediment, water and sediment) by applying site-specific information for L_B and ϕ to the baseline BAF.

EPA (2003) describes four methods for the derivation of the baseline BAF, ordered by method hierarchy, from highest to lowest:

- Method 1: Deriving the baseline BAF from experimental data (the fraction of freely dissolved chemical in water and lipid fraction are critical data points using this method, as the baseline BAF is essentially normalized for these two parameters);

- Method 2: Deriving the baseline BAFs from biota-sediment bioaccumulation factors (BSAF);
- Method 3: Deriving baseline BAFs from laboratory-measured bioconcentration factors (BCF) and food-chain multipliers (FCM); and
- Method 4: Deriving baseline BAFs from the octanol-water partitioning coefficient (K_{OW}) and the food-chain multiplier (presumably equivalent to the overall food web biomagnification factor).

Figure 3-1 of EPA (2003) shows a decision framework for selection of the method for deriving the baseline BAF. For a non-ionic substance with a log K_{OW} > 4.0 with low or unknown biotransformation, Figure 3-1 indicates that estimation from K_{OW} is the least-preferred of the four methods.

EPA needs to explain why the method based on K_{OW} was selected from the four methods presented in historical EPA guidance (EPA, 2003), focusing on how the proposed approach (using BCFBAF™ to estimate national BAFs) is an improvement over historic EPA guidance on developing BAFs, especially as it pertains to the ability to extrapolate BAFs from one ecosystem to another.

Comment 6. EPA's use of the BCFBAF model™ for estimating national BAFs is not appropriate given that the model was calibrated in large part with data representative of the Great Lakes.

Summary: The original QSAR model published by Arnot and Gobas (2003) is generally applicable to any water body provided the (extensive) data necessary for model calibration are available and Arnot and Gobas (2003) chose to use data representative of the Great Lakes in their work. Therefore, by default, results published by Arnot and Gobas (2003) reflect the chemical-, biological, and food web-specific parameters of the Great Lakes, a set of waters EPA considers so unique and distinct from other waters of the U.S. that it developed Great Lakes-specific HHWQC because national HHWQC were judged by EPA insufficiently protective of populations consuming Great Lakes fish (the Great Lakes Initiative (GLI)) (EPA, 1995a). This decision can be interpreted to be acknowledgment on the part of EPA that the resulting GLI HHWQC would not be applicable and would likely be overprotective if applied to other waters of the US. Despite this, EPA is now proposing that BAFs based in large part on Great Lakes data should be applied to all US waters. This is not only contrary to EPA's historic position, it is also scientifically indefensible.

Discussion: The Great Lakes constitute a highly unique ecosystem that is not representative of other U.S. surface waters. In fact, their characteristics are so distinct from other U.S. surface waters that specific water quality guidance was developed for the Great Lakes under the Great Lakes Initiative (GLI). Paragraph III.B. of the GLI preamble (60 FR 15369) states:

The final Guidance also reflects the unique nature of the Great Lakes Basin Ecosystem by establishing special provisions for chemicals of concern. EPA and the Great Lakes States believe it is reasonable and appropriate to establish special provisions for the chemicals of most concern because of the physical, chemical and biological characteristics of the Great Lakes System, and the documented environmental harm to the ecosystem from the past and continuing presence of these types of pollutants.

EPA's choice to calibrate the BCFBAF™ model for estimation of national BAFs using many data specific to the Great Lakes is somewhat ironic in that EPA has acknowledged the unique nature of the Great Lakes as the impetus for the GLI, yet is now proposing a methodology that assumes that several inputs specific to the Great Lakes are suitable for the rest of the country. This is a fundamental disconnect that will produce unreliable BAF estimates for U.S. surface waters and is not scientifically defensible. Bioaccumulation is based on many chemical-, biological- (e.g., organism weight, lipid fraction, metabolism rates), food web- (e.g., number of trophic levels, food web structure, feeding habits of foraging fish) and environmental-specific (e.g., water temperature) parameters, which as discussed in Comment 9 of this document, have a wide distribution of values across U.S. surface waters. The waters of the U.S. range from clear mountain lakes to stagnant bayous and from fast-moving, clear cold water streams to meandering, warm, black water rivers. Given the huge variation in physical, biological, and ecological characteristics of the surface waters in the U.S., EPA's proposed approach to use a single set of BAFs to describe bioaccumulation in the entire country contradicts common sense and is not scientifically defensible. In fact, as a large ecosystem, the Great Lakes themselves may not be similar enough to allow for a single set of scientifically-defensible BAFs to describe the complex process of bioaccumulation in TL 2, 3 and 4 fishes (e.g., Burkhard et al. 2006).

To demonstrate the bias associated with this approach, Comment 9 of this document compares values proposed by EPA for key input parameters to the distributions of these parameters in national surface waters. As is discussed in that comment, EPA appears to have selected values that are not representative of the country and that result in BAFs that overestimate bioaccumulation in most waters of the United States.

We urge EPA to develop a BAF modeling strategy that is transparent and accounts for the key parameters influencing site-specific bioaccumulation. Ultimately, whatever approach is used to estimate BAFs it should allow users to enter site-specific inputs, which reflect regional and state-specific differences, for the most sensitive parameters and establish default values for insensitive parameters (see the sensitivity analysis in this document showing sensitivity of the BCFBAF™ model to key input parameters). The AQUAWEB model originally published in Arnot and Gobas (2004) is a good example of a mechanistic model that allows users to enter site-specific information pertaining to chemical-, biological-, food web- and environmental-specific parameters. A trade-off exists between collecting the considerable amount of site-specific data required for any site-specific modeling versus just measuring the BAF directly. Therefore, a simplified version of the AQUAWEB model, which allows for inclusion of key site-specific parameters while incorporating default values for others shown to be less sensitive, would offer more flexibility to users by allowing them to use site-specific information (when available) rather than relying on national default assumptions for sensitive parameters.

Comment 7. Invertebrates were not included in the calibration of the biotransformation rate constant (kM) model in BCFBAF™.

Summary: As summarized in the BCFBAF™ user guidance document, the whole-body biotransformation rate constant (kM) "reflects the rate of change of the parent substance to another molecule or a conjugated form of the parent substance". The whole-body primary biotransformation rate constant model for fish used in BCFBAF™ was developed and validated against a database of kM estimates for several species of finfish (Arnot et al., 2008a), meaning that invertebrates were not considered for this model parameter. EPA needs to provide justification for the selection of a biotransformation model developed specifically for finfish to derive HHWQC that reflect consumption of aquatic invertebrates by humans and show that the proposed approach is protective of such exposures to chemicals in invertebrates.

Discussion: The whole-body biotransformation rate constant (kM) reflects the rate of change of the parent substance to another molecule or a conjugated form of the parent substance (i.e., the fraction of the mass in the whole body biotransformed per unit of time). The biotransformation model used in BCFBAF™ was developed and validated against a database of kM estimates found in Arnot et al. (2008a). In this paper, kM values are estimated (assuming first order processes) from laboratory-derived bioconcentration data for several species of finfish, including: rainbow trout, guppy, sheepshead minnow, fathead minnow, medaka, and bluegill sunfish (Arnot et al., 2008a, 2008b). Invertebrates were not included in the development of this model even though many invertebrates, including shrimp, crabs, lobster and clams; are commonly consumed as part of the human diet and are included in the UFCR. Because these taxa were not included as part of the parameterization of BCFBAF™, which relies on kM estimates specifically for finfish, the level of protection afforded by the draft updated HHWQC is unknown. EPA needs to demonstrate the BAFs derived using BCFBAF™ are representative of invertebrates as well as finfish and that the proposed approach is protective of public health.

Comment 8. EPA has not provided sufficient documentation for key input values for the BCFBAF™ model.

Summary: EPA's proposed methodology includes a number of changes to the original input parameters described in Arnot and Gobas (2003) with insufficient description of what the updated values represent or justification of why they are suitable to estimate BAFs for all surface waters of the U.S. Most of the documentation that is provided is incomplete and not transparent. EPA needs to provide detailed documentation for the selection of each of the model's input parameters, particularly those that differ from the inputs of the Arnot and Gobas (2003), model and for each parameter, document why it is acceptable to use the proposed values for all surface waters of the U.S.

Discussion: The BCFBAF™ user guidance documentation is apparently the only source of documentation for the estimation of national BAFs used in the development of the draft updated HHWQC. The 94 chemical-specific *Draft Update of Human Health Ambient Water Quality Criteria* documents appear to contain no information justifying the basis for the methodology used to estimate the national BAFs.

Users interested in understanding the basis for the BAFs must rely on Arnot and Gobas (2003) and Arnot et al. (2009), which is presumably the publication upon which the biotransformation rate constant (kM) methodology in BCFBAF™ is based, to begin to understand the methodology EPA used to derive the BAFs used as the basis for the draft updated HHWQC. As shown in Table 4 below, many of the input parameters of Arnot and Gobas (2003) have been modified by EPA for BCFBAF™. In other cases, the inputs are the same between the models; however, the original publication fails to provide adequate documentation of its assumptions for model input parameters (e.g., lipid content of lowest trophic level organisms).

Table 4 **Comparison of Key Input Parameters in Arnot and Gobas (2003) and the BCFBAF™ Model**

Parameter	Arnot and Gobas (2003)	BCFBAF™ Model
Weight of organism (kg)	1 (TL4)	1.43 (TL4) 0.183 (TL3) 0.096 (TL2)
Mean water temperature	10 °C (Canadian conditions)	10 °C
Overall food web biomagnification factor	130 (TL4)	62.7 (TL4) 30.1 (TL3) 16.1 (TL2)
Maximum trophic dilution factor (τ)	1 (default value) $\tau = (0.0065/(kM + 0.0065))^2$ (TL4)	$\tau = (0.0065 / ((0.447kM + 0.0065))^2$ (TL4) $\tau = (0.01 / ((0.760kM + 0.01))^2$ (TL3) $\tau = (0.02 / ((0.889kM + 0.02))^2$ (TL2)
Lipid content of lowest trophic level organisms	0.01 (TL 1)	0.01 (TL 1)
Lipid fraction	0.2 (TL4)	0.107 (TL4) 0.0685(TL3) 0.0598 (TL2)
Fraction of freely dissolved chemical in the water	$1/(1+ c_{POC} * 0.35 * K_{OW} + c_{DOC} * 0.1 * 0.35 * K_{OW})$	$1/(1+ c_{POC} * 0.35 * K_{OW} + c_{DOC} * 0.08 * K_{OW})$

kM = biotransformation rate constant

K_{OW} = octanol-water partitioning coefficient

c_{DOC} = fraction of dissolved organic carbon

c_{POC} = fraction of particulate organic carbon

Each of these modifications is described below in more detail.

(a) Weight of organism

As shown in Table 4 above, Appendix K of the BCFBAF™ user guidance indicates default values of 0.096, 0.183 and 1.43 kg were assumed for TL 2, 3 and 4 fishes, respectively. EPA provides no documentation of how these weights were derived (i.e., do they reflect the median or 95th percentile on the mean) or why they are acceptable default values to reflect the weight of TL 2, 3 and 4 fishes in surface waters throughout the U.S.

(b) Mean water temperature

In the BCFBAF™ model, a default water temperature of 10 °C is assumed for all surface waters of the U.S. While Arnot and Gobas (2003) state that this temperature was chosen to reflect the mean annual temperature of Canadian surface waters, EPA provides no documentation to support using the same mean annual temperature for all waters of the U.S. In fact, the decision to apply a temperature originally selected for Canadian surface waters to all waters in the U.S. contradicts EPA's BCFBAF™ user guidance document, which acknowledges that the model results should not be used for regions deviating from the default assumption for water temperature:

The default temperature for the BCF and BAF calculations is 10°C (temperate regions); therefore, the model predictions are not recommended for arctic, sub-tropical or tropical regions or for comparisons with other vastly different conditions (e.g., laboratory tests at ~25°C). Site-specific food web models, bioaccumulation models and bioconcentration models are available for specific modeling requirements (e.g., http://www.rem.sfu.ca/toxicology/models/models.htm, http://www.trentu.ca/cemc).

A significant portion of the southern U.S. has a climate that results in water temperatures greater than 10 °C and perhaps even 20 °C for much of the year. The BCFBAF™ model user guidance explicitly states to not use the results of the model for such areas, yet by using BCFBAF™ with its default values for temperature for all waters of the U.S., EPA has used BCFBAF™ in exactly a way the guidance says it should not be used.

Supporting the influence of temperature on the estimated BAFs, Zhang et al. (2008) investigated the sensitivity of polychlorinated biphenyl (PCB) BAFs estimated by a bioenergetics model (originally published in Zhang, 2006) to temperature, using both an average exposure temperature for a food web in Lake Michigan and a species-specific exposure temperature. The difference in responses between the average exposure temperature and individualized exposure temperature increased with increasing K_{OW} of the PCB and was typically greater than 60%. The authors conclude that "the fact that model outputs for highly hydrophobic PCB congeners are affected strongly by the values of exposure temperature suggests the importance of accurate characterization of exposure temperatures in the applications of food web models for real contaminant issues." They note that the results of their experiment do not extend to other bioaccumulation models such as the one originally published in Gobas (1993). They do caution that a "'food web-averaged' value for exposure temperature used in model simulations is an overly simplified representation of the real world situation and is likely to introduce potential substantial uncertainty in [the] model output."

EPA needs to provide justification for the selection of a water temperature of 10 °C to represent U.S. surface waters (ideally with actual data), including a discussion of why selection of a single temperature for all waters of the U.S. will not lead to biased results.

(c) Overall food web biomagnification factor (β)

Arnot and Gobas (2003) state that the default overall food web biomagnification factor (β) of 130 for TL 4 was derived by calibrating the model to the empirical BAF data and results in BAFs that are exceeded by only 2.5% of the available data (i.e., was selected to be conservative 97.5% of the time). They also state that "the calibration of the model to the data is designed to produce a QSAR for the BAF in higher trophic levels of a Canadian food web." Appendix K of the BCFBAF™ user guidance indicates β values of 62.7, 30.1 and 16.2 were selected for TLs 2, 3 and 4 (see also Table 4), respectively and provides the following explanation as the basis for the methodology "the overall food web biomagnification factors (β) in the BAF model are calibrated to each trophic level of measured BAF values (Arnot and Gobas, 2003)."

This explanation provides no reason for why the β value of 130 for TL 4 used by Arnot and Gobas (2003) was changed by EPA to 62.7. Nor does EPA provide documentation of the assumptions and methodology used to derive the β values used for the other trophic levels in BCFBAF™. Nor does the user guidance discuss the characteristics of food webs that affect β or the extent of variation of these characteristics among surface waters of the U.S. In short, EPA has provided essentially no explanation of or justification for the β values used for the three trophic levels in BCFBAF™. EPA should provide the public more information on the derivation of the default β values hardwired into BCFBAF™ to permit a thorough review of the methodology, particularly given the results of the sensitivity analysis presented at the end of these comments that shows BAFs for compounds that have high K_{OW} values and are not metabolized are relatively sensitive to this parameter.

(d) Maximum trophic dilution factor (τ)

In Arnot and Gobas (2003), the maximum trophic dilution factor (τ) was set to a default value of 1, indicating no trophic dilution. However, an equation is presented, relating τ to the biotransformation rate constant (kM), as shown in Table 4 above:

$$\tau = \left[\frac{0.0065}{kM + 0.0065^{2}}\right]^{n-1}$$

Where, as stated in Arnot and Gobas (2003), 0.0065 "reflects the rate at which metabolic transformation becomes greater than the other routes of chemical elimination (i.e., k_2, k_E and k_G) for a lower trophic level aquatic species" and n is the trophic level being considered.

As documented in Appendix K of the BCFBAF™ user guidance, EPA has apparently retained the 0.0065 term for the highest modeled trophic level (i.e., TL4 fish) rather than for a lower trophic level species (as specified in Arnot and Gobas [2003]), and replaced the factor of 0.0065 with 0.02 and 0.01 for TLs 2 and 3, respectively. No documentation is provided in the guidance as to why 0.0065 was used for TL 4 instead of TL 2 or how the factors of 0.01 and 0.02 were derived for TLs 2 and 3. Additionally, whereas Arnot and Gobas (2003) include the term 1kM, as shown in the equation above, Appendix K of the BCFBAF™ user guidance includes terms of 0.889kM (i.e., $[0.016/0.01]^{-0.25}$), 0.760kM (i.e., $[0.03/0.01]^{-0.25}$) and 0.447kM (i.e., $[0.25/0.01]^{-0.25}$) for TLs 2, 3 and 4, respectively, with no documentation of what these terms represent or why they were included in the calculation. (Although, it is clear that a decrease in kM increases the trophic dilution factor which ultimately increases the estimated BAF for each trophic level).

(e) Lipid content of lowest trophic level organism and number of trophic interactions in the food web

Arnot and Gobas (2003) and the BCFBAF™ model user guidance both state that percent body mass that is lipid for the lowest trophic level (i.e., invertebrates or plankton) in the food web is 1%. No documentation is provided in either reference to support a value of 1%. Given that waters of the U.S. are far more diverse than the Great Lakes and contain a variety of food webs, it is not clear that a single value for TL1 is appropriate nor is it clear that 1% is the appropriate lipid content. EPA needs to provide justification for the selection of 1% as the TL1 lipid content, particularly given the results of the sensitivity analysis presented later in these comments that show BAFs for several compounds are sensitive to this parameter.

(f) Lipid Fraction

As part of deriving the GLI BAFs, EPA developed consumption-weighted default mean values for the lipid content of TL3 and TL4 fish, and EPA provided a detailed narrative outlining the genesis of these numbers (EPA, 1995b). The resulting values were 1.82% for TL3 fish and 3.10% for TL4 fish (EPA, 1995b). These values theoretically reflect Great Lakes consumption patterns and lipid contents. These values were updated in EPA (2003), which proposed consumption-weighted mean lipid fractions of 1.9%, 2.6% and 3.0% for TL 2, 3 and 4 fishes, respectively. However, the BCFBAF™ model user guidance states that the assumed percent lipid fractions for TL 2, 3 and 4 fishes are 5.98, 6.85 and 10.7%, respectively. Therefore, in the current approach, the basis for the lipid fraction values used in the derivation of the draft updated HHWQC is unclear and not explained. It is also unclear whether they reflect whole-body lipid fraction or the edible tissue lipid fraction. Nor is it clear whether BAFs should be adjusted based on site, region or state-specific lipid contents. As described below in the sensitivity analysis, such data are available for several regions of the country and those data indicate lipid contents are substantially lower than assumed by BCFBAF™. EPA needs to provide the basis for the lipid contents used in BCFBAF™ and how BAFs are to be adjusted when lipid content of fish in other regions of the US differ from the values assumed by BCFBAF™.

(g) Fraction of freely dissolved chemical in the water (ϕ)

In Arnot and Gobas (2003), the fraction of freely dissolved chemical in the water (ϕ), is calculated as follows (as shown in Table 4 above):

$$\phi = \frac{1}{1 + \mathrm{cPOC} * 0.35 * Kow + \mathrm{cDOC} * 0.35 * 0.1 * Kow}$$

As documented in Appendix K of the BCFBAF™ user guidance, EPA has apparently replaced the α_{DOC} term of 0.35 cited in Arnot and Gobas (2003) with 0.08, as suggested by Burkhard (2000) and referenced in Arnot and Gobas (2004) without any documentation of what the factor of 0.08 represents or how it was derived. EPA needs to provide such documentation.

(h) Summary

The user guidance for the BCFBAF™ model is incomplete and not sufficiently transparent to allow a thorough review of the BAF-estimation methodology used to develop the draft updated HHWQC. While the equations used by the BCFBAF™ model to estimate bioaccumulation are based on peer-reviewed publications and appear to be scientifically defensible, insufficient or no documentation is provided to verify the values used for most of the parameters in the equations or that those values can be used to represent surface waters throughout the U.S. Prior to use in the development of HHWQC, the BCFBAF™ documentation should be revised and expanded and provided to the public for review allowing for a full and thorough evaluation.

Comment 9. For several BCFBAF™ model parameters, EPA appears to have selected default inputs that will result in BAFs that will overestimate bioaccumulation in most waters of the U.S.

Summary: The predicted BAFs from BCFBAF™ reflect the values of the default inputs for each of the parameters that affect bioaccumulation. As described in preceding comments, EPA has provided little or no supporting documentation describing the basis for the default inputs. Nor has EPA provided any information on the sensitivity of predicted BAFs to changes in input values or the variability of key inputs likely to manifest across waters of the U.S. and the effect of such variation on BAFs predicted by BCFBAF™. For several key parameters (lipid content of fish in TLs 2, 3 and 4; DOC and POC concentrations; food-web biomagnification factor [β]), EPA appears to have selected inputs that are likely to overestimate BAFs, perhaps substantially. For other parameters (e.g., temperature) the default value may underestimate BAFs. And for still other parameters (lipid content of TL 1) relatively few data are readily available making it hard to discern the effect of applying the default value to all waters of the U.S.

This section provides an overview of the historical view EPA has taken for each of three key input parameters (lipid content of fish in TLs 2, 3 and 4; DOC and POC concentrations; and β) and compares those to the proposed input values. This section also presents a sensitivity analysis of six key input parameters to help identify several inputs to which the BCFBAF™ model appears very sensitive. Table 5 lists the default values selected by EPA for BCFBAF™ model parameters and also the values used in the sensitivity analysis. This review indicates that EPA needs to provide justification for the proposed defaults used by the BCFBAF™ and also helps to prioritize those inputs for which predicted BAFs are the most sensitive and those defaults that appear to differ most from values expected in many waters of the U.S.

Table 5 Input parameters used for BCFBAF™ model sensitivity analysis

Name	Parameter	BCFBAF™ Value	Values for Sensitivity Analysis†
TL2 β	Food web biomagnification factor	16.1	1.6, 8.05, 32.2
TL3 β	Food web biomagnification factor	30.1	3.01, 15.1, 60.2
TL4 β	Food web biomagnification factor	62.7	6.27, 31.4, 125.4
DOC	Dissolved organic content (mg/L)	0.5	0.05, 5, 25
TL1 Lipid Fraction	Lipid fraction of lowest trophic level organism	0.01	0.005, 0.02, 0.1
POC	Particulate organic content (mg/L)	0.5	0.05, 5
Temperature	Water temperature (°C)	10	5, 20, 25
TL2 Weight	Organism weight (kg)	0.096	0.048, 0.192
TL3 Weight	Organism weight (kg)	0.184	0.092, 0.368
TL4 Weight	Organism weight (kg)	1.53	0.765, 3.06
TL2 Lipid Fraction	Whole-body lipid fraction of organism	0.0598	0.00524, 0.0093, 0.017
TL3 Lipid Fraction	Whole-body lipid fraction of organism	0.0685	0.0053, 0.0107, 0.017, 0.0195
TL4 Lipid Fraction	Whole-body lipid fraction of organism	0.107	0.00835, 0.0135, 0.017, 0.0247

† Values used in the sensitivity analysis were selected to be representative of possible values in U.S. surface waters.

Discussion:

(a) Lipid fraction

As discussed in Comment 8, EPA has not provided documentation supporting the proposed lipid fraction values of 5.98%, 6.85% and 10.7% for TL 2, 3 and 4 fishes. These lipid contents represent a 2 to 3-fold increase compared to lipid contents proposed previously by EPA (EPA 1995b, 2000, 2003). We compared the TL-specific lipid fraction input values obtained from the BCFBAF™ user guidance to TL-specific values obtained from the publically-available EMAP and STORET databases, both of which are maintained by EPA. As part of the water quality and toxicity data contained in both of these databases, fish lipid content is frequently reported. These databases provide a large quantity of lipid data from several regions throughout the United States and on numerous species and, thus, enable the development of specific fish lipid distributions based on region and trophic level. Distributions of lipid content in edible portions of fish were created using the observations obtained from the online databases noted above. Data points were subdivided into distinct geographic regions based on their location. Regions included Northern Atlantic, Mid-Atlantic, Midwest, and Hawaii. The databases did not include data from regions in the southern or western portions of the United States. Data were also subdivided into TLs 2, 3, and 4, based on trophic levels classified in EPA (2014a). The mean and 95th percentile upper confidence limit on the mean for all data, and for each region, as well as the default lipid contents used by BCFBAF™, is presented in Table 6. This table also shows the mean and 95th percentile upper confidence limit on the mean from a Florida statewide dataset of lipid content of near-shore marine and freshwater fish of all trophic levels.

Table 6 Regional Mean, 5th Percentile, and 95th Percentile Lipid Fractions

Dataset	BCFBAF™ Inputs*	Total			North-Atlantic			Mid-Atlantic		
		5%tile	Mean	95%tile	5%tile	Mean	95%tile	5%tile	Mean	95%tile
TL4 Edible tissue	0.107	0.0025	0.0135	0.0427	0.0015	0.00835	0.0215	0.0051	0.0247	0.0698
TL3 Edible tissue	0.0685	0.0027	0.0107	0.032	0.0029	0.00524	0.008	0.0009	0.0195	0.0444
TL2 Edible tissue	0.0598	0.0017	0.0093	0.022	0.0015	0.00524	0.0113	n/a	n/a	n/a
Florida	n/a	0.0076	0.017	0.033	nd	nd	nd	nd	nd	nd

* Not stated whether this is whole-body or edible tissue.

n/a = not applicable

nd = data not available

Lipid concentrations used in the BCFBAF™ model exceed the 95th percentile values of all trophic levels. In fact, the highest 95th percentile lipid value observed was 6.98% for TL 4 for the Mid-Atlantic region. Demonstrating the bias of EPA's lipid fractions, this 95th percentile for TL 4 is lower than the point estimate of 6.85% used by the BCFBAF™ model for TL 3. A comparison of the trophic level point estimates used by the BCFBAF™ model to the mean and 95th percentile of regionally composited distributions for each trophic level are displayed in Table 6. The BCFBAF™ model point values are substantially higher than all of the corresponding values from the distributions obtained using the national online databases.

Additionally, the BCFBAF™ model default inputs are higher than those developed in the past by several state agencies. For instance, Florida developed a statewide Florida specific distribution of lipid content of near-shore marine and freshwater fish of all trophic levels using methods consistent with EPA recommendations (FDEP, 2013). The 5th percentile, mean and 95th percentile values of this distribution (0.76%, 1.7% and 3.3%, respectively) correspond much more closely to the values obtained from the distributions developed using national online databases than to the point values used by the BCFBAF™ model.

(b) Concentration of dissolved organic carbon (DOC) and particulate organic carbon (POC)

As part of historic guidance on development of national BAFs, EPA (2000, 2003) used default POC and DOC concentrations of 0.5 ppm and 2.9 ppm, respectively. According to EPA (2003), these values represent the median (50th percentile) values from approximately 110,000 DOC measurements and 86,000 POC measurements encompassing fresh and estuarine waters in all 50 states, and EPA consciously chose these central-tendency estimates "for consistency with the goal of national BAFs" (EPA, 2003). In the current draft updated HHWQC and without providing any justification, EPA is proposing to use a default value of 0.5 ppm for both POC and DOC, which is equivalent to using the median POC concentration but a DOC concentration less than the 5th percentile of DOC concentrations (EPA, 2003). The currently proposed concentration for DOC appears to be biased low by about 6-fold. EPA provides no basis for this change in DOC concentration or, for that matter, any documentation to support either the default POC or DOC concentrations.

(c) Food web biomagnification factor (β)

According to the BCFBAF™ model user guidance, EPA has selected food web biomagnification factor (β) values of 16.1, 30.1 and 62.7, which have been "calibrated to each trophic level of measured BAF values" (Arnot and Gobas, 2003). However, Arnot and Gobas (2003) caution that β is "highly dependent on the species of interest, food web structure, environmental conditions, and ecosystem characteristics" and, most importantly, that its selection should be based on calibration with an appropriate dataset. In the current approach, EPA uses a dataset based on a food web and conditions found in the Great Lakes to calibrate β for all other food webs in national surface waters. This approach fails to take many food-web specific factors into account, most notably that food web structures in the Great Lakes are likely to consist of a much larger food chain and thus, will produce higher BAFs, particularly among the higher trophic levels. Furthermore, the basis for food chains in deep water, cold lakes (such as the Great Lakes) is likely to be different from the basis in cold, shallow mountain streams, as well as in any shallow lake or estuary, where large amounts of submerged aquatic vegetation (SAV) can be present. Ultimately, EPA needs to provide some justification for the default β values used by the BCFBAF™ model. Such justification should include a discussion of how different water body and food web characteristics affect β, a summary of β values either measured or predicted in a range of different U.S. waters, whether β varies in a predictable pattern either by water body type or geographic region of the U.S. and how BAFs are to be adjusted for state, region or water body-specific differences in β from the defaults assumed by the BCFBAF™ model.

Sensitivity analysis on select inputs for estimating national BAFs using the BCFBAF™ model

The sensitivity of the BCFBAF™ model to changes in several input parameters (organism whole-body lipid fraction, water temperature, DOC, POC, organism weight, and β) for six different chemicals (acenaphthene, aldrin, benzene, benzo[a]pyrene, chlordane, and chrysene) was examined. Table 5 lists the values used both by EPA in the BCFBAF™ model and the values used in the sensitivity analysis. Other parameters could have been included as well, but the limited information provided for the basis of the assumptions used by the BCFBAF™ model and the available time for review of the draft updated HHWQC precluded a full evaluation of the sensitivity of the model to all parameters. The range of values used for each parameter represents the range that might occur in surface waters across the U.S (Table 5). The six chemicals were selected to represent a range of chemical types (PAHs, volatile organics, and pesticides) and K_{OW} values (log K_{OW} values ranged from 2.13 to 6.50). The analysis was conducted by varying the input values for one parameter while holding all other parameters constant at the default value used by the BCFBAF™ model (Table 5). The apparent sensitivity of the model to each parameter is discussed briefly below and is plotted in Figures 1a-1c, where each figure represents the sensitivity analysis results for a specific trophic level. The sensitivity of BAFs predicted by the BCFBAF™ model to a particular parameter is represented by the height of the lines shown on the figures. Increases in BAFs compared to those predicted by the BCFBAF™ model are shown as lines above a ratio of 1.0 and decreases in BAFs compared to those predicted by the BCFBAF™ model are shown as lines below a ratio of 1.0.

Food web bioaccumulation factor (β) - Beta represents the overall biomagnification factor for each trophic level in the BCFBAF™ model, which uses default β inputs of 16.1, 30.1 and 62.7 for TLs 2, 3 and 4, respectively. The sensitivity analysis used input values ranging from a ten-fold decrease to a two-fold increase in β compared to the BCFBAF™ model's default inputs. The sensitivity analysis assumed β of 1.6, 8.05, and 32.2 for TL2, 3.01, 60.2, and 15.1 for TL3, and 6.27, 31.4, and 125.4 for TL4 (Table 5).The BAFs for aldrin and chlordane were the most sensitive to changes in β for all three trophic levels, while chrysene and benzo[a]pyrene were somewhat sensitive to β for TLs 2 and 3. The range β typical of U.S. surface waters appears more likely to decrease rather than increase estimated BAFs (Figures 1a – c).

Dissolved organic carbon (DOC) and particulate organic carbon (POC) - The BCFBAF™ model uses default DOC and POC values of 0.5 mg/L. A sensitivity analysis was conducted separately for DOC and POC. Input values for DOC ranged from a ten-fold decrease to a 50-fold increase from the default EPA input values, reflecting the DOC data distribution (minimum to 95th percentile) found in USGS National Water Information Database (USGS, 2001). Input values for POC ranged from a ten-fold decrease to a ten-fold increase from the default EPA input value, reflecting the POC data distribution (minimum to 95th percentile) found in USGS National Water Information Database (USGS, 2001). For the sensitivity analysis the POC was assumed to be 0.05 and 5 compared to a default POC of 0.5 used by EPA in BCFBAF™ (Table 5). The POC values used in the sensitivity analysis correspond to a 10 fold increase and a 10 fold decrease, respectively, over the EPA default value. For the sensitivity analysis the DOC was assumed to be 0.05, 5, and 25 compared to a default DOC of 0.05 used by EPA in BCFBAF™ (Table 5). The DOC values used in the sensitivity analysis correspond to 10 fold decrease, 10 fold increase, and 100 fold increase, respectively, over the EPA default value. Model-calculated BAFs were very sensitive to changes in DOC and POC for aldrin and chlordane, and were somewhat sensitive for benzo[a]pyrene at all three trophic levels. Values typical of DOC and POC in U.S. surface waters appear to result in lower BAFs than predicted by the defaults used in the BCFBAF™ model (Figures 1a – c).

Lipid Content of Lowest Trophic Level (Level 1) - The default lowest trophic level (i.e., TL 1 or primary producers) lipid fraction value used in BCFBAF™ is 0.01, a value derived for Canadian surface waters (and to be representative of the Great Lakes) by Arnot and Gobas (2003). For the sensitivity analysis the lipid fraction of TL 1 fish was assumed to be 0.005, 0.02, and 0.1 compared to a default lipid fraction of 0.01 used by EPA in BCFBAF™ (Table 5). The TL 1 lipid fractions correspond to a 2 fold decrease, a 2 fold increase, and a 10 fold increase, respectively, over the default EPA value. Resulting BAF's calculated by the BCFBAF™ model appear to be sensitive to changes ranging from a two-fold decrease to a ten-fold increase from EPA's default value in lipid fraction inputs at each of the three trophic levels primarily for aldrin, benzo[a]pyrene, chlordane, and chrysene (Figures 1a – c). The sensitivity to the lipid fraction of TL1 occurs at all trophic levels. Whether BAFs are actually underestimated by as much 10-fold in some surface waters will depend upon the actual lipid content of TL 1 organisms and whether other parameters interact with the lipid assumption about TL1 to reduce bioaccumulation.

Water temperature - The BCFBAF™ model assumes a default water temperature of 10 °C, a value also used in the BCFBAF™ model developed by Arnot and Gobas (2003). This default parameter was selected to represent Canadian aquatic habitats by Arnot and Gobas (2003), and may be appropriate for northern U.S. waters, but is unlikely to be applicable to warmer waters found in the southern portions of the U.S. For the sensitivity analysis the water temperature was assumed to be 5, 10, and 25 °C compared to a default temperature of 10°C used by EPA in BCFBAF™ (Table 5). The water temperatures used in the sensitivity analysis represent a range of temperatures found in US surface waters (EPA STORET database).

BAFs calculated using the BCFBAF™ model do not appear to be very sensitive to water temperatures ranging from 5, 20, and 25 °C. Aldrin, benzo[a]pyrene, chlordane, and chrysene show the greatest variation in BAFs with variation in water temperature model inputs but only at some of the trophic levels (Figures 1a – c).

Organism weight - BAFs were calculated from the BCFBAF™ model over a range of organism weight inputs that ranged from a two-fold decrease to a two-fold increase from EPA's default input parameters for each trophic level. The sensitivity analysis assumed weights (in kg) of 0.048 and 0.192 for TL2, 0.092 and 0.368 for TL3, and 0.765 and 3.06 for TL4 (Table 5) compared to default values of 0.096, 0.184 and 1.53 kg for TLs 2, 3 and 4, respectively used by EPA in the BCFBAF™ model.

Changes in organism weight did not substantially affect the calculated BAFs at any trophic level for any of the six chemicals examined (Figures 1a – c).

Lipid content. The default organism lipid fraction values for each of the three fish trophic levels used in the BCFBAF™ model were based on values derived for Canadian surface waters in Arnot and Gobas (2003). These lipid fraction values are almost twice as high as lipid fraction mean and 95th upper confidence limit on the mean (UCL) values derived from EPA's own databases (STORET and EMAP; see Table 6). For the sensitivity analysis the lipid fraction of TL 2 fish was assumed to be 0.00524, 0.0093 and 0.017 compared to a default lipid fraction of 0.0598 used by EPA in BCFBAF™ (Table 5). The lipid fraction of TL 3 fish was assumed to be 0.0053, 0.0107, 0.017 and 0.0195 compared to a default lipid fraction of 0.0685 used by EPA in BCFBAF™ (Table 5). The lipid fraction of TL 4 fish was assumed to be 0.00835, 0.0135, 0.017 and 0.0247 compared to a default lipid fraction of 0.107 used by EPA in BCFBAF™ (Table 5). The sensitivity of the BCFBAF™ model to lipid content of TL 2, 3 and 4 appears to vary between chemical but not a great deal between trophic levels. Acenaphthene, benzene, and chlordane appear to be most sensitive to lipid content of

TL 2, TL 3 and TL 4 (Figures 1a – c). Because the default lipid contents in BCFBAF™ lie within the upper percentiles of the distribution of lipid content for several areas of the U.S., use of more representative lipid contents will result in lower BAFs, indicating that draft updated HHWQC for many chemicals are more stringent than necessary.

Summary of sensitivity analysis findings:

The BCFBAF™ model-calculated BAFs for the pesticides aldrin and chlordane appeared to be the most sensitive to changes in many of the input parameters examined in the sensitivity analysis. Although these two chemicals have the highest log K_{OW} values of the six chemicals examined (aldrin log K_{OW} = 6.50; chlordane log K_{OW} = 6.22), the PAH benzo[a]pyrene, which has a log K_{OW} value of 6.13, did not exhibit as much sensitivity to variations in most of the input parameters. The PAH chrysene was also moderately sensitive to most of the input parameters, while both the PAH acenapthene and the volatile organic benzene showed very little sensitivity to most input parameters, except for lipid fraction of the high, middle, and low fish trophic levels.

Model-calculated BAFs for all of the chemicals examined except chlordane and benzene exhibited little sensitivity to changes in the lipid fractions of organisms at the high, middle, and low fish trophic levels. This is surprising because as the lipid fraction of an organism increases, a proportional increase in the amount of chemical accumulation in that organism's tissue is expected. The apparent absence of such a predicted response by the BCFBAF™ model requires explanation. Aldrin, benzo[a]pyrene, chlordane, and chrysene were, however, sensitive to variation in the lipid fraction of the lowest trophic level.

Sensitivity analyses, such as the one presented above, can be used to help guide the development of documentation necessary for models such as BCFBAF™ and to determine whether such models can be used to develop BAFs for use in the derivation of national HHWQC. The results of the sensitivity analysis indicate that the BCFBAF™ model, as currently configured and used by EPA to develop the draft updated HHWQC, should not be used to derive national HHWQC. The review of available data indicate that several of the default inputs used by the BCFBAF™ model are not representative of most waters of the U.S. and that the defaults used by the BCFBAF™ model are likely to overestimate bioaccumulation in surface waters for large portions of the U.S. EPA needs to develop a transparent methodology using the BCFBAF™ model, or an alternative model, that allows users to incorporate region specific inputs for key parameters that govern bioaccumulation and predict region, state and water body-specific BAFs.

Comment 10. EPA has not addressed the uncertainty associated with the default K_{OW} values used in the BCFBAF™ model.

Summary: EPA has chosen the BCFBAF™ model for the estimation of BAFs. Although K_{OW} is one of the primary predictive variables in the calculation of the BAFs in the module, EPA has largely ignored the uncertainty associated with the default K_{OW} values used in the BCFBAF™ module. EPA should seek SAB review of the K_{OW} selection methods utilized by BCFBAF module and clarify the selection of K_{OW} values, especially when multiple values are available.

Discussion: EPI Suite uses K_{OW} as a primary variable in the calculation of the BAF. The SAB reviewed the QSAR (Quantitative structure activity relationships) based method utilized by KOWWIN™ (USEPA, 2007). In addition, alternative QSAR based methods for the estimation of the portioning behavior of organic chemicals exist (e.g., Van Noort et al. [2010], Hawthorne et al. [2011]). For some PCB congeners, these methods can different from the KOWWIN™ values by as much as three orders of magnitude.

EPI Suite™ also includes a database of measured K_{OW} values compiled by SRC Inc. There is limited documentation regarding the criteria for inclusion in the database. As discussed in Beyer et al. (2002), experimentally derived K_{OW} values can vary by 30% or more. The SAB concluded that KOWWIN™ provides a suitably accurate estimation of K_{OW}. The SAB provides no review of the K_{OW} database and the process by which EPI Suite selects a preferred K_{OW} from this database. Neither EPI Suite™ nor the SAB provide guidance on how to resolve any differences between the experimental and modeled K_{OW} values. In addition, experimentally derived physicochemical parameters can be inconsistent and EPI Suite™ does not utilize methods such as those proposed by Beyer et al. (2002) to develop a consistent set of parameters.

The BCFBAF™ model uses experimentally derived K_{OW} values in preference to the KOWWIN™ derived values[2]. These two sets of values can vary significantly, resulting in significant uncertainty in the BAFs estimated by BCFBAF™. These differences are

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[2] Note that the experimentally-derived K_{OW} is the default K_{OW} passed to all other EPI Suite™ modules.

summarized for the six chemicals included in the sensitivity analysis. Table 7 compiles the percent change in the BAF when the KOWWIN™ model K_{OW} was used in preference of the value from the K_{OW} database for these chemicals.

Table 7 Percent changes in estimated BAFs using KOWWIN™-derived K_{OW} values compared to values from the experimental K_{OW} database

	Acenaphthene	Aldrin	Benzo[a]pyrene	Benzene	Chlordane	Chrysene
Percent Change	0.00	29.12	0.69	34.59	8.14	13.50

The results show a change in the BAF of as much as almost 35% for these six chemicals when the values estimated by the SAB reviewed KOWWIN™ module are used in preference to the values selected from the K_{OW} database. An extensive evaluation of all 94 chemicals for which EPA had developed draft updated HHWQC was not conducted but it is reasonable to assume that differences of 30% or more are relatively common, with larger differences being almost certain. Beyer et al. (2002) similarly observed that the range of experimentally derived K_{OW} values routinely spans 30%, or more. Given that K_{OW} values are routinely reported in $\log_{10}$ units, differences of 30% in arithmetic units are often overlooked, but they are potentially significant nonetheless. The differences between QSAR based estimates of K_{OW} also results in different estimates of the BAF. For example, KOWWIN™ estimates a log K_{OW} of 8.27, resulting in a BAF of 7.05×10^6; while Hawthorne et al. (2011) estimated a $\log_{10} K_{OW}$ of 7.12, resulting in a BAF 8.0×10^6.

This simple analysis shows that the BCFBAF™ module is sensitive to routine variability in the estimate of K_{OW} for a single compound. The selection of the default K_{OW} values used by BCFBAF™ should be more thoroughly documented and based on a peer reviewed methodology.

Comment 11. The BCFBAF™ model does not account for metabolism in the gut.

Summary: EPA has proposed to use the steady-state bioaccumulation model originally published by Arnot and Gobas (2003) to predict substance-specific BAFs in fish from three trophic levels as input into calculations used to derive HHWQC. This model also incorporates a QSAR for estimating the biotransformation rate in fish tissue or kM (Arnot et al., 2009). This is an important modeling advance since this process can significantly mitigate the extent of bioaccumulation for more hydrophobic substances. However, a key limitation of the current BCFBAF™ model formulation is that while metabolism in tissue is quantitatively considered, metabolism in the gut is ignored. As discussed below, this process is critical in limiting the role of dietary uptake and subsequent bioaccumulation in the food web for a number of chemicals.

Discussion: The key model parameter that is influenced by gut metabolism is the chemical assimilation efficiency (AE) which is expressed as a fraction of chemical absorbed to that ingested via the diet in an uncontaminated fish. Currently, this key process appears to be modeled with a simple relationship that predicts AE based on the substance's log K_{OW} as reported by Kelly et al. (2004) and is described by the following equation;

$$AE = 1/(5x10^{-8} \text{ x } K_{OW} + 2)$$

It is stated in this paper that this relationship is based on the much earlier compilation of empirical AE data in fish by Gobas et al. (1988) for recalcitrant compound classes. Figure 1 shows that empirical AE data reported in this paper for polychlorinated biphenyls (PCBs) and three chlorinated insecticides (DDT, chloroane, mirex) are consistent with the above equation as denoted by the solid red line. As a result, the present AE model cannot be assumed to be broadly reliable across chemical classes for which EPA has derived HHWQC.

To support this point, empirical data on AE values obtained with trout for polyaromatic hydrocarbons (PAHs) were compiled from three earlier studies (Table 8). These data are plotted in Figure 2 as blue symbols and show the significantly lower AE values than are assumed in the current BCFBAF™ model as a consequence of gut metabolism. These empirical data were used to fit a revised relationship:

$$AE = 1/(3 \text{ x } 10^{-4} \text{ x } K_{OW} + 2.5) + 0.01$$

This relationship provides a conservative upper bound value of 0.01 at high log K_{OW} and is shown for comparison to the default model used in BCFBAF™ (Figure 3).

PAHs are not the only class of compounds that exhibit lower AEs than recalcitrant compounds like PCBs. For example, studies with individual dialkyl phthalate esters (DPEs) in staghorn sculpin demonstrated that these compounds were very effectively transformed in the gut with no significant accumulation from dietary exposure indicating very low (<0.01) assimilation efficiencies (Webster et al., 2003).

Table 8 **Experimental data characterizing AE in fish for selected chemicals**

Substance	Log K_{OW}	AE	Reference
Acenathalene	3.94	0.32	Niimi and Dookhran (1989)
9H-Fluorene	4.02	0.14	Niimi and Palazzo (1986)
Anthracene	4.35	0.01	Niimi and Palazzo (1986)
Phenanthrene	4.35	0.04	Niimi and Palazzo (1986)
Phenanthrene	4.46	0.12	Hellou and Leonard (2004)
Pyrene	4.88	0.02	Hellou and Leonard (2004)
2-Methyl Anthracene	4.89	0.14	Niimi and Dookhran (1989)
9-Methyl Anthracene	4.89	0.01	Niimi and Dookhran (1989)
Fluoranthene	4.93	0.01	Niimi and Palazzo (1986)
Fluoranthene	4.93	0.06	Hellou and Leonard (2004)
Triphenylene	5.52	0.04	Niimi and Dookhran (1989)
Benzo[a]pyrene	6.11	0.01	Niimi and Palazzo (1986)
Perylene	6.11	0.02	Niimi and Dookhran (1989)
Butylbenzyl Phthalate	4.73	<0.01	Webster (2003)
Bis(2-Ethylhexyl) Phthalate	7.60	<0.01	Webster (2003)

To demonstrate the impact of AE assumptions on BAF predictions, the spreadsheet version of the BCFBAF™ model was obtained from Dr. Arnot and used to perform sensitivity analyses. For PAHs the dietary uptake term in column D of the worksheet for lower, middle and upper trophic level fish was modified by multiplying by this term by the ratio of the revised to default AEs determined by equations [2] and [1], respectively. For DPEs, an upped bound revised assimilation efficiency of 0.01 was assumed so that the ratio was computed by dividing this value by the default AE predicted using equation [1]. The default and revised AEs are summarized in Table 2. A comparison of the predicted BAFs obtained with the default model (i.e. BAFs included in EPA's supporting Table summarizing updated input values for 2014 draft updated human health criteria) to values generated using the revised AE assumptions is provided in Table 9.

Table 9 **Summary of predicted 2, 3 and 4 trophic level fish BAFs using default (BCFBAF™) and revised (including gut metabolism) assumptions for the assimilation efficiency of the substance from ingested diet**

Substance	CAS Number	Log Kow	Default AE	Revised AE	Default BAF TL2	Revised BAF TL2	Default BAF TL3	Revised BAF TL3	Default BAF TL4	Revised BAF TL4
PAHs										
Acenaphthene	83-32-9	3.92	0.50	0.21	123	122	116	116	95	95
Fluorene	86-73-7	4.18	0.50	0.15	763	454	790	454	909	429
Anthracene	120-12-7	4.45	0.50	0.10	1212	844	1169	839	1151	787
Pyrene	129-00-0	4.88	0.50	0.05	1322	333	1058	303	785	227
Fluoranthene	206-44-0	5.16	0.50	0.03	790	575	563	513	388	380
Benzo(a) Anthracene	56-55-3	5.76	0.49	0.02	1577	603	749	537	406	398
Benzo(b) Fluoranthene	205-99-2	5.78	0.49	0.02	5325	1572	2643	1371	1165	993
Chrysene	218-01-9	5.81	0.49	0.02	8997	1700	4739	1555	1993	1154
Benzo(k) Fluoranthene	207-08-9	6.11	0.48	0.01	1883	479	676	398	301	288
Benzo(a) Pyrene	50-32-8	6.13	0.48	0.01	2736	500	984	419	396	300
Dibenzo(a,h)Anthracene	53-70-3	6.54	0.46	0.01	24690	1719	10700	1340	2863	889
Ideno(1,2,3-cd)Pyrene	193-39-5	6.70	0.44	0.01	5370	466	1465	354	317	243
DPEs										
Butylbenzyl Phthalate	85-68-7	4.73	0.50	0.01	62	23	55	21	40	16
Bis(2-Ethylhexyl)	117-81-7	7.60	0.25	0.01	17370	131	6120	56	1040	31

Results from Table 9 are depicted graphically by plotting the ratio of the default to revised BAF for each trophic level (denoted by different colored symbols) as a function of the log K_{OW} of the substance (see Figure 3). Result indicate that for substances with a log K_{OW} smaller than five, the additional conservatism introduced is within a factor of 5, while for substances with a log K_{OW} greater than five but smaller than seven, the factor increases to about 20 and for substances with a log Kow of greater than seven this factor can increase to more than100. Discrepancies are most pronounced for TL 2 fish as the role of fish biotransformation at subsequent trophic levels decreases the predicted BAF. These results have important implications for derivation of water quality criteria for these and other substances that are subject to transformation in the gut. Given the order of magnitude differences that are observed depending on AE assumptions it is apparent that the present BCFBAF™ model is overly conservative and cannot be reliably used to support criterion development without careful substance-specific calibration.

Comment 12. Development of an alternative model or methodology to predict state-, region- and water body-specific BAFs.

<u>Summary:</u> For the reasons described in the preceding comments, adopting single default values for national BAFs, especially if based on a Great Lakes food web, is not scientifically justified. In addition, many of EPA's default inputs to the BCFBAF™ model appear to contribute high bias to the resulting BAFs, particularly when taking into consideration characteristics of other U.S. waters. Such state-, region- and water body-specific characteristics, if they have an important effect on bioaccumulation, need to be accounted for. However, it appears that the BCFBAF™ model cannot fully accommodate user input of critical metrics that are known to vary on a site-specific basis. To address this critical shortcoming, we recommend that, prior to adopting any national BAFs, EPA evaluate alternatives to BCFBAF™ more amenable to development of state-, region- and water body-specific BAFs.

<u>Discussion:</u> There are alternative models for estimating BAFs which may be better suited for estimating site-specific BAFs, and EPA itself (Burkhard et al. 2006) has demonstrated an approach for extrapolating BAFs across ecosystems using AQUAWEB (Arnot and Gobas, 2004). In addition, AQUAWEB was identified by EPA's SAB (EPA 2007) as a potentially useful model for estimating BAFs (EPA 2007). Thus, it's unclear why EPA has selected to use BCFBAF™. Regardless, given the range of options for developing BAFs, EPA needs to provide some justification for its decision to use any one approach, including use of BCFBAF™. At the very least, EPA needs to directly compare the utility of BCFBAF™ and AQUAWEB for development of national default BAFs, paying particular attention to how amenable each approach might be to adjustment for site-, regional- or ecosystem-specific conditions. Ideally, EPA would request input for the SAB on this.

Ultimately, we suggest that EPA should specify use of some mechanistic food web model allowing use of site-specific values for all critical parameters for estimating site-specific BAFs and allow time for States and authorized Tribes to apply this model using region-, state-, or water body-specific data: a less preferred option would be for EPA to use the same model to develop default numeric BAFs appropriate for a range of waters (i.e., food webs) and afford some flexibility to States and authorized Tribes in identifying the correct BAFs for specific water bodies. Either of these options is preferable to simply adopting a single set of BAFs as national defaults. Finally, as we have stated multiple times throughout these comments, we believe it is very important that any methodology for estimating national BAFs should be reviewed by EPA's Science Advisory Board (SAB) prior to being used in development of HHWQC.

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Figures

Figure 1a - Sensitivity Analysis results for TL 2: Ratio of “user-defined BAF: BCFBAF™ default BAF” plotted for each each of six BCFBAF™ inputs (β, DOC, TL 1 lipid fraction, POC, water temperature, organism weight, and TL-specific lipid fraction) for six chemicals (acenaphthene, aldrin, benzo[a]pyrene, benzene, chlordane, and chrysene) for trophic level 2.

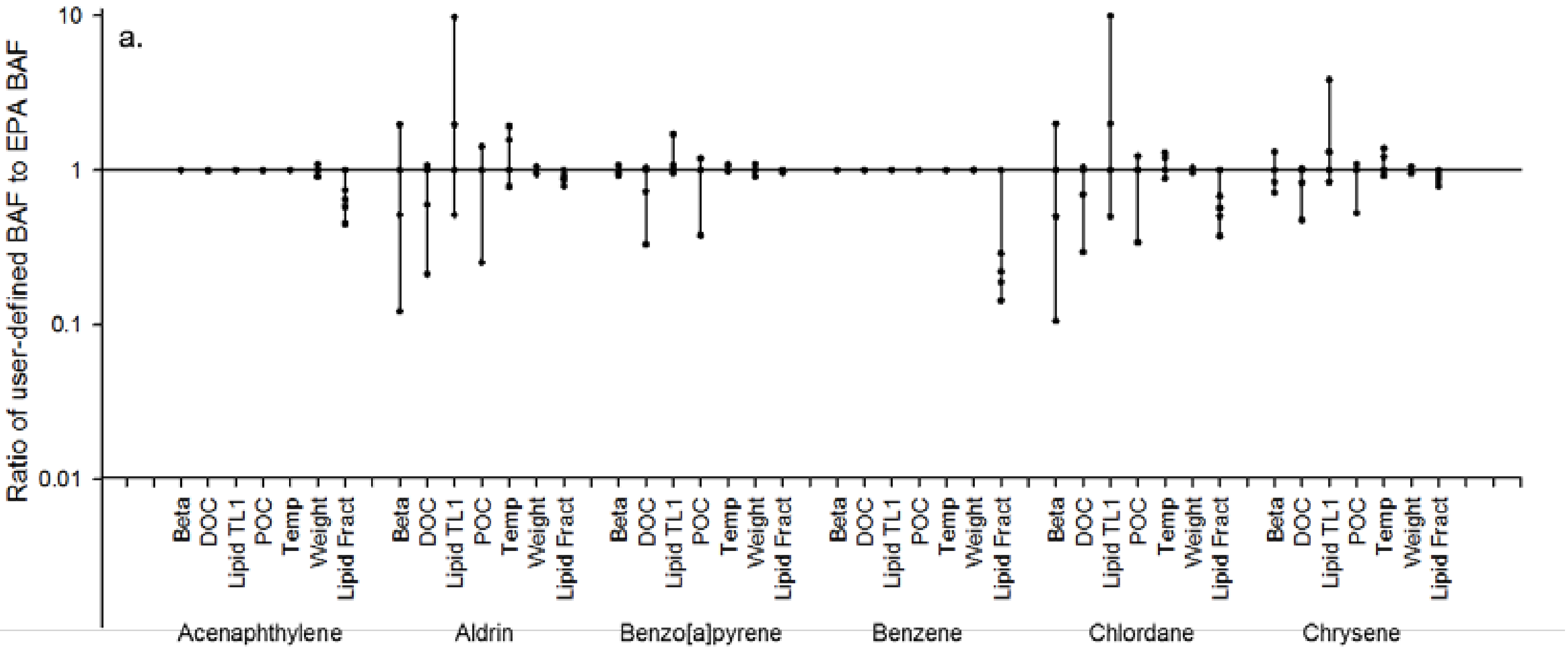

Figure 1b - Sensitivity Analysis results for TL 3: Ratio of "user-defined BAF: BCFBAF™ default BAF" plotted for each each of six BCFBAF™ inputs (β, DOC, TL 1 lipid fraction, POC, water temperature, organism weight, and TL-specific lipid fraction) for six chemicals (acenaphthene, aldrin, benzo[a]pyrene, benzene, chlordane, and chrysene) for trophic level 3.

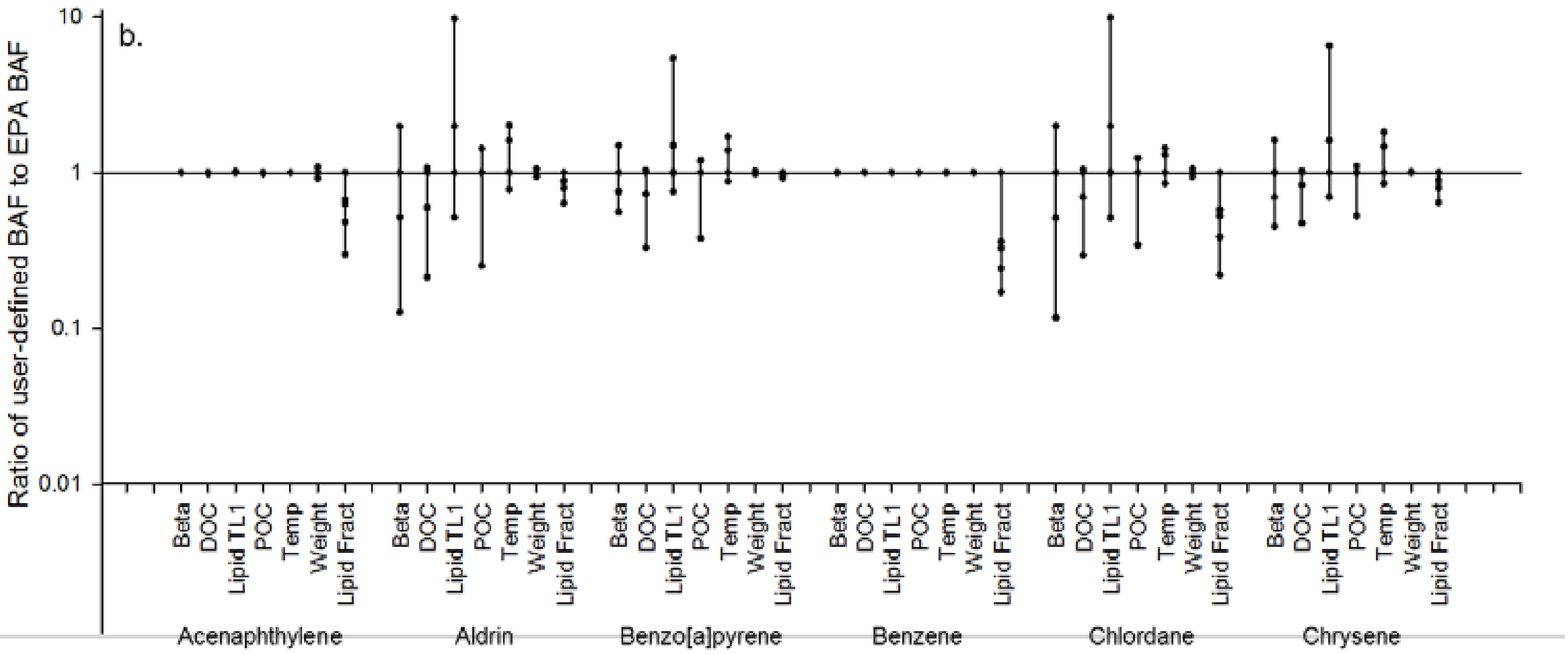

Figure 1c - Sensitivity Analysis results for TL 4: Ratio of “user-defined BAF: BCFBAF™ default BAF” plotted for each each of six BCFBAF™ inputs (β, DOC, TL 1 lipid fraction, POC, water temperature, organism weight, and TL-specific lipid fraction) for six chemicals (acenaphthene, aldrin, benzo[a]pyrene, benzene, chlordane, and chrysene) for trophic level 4.

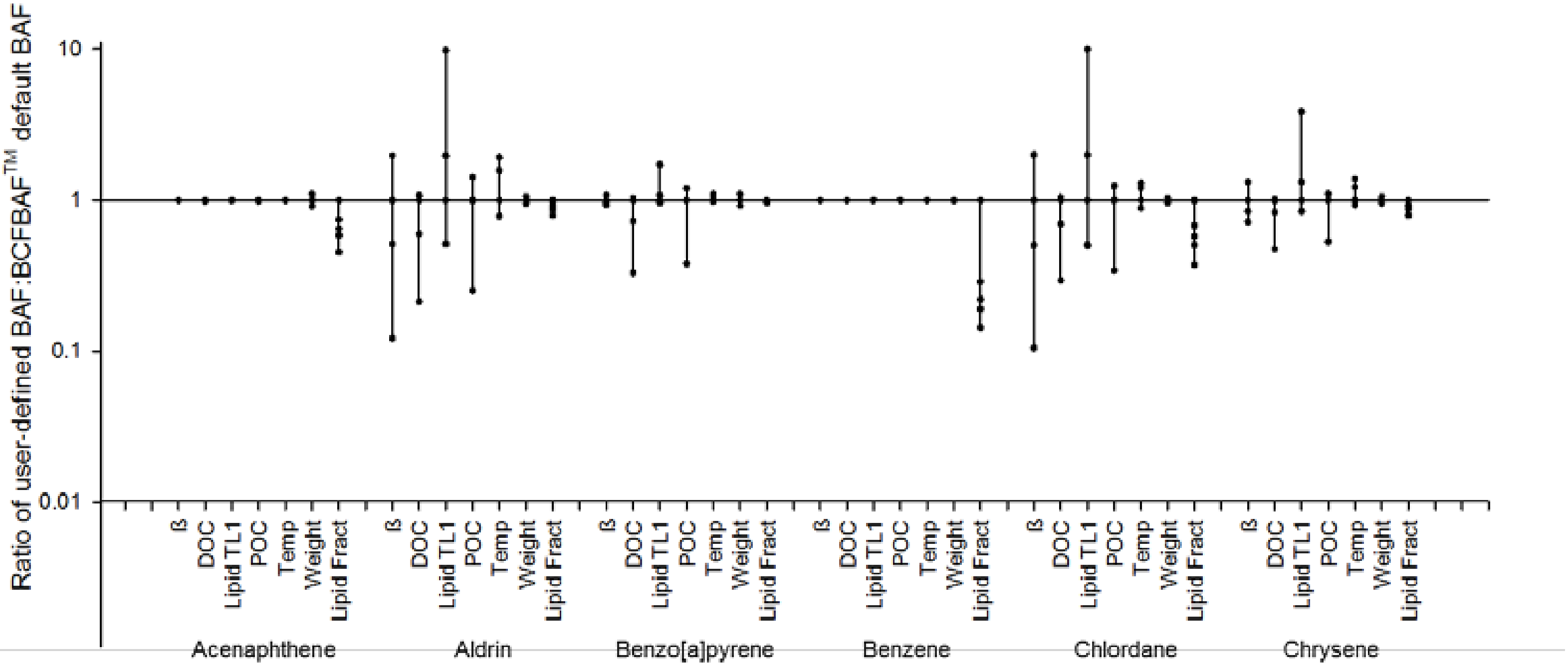

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Figure 2. Relationship between substance assimilation efficiency in ingested diet for fish with substance Log Kow. Recalcitrant compounds (red); Polyaromatic hydrocarbons (blue).

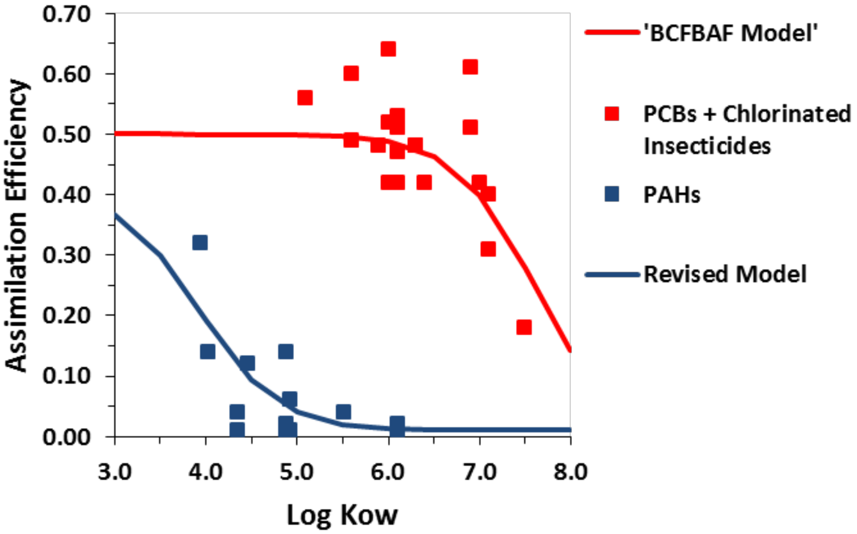
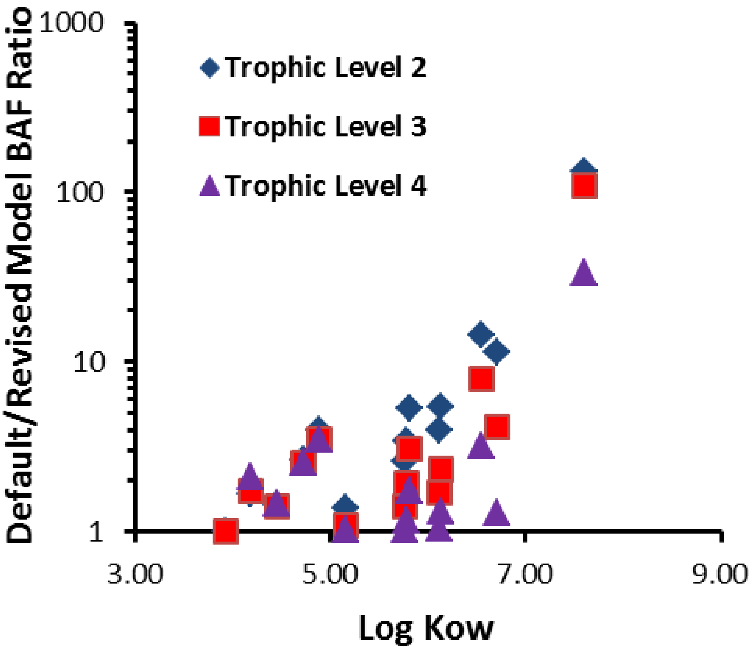


Figure 3. Sensitivity of BCFBAF model predictions to different assumptions for the substance specific assimilation efficiency (AE) input parameter.



E

Date October 15, 2015

TO: Adriane Borgias, Water Quality Program, Ecology

THROUGH: Dale Norton, Unit Supervisor, Environmental Assessment Program, Ecology

CC: Chris Kuperstein, City of Spokane
Jeffery Donovan, City of Spokane
Dale Arnold, City of Spokane
Chris Page, Ruckelshaus Center
Kara Whitman, Ruckelshaus Center
Spokane River Toxics Task Force

FROM: William Hobbs, Environmental Assessment Program, Ecology

SUBJECT: **Spokane Stormwater**

Background: The first comprehensive sampling of the City of Spokane stormwater discharges (4 CSO basins and 10 stormwater basins) occurred in May and June 2007 by Ecology and Parsons (Parsons, 2007). This sampling event, coupled with the Spokane River PCB Source Assessment (Serdar et al, 2011) suggested that stormwater was a significant contributor of PCBs to the Spokane River. In 2009-2011, Ecology collected some samples from select basins (e.g. Union) in an effort to trace sources. From 2012 through 2014, the City of Spokane monitored 3 MS4 stormwater basins (Cochran, Union, Washington) and 2 CSO basins (CSO34 and CSO06) regularly (nearly monthly). The monitoring was part of City's Integrated Clean Water Plan (City of Spokane, 2015). The monitoring began in October 2012 for 2 of the MS4s (Cochran and Union) and in spring 2013 for the Washington MS4 basin and CSO 34, and late 2013 for CSO 6. The City of Spokane has completed a significant amount of work on the stormwater infrastructure since the 2007 sampling. Many of the basins have changed configuration and CSOs have been re-routed. Furthermore, sampling techniques are different between the 2007 (grab) and 2012-13 (composite) sampling periods. Comparison between the sample periods is therefore difficult. However, rough comparisons between available data suggests that there have been minimal changes in the PCB concentrations of stormwater. Loads were not compared because previous loads were annual, while the current loads are storm event-based. The City of Spokane has 129 stormwater basins and 24 CSOs that discharge to the river via 20 outfalls. The current area sampled by the City represents 43% of the total stormwater catchment area, leaving 57% un-sampled.

Goal: To provide an understanding of current stormwater quantity and quality in order to refine our understanding of stormwater loading to the Spokane River. This information will be useful to the Spokane River Regional Toxics Task Force (SRRTTF) in designing sampling to fill data gaps in our understanding of stormwater loading. This analysis involved three components:

1. Evaluation of hydrologic contributions of stormwater
2. Evaluation of PCB concentrations over time
3. Mass loading of PCBs to the river

***Runoff Quantity* :** Runoff quantity was assessed by comparing 2 individual storm events (October 25-29, 2012 and May 21-23, 2013) that have measured flow volume and precipitation data with the USGS recorded flow of the Spokane River for the same period of time. The USGS station (12422500) at Spokane was used. The City of Spokane supplied the measured flow volumes and precipitation data from their ongoing monitoring program. The calculations therefore do not encompass all stormwater contributions to the Spokane River, only the monitored outfalls. Storms were selected in October 2012 and May 2013 based on the completeness of the data. The amount of precipitation varied across the City of Spokane. The October 2012 event ranged from 0.03 - 0.43 inches of precipitation, and 1.09 - 0.25 inches in May 2013. The flow of the Spokane River during the October 2012 event was near average, whereas the flow during the May 2013 event was at and below average (Figure 1).

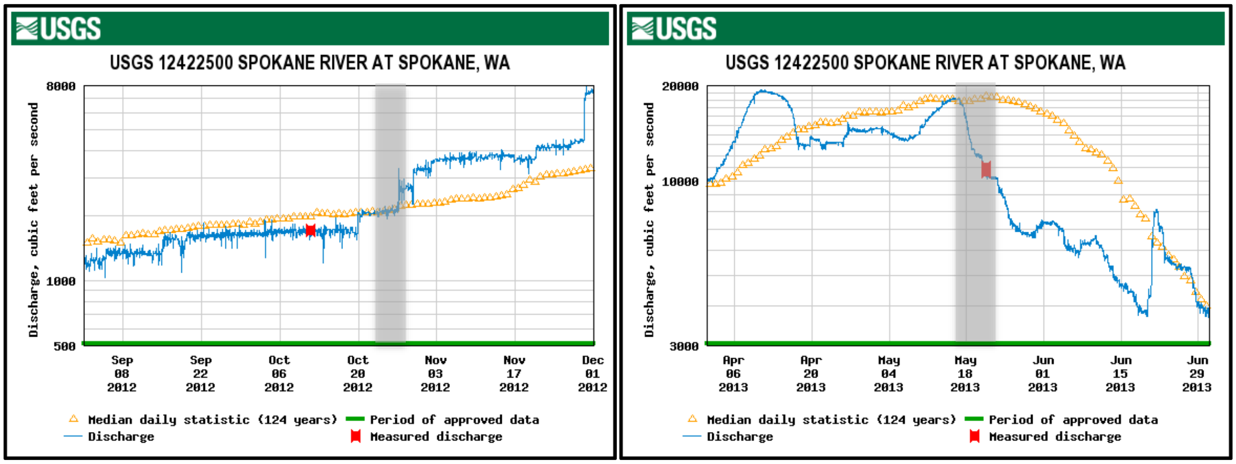


Figure 1: Hydrographs of Spokane River discharge for October 2012 (left panel) and May 2013 (right panel). Grey shading indicates the period of time used in comparison to stormwater flow.

The results show that during the October 2012 storm the stormwater contributed approximately 0.25% of the volume of water present in the Spokane River (Table 1). During May, the percent contribution was an even smaller fraction of the (0.03%) of the total volume of the Spokane (Table 1).

Table 1: % contribution of measured stormwater/CSOs during the October 2012 and May 2013 storm event by absolute volume.

	hydrology (liters)
October 2012	
Spokane River	6.65×10^{9}
stormwater/CSO	1.60×10^{7}
	0.240%
May 2013	
Spokane River	3.72×10^{10}
stormwater/CSO	1.20×10^{7}
	0.032%

The measured stormwater and CSO discharge volumes were also compared with volumes derived using standard approaches to estimating runoff. These standard methods are based on the “Simple Method” and were used in both the Parsons (Parsons, 2007) and Ecology (Serdar et al. 2011) previous studies. The Simple Method estimates stormwater runoff pollutant loads from urban areas (Shueler, 1987). The Simple Method estimates annual runoff as a product of annual runoff volume and the runoff coefficient (Rv); where Rv is unitless and can be estimated using the formula:

$$Rv = 0.05 + 0.9 * fraction\ of\ impervious\ cover\ (Ia)$$

In reality the runoff coefficient is simply the ratio of volume of precipitation falling onto a catchment basin : volume of runoff from the catchment basin. The measured runoff coefficients were calculated for each storm event for approximately 2 years of sampling using the City of Spokane data and compared to estimated values from the Simple Method. The measured values are an order of magnitude lower than those estimated using the Simple Method. Table 2 describes the measured and estimated percent of the rainfall that becomes runoff from the three main basins runoff. This would mean that actual runoff volumes are lower than those estimated using the Simple Method. Furthermore, the runoff coefficients vary from storm to storm and would likely vary with the season. The estimated runoff volumes were used in the previous assessment of PCB load from stormwater and therefore it was likely an over-estimate of actual runoff volumes. The over-estimate of runoff volumes would result in an over-estimate of PCB loads. It would be preferable that the runoff coefficient be as accurate as possible when used to estimate runoff volumes. It may be possible to calculate an adjustment factor between measured and estimated runoff coefficients for Spokane.

Table 2: Estimated and measured runoff coefficients as percentages for 3 main stormwater basins. The values are the percent of the rainfall that becomes runoff. The measured coefficients are described as median values with total number of values used (n) and the standard deviation of the data (sd).

	Measured runoff coefficient			**Estimated runoff coefficient (simple method)**
	Median	**n**	**sd**	
Trent & Erie (Union Basin)	8.72%	8	4.2%	31%
Cleveland & Nettleton (Cochran Basin)	7.17%	21	31.9%	23%
Washington St Bridge (Washington Basin)	6.70%	7	5%	29%

PCB Concentrations: The City of Spokane has 2 years of high resolution PCB data for the Union storm basin. Union basin has not changed considerably since the Parsons sampling in 2007. Alterations to the Cochran basin prevent comparisons between Ecology and City of Spokane sampling. The concentrations obtained during the Union sampling by Parsons and later by Ecology can be compared to gauge whether

PCB concentrations have changed. However, it should be acknowledged that sampling protocols were different between the sampling events; grab sampling in the Parsons and Ecology and composite sampling by the City of Spokane. Composite samples are more representative of event mean concentrations for a storm event. Sampling events were compared as three groups of data (Ecology/Parsons 2007, Ecology-2009-2011, and City of Spokane 2012-2013) (Table 3 and Figure 2). Data was also explored in groups of data separated by cleaning events in the Union lines (Table 3). Data was grouped by pre-cleaning, post-maintenance (2010), and post-maintenance (2012) (Figure 2). All data was tested for statistical significance using an analysis of variance on log transformed data to assure normality of the data.

Table 3: PCB data from City of Spokane (2014) report (Table 5) and Parsons (2007) report from Union basin.

SAMPLE/ ORGANIZATION	**DATE**	**Sample Type**	**Precipitation (inches)**	**PCBs (pg/l)**
Ecology/Parsons (UNION)	5/2/2007	Grab	unk	168,160
	5/21/2007	Grab	unk	16,100
Ecology (UNIONLPT Sample Location)	6/8/2009	Grab	0.29	73,000
	10/2/2009	Grab	0.11	58,200
	2/16/2010	Grab	0.12	460,000
	4/29/2010	Grab	0.48	60,600
	Union Basin Pipe Cleaning and Lee/Springfield Plug Installed June 2010; Remedial Maintenance July-Aug 2010			
	9/9/2010	Grab	0.06	256,000
	1/7/2011	Grab	0.19	55,300
City of Spokane (Trent & Erie Sample Location)	10/29/2012	Composite	0.43	37,346
	Union Basin Remedial Maintenance 10/29/12 to 11/5/12			
	11/1/2012	Composite	0.11	43,841
	11/3/2012	Composite	0.24	47,972
	11/8/2012	Composite	0.34	18,113
	11/12/2012	Composite	0.33	48,862
	3/20/2013	Composite	0.26	19,403
	4/10/2013	Composite	0.07	13,766
	5/13/2013	Composite	0.31	47,455

Union basin continues to have the highest measured concentrations of PCBs out of all basins monitored by the City. Sampling of the Union basin over time has shown a decrease in concentrations (Figure 2). Overall, there is a statistically significant difference over time (ANOVA *p*=0.045). This difference is because of the decrease between the Ecology 2009 and City of Spokane 2012-13 sampling (*p*=0.036); there is no difference between the Ecology 2007 and 2009 samples. It is possible that the observed difference in concentration is due to differences in sampling technique. The Ecology 2007 and 2009 samples were collected as grab samples, whereas the City samples in 2012/13 were composite samples.

Composite samples would better represent the storm event mean concentrations and therefore be more reliable.

In addition, the City has cleaned the stormwater pipes in the Union basin on two occasions (2010 and 2012), as detailed in Table 3. The analysis of data pre- and post-cleaning of the pipes includes both grab and composite samples. Cleaning of the Union line has not reduced the PCB concentrations to a level of statistical significance (ANOVA *p*=0.124) (Figure 2).

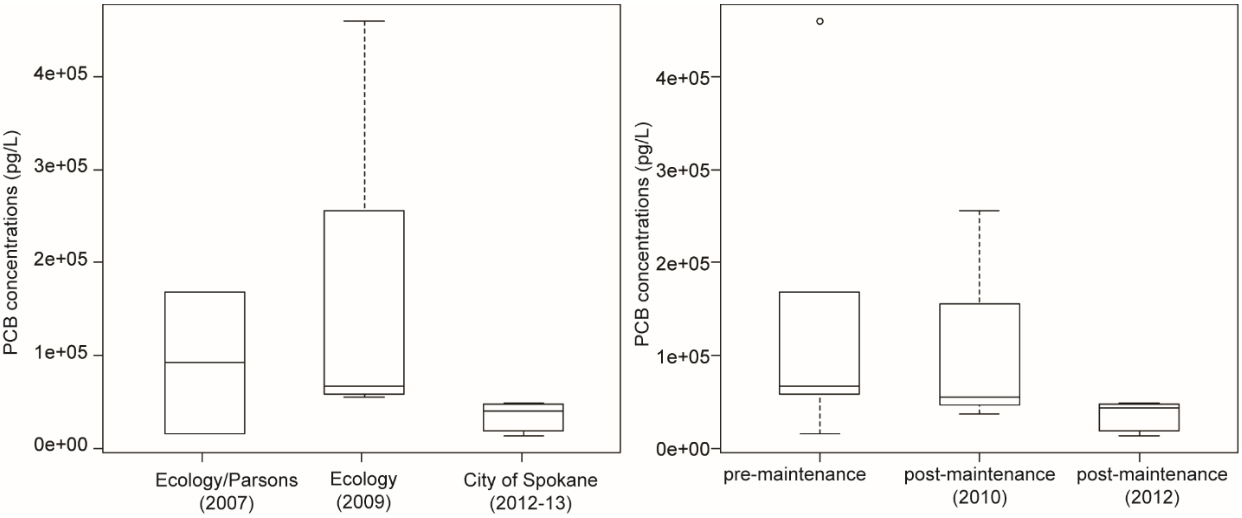


Figure 2: Boxplot of PCB concentrations from the Union basin over time (left panel) and pre- and post-maintenance of the lines (right panel). Horizontal lines within the boxes are median concentrations and the limits of the boxes are 25th and 75th percentiles of the data.

The Washington storm basin was sampled by Ecology in 2007 and by the City of Spokane in 2012. It appears there are higher PCB concentrations during the more recent City sampling (Figure 3), however there is no statistical difference between the two sample periods (t-test *p*=0.052).

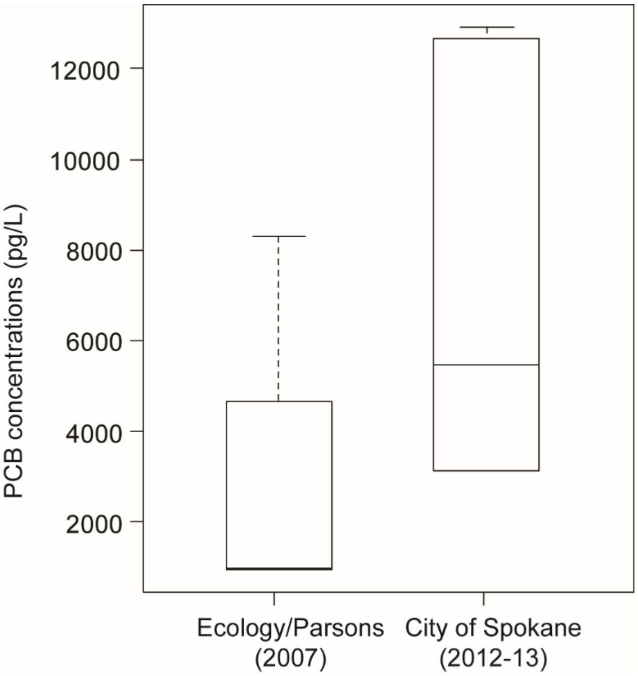


Figure 3: Boxplot of PCB concentrations from Washington basin, comparing the 2007 and 2012 sampling periods. There is no significant difference.

PCB Loading: In a similar approach to assessing water quantity, the PCB concentrations were used to compare the measured PCB mass (load) contributed during the October 2012 and May 2013 storm events with the total PCB mass in the Spokane River over the same period of time. PCB mass was summed from the monitored stormwater / CSO basins. The PCB mass in the Spokane River during each storm event was calculated using the USGS flow data over the period of sampling and the concentration data from Era-Miller (2013). The Era-Miller (2013) data were accessed through Ecology's EIM system using the project code "BERA0009" (https://fortress.wa.gov/ecy/eimreporting/). Comparisons were made for 2 locations in the Spokane River (Table 4). The measurements of flow and PCB mass from the Spokane River are not co-located, but the timing of river and stormwater sampling do overlap.

During the October 2012 storm event the measured outfalls contributed 51% of the PCB mass (Table 4). No samples exist during October 2012 from the Spokane River upriver of the storm outfalls. During the May 2013 storm event the measured outfalls contributed about 18% of the PCB mass (mg) (Table 4).

Table 4: % contribution of measured stormwater/CSOs during the October 2012 and May 2013 storm event by absolute PCB mass.

	Upriver Dam - PCB mass (mg)	**Above Latah - PCB mass (mg)**
October 2012		
Spokane River	ns	112
stormwater/CSO	ns	57.3
	ns	**50.97%**
May 2013		
Spokane River	1438	906
stormwater/CSO	166	166
	11.52%	**18.29%**

Un-sampled Load: The City of Spokane has 129 stormwater basins and 24 CSOs (Table 5). The basins currently sampled are all above the 80th percentile by area (Figure 4) and represent 43% of the total drainage area of Spokane. Delineation of the all the catchments exists, but no flow or PCB data for the basins outside those targeted in the Integrated Clean Water Plan (5 basins, 6 sample sites) is available.

The original Parsons report (2007) estimated contributions from un-sampled CSOs using the Simple Method for a "high CSO load scenario". The flow from a CSO is not described by the Simple Method and the runoff coefficients therein because it does not flow continuously, which is what the Simple Method assumes. Therefore only the "low CSO load scenario" (as estimated by Parsons, 2007) that relies on measured flow should be used. Un-sampled CSO basins do have continuous flow monitoring; therefore we can take a median CSO concentration and apply to the individual flows to get an estimate of un-sampled CSO PCB contributions.

Table 5: Statistical summary of Spokane storm basin areas in acres.

number of basins	minimum	maximum	mean	25%	median (50%)	75%	90%	95%
153	0.07	5245.00	115.5	0.85	4.15	54.35	188.94	458.37

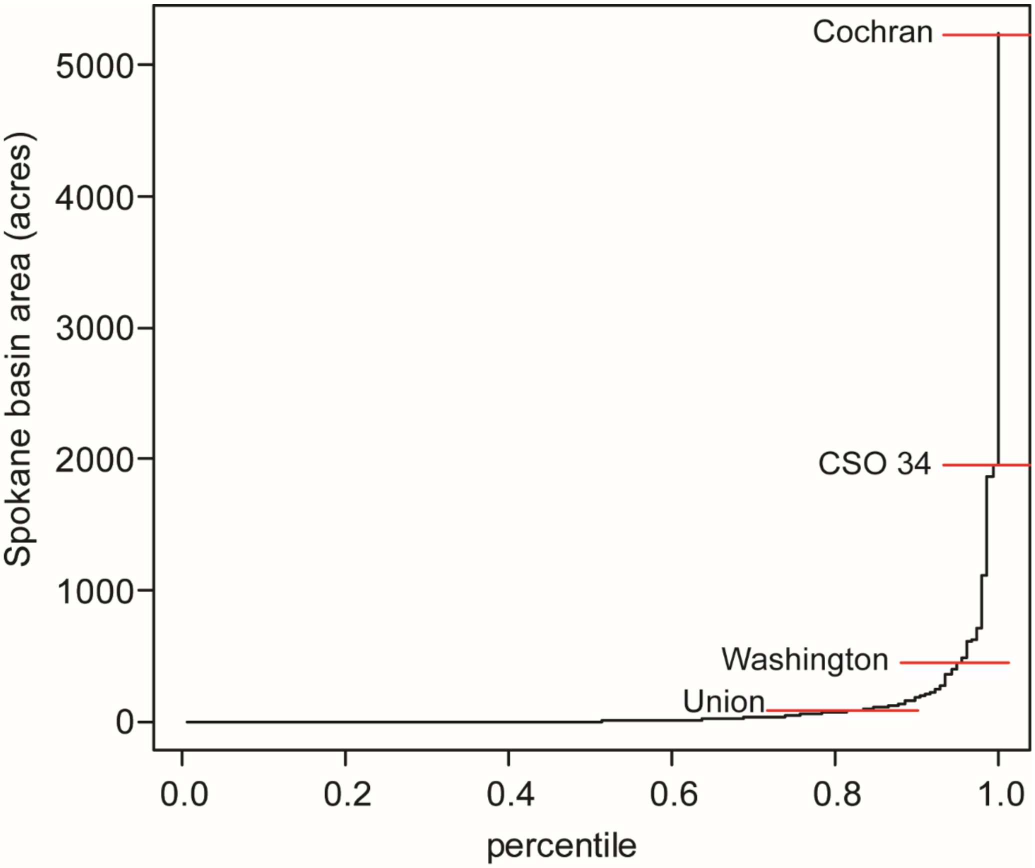


Figure 4: Empirical density function (EDF) of stormwater and CSO basin area (acres). Shows the distribution of all the basins by size. The basins currently monitored by the City of Spokane are highlighted by red lines. Percentile represents the percentage of basins smaller; for example the Washington basin is at percentile 0.94, meaning 94% of the basins are smaller than the Washington basin.

The flow from the Cochran basin is currently being modeled by the City of Spokane to understand the measured flow. Once this is complete it will provide a means to estimate flow from un-sampled basins more accurately. Unfortunately, this will not be completed in time for any potential sampling events in the Fall of 2015. In the interim estimating the un-sampled flow from all MS4 stormwater basins may be possible using established precipitation-runoff relationships from the sampled catchments and a corrected Simple Model for the un-sampled basins. The PCB load could then be estimated using the median PCB concentrations from the 2 years of sampling by the City.

An attempt was made here to use the precipitation – runoff relationships to estimate annual runoff volume and annual PCB load. However, verifying the results with the model established for the Cochran basin showed that simple estimates based on the precipitation – runoff model overestimated annual runoff by 200%. Further work with the City of Spokane is required to be able to use precipitation-runoff relationships and existing stormwater models.

In addition, the previous estimates were based on one annual rainfall total. There is spatial variability among the Spokane rain gauges and each basin rainfall total should be triangulated to the nearest stations.

Summary of findings

- Based on recent sampling (2012-2013), the mass of PCBs discharged in the MS4 and CSO systems of Spokane, seem to represent a significant fraction of what's in the river during storm events. The 2 storm events analyzed suggest a range of 18-50% based on 2012-13 data.
- It does not appear that PCB concentrations have significantly changed between the 2007 (Parsons, 2007) and the 2013 (City of Spokane, 2014) sampling periods.
- The biggest gap in estimating PCB loads for all stormwater discharges is understanding the actual runoff volume.

Recommendations

- The simple method for estimating flow should not be applied to Spokane basins, unless a suitable correction factor or revision of coefficients is possible.
- CSO flow should rely on measured values from the City of Spokane system.
- Continue to develop the model for the Cochran basin; consider what would be necessary to measure during future sampling events to allow this model to be applicable to other smaller basins to get a decent estimate of flow.
- Consider sampling a subsection of the small basins which have not been monitored to give some estimate of concentrations and flow.
- Alternatively, consider sampling more of the larger basins to increase the total percent of Spokane drainage area sampled:
  - ► Sampling all the basins larger than Union, which is 30 basins, would capture 92% of the drainage area of Spokane
  - ► Sampling the top 10 basins by area, which are mainly CSOs, plus Union basin would capture 75% of the Spokane drainage area.
- All planning for future stormwater sampling should be done in consultation with the City of Spokane.

References

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11/8/84

EPA POLICY FOR THE ADMINISTRATION OF ENVIRONMENTAL PROGRAMS ON INDIAN RESERVATIONS

INTRODUCTION

The President published a Federal Indian Policy on January 24, 1983, supporting the primary role of Tribal Governments in matters affecting American Indian reservations. That policy stressed two related themes: (1) that the Federal Government will pursue the principle of Indian "self-government" and (2) that it will work directly with Tribal Governments on a "government-to-government" basis.

The Environmental Protection Agency (EPA) has previously issued general statements of policy which recognize the importance of Tribal Governments in regulatory activities that impact reservation environments. It is the purpose of this statement to consolidate and expand on existing EPA Indian Policy statements in a manner consistent with the overall Federal position in support of Tribal "self-government" and "government-to-government" relations between Federal and Tribal Governments. This statement sets forth the principles that will guide the Agency in dealing with Tribal Governments and in responding to the problems of environmental management on America Indian reservations in order to protect human health and the environment. The Policy is intended to provide guidance for EPA program managers in the conduct of the Agency's congressionally mandated responsibilities. As such, it applies to EPA only and does not articulate policy for other Agencies in the conduct of their respective responsibilities.

It is important to emphasize that the implementation of regulatory programs which will realize these principles on Indian Reservations cannot be accomplished immediately. Effective implementation will take careful and conscientious work by EPA, the Tribes and many others. In many cases, it will require changes in applicable statutory authorities and regulations. It will be necessary to proceed in a carefully phased way, to learn from successes and failures, and to gain experience. Nonetheless, by beginning work on the priority problems that exist now and continuing in the direction established under these principles, over time we can significantly enhance environmental quality on reservation lands.

POLICY

In carrying out our responsibilities on Indian reservations, the fundamental objective of the Environmental Protection Agency is to protect human health and the environment. The keynote of this effort will be to give special consideration to Tribal interests in making Agency policy, and to insure the close involvement of Tribal Governments in making decisions and managing environmental programs affecting reservation lands. To meet this objective, the Agency will pursue the following principles:

1. **THE AGENCY STANDS READY TO WORK DIRECTLY WITH INDIAN TRIBAL GOVERNMENTS ON A ONE-TO-ONE BASIS (THE "GOVERNMENT-TO-GOVERNMENT" RELATIONSHIP). RATHER THAN AS SUBDIVISIONS OF OTHER GOVERNMENTS.**

EPA recognizes Tribal Governments as sovereign entities with primary authority and responsibility for the reservation populace. Accordingly, EPA will work directly with Tribal Governments as the independent authority for reservation affairs, and not as political subdivisions of States or other governmental units.

2. **THE AGENCY WILL RECOGNIZE TRIBAL GOVERNMENTS AS THE PRIMARY PARTIES FOR SETTING STANDARDS, MAKING ENVIRONMENTAL POLICY DECISIONS AND MANAGING PROGRAMS FOR RESERVATIONS, CONSISTENT WITH AGENCY STANDARDS AND REGULATIONS.**

In keeping with the principle of Indian self-government, the Agency will view Tribal Governments as the appropriate non-Federal parties for making decisions and carrying out program responsibilities affecting Indian reservations, their environments, and the health and welfare of the reservation populace. Just as EPA's deliberations and activities have traditionally involved the interests and/or participation of State Governments, EPA will look directly to Tribal Governments to play this lead role for matters affecting reservation environments.

3. **THE AGENCY WILL TAKE AFFIRMATVE STEPS TO ENCOURAGE AND ASSIST TRIBES IN ASSUMING REGULATORY AND PROGRAM MANAGEMENT RESPONSIBILITIES FOR RESERVATION LANDS.**

The Agency will assist interested Tribal Governments in developing programs and in preparing to assume regulatory and program management responsibilities for reservation lands. Within the constraints of EPA's authority and resources, this aid will include providing grants and other assistance to Tribes similar to that we provide State Governments. The Agency will encourage Tribes to assume delegable responsibilities, (i.e. responsibilities which the Agency has traditionally delegated to State Governments for non-reservation lands) under terms similar to those governing delegations to States.

Until Tribal Governments are willing and able to assume full responsibility for delegable programs, the Agency will retain responsibility for managing programs for reservations (unless the State has an express grant of jurisdiction from Congress sufficient to support delegation to the State Government). Where EPA retains such responsibility, the Agency will encourage the Tribe to participate in policy-making and to assume appropriate lesser or partial roles in the management of reservation programs.

4. **THE AGENCY WILL TAKE APPROPRIATE STEPS TO REMOVE EXISTING LEGAL AND PROCEDURAL IMPEDIMENTS TO WORKING DIRECTLY AND EFFECTIVELY WITH TRIBAL GOVERNMENTS ON RESERVATION PROGRAMS.**

   A number of serious constraints and uncertainties in the language of our statues and regulations have limited our ability to work directly and effectively with Tribal Governments on reservation problems. As impediments in our procedures, regulations or statues are identified which limit our ability to work effectively with Tribes consistent with this Policy, we will seek to remove those impediments.

5. **THE AGENCY, IN KEEPING WITH THE FEDERAL TRUST RESPONSIBILITY, WILL ASSURE THAT TRIBAL CONCERNS AND INTERESTS ARE CONSIDERED WHENEVER EPA'S ACTIONS AND/OR DECISIONS MAY AFFECT RESERVATION ENVIRONMENTS.**

   EPA recognizes that a trust responsibility derives from the historical relationship between the Federal Government and Indian Tribes as expressed in certain treaties and Federal Indian Law. In keeping with that trust responsibility, the Agency will endeavor to protect the environmental interests of Indian Tribes when carrying out its responsibilities that may affect the reservations.

6. **THE AGENCY WILL ENCOURAGE COOPERATION BETWEEN TRIBAL, STATE AND LOCAL GOVERNMENTS TO RESOLVE ENVIRONMENTAL PROBLEMS OF MUTUAL CONCERN.**

   Sound environmental planning and management require the cooperation and mutual consideration of neighboring governments, whether those governments be neighboring States, Tribes, or local units of government. Accordingly, EPA will encourage early communication and cooperation among Tribes, States and local governments. This is not intended to lend Federal support to any one party to the jeopardy of the interests of the other. Rather, it recognizes that in the field of environmental regulation, problems are often shared and the principle of comity between equals and neighbors often serves the best interests of both.

7. **THE AGENCY WILL WORK WITH OTHER FEDERAL AGENCIES WHICH HAVE RELATED RESPONSIBILITIES ON INDIAN RESERVATIONS TO ENLIST THEIR INTEREST AND SUPPORT IN COOPERATIVE EFFORTS TO HELP TRIBES ASSUME ENVIRONMENTAL PROGRAM RESPONSIBILITIES FOR RESERVATIONS.**

   EPA will seek and promote cooperation between Federal agencies to protect human health and the environment on reservations. We will work with other agencies to clearly identify and delineate the roles, responsibilities and relationships of our respective organizations and to assist Tribes in developing and managing environmental programs for reservation lands.

8. THE AGENCY WILL STRIVE TO ASSURE COMPLIANCE WITH ENVIRONMENTAL STATUTES AND REGULATIONS ON INDIAN RESERVATIONS.

In those cases where facilities owned or managed by Tribal Governments are not in compliance with Federal environmental statues, EPA will work cooperatively with Tribal leadership to develop means to achieve compliance, providing technical support and consultation as necessary to enable Tribal facilities to comply. Because of the distinct status of Indian Tribes and the complex legal issues involved, direct EPA action through the judicial or administrative process will be considered where the Agency determines, in its judgement, that: (1) a significant threat to human health or the environment exists, (2) such action would reasonably be expected to achieve effective results in a timely manner, and (3) the Federal Government cannot utilize other alternatives to correct the problem in a timely fashion.

In those cases where reservation facilities are clearly owned or managed by private parties and there is no substantial Tribal interest or control involved, the Agency will endeavor to act in cooperation with the affected Tribal Government, but will otherwise respond to noncompliance by private parties on Indian reservations as the Agency would to noncompliance by the private sector elsewhere in the country. Where the Tribe has a substantial proprietary interest in, or control over, the privately owned or managed facility, EPA will respond as described in the first paragraph above.

9. THE AGENCY WILL INCORPORATE THESE INDIAN POLICY GOALS INTO ITS PLANNING AND MANAGEMENT ACTIVITIES, INCLUDING ITS BUDGET, OPERATING GUIDANCE, LEGISLATIVE INITIATIVES, MANAGEMENT ACCOUNTABILITY SYSTEM AND ONGOING POLICY AND REGULATION DEVELOPMENT PROCESSES.

It is a central purpose of this effort to ensure that the principles of this Policy are effectively institutionalized by incorporating them into the Agency's ongoing and long-term planning and management processes. Agency managers will include specific programmatic actions designed to resolve problems on Indian reservations in the Agency's existing fiscal year and long-term planning and management processes.

William D. Ruckelshaus

Szelag, Matthew

From: Szelag, Matthew
Sent: Tuesday, July 14, 2015 9:37 AM
To: Edgell, Joe; Szalay, Endre; Ford, Peter
Cc: Fleisig, Erica; Schroer, Lee; Fabiano, Claudia; Buffo, Corey; Castanon, Lisa; Chung, Angela
Subject: RE: Federal Water Quality Coalition Letter to EPA re Human Health Standards

Thanks for your thoughts everyone. I agree that it makes sense to refer Cheryl to our comment letter and the Maine documents. I know she's read through these items carefully but it's a good idea to direct her to the specific areas you pointed out. I'm sure she'll also be interested if we respond to the letter from the Federal Water Quality Coalition.

I think that is sufficient for our initial response on this. Thanks for the assistance.

Matthew Szelag | Water Quality Standards Coordinator
U.S. Environmental Protection Agency | Region 10
1200 6th Avenue, Suite 900, OWW-191 | Seattle, WA 98101
P: (206) 553.5171 | szelag.matthew@epa.gov

From: Edgell, Joe
Sent: Tuesday, July 14, 2015 9:28 AM
To: Szalay, Endre; Ford, Peter; Szelag, Matthew
Cc: Fleisig, Erica; Schroer, Lee; Fabiano, Claudia; Buffo, Corey; Castanon, Lisa
Subject: RE: Federal Water Quality Coalition Letter to EPA re Human Health Standards

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Exemptions [5] Attorney Client Priviledge

Joe

From: Szalay, Endre
Sent: Tuesday, July 14, 2015 11:47 AM
To: Ford, Peter; Szelag, Matthew
Cc: Fleisig, Erica; Schroer, Lee; Fabiano, Claudia; Buffo, Corey; Edgell, Joe; Castanon, Lisa
Subject: RE: Federal Water Quality Coalition Letter to EPA re Human Health Standards

Thanks, Pete. I agree. Refer her to the relevant sections in our March 23 comments. Exemptions [5] Attorney Client Priviledge
Exemptions [5] Attorney Client PriviledgeExemptions [5] Attorney Client Priviledge
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Exemptions [5] Attorney Client Priviledge Along those lines, you could refer Cheryl to our disapproval in Maine and associated documents. For example, the January 30 letter from DOI to Avi re WQS and tribal fishing rights (attached). Pages 7-10 discuss the legal basis for concluding that tribal fishing rights include the right to sufficient water quality.

Endre Szalay
US EPA Region 10
206-553-1073

From: Ford, Peter
Sent: Tuesday, July 14, 2015 5:52 AM
To: Szelag, Matthew; Szalay, Endre
Cc: Fleisig, Erica; Schroer, Lee; Fabiano, Claudia; Buffo, Corey; Edgell, Joe
Subject: RE: Federal Water Quality Coalition Letter to EPA re Human Health Standards

We sort of spelled out the answer to her question re CRL on p. 5 of our Mar 23 comment letter when we said: “Here, the state has not demonstrated how its use of a CRL of 10-5 would result in WQC that adequately protect tribal fish consumers as the target general population as opposed to a highly exposed subpopulation within the broader general population in WA. For example, the CRL for tribal members whose consumption is not suppressed (i.e., greater than 175 g/day), would very likely be higher than 10-5.” [redacted] “It should also be noted that the 2000 HH Meth did not consider how CWA decisions should account for applicable treaty-reserved fishing rights, and the treaties themselves may require higher levels of protection.” [redacted] “Therefore, the EPA supports the state’s decision to derive the HHC using a FCR of 175 g/day so long as the state also retains a CRL of 10-6, which the tribes have generally viewed as a compromise minimum value in tribal consultation.” [redacted] You could direct her to these sentences if OW and R10 ok with doing that.

I’m adding others (Lee, Joe, Claudia, Corey) so they’re in the loop.

Peter Z. Ford
U.S. EPA Office of General Counsel
202.564.5593

From: Szelag, Matthew
Sent: Monday, July 13, 2015 6:59 PM
To: Ford, Peter; Szalay, Endre
Cc: Fleisig, Erica
Subject: FW: Federal Water Quality Coalition Letter to EPA re Human Health Standards

Hi Pete and Endre,
Any thoughts on how to respond to Cheryl? I’m planning to give her a call tomorrow morning. [redacted]

Let me know if you have any additional thoughts. Thanks,

Matthew Szelag | Water Quality Standards Coordinator
U.S. Environmental Protection Agency | **Region 10**
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P: (206) 553.5171 | szelag.matthew@epa.gov

From: Niemi, Cheryl (ECY) [mailto:cnie461@ECY.WA.GOV]
Sent: Monday, July 13, 2015 12:43 PM
To: Szelag, Matthew
Subject: FW: Federal Water Quality Coalition Letter to EPA re Human Health Standards

Hi Matt. Just saw this letter today.

Does EPA have an OGC or other legal opinion or rationale on how risk level and treaty tribal rights are connected, and why 10-6 is looked upon by EPA as fulfilling the rights, and 10-5 is not? Could you send me a copy of the opinion/rationale document?

Thanks,

Cheryl

Cheryl A. Niemi
Surface Water Quality Standards Specialist
Department of Ecology
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From: Johnson, Ken [mailto:ken.johnson@weyerhaeuser.com]
Sent: Friday, July 10, 2015 1:27 PM
To: Susewind, Kelly (ECY); Gildersleeve, Melissa (ECY); Niemi, Cheryl (ECY)
Subject: Federal Water Quality Coalition Letter to EPA re Human Health Standards

Ken Johnson
Weyerhaeuser Company
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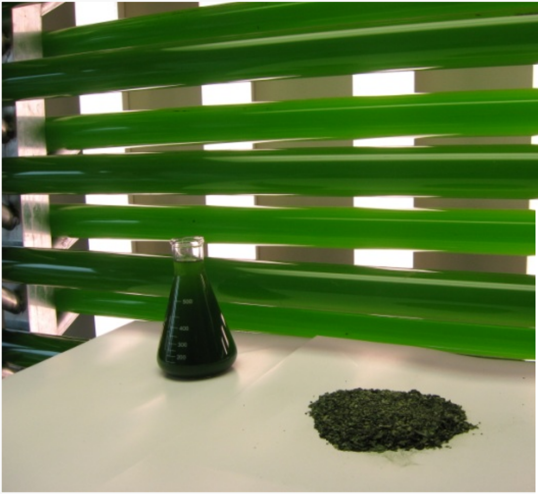
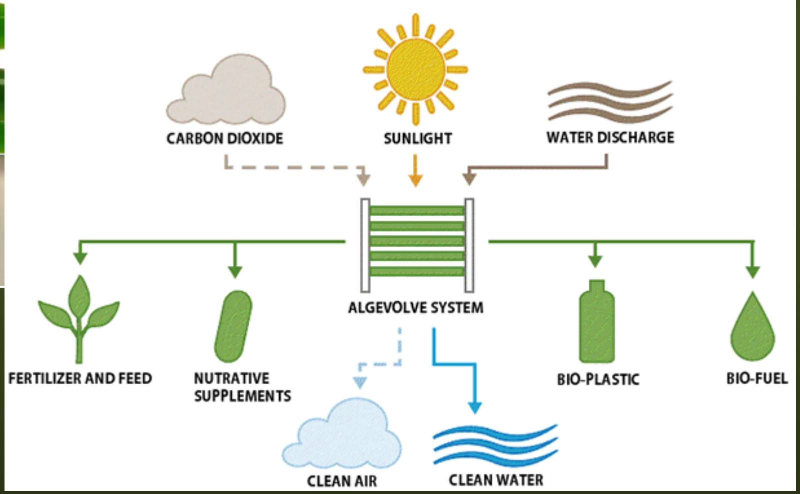
Inland Empire Paper Company

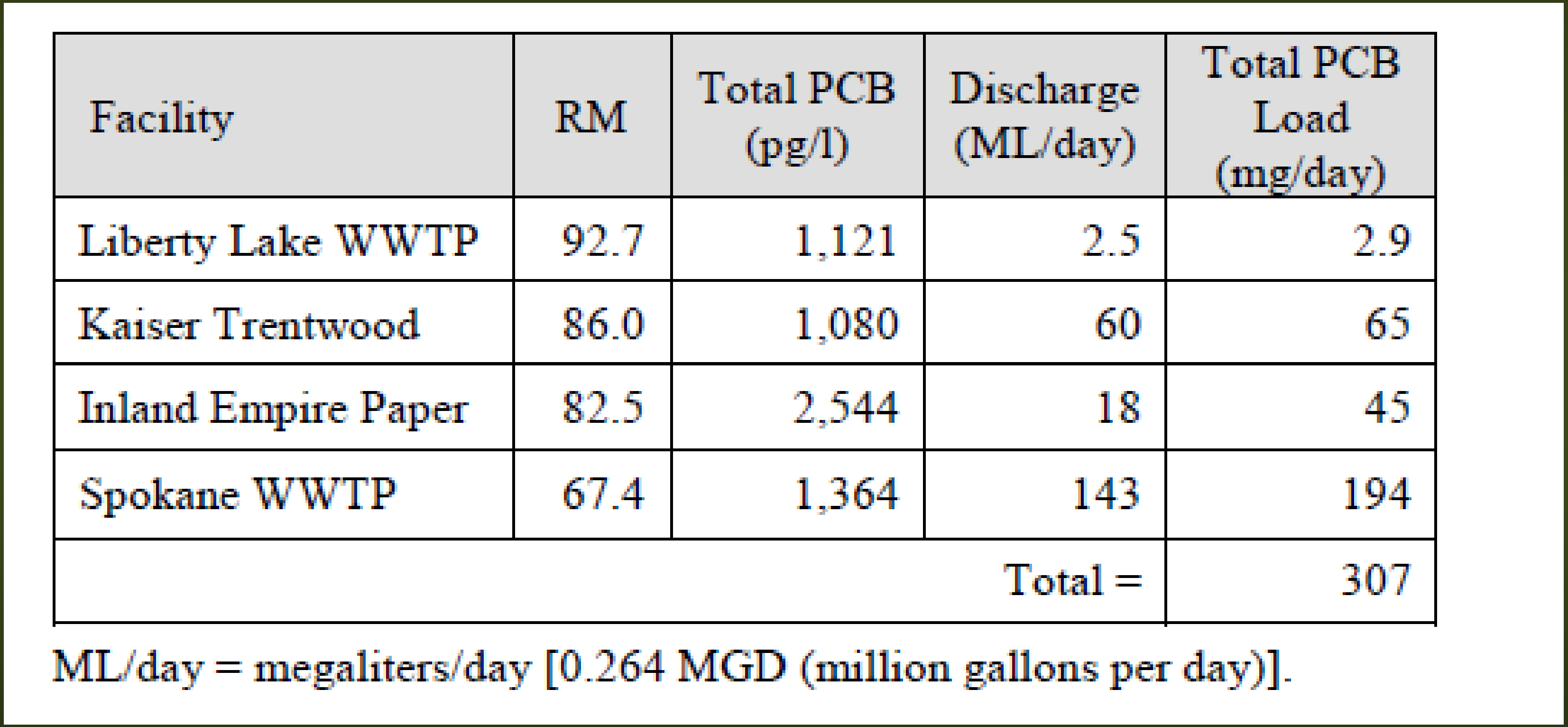




2012 NCASI West Coast Conference
Dealing with PCB’s in the Spokane River

October 2, 2012

Spokane River PCB Source Assessment

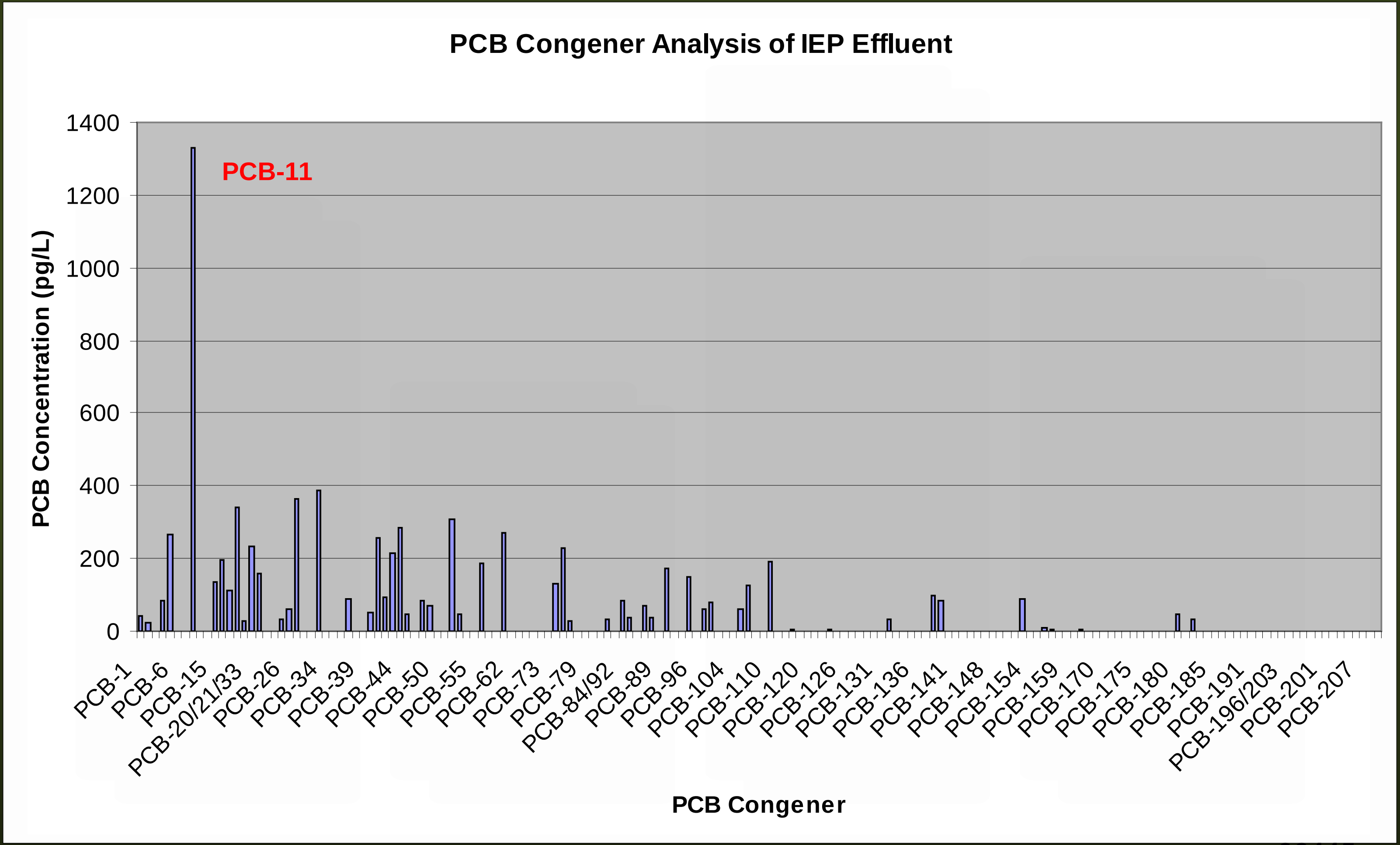


Facility	RM	Total PCB (pg/l)	Discharge (ML/day)	Total PCB Load (mg/day)
Liberty Lake WWTP	92.7	1,121	2.5	2.9
Kaiser Trentwood	86.0	1,080	60	65
Inland Empire Paper	82.5	2,544	18	45
Spokane WWTP	67.4	1,364	143	194
			Total =	307

ML/day = megaliters/day [0.264 MGD (million gallons per day)].

*Using EPA Method 1668A with a 100 pg/L PQL per congener

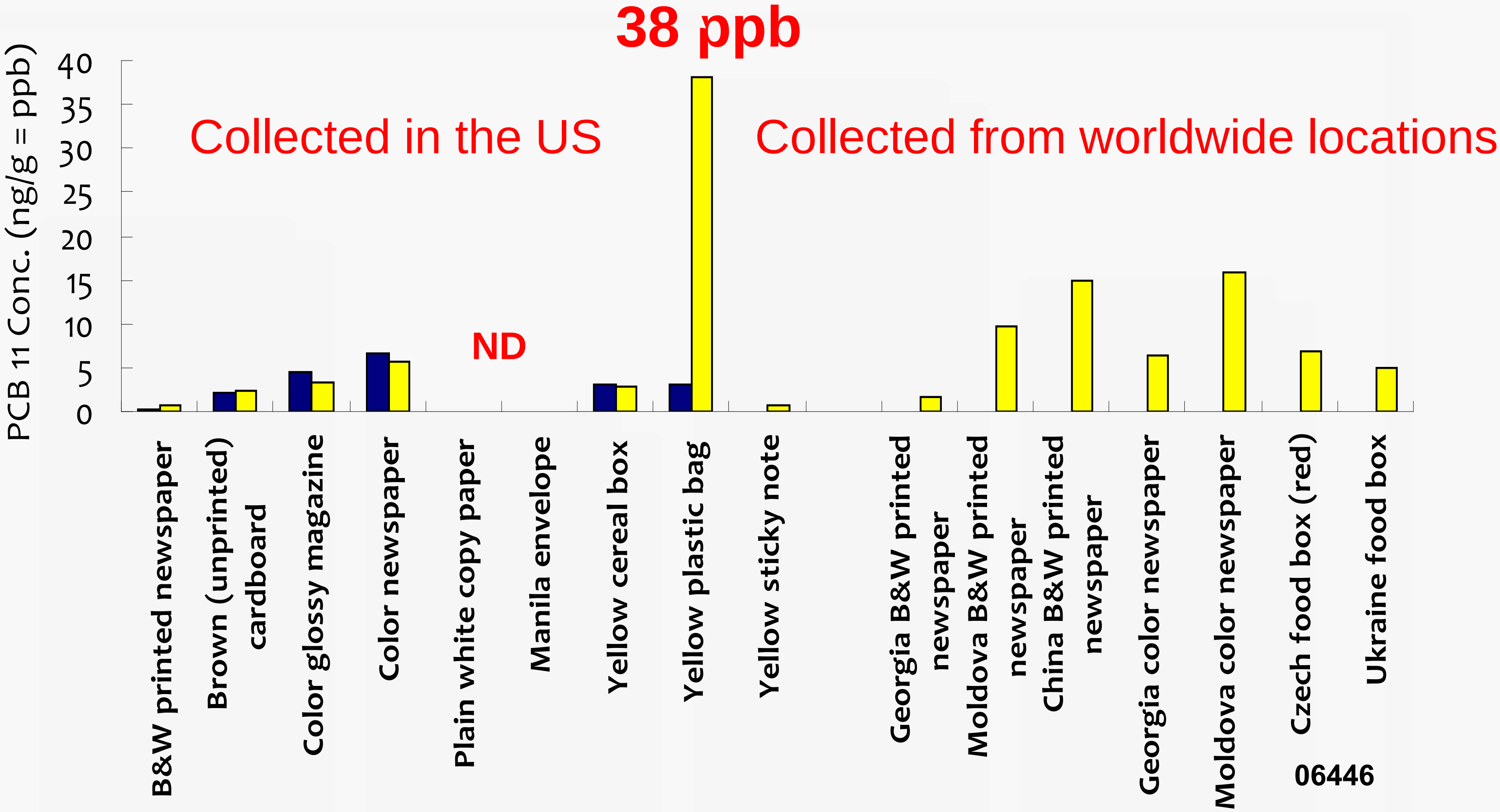
PCB Analysis at IEP



PCB 11 Concentration in Consumer Goods

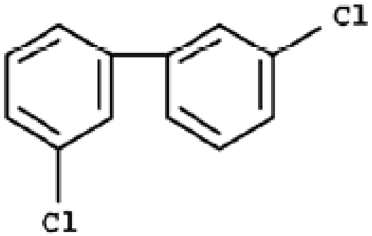
PCB 11 mostly associated with materials printed with yellow ink

One cereal box can contaminate ~ **2,000 L** of water at the WQS of **64 pg/L**



06446

Production of PCB 11



- 2006 worldwide production of color organic pigments ~ **250M** t
- 25% of this production is diarylide yellow, containing a few **ppb** of PCB 11
- 65% of all diarylide yellow is used in printing
- We estimate worldwide production of PCB 11 ~ **1.5 metric tons** in 2006 (Rodenburg et al. 2009, ES&T)

Other PCBs in Pigments

From Hu and Hornbuckle, 2010

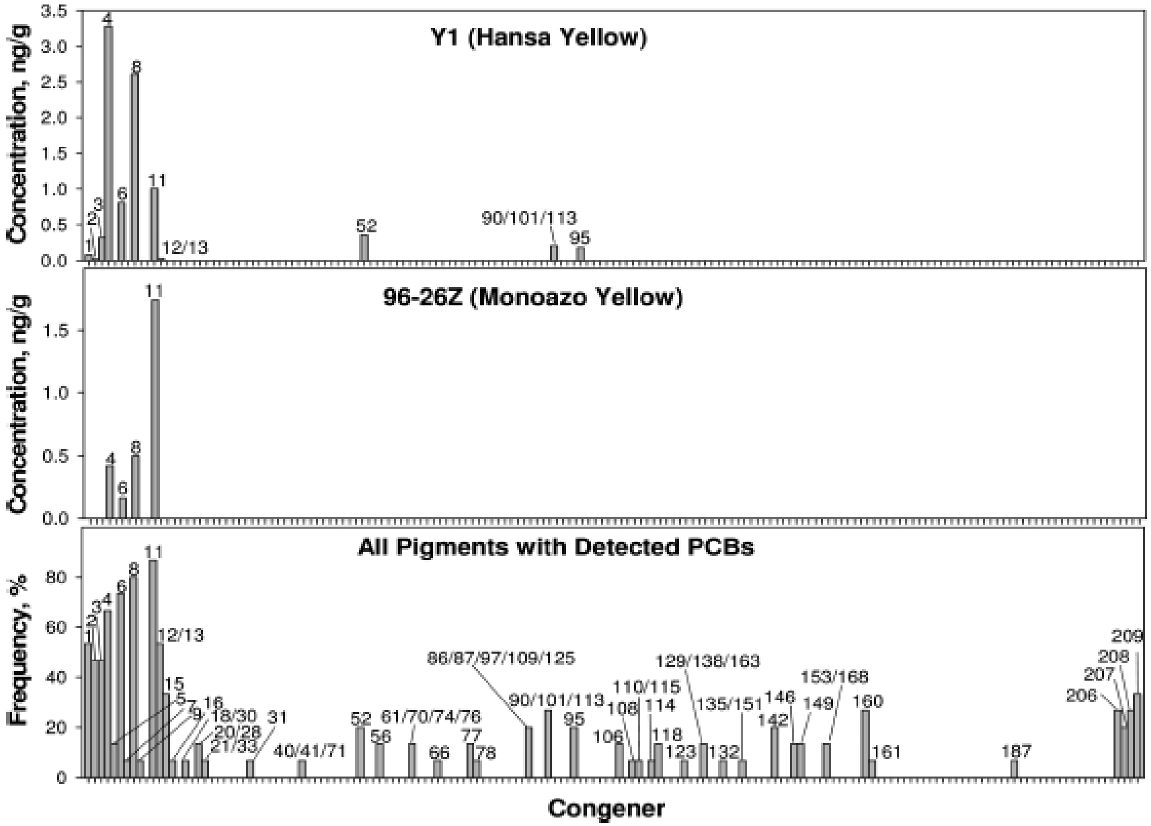


FIGURE 2. Examples of PCB profiles in paint pigments (top two plots) and the frequency of congener detection in the 15 pigments with detected PCBs (bottom plot).

Federal Regulations

SUBCHAPTER R - TOXIC SUBSTANCES CONTROL ACT, PART 761

- Manufacturing and processing of PCBs was banned under TSCA in 1979

- …pigments that contain 50 ppm or greater PCB may be processed, distributed in commerce, and used in a manner other than a totally enclosed manner until January 1, 1982…*40 C.F.R. § 761.3 (g), Reserved after 1999*

- The concentration of inadvertently generated PCBs in products leaving any manufacturing site or imported into the United States must have an annual average of less than 25 ppm, with a 50 ppm maximum" *40 C.F.R. § 761.3 (1)*

PCB Paradox

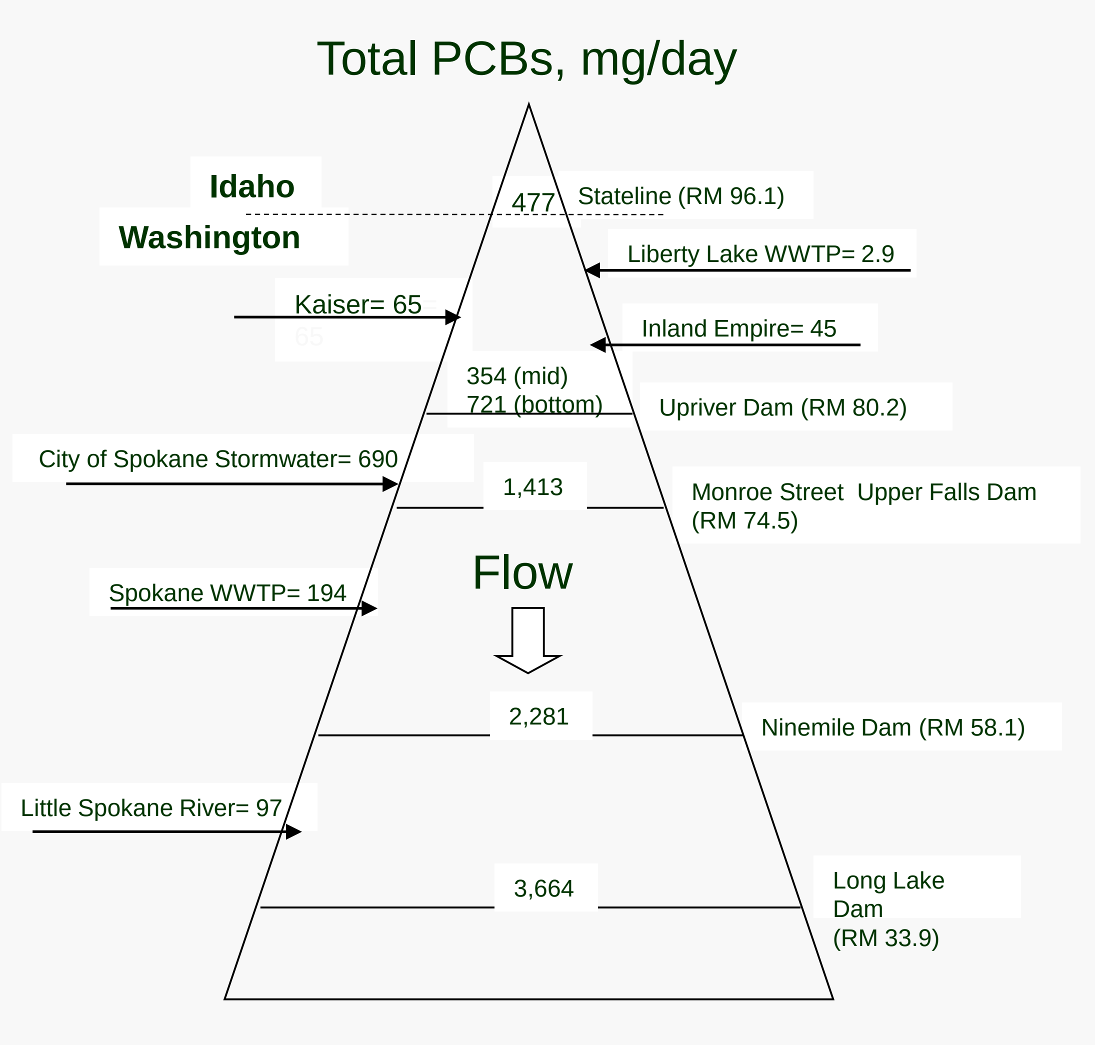
Reference	**PCB Concentration (ppm)**	**Magnitude Difference**
Federal Allowance	50	----
IEP's Effluent	0.0000024	20,833,333
WA Current HHWQC	0.00000017	294,117,647
EPA Current HHWQC	0.000000064	781,250,000
*Spokane Tribe WQS	0.0000000013	38,461,538,462

*Adopted a Fish Consumption Rate 1.9 pounds/day

Reductions Needed to Meet Standards

Location on Spokane River	Current t-PCB Load (mg/day)	Target t-PCB Load (mg/day) at Water Quality Criterion		t-PCB Load Reduction Required to Meet Water Quality Criterion	
		NTR (170 pg/l)	Spokane Tribe (3.37 pg/l)	NTR	Spokane Tribe
Stateline	477	766	15	none required	97%
Upriver Dam	537	780	15		97%
Monroe St.	1,413	1,208	24	15%	98%
Ninemile	2,281	1,243	25	46%	99%
Little Spokane River	97	83	2	15%	98%
Lake Spokane (lower)	3,664	1,562	31	57%	99%
Little Falls	3,664	1,562	31	57%	99%
Spokane Arm	3,664	1,562	31	57%	99%

PCB Loading in Spokane River



Total PCBs, mg/day

Idaho

Washington

477

Stateline (RM 96.1)

Liberty Lake WWTP= 2.9

Kaiser= 65

65

Inland Empire= 45

354 (mid)
721 (bottom)

Upriver Dam (RM 80.2)

City of Spokane Stormwater= 690

1,413

Monroe Street Upper Falls Dam (RM 74.5)

Flow

Spokane WWTP= 194

2,281

Ninemile Dam (RM 58.1)

Little Spokane River= 97

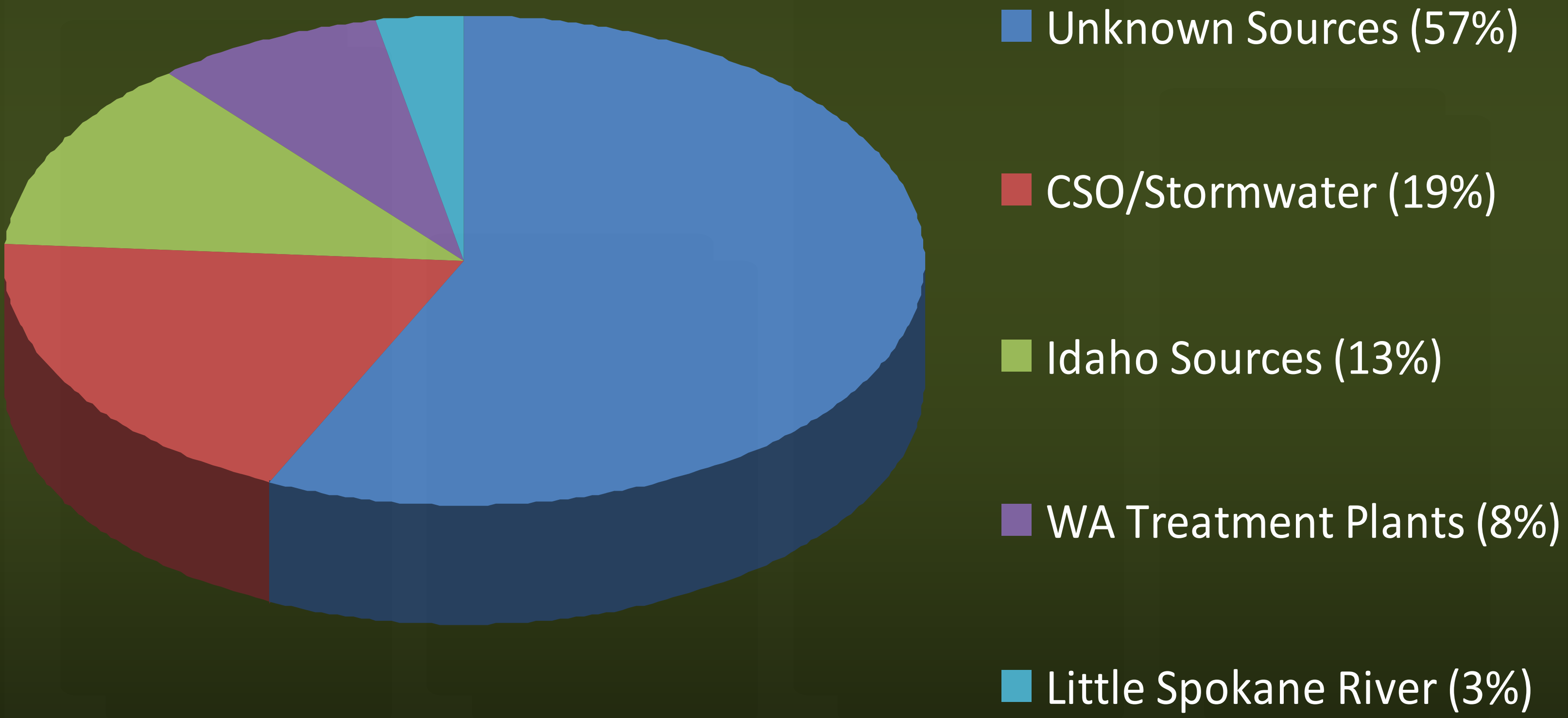
3,664

Long Lake Dam (RM 33.9)

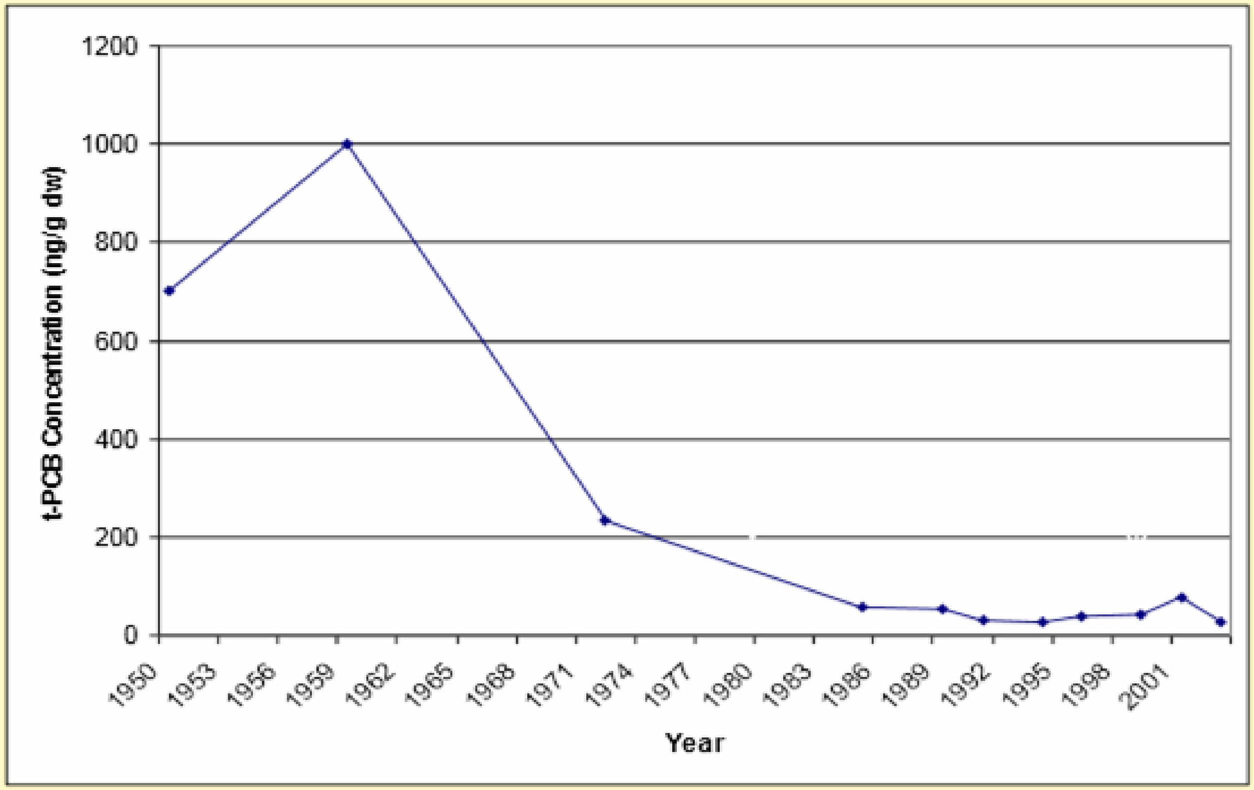
Source	Load (mg/day)
City of Spokane Stormwater	690
Stateline	477
Spokane WWTP	194
Little Spokane River	95
Kaiser	65
Inland Empire Paper	45
Liberty Lake WWTP	2.9
Total Measured	1569
Long Lake	3,664

Measured 43% of Load

PCB Sources to Spokane River



PCBs History from Sediment Record Lower Lake Spokane



Total PCBs in Age Dated Sediment Core (2003)

- Steep declines from 1960s through mid-1980s
- Approximately 50% decline in 20 years (1980-2000)

IEP NPDES Permit

- Conservation groups threatened to appeal permits for not including a WLA for PCB's
- **S7. REGIONAL TOXICS TASK FORCE:**

  "The goal of the Regional Toxics Task Force is to develop a comprehensive plan to bring the Spokane River into compliance with applicable water quality standards for PCBs."
- Termed "Straight to Implementation (STI)"
- Also effluent testing Method 1668 & BMP's

Toxics Task Force (SRRTTF)

Memorandum of Agreement

- Spokane County
- Liberty Lake Sewer and Water District
- Inland Empire Paper Company
- Kaiser Aluminum
- City of Spokane
- Spokane Regional Health District
- Washington State Department of Health
- Lake Spokane Association
- The Lands Council
- Spokane Riverkeeper
- Avista
- Washington State Department of Ecology
- U.S. Environmental Protection Agency
- Idaho Municipal Dischargers (Coeur d'Alene, Post Falls and Hayden)
- Idaho Department of Environmental Quality
- Spokane & Coeur d'Alene Tribe of Indians

Toxics Task Force (SRRTTF)

Technical Workshop

- National experts on PCBs
- Work in other watersheds:
    - Delaware River Basin
    - Hudson River & NY/NJ Harbor
    - Indiana Harbor to Lake Michigan
    - Puget Sound
    - Lower Duwamish
    - Portland Harbor

Toxics Task Force (SRRTTF)

Technical Workshop

- What did we learn (hear):
  - Most watersheds are dealing in ppm and pounds, we are dealing with ppq and grams
  - Atmospheric deposition by itself will likely cause exceedance of WQS
  - Idaho 30%, Stormwater 44%
  - Rainwater has been measured at concentrations >100 ppq
  - Snow is 100 times more effective than rain at scavenging PCBs
  - Stormwater in our basin is largest contributor
  - +90% of PCB's in Spokane River samples are in dissolved phase
  - Total PCB levels below 1,000 pg/L are variable and highly blank influenced
  - See www.srrttf.org for archive of presentations

Threats to SRRTTF

- Sierra Club in Spokane has 2 pending lawsuits regarding PCB’s:
  - Appeal of new Spokane County Permit
  - Unlawful to issue a permit for a new discharge without an approved TMDL for PCBs (Hearing before the PCHB in March 2013)

  - Federal Court action against EPA
  - EPA unlawfully approved a decision by the state of Washington to not prepare a PCB TMDL (July 2013)
- Not Demonstrating “Measurable Progress”

“If Ecology determines the Regional Toxics Task Force is failing to make measurable progress toward meeting applicable water quality criteria for PCBs, Ecology would be obligated to proceed with development of a TMDL in the Spokane River for PCBs or determine an alternative to ensure water quality standards are met.”

Other Efforts

- 2010 Advance Notice of Proposed Rulemaking addressing PCB Reassessment of Use Authorizations
    - IEP submitted comments in collaboration with the Spokane Riverkeepers and the Lands Council

- ECOS
    - Collaborative presentations with Riverkeepers & Rutgers
    - Resulted in a Resolution from the ECOS Committee

ECOS Resolution

- Recommends that EPA, industry, and states work together to develop alternative pigment and ink manufacturing processes in the next five years that do not generate PCBs;
- Supports a national R & D effort to reduce or eliminate inadvertently-created PCB products;
- Supports EPA’s proposed rulemaking to reassess the current use authorizations for PCBs, which includes products with PCBs and products with inadvertently-generated PCBs;
- Recommends that U.S. EPA continue its efforts to reduce PCBs and work with the international community on the elimination of PCBs

PCBs are Nationwide Issue

- Up to 200 known chemical processes that may inadvertently create PCB byproducts:
  - Paint
  - Inks
  - Titanium Dioxide (white pigments)
  - Ag chemicals
  - Plastics
  - Soaps
  - Silicone rubber
  - Caulk measured up to = 300,000 ppm
- 2010 – 1,084 fish advisories for PCB’s in 40 States
- 5,578 water bodies on 303(d) list for PCBs
- Many States are adopting revised FCR

Questions?

INLAND EMPIRE
PAPER COMPANY

Szelag, Matthew

From: Szelag, Matthew
Sent: Tuesday, March 17, 2015 12:47 PM
To: Ford, Peter; Schroer, Lee; Guadagno, Tony; Edgell, Joe; Szalay, Endre; Castanon, Lisa; Fleisig, Erica; Buffo, Corey; Chung, Angela; Fabiano, Claudia; Kissinger, Lon
Subject: RE: WA HHC comments

Hi everyone,
Thanks again for your time on the call earlier today, I thought it was very helpful. Here's the latest (clean) version with the edits we discussed plus a few relatively minor revisions.

We're sharing this version with Dan and Dennis and I know Pete needed a version to share with Ethan.

Our call with the tribes went well earlier today. The biggest message we heard was that 175 g/day and 10-6 is a <u>minimum</u> compromise. We've made a minor adjustment in our comments to reflect that.

WA HHC
comments 3/17 ...

Let me know if you have any questions and thanks again.

Matthew Szelag | Water Quality Standards Coordinator
U.S. Environmental Protection Agency | **Region 10**
1200 6th Avenue, Suite 900, OWW-191 | Seattle, WA 98101
P: (206) 553.5171 | szelag.matthew@epa.gov

From: Szelag, Matthew
Sent: Tuesday, March 17, 2015 8:14 AM
To: Ford, Peter; Schroer, Lee; Guadagno, Tony; Edgell, Joe; Szalay, Endre; Castanon, Lisa; Fleisig, Erica; Buffo, Corey; Chung, Angela; Fabiano, Claudia; Kissinger, Lon
Subject: RE: WA HHC comments

I've put the latest version (the one Joe sent yesterday at 5:21 eastern) in Sharepoint. This is the version we will be discussing on the call shortly.

Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]
Exemption [6]Exemption [6]Exemption [6]
Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]Exemption [6]

Thanks everyone,

Matthew Szelag | Water Quality Standards Coordinator
U.S. Environmental Protection Agency | **Region 10**
1200 6th Avenue, Suite 900, OWW-191 | Seattle, WA 98101
P: (206) 553.5171 | szelag.matthew@epa.gov

-----Original Appointment-----
From: Szelag, Matthew
Sent: Friday, March 13, 2015 4:42 PM
To: Szelag, Matthew; Ford, Peter; Schroer, Lee; Guadagno, Tony; Edgell, Joe; Szalay, Endre; Castanon, Lisa; Fleisig, Erica; Buffo, Corey; Chung, Angela; Fabiano, Claudia; Kissinger, Lon
Subject: WA HHC comments
When: Tuesday, March 17, 2015 8:30 AM-9:30 AM (UTC-08:00) Pacific Time (US & Canada).
Where: Exemption [6]Exemption [6]Exemption [6]

Discuss the latest edits to our comments on Washington’s human health criteria.

Szelag, Matthew

From: Brown, Katherine
Sent: Friday, June 05, 2015 6:57 AM
To: Duncan, Bruce
Cc: Fleming, Sheila; Szelag, Matthew; Kissinger, Lon
Subject: Re: Updates on Tribal Work - Hot Topics on QA, seafood consumption, climate change, and Tribal Science Council

Thank you!!

From: Duncan, Bruce
Sent: Thursday, June 4, 2015 3:52 PM
To: Brown, Katherine
Cc: Fleming, Sheila; Szelag, Matthew; Kissinger, Lon
Subject: RE: Updates on Tribal Work - Hot Topics on QA, seafood consumption, climate change, and Tribal Science Council

Hi Katherine – here is an update from Lon and cleared by Matt for the WA information.

Thanks Lon for carving out some time for this.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

WA: Washington's human health criteria are based on a fish consumption rate of 6.5 grams per day and therefore are not sufficiently protective of high fish consumers. Ecology has missed several deadlines to update the criteria and has proposed a rule with a higher fish consumption rate of 175 grams per day, but a less stringent cancer risk level of 10-5. On March 23, EPA submitted extensive comments on Ecology's proposed human health criteria. The tribes regard the 175 grams per day value as a compromise and a minimum acceptable value. Ecology is responding to comments and may adopt the human health criteria between 7/1 to 8/3. If the state adopts the proposed rule, Ecology will submit materials to EPA for approval or disapproval under the Clean Water Act. In addition, EPA has initiated the process to update the National Toxics Rule for Washington's human health criteria to take into account the best available science, including local and regional information, as well as applicable EPA policies, guidance, and legal requirements, in case the State is unable to adopt a protective rule in a timely manner. EPA is working internally to develop a rule proposal and has engaged the tribes for their input. The earliest EPA could propose a federal rule is fall 2015.

From: Duncan, Bruce
Sent: Tuesday, June 02, 2015 8:04 AM
To: Cox, Michael; Kissinger, Lon; Cope, Ben; Elleman, Robert; Matheny, Don
Subject: Updates on Tribal Work - Hot Topics on QA, seafood consumption, climate change, and Tribal Science Council
Importance: High

Hi all

Next meeting of Tribal Specialists is tomorrow. I only need a bullet for any updates in the past month – I will keep these from now on and reflect them back each month for any changes. I will try stop by as well today.

Lon: Updates on
1. Tribal Science Council
2. Tribal seafood consumption

Mike: Updates on climate change related to Tribes

Ben: Interactions/support/meetings with Tribes this past month?

Don: Any interactions/support/etc. with Tribes this past month?

Thanks,

Bruce

Bruce Duncan
Regional Science Liaison to Office of Research & Development

U.S. Environmental Protection Agency | Region 10
1200-6th Ave, Suite 900, OEA-095; Seattle, WA 98101
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ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 131

[WH-FRL-4029-2]

Amendments to the Water Quality Standards Regulation To Establish the Numeric Criteria for Priority Toxic Pollutants Necessary to Bring All States Into Compliance With Section 303(c)(2)(B)

AGENCY: Environmental Protection Agency.

ACTION: Proposed rule.

SUMMARY: This proposed rulemaking would promulgate the chemical-specific, numeric criteria for priority toxic pollutants necessary to bring all States into compliance with the requirements of section 303(c)(2)(B) of the Clean Water Act (CWA). States which have been determined by EPA to fully comply with section 303(c)(2)(B) requirements would not be affected by today's proposed rulemaking.

The proposed rulemaking addresses several situations. For a few States EPA would promulgate only a limited number of criteria because the Agency previously identified, in disapproval letters to such States, the specific priority toxic pollutants that require new or revised criteria. For these States, EPA would promulgate Federal criteria only for the priority toxic pollutants which require new or revised criteria. In the vast majority of States, EPA would promulgate, at a minimum, broadly applicable Federal criteria for all priority toxic pollutants for which EPA has issued section 304(a) water quality criteria guidance and that are not the subject of approved State criteria.

For those priority toxic pollutants included in today's proposed rulemaking where the section 304(a) criteria recommendation is based on carcinogenicity, the proposed criteria are based on an incremental one in one million cancer risk level (i.e., 10^{-6}).

The primary focus of this rule is the inclusion of the water quality criteria for pollutant(s) in State standards as necessary to support water quality-based control programs. The Agency is accepting comment on the criteria proposed in today's rule. However, Congress has established a very ambitious schedule for the promulgation of the final criteria. The statutory deadline in section 303(c)(4) clearly indicates that Congress intended the Agency to move very expeditiously when Federal action is warranted. The Agency believes that the limited time available for promulgation of the regulation can be used most efficiently and effectively by addressing those issues that have not already come before the Agency.

DATES: All written comments received on or before December 19, 1991, will be considered in the preparation of any final rulemaking.

A public hearing will be held on December 19, 1991, in Washington, DC, beginning at 9 a.m. The hearing officer reserves the right to limit oral testimony to 10 minutes, if necessary.

ADDRESSES: Comments, in quadruplicate, on this proposed rule should be addressed to William R. Diamond, Director, Standards and Applied Science Division (WH-585), Office of Science and Technology, 401 M Street, SW., Washington, DC 20460 (Telephone: 202-260-1315). The public may inspect the administrative record for this rulemaking, including documentation supporting the aquatic life and human health criteria, and all comments received on this proposed rule at EPA's Public Information Reference Unit, EPA Library, room 2904, Waterside Mall, 401 M Street, SW., Washington, DC 20460 (Telephone: 202-260-5926) on weekdays during the Agency's normal business hours of 8 a.m. to 4:30 p.m. Each of EPA's ten Regional offices will also have copies for public inspection and copying of the administrative records for the States in that Region. These records will be available in the Water Management Divisions of each respective Regional office. A reasonable fee will be charged for photocopies.

The public hearing will be held in the EPA auditorium, 401 M Street, SW., Washington, DC.

FOR FURTHER INFORMATION CONTACT: David K. Sabock or R. Kent Ballentine, Telephone 202-260-1315.

SUPPLEMENTARY INFORMATION:

This preamble is organized according to the following outline:

A. Introduction and Overview

1. Introduction

This section of the preamble introduces the topics which are addressed subsequently and provides a brief overview of EPA's basis and rationale for proposing to promulgate Federal criteria for priority toxic pollutants. Section B of this preamble presents a description of the evolution of the Federal Government's efforts to control toxic pollutants beginning with a discussion of the authorities in the Federal Water Pollution Control Act Amendments of 1972. Also described in some detail is the development of the water quality standards review and revision process which provides for establishing both narrative goals and enforceable numeric requirements for controlling toxic pollutants. This discussion includes the recent changes enacted in the 1987 Clean Water Act Amendments which are the basis for this proposed rulemaking. Section C summarizes State efforts since 1987 to comply with the requirements of Section 303(c)(2)(B). Section D describes EPA's procedure for determining whether a State has fully complied with Section 303(c)(2)(B). Section E sets out the rationale and approach for developing today's proposed rulemaking, including a discussion of EPA's legal basis. Section F describes the development of the criteria included in today's proposed rulemaking. Section G summarizes the provisions of the proposed rule and Section H highlights certain issues raised by the proposal for public comment. Sections I, J, and K address the requirements of Executive Order 12291, the Regulatory Flexibility Act, and the Paperwork Reduction Act, respectively. Section L provides a list of subjects covered in today's proposed rulemaking.

2. Overview

Today's proposed rulemaking to establish Federal toxics criteria for States is important for a number of environmental, programmatic and legal reasons.

First, control of toxic pollutants in surface waters is an important priority to achieve the Clean Water Act's goals and objectives. The most recent National Water Quality Inventory indicates that one-third of monitored river miles, lake acres, and coastal waters have elevated levels of toxics. Forty-seven States and Territories have reported elevated levels of toxic pollutants in fish tissues. States have issued a total of 586 fishing advisories and 135 bans, attributed mostly to industrial discharges and land disposal.

The absence of State water quality standards for toxic pollutants undermines EPA's overall toxic control efforts to address these problems. Without clearly established water quality goals, the effectiveness of many of EPA's water programs is jeopardized. Permitting, enforcement, coastal water quality improvement, fish tissue quality protection, certain nonpoint source controls, drinking water quality protection, and ecological protection all depend to a significant extent on complete and adequate water quality standards. Numeric criteria for toxics are essential to the process of controlling toxics because they allow States and EPA to evaluate the adequacy of existing and potential control measures to protect aquatic ecosystems and human health. Formally adopted standards form the legal basis for including water quality-based effluent limitations in NPDES permits to control toxic pollutant discharges. The critical importance of controlling toxic pollutants has been recognized by Congress and is reflected, in part, by the addition of section 303(c)(2)(B) to the Act. Congressional impatience with the pace of State toxics control programs is well documented in the legislative history of the 1987 CWA amendments. In order to protect human health, aquatic ecosystems, and successfully implement toxics controls, EPA believes that all actions which are available to the Agency must be taken to ensure that all necessary numeric criteria for priority toxic pollutants are established in a timely manner.

Second, as States and EPA continue the transition from an era of primarily technology-based controls to an era in which technology-based controls are integrated with water quality-based controls, it is important that EPA ensures timely compliance with CWA requirements. An active Federal role is essential to assist States in getting in place complete toxics criteria as part of their pollution control programs. While most States recognize the need for enforceable water quality standards for toxic pollutants, their recent adoption efforts have often been stymied by a variety of factors including limited resources, competing environmental priorities, and difficult scientific, policy and legal challenges. Although many water quality criteria for toxic pollutants have been available since 1980 and the water quality standards regulation has required State adoption of numeric criteria for toxic pollutants since 1983 (see 40 CFR 131.11), a preliminary assessment of the water quality standards for all States in February of 1990 showed that only six States had established fully acceptable criteria for toxic pollutants. This rate of toxics criteria adoption is contrary to the CWA requirements and is a reflection of the difficulties faced by States. EPA should exercise its CWA authorities to assist States in such circumstances.

EPA's proposed action will also help restore equity among the States. The CWA is designed to ensure all waters are sufficiently clean to protect public health and the environment. The CWA allows some flexibility and differences among States in their adopted and approved water quality standards, but it was not designed to reward inaction and inability to meet statutory requirements.

Although most States have made some progress toward satisfying CWA requirements, many appear to have failed to fully comply with section 303(c)(2)(B). The CWA assigns EPA the legal responsibility to promulgate standards where necessary to meet the requirements of the Act. Where States have not satisfied the CWA requirement to adopt water quality standards for toxic pollutants, which was re-emphasized by Congress in 1987, it is imperative that EPA take action.

EPA's ability to oversee State standards-setting activities and to correct deficiencies in State water quality standards is critical to the effective implementation of section 303(c)(2)(B). This proposed rulemaking is a necessary and important component of EPA's implementation of section 303(c)(2)(B) as well as EPA's overall efforts to control toxic pollutants in surface waters.

B. Statutory and Regulatory Background

1. Pre-Water Quality Act Amendments of 1987 (Pub. L. 100-4)

Section 303(c) of the 1972 Federal Water Pollution Control Act Amendments (FWPCA) (33 U.S.C. 1313(c)) established the statutory basis for the current water quality standards program. It completed the transition from the previously established program of water quality standards for interstate waters to one requiring standards for all surface waters of the United States.

Although the major innovation of the 1972 FWPCA was technology-based controls, Congress maintained the concept of water quality standards both as a mechanism to establish goals for the Nation's waters and as a regulatory requirement when standardized technology controls for point source discharges and/or nonpoint source controls were inadequate. In recent years these so-called water quality-based controls have received new emphasis by Congress and EPA in the continuing quest to enhance and maintain water quality to protect the public health and welfare.

Briefly stated, the key elements of section 303(c) are:

(a) A water quality standard is defined as the designated beneficial uses of a water segment and the water quality criteria necessary to support those uses;

(b) The minimum beneficial uses to be considered by States in establishing water quality standards are specified as public water supplies, propagation of fish and wildlife, recreation, agricultural uses, industrial uses and navigation;

(c) A requirement that State standards must protect public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act;

(d) A requirement that States must review their standards at least once each three year period using a process that includes public participation;

(e) The process for EPA review of State standards which may ultimately result in the promulgation of a superseding Federal rule in cases where a State's standards are not consistent with the applicable requirements of the CWA, or in situations where the Agency determines Federal standards are necessary to meet the requirements of the Act.

Another major innovation in the 1972 FWPCA was the establishment of the

National Pollutant Discharge Elimination System (NPDES) which requires point source dischargers to obtain a permit before legally discharging to the waters of the United States. In addition to the permit limits established on the basis of technology (e.g. effluent limitations guidelines), the Act requires dischargers to meet instream water quality standards. (See section 301(b)(1)(C), 33 U.S.C. 1311(b)(1)(C)).

Thus water quality standards serve a dual function under the Clean Water Act regulatory scheme. Standards establish narrative and numeric definitions and quantification of the Act's goals and policies (see section 101, 33 U.S.C. 1251) which provide a basis for identifying impaired waters. Water quality standards also establish regulatory requirements which are translated into specific discharge requirements. In order to fulfill this critical function, adopted State criteria must contain sufficient parametric coverage to protect both human health and aquatic life.

In its initial efforts to control toxic pollutants, the FWPCA, pursuant to section 307, required EPA to designate a list of toxic pollutants and to establish toxic pollutant effluent standards based on a formal rulemaking record. Such rulemaking required formal hearings, including cross-examination of witnesses. EPA struggled with this unwieldy process and ultimately promulgated effluent standards for six toxic pollutants, pollutant families or mixtures. (See 40 CFR part 129.) Congress amended section 307 in the 1977 Clean Water Act Amendments by endorsing the Agency's alternative procedure of regulating toxic pollutants by use of effluent limitationguidelines, by amending the procedure for establishing toxic pollutant effluent standards to provide for more flexibility in the hearing process for establishing a record, and by directing the Agency to include sixty-five specific pollutants or classes of pollutants on the toxic pollutant list. EPA published the required list on January 31, 1978 (43 FR 4109). This toxic pollutant list was the basis on which EPA's efforts on criteria development for toxics was focused.

During planning efforts to develop effluent limitation guidelines and water quality criteria, the list of sixty-five toxic pollutants was judged too broad as some of the pollutants were, in fact, general families or classes of organic compounds consisting of many individual chemicals. EPA selected key chemicals of concern within the 65 families of pollutants and identified a more specific list of 129 priority toxic pollutants. Three volatile chemicals were removed from the list (see 46 FR 2266, January 8, 1981; 46 FR 10723, February 4, 1981) so that at present there are 126 priority toxic pollutants. This list is published as Appendix A to 40 CFR part 423.

Another critical section of the 1972 FWPCA was section 304(a) (33 U.S.C. 1314(a)). Section 304(a)(1) provides, in pertinent part, that EPA

> * * * shall develop and publish * * * criteria for water quality accurately reflecting the latest scientific knowledge (A) on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water, * * * and (C) on the effects of pollutants on biological community diversity, productivity, and stability, * * *

In order to avoid confusion, it must be recognized that the Clean Water Act uses the term "criteria" in two separate ways. In section 303(c), which is discussed above, the term is part of the definition of a water quality standard. That is, a water quality standard is comprised of designated uses and the criteria necessary to protect those uses. Thus, States are required to adopt regulations or statutes which contain legally achievable criteria. However, in section 304(a), the term criteria is used in a scientific sense and EPA develops recommendations which States consider in adopting regulatory criteria.

In response to this legislative mandate and an earlier similar statutory requirement, EPA and a predecessor agency have produced a series of water quality criteria documents. Early Federal efforts were Water Quality Criteria (1968 "Green Book") and Quality Criteria for Water (1976 "Red Book"). EPA also sponsored a contract effort with the National Academy of Science—National Academy of Engineering which resulted in Water Quality Criteria, 1972 (1973 "Blue Book"). These early efforts were premised on the use of literature reviews and the collective scientific judgment of Agency and advisory panels. However, when faced with the list of 65 toxic pollutants and the need to develop criteria for human health as well as aquatic life, the Agency determined that new procedures were necessary. Continued reliance solely on existing scientific literature was now inadequate, since for many pollutants essential information was not available. EPA scientists developed formal methodologies for establishing scientifically defensible criteria. These were subjected to review by the Agency's Science Advisory Board and the public. This effort culminated on November 28, 1980, when the Agency published criteria development guidelines for aquatic life and for human health, along with criteria for 64 toxic pollutants. (See 45 FR 79318.) Since that initial publication, the aquatic life methodology was slightly amended (50 FR 30784, July 29, 1985) and additional criteria were proposed for public comment and finalized as Agency criteria guidance. EPA summarized the available criteria information in Quality Criteria for Water 1986 (1986 "Gold Book") which is updated from time-to-time. However, the individual criteria documents, as updated, are the official guidance documents.

EPA's criteria documents provide a comprehensive toxicological evaluation of each chemical. For toxic pollutants, the documents tabulate the relevant acute and chronic toxicity information for aquatic life and derive the criteria maximum concentrations (acute criteria) and criteria continuous concentrations (chronic criteria) which the Agency recommends to protect aquatic life resources. For human health criteria, the document provides the appropriate reference doses, and if appropriate the carcinogenic slope factors, and derives recommended criteria. The details of this process are described more fully in a following part of this preamble.

Programmatically, EPA's initial efforts were aimed at converting a program focused on interstate waters into one addressing all interstate and intrastate surface waters of the United States. Guidance was aimed at the inclusion of traditional water quality parameters to protect aquatic life (e.g., pH, temperature, dissolved oxygen and a narrative "free from toxicity" provision), recreation (e.g., bacteriological criteria) and general aesthetics (e.g., narrative "free from nuisance" provisions). EPA also required State adoption of an antidegradation policy to maintain existing high quality or ecologically unique waters as well as maintain improvements in water quality as they occur.

The initial water quality standards regulation was actually a part of EPA's water quality management regulations implementing section 303(e) (33 U.S.C. 1313(e)) of the Act. It was not comprehensive and did not address toxics or any other criteria specifically. Rather, it simply required States to adopt appropriate water quality criteria necessary to support designated uses. (See 40 CFR 130.17 as promulgated in 40 FR 55334, November 28, 1975).

After several years of effort and faced with increasing public and Congressional concerns about toxic pollutants, EPA realized that proceeding under section 307 of the Act would not comprehensively address in a timely manner the control of toxics through either toxic pollutant effluent standards or effluent limitations guidelines because these controls are only applicable to specific types of discharges. EPA sought a broader, more generally applicable mechanism and decided to vigorously pursue the alternative approach of EPA issuance of scientific water quality criteria documents which States could use to adopt enforceable water quality standards. These in turn could be used as the basis for establishing State and EPA permit discharge limits pursuant to section 301(b)(1)(C) which requires NPDES permits to contain

> * * * any more stringent limitation, including those necessary to meet water quality standards * * *, or required to implement any applicable water quality standard established pursuant to this Act.

Thus, the adoption by States of appropriate toxics criteria applicable to their surface waters, such as those recommended by EPA in its criteria documents, would be translated by regulatory agencies into point source permit limits. Through the use of water quality standards, all discharges of toxics are subject to permit limits and not just those discharged by particular industrial categories. In order to facilitate this process, the Agency amended the water quality standards regulation to explicitly address toxic criteria requirements in State standards. The culmination of this effort was the promulgation of the present water quality standards regulation on November 8, 1983 (40 CFR part 131, 48 FR 51400).

The current water quality standards regulation (40 CFR part 131) is much more comprehensive than its predecessor. The regulation addresses in detail both the beneficial use component and the criteria component of a water quality standard. Section 131.11 of the regulation requires States to review available information and,

> * * * to identify specific water bodies where toxic pollutants may be adversely affecting water quality or the attainment of the designated water use or where the levels of toxic pollutants are at a level to warrant concern and must adopt criteria for such toxic pollutants applicable to the water body sufficient to protect the designated use.

The regulation provided that either or both numeric and narrative criteria may be appropriately used in water quality standards.

EPA's water quality standards emphasis since the early 1980's reflected the increasing importance placed on controlling toxic pollutants. States were strongly encouraged to adopt criteria in their standards for the priority toxic pollutants, especially where EPA had published criteria guidance under Section 304(a) of the Act.

Under the statutory scheme, during the 3-year triennial review period following EPA's 1980 publication of water quality criteria for the protection of human health and aquatic life, States should have reviewed those criteria and adopted standards for many priority toxic pollutants. In fact, State response to EPA's criteria publication and toxics initiative was disappointing. A few States adopted large numbers of numeric toxics criteria, although primarily for the protection of aquatic life. Most other States adopted few or no water quality criteria for priority toxic pollutants. Some relied on a narrative "free from toxicity" criterion, and so-called "action levels" for toxic pollutants or occasionally calculated site-specific criteria. Few States addressed the protection of human health by adopting numeric human health criteria.

In support of the November, 1983, water quality standards rulemaking, EPA issued program guidance entitled, Water Quality Standards Handbook (December 1983) simultaneously with the publication of the final rule. The foreword to that guidance noted EPA's two-fold water quality based approach to controlling toxics: chemical specific numeric criteria and biological testing in whole effluents or ambient waters to comply with narrative "no toxics in toxic amounts" standards. More detailed programmatic guidance on the application of biological testing was provided in the Technical Support Document for Water Quality Based Toxics Control (TSD) (EPA 440/4–85–032, September 1985). This document provided the needed information to convert chemical specific and biologically based criteria into water quality standards for ambient receiving waters and permit limits for discharges to those waters. The TSD focused on the use of bioassay testing of effluents (so-called whole effluent testing or WET methods) to develop effluent limitations within discharge permits. Such effluent limits were designed to implement the "free from toxicity" narrative standards in State water quality standards. The TSD also focused on water quality standards. Procedures and policy were presented for appropriate design flows for EPA's section 304(a) acute and chronic criteria. EPA revised the TSD. (Technical Support Document for Water Quality-based Toxics Control, EPA 505/2–90–001, March 1991.) A Notice of Availability was published in the **Federal Register** on April 4, 1991 (56 FR 13827). All references in this Preamble are to the revised TSD.

The Water Quality Standards Handbook and the TSD are examples of EPA's efforts and assistance that were intended to help, encourage and support the States in adopting appropriate water quality standards for the protection of their waters against the deleterious effects of toxic pollutants. In some States, more and more numeric criteria for toxics were being included as well as more aggressive use of the "free from toxics" narratives in setting protective NPDES permit limits. However, by the time of Congressional consideration and action on the CWA reauthorization, most States had adopted few, if any, water quality standards for priority toxic pollutants.

State practices of developing case-by-case effluent limits using procedures that were not standardized in State regulations made it difficult to ascertain whether such procedures were consistently applied. The use of approaches to control toxicity that did not rely on the statewide adoption of numeric criteria for the priority toxic pollutants generated frustration in Congress. Senator Robert Stafford, first chairman and then ranking minority member of the authorizing committee, noted during the Senate debate:

> An important problem in this regard is that few States have numeric ambient criteria for toxic pollutants. The lack of ambient criteria (for toxic pollutants) make it impossible to calculate additional discharge limitations for toxics * * * It is vitally important that the water quality standards program operate in such a way that it supports the objectives of the Clean Water Act to restore and maintain the integrity of the Nation's Waters. (bracketed material added). A Legislative History of the Water Quality Act of 1987 (Pub. L. 100–4), Senate Print 100–144, USGPO, November 1988 at page 1324.

Other comments in the legislative history similarly note the Congressional perception that the States were failing to aggressively address toxics and that EPA was not using its oversight role to push the States to move more quickly and comprehensively. Thus Congress developed the water quality standards amendments to the Clean Water Act for reasons similar to those strongly stated during the Senate debate by a chief sponsor, Senator John Chaffee,

> A cornerstone of the bill's new toxic pollution control requirements is the so called beyond-BAT program. * * * Adopting the beyond BAT provisions will assure that EPA continues to move forward rapidly on the program. * * * If we are going to repair the damage to those water bodies that have become highly degraded as a result of toxic substances, we are going to have to move forward expeditiously on this beyond-BAT program. The Nation cannot tolerate endless delays and negotiations between EPA and States on this program. Both entities must move aggressively in taking the necessary steps to make this program work within the time frame established by this Bill * * * Ibid, at page 1309.

This Congressional impatience with the pace of State and EPA progress and an appreciation that the lack of State standards for toxics undermined the effectiveness of the entire CWA-based scheme, resulted in the 1987 adoption of stringent new water quality standard provisions in the Water Quality Act amendments.

2. *The Water Quality Act Amendments of 1987 (Pub. L. 100-4)*

a. Description of the New Requirements

The 1987 Amendments to the Clean Water Act added section 303(c)(2)(B) which provides:

> Whenever a State reviews water quality standards pursuant to paragraph (1) of this subsection, or revises or adopts new standards pursuant to this paragraph, such State shall adopt criteria for all toxic pollutants listed pursuant to section 307(a)(1) of this Act for which criteria have been published under section 304(a), the discharge or presence of which in the affected waters could reasonably be expected to interfere with those designated uses adopted by the State, as necessary to support such designated uses. Such criteria shall be specific numerical criteria for such toxic pollutants. Where such numerical criteria are not available, whenever a State reviews water quality standards pursuant to paragraph (1), or revises or adopts new standards pursuant to this paragraph, such State shall adopt criteria based on biological monitoring or assessment methods consistent with information published pursuant to section 304(a)(8). Nothing in this section shall be construed to limit or delay the use of effluent limitations or other permit conditions based on or involving biological monitoring or assessment methods or previously adopted numerical criteria.

b. EPA's Initial Implementing Actions for Sections 303(c) and 304(l)

This new requirement to the existing water quality standards review and revision process of section 303(c) did not change the existing procedural or timing provisions. For example, section 303(c)(1) still requires that States review their water quality standards at least once each 3 year period and transmit the results to EPA for review. EPA's oversight and promulgation authorities and statutory schedules in section 303(c)(4) were likewise unchanged. Rather, the provision required the States to place heavy emphasis on adopting numeric chemical-specific criteria for toxic pollutants (i.e., rather than just narrative approaches) during the next triennial review cycle. As discussed in the previous section, Congress was frustrated that States were not using the numerous section 304(a) criteria that EPA had developed, and was continuing to develop, to assist States in controlling the discharge of priority toxic pollutants. Congress therefore took an usual action; for the first time in the history of the Clean Water Act, it explicitly mandated that States adopt numeric criteria for specific toxic pollutants.

In response to this new Congressional mandate, EPA redoubled its efforts to promote and assist State adoption of water quality standards for priority toxic pollutants. EPA's efforts included the development and issuance of guidance to the States on acceptable implementation procedures for several new sections of the Act, including Sections 303(c)(2)(B) and 304(l).

The 1987 CWA Amendments added to, or amended, other CWA sections related to toxics control. Section 304(l) (33 U.S.C. 1314(l)) was an important corollary amendment because it required States to take actions to identify waters adversely affected by toxic pollutants, particularly those waters entirely or substantially impaired by point sources. Section 304(l) entitled "Individual Control Strategies for Toxic Pollutants," requires in part, that States identify and list waterbodies where the designated uses specified in the applicable water quality standards cannot reasonably be expected to be achieved because of point source discharge of toxic pollutants. For each segment so identified, the State is required to develop individual control strategies to reduce the discharge of toxics from point sources so that in conjunction with existing controls on point and nonpoint sources, water quality standards will be attained. To assist the States in identifying waters under section 304(l), EPA's guidance listed a number of potential sources of available data for States to review. States generally assembled data for a broad spectrum of pollutants, including the priority toxic pollutants, which could be useful in complying with sections 304(l) and 303(c)(2)(B). In fact, between February 1988 and October 1988, EPA assembled pollutant candidate lists for section 304(l) which were then transmitted to each jurisdiction. Thus, each State had a preliminary list of pollutants that had been identified as present in, or discharged to, surface waters. Such lists were limited by the quantity and distribution of available effluent and ambient monitoring data for priority toxic pollutants. This listing exercise further emphasized the need for water quality standards for toxic pollutants. Lack of standards increased the difficulty of identifying impaired waters. On the positive side, the data gathered in support of the 304(l) activity proved helpful in identifying those pollutants most obviously in need of water quality standards.

EPA, in devising guidance for section 303(c)(2)(B), attempted to provide the maximum flexibility in its options that not only complied with the express statutory language but also with the ultimate congressional objective: Prompt adoption of numeric toxics criteria. EPA believed that flexibility was important so that each State could comply with section 303(c)(2)(B), accommodate its existing water quality standards regulatory approach, and not violate the resource constraints specific to the State. These options are described in the next Section of this preamble. EPA's program guidance was issued in final form on December 12, 1988 but was not substantially different from earlier drafts available for review by the States. The availability of the guidance was published in a **Federal Register** notice on January 5, 1989 (54 FR 346).

3. EPA's Program Guidance for Section 303(c)(2)(B)

EPA's section 303(c)(2)(B) program guidance identified three options that could be used by a State to meet the requirement that the State adopt toxic pollutant criteria "* * * the discharge or presence of which in the affected waters could reasonably be expected to interfere with those designated uses adopted by the State, as necessary to support such designated uses."

Option 1. Adopt statewide numeric criteria in State Water Quality Standards for all section 307(a) toxic pollutants for which EPA has developed criteria guidance, regardless of whether the pollutants are known to be present.

This option is the most comprehensive approach to satisfy the statutory requirements because it would include all of the priority toxic pollutants for which EPA has prepared section 304(a) criteria guidance for either or both aquatic life protection and human health protection. In addition to a simple adoption of EPA's section 304(a) guidance as standards, a State must select a risk level for those toxic pollutants which EPA believes are carcinogens (i.e., that cause, or may cause cancer in humans). EPA also recommended that States should supplement this comprehensive approach with a water quality standard variance and/or a site-specific criteria methodology to provide the opportunity for flexibility in applying criteria.

Many States found this option attractive because it ensured comprehensive coverage of the priority toxic pollutants with scientifically defensible criteria without the need to conduct a resource-intensive evaluation of the particular segments and pollutants requiring criteria or future prevalence of priority toxic pollutants in their waters. It was also determined this option would not be more costly to dischargers than the other options because permit limits would only be based on the regulation of the particular toxic pollutants in their discharges and not on the total listing in the water quality standards. Thus, actual permit limits should be the same under any of the options.

Option 2. Adopt chemical-specific numeric criteria for priority toxic pollutants that are the subject of EPA section 304(a) criteria guidance, where the State determines based on available information that the pollutants are present or discharged and can reasonably be expected to interfere with designated uses.

This option results in the adoption of numeric water quality standards for some subset of those pollutants for which EPA has issued section 304(a) criteria guidance based on a review of current information. To satisfy this option, the guidance recommended that States use the data gathered during the section 304(l) water quality assessments as a starting point to identify those water segments that need water quality standards for priority toxic pollutants. That data would be supplemented by a State and public review of other data sources to ensure sufficient breadth of coverage to meet the statutory objective. Among the available data to be reviewed were: (1) Ambient water monitoring data, including those for the water column, sediment, and aquatic life (e.g., fish tissue data); (2) NPDES permit-applications and permittee self-monitoring reports; (3) effluent guideline development documents, many of which contain priority toxic pollutant scans; (4) pesticide and herbicide application information and other records of pesticide or herbicide inventories; (5) public water supply source monitoring data noting pollutants with maximum contaminant levels (MCLs); and (6) any other relevant information on toxic pollutants collected by Federal, State, industry, agencies, academic groups, or scientific organizations. EPA also recommended that States adopt a translator provision similar to that described in Option 3 but applicable to all chemicals causing toxicity, and not just priority toxic pollutants.

This Option 2 review resulted in a State proposing new or revised water quality standards and providing an opportunity for public review and comment on the pollutants, criteria, and water bodies included. Throughout this process, EPA's Regional Offices were available to assist States by providing additional guidance and technical assistance on applying EPA's recommended criteria to particular situations in the States.

Option 3. Adopt a procedure to be applied to a narrative water quality standard provision prohibiting toxicity in receiving waters. Such procedures would be used by the State in calculating derived numeric criteria which must be used for all purposes under section 303(c) of the CWA. At a minimum, such criteria need to be developed for section 307(a) toxic pollutants, as necessary to support designated uses, where these pollutants are discharged or present in the affected waters and could reasonably be expected to interfere with designated uses.

The combination of a narrative standard (e.g., "free from toxics in toxic amounts") and an approved translator mechanism as part of a State's water quality standards satisfies the requirements of section 303(c)(2)(B). As noted above, such a procedure is also a valuable supplement to either option 1 or 2. There are several regulatory and scientific requirements EPA's guidance specifies are essential to ensure acceptable scientific quality and full involvement of the public and EPA in this approach. Briefly stated these are:

- The procedure (i.e., narrative criterion and translator) must be used to calculate numeric water quality criteria;
- The State must demonstrate to EPA that the procedure results in numeric criteria that are sufficiently protective to meet the goals of the Act;
- The State must provide for full opportunity for public participation during the adoption of the procedure;
- The procedure must be formally adopted as a State rule and be mandatory in application; and
- The procedure must be submitted for review and approval by EPA as part of the State's water quality standards regulation.

Several States currently apply translators that have been approved by EPA. The scientific elements of a translator are similar to EPA's 304(a) criteria methodologies when applied on a site-specific basis. For example, aquatic criteria are developed using a sufficient number and diversity of aquatic species representative of the biological assemblage of a particular water body. Human health criteria focus on determining appropriate exposure conditions (e.g. amount of aquatic life consumed per person per day) rather than underlying pollutant toxicity. The results of the procedures are scientifically defensible criteria that are protective for the site's particular conditions. EPA review of translator procedures includes an evaluation of the scientific merit of the procedure using the Section 304(a) methodolgy as a guide.

Ideally, States adopting option 3 translator procedures should prepare a preliminary list of criteria and specify the waters the criteria apply to at the time of adoption. Although under option 3 the State retains flexibility to derive new criteria without revising the adopted standards, establishing this preliminary list of derived criteria at the time of the triennial review will assist the public in determining the scope of the adopted standards, and help ensure that the State ultimately complies with the requirement to establish criteria for all pollutants that can "reasonably be expected" to interfere with uses. EPA believes that States selecting solely option 3 should prepare an analysis similar to that required of option 2 States at the time of the triennial review.

EPA's December 1988 guidance also addressed the timing issue for State compliance with section 303(c)(2)(B). The statutory directive was clear: All State standards triennial reviews initiated after passage of the Act must include a consideration of numeric toxic criteria.

The structure of section 303(c) is to require States to review their water quality standards at least once each three year period. Section 303(c)(2)(B) instructs States to include reviews for toxics criteria whenever they initiate a triennial review. EPA initially looked at February 4, 1990, the 3-year anniversary of the 1987 CWA amendments, as a convenient point to index State compliance. The April 1990 **Federal Register** notice used this index point for the preliminary assessment. However, some States were very nearly completing their State administrative processes for ongoing reviews when the 1987 amendments were enacted and could not legally amend those proceedings to address additional toxics criteria. Therefore, in the interest of fairness, and to provide such States a full 3-year review period, EPA's FY 1990 Agency Operating Guidance provided that "By the end of the FY 88–90 triennium, States should have completed adoption of numeric criteria to meet the section 303(c)(2)(B) requirements." (p. 48.) The FY 88–90 triennium ended on September 30, 1990.

Clean Water Act section 303(c) does not provide penalties for States that do not complete timely water quality standards reviews. In no previous case has the EPA Administrator found that State failure to complete a review within three years jeopardized the public health or welfare to such an extent that promulgation of Federal standards pursuant to section 303(c)(4)(B) was justified. The pre-1987 CWA never mandated State adoption of priority toxic pollutants or other specific criteria. EPA relied on its water quality standards regulation (40 CFR 131.11) and its criteria and program guidance to the States on appropriate parametric coverage in State water quality standards, including toxic pollutants. However, because of Congressional concern exhibited in the legislative history for the 1987 Clean Water Act amendments regarding undue delays by States and EPA, and because States have been explicitly required to adopt numeric criteria for appropriate priority toxic pollutants since 1963, the Agency in this proposed rulemaking is proceeding pursuant to section 303(c)(4)(B) and 40 CFR 131.22(b).

4. Revisions to the Water Quality Standards Regulation to Incorporate the Requirements of Section 303(c)(2)(B)

In a rulemaking separate from today's proposal, EPA intends to propose amendments to the Water Quality Standards Regulation to incorporate the requirements of section 303(c)(2)(B). EPA views the effects of that intended rulemaking to be prospective only. EPA's expected regulatory change would provide principally more consistency among the States in their approaches to adopting appropriate toxic and other criteria in future triennial reviews.

The current requirements for water quality criteria in State water quality standards are addressed in 40 CFR 131.11. EPA's intended rulemaking will propose amendments to this section and incorporate the three options described in its December 12, 1988 guidance. Of special concern are the specific requirements for the translator provision described as option 3.

The current regulation at 40 CFR part 131 in conjunction with the statutory language provides a clear and unambiguous basis and process for today's proposed Federal promulgation.

C. State Actions Pursuant to Section 303(c)(2)(B)

There has been substantial progress by many States in the adoption, and EPA approval, of water quality standards for toxic pollutants. For example, for freshwater aquatic life uses, the average number of priority toxic pollutants with criteria adopted has tripled from ten per State in 1986 to thirty per State on February 4, 1990. In addition, the number of States with at least some aquatic life criteria adopted has increased from thirty-three in April 1986 to forty-five as of February 4, 1990.

Furthermore, virtually all States have at least proposed new toxics criteria for priority toxic pollutants since section 303(c)(2)(B) was added to the CWA in February of 1987. Unfortunately, not all such State proposals address, in a comprehensive manner, the requirements of section 303(c)(2)(B). For example, some States have proposed to adopt criteria to protect aquatic life, but not human health; other States have proposed human health criteria which do not address major human exposure pathways. In addition, in some cases final adoption of proposed State toxics criteria which would be approvable by EPA has been substantially delayed due to controversial and difficult issues associated with the toxics criteria adoption process. For purposes of today's proposed rulemaking, it is EPA's judgment that only 35 States completed actions which fully satisfy the requirements of section 303(c)(2)(B).

The difficulties faced by States in adopting criteria for priority toxic pollutants are exemplified by recent State efforts to adopt criteria for the priority toxic pollutant 2,3,7,8–TCDD (dioxin). As is generally true of State section 303(c)(2)(B) efforts, State efforts to adopt numeric human health dioxin criteria have been slow and controversial, but in many respects impressive. For example, since 1987, a total of 34 States have adopted numeric human health criteria for dioxin which have been approved by EPA. In total, 38 States have adopted numeric human health criteria for dioxin. Twenty-five of these 38 States adopted criteria during calendar year 1991, showing that the pace of State actions to adopt dioxin criteria has accelerated substantially.

The progress which has been made by States in adopting dioxin criteria is particularly impressive in light of the substantial attention and controversy which has been focused on such actions. EPA, States, dischargers, environmental groups, and the public at large have been involved in discussions concerning the ambient level of protection that is protective of public health. In some States, the struggle to select an appropriate dioxin criterion has been the major impediment to successful completion of section 303(c)(2)(B) actions.

At issue are scientific questions specific to dioxin, such as determining the carcinogenic potency of the pollutant and the extent to which the pollutant tends to accumulate in fish tissues. Other issues are generic to EPA'S human health criteria, such as determining the rate at which humans consume fish and other forms of aquatic life, and the necessity of setting ambient criteria at levels which may not be detected by state-of-the-art laboratories. Most of these issues relate, directly or indirectly, to concerns expressed by dischargers regarding the cost of complying with water quality-based effluent limits for dioxin which, although variable from State to State, generally are based on State numeric water quality criteria that allow only minute quantities of dioxin per liter of water. For example, twelve States have adopted EPA's recommended ambient water column concentration of 0.013 picograms per liter.

Currently, a total of eleven States have proposed, or are expected to propose, numeric human health-based criteria for dioxin. These States could face the same issues, obstacles, and resource requirements that the 38 States which previously adopted criteria have faced.

In summary, States have devoted substantial resources, and have made substantial progress, in adopting new or revised numeric criteria for priority pollutants. In so doing they have addressed a number of significant and difficult issues. These issues and the attendant controversy has accounted, at least in part, for the fact that 22 jurisdictions still have not adopted numeric toxics criteria that fully comply with section 303(c)(2)(B). For a more detailed State-specific outline of actions taken in response to section 303(c)(2)(B), refer to part III of appendix 1, which itemizes State actions to adopt toxics criteria for States approved by EPA as being in full compliance as well as States which EPA has not approved as being in full compliance with section 303(c)(2)(B).

D. Determining State Compliance With Section 303(c)(2)(B)

1. EPA's Review of State Water Quality Standards for Toxics

The EPA Administrator has delegated the responsibility and authority for review and approval or disapproval of all State water quality standards actions to the 10 EPA Regional Administrators (see 40 CFR 131.21). State section 303(c)(2)(B) actions are thus submitted to the appropriate EPA Regional Administrator for review and approval. This de-centralized EPA system for State water quality standards review and approval is guided by EPA Headquarter's Office of Water, which issues national policies and guidance to the States and Regions such as the annual Office of Water Operating Guidance and various technical operating guidance manuals.

For purposes of evaluating State compliance with CWA section 303(c)(2)(B), EPA relied on the language of section 303(c)(2)(B), the existing water quality standards regulation, and section 303(c)(2)(B) national guidance to provide the basis for EPA review. In some cases, individual Regions also used Regional policies and procedures in reviewing State section 303(c)(2)(B) actions. The flexibility provided by the national guidance, coupled with subtle differences in Regional policies and procedures, contributed to some differences in the approaches taken by States to satisfy section 303(c)(2)(B) requirements.

As discussed previously, EPA's final guidance on compliance with section 303(c)(2)(B) was developed to provide States with the necessary flexibility to allow State standards revisions that would complement the State's existing water quality standards program, fully comply with section 303(c)(2)(B), and not violate State-specific resource constraints. As guidance, it did not contain clearly defined limits on the range of acceptable approaches, but rather described EPA's recommendations on approaches States could use to satisfy the statutory requirements. Some innovative State approaches were expected as well as differences in terms of criteria coverage, stringency and application procedures.

Although the guidance provided for State flexibility, it was also consistent with existing water quality standards regulation requirements at 40 CFR 131.11 that explicitly require State criteria to be sufficient to protect designated uses. Such water quality criteria also must be based on sound scientific rationale and support the most sensitive use designated for a water body.

The most complicated EPA compliance determinations involve States that select EPA Options 2 or 3. Since most States use EPA's Section 304(a) criteria guidance, where States select Option 1, EPA normally is able to focus Agency efforts on verifying that all available EPA criteria are included, appropriate cancer risk levels are selected, and that sufficient application procedures are in place (e.g. laboratory analytical methods, mixing zones, flow condition, etc.).

However, for States using EPA's Option 2 or 3, substantially more EPA evaluation and judgment is required because the Agency must evaluate which priority pollutants and, in some cases, segments or designated uses, require numeric criteria. Under these options, the State must adopt or derive numeric criteria for priority toxic pollutants for which EPA has section 304(a) criteria, "* * * the discharge or presence of which in the affected waters could reasonably be expected to interfere with those designated uses adopted by the State * * *" The necessary justification and the ultimate coverage and acceptability of a State's actions vary State-to-State because of differences in the adequacy of available monitoring information, local water bodies use designations, the effluent and nonpoint source controls in place, and different approaches to the scientific basis for criteria.

In submitting criteria for the protection of human health, States are not limited to a 1 in 1 million risk level (10^{-6}). EPA generally regulates pollutants treated as carcinogens in the range of 10^{-6} to 10^{-4} for average exposed individuals. If a State selects a criterion that represents an upper bound risk level less protective than 1 in 100,000 (i.e., 10^{-5}), however, the State will need to have substantial support in the record for this level. This support should focus on two distinct issues. First, the record must include documentation that the decision maker considered the public interest of the State in selecting the risk level, including documentation of public participation in the decision making process as required by the water quality standards regulation at 40 CFR 131.20(b). Second, the record must include an analysis showing that the risk level selected, when combined with other risk assessment variables, is a balanced and reasonable estimate of actual risk posed, based on the best and most representative information available. The importance of the estimated actual risk increases as the degree of conservatism in the selected risk level diminishes. EPA will carefully evaluate all assumptions used by a State if the State chooses to alter any one of the standard EPA assumption values.

Where States select Option 3, EPA reviews must also include an evaluation of the scientific defensibility of the translator procedure. EPA must also verify that a requirement to apply the translator whenever toxics may reasonably be expected to interfere with designated uses (e.g., where such toxics exist or are discharged) is included in the State's water quality standards. Satisfactory application procedures must also be developed by States selecting Option 3.

In general, each EPA Region made compliance decisions based on whatever information was available to the State at the time of the triennial review. For some States, information on the presence and discharge of priority toxic pollutants is extremely limited. Nevertheless, during the period of February 1988 to October 1990, to supplement State efforts, EPA assembled the available information and provided each State with various pollutant candidate lists in support of the section 304(l) and section 303(c)(2)(B) activities. These were based in part on computerized searches of existing Agency data bases.

Beginning in 1988, EPA provided States with candidate lists of priority toxic pollutants and water bodies in support of CWA section 304(l) implementation. These lists were developed because States were required to evaluate existing and readily available water-related data in order to comply with section 304(l). 40 CFR 130.10(d). A similar "strawman" analysis of priority pollutants potentially requiring adoption of numeric criteria under section 303(c)(2)(B) was furnished to most States in September or October of 1990 for their use in on-going and subsequent triennial reviews. The primary differences between the "strawman" analysis and the section 304(l) candidate lists were that the "strawman" analysis: (1) Organized the results by chemical rather than by water body, (2) included data for certain STORET monitoring stations that were not used in constructing the candidate lists, (3) included data from the Toxics Release Inventory database, and (4) did not include a number of data sources used in preparing the candidate lists (e.g., those, such as fish kill information, that did not provide chemical specific information).

In its 1988 section 303(c)(2)(B) guidance, EPA urged States, at a minimum, to use the information gathered in support of section 304(l) requirements as a starting point for identifying which priority toxic pollutants require adoption of numeric criteria. EPA also encouraged States to consider the presence or potential construction of facilities that manufacture or use priority toxic pollutants as a strong indication of the need for toxics criteria. Similarly, EPA indicated to States that the presence of priority pollutants in ambient waters (including those in sediments or in aquatic life tissue) or in discharges from point or nonpoint sources also be considered as an indication that toxics criteria should be adopted. A limited amount of data on the effluent characteristics of NPDES discharges was readily available to States. States were also expected to take into account newer information as it became available, such as information in annual reports from the Toxic Chemical Release Inventory requirements of the Emergency Planning and Community Right-To-Know Act of 1986. (Title III, Pub. L. 99–499.)

In summary, EPA and the States had access to a variety of information gathered in support of section 304(l), section 303(c)(2)(B), and section 305(b) activities. For some States, as noted above, such information for priority toxic pollutants is extremely limited. In the final analysis, the Regional Administrator made a judgment on a duly submitted State standards triennial review based on the State's record and the Region's independent knowledge of the facts and circumstances surrounding the State's actions. These actions, taken in consultation with the Office of Water, determined which State actions were sufficiently consistent with the coverage contemplated in the statute to justify approval. These approval actions include allowable variations among State water quality standards. EPA approval indicates that, based on the record, the State water quality standards met the requirements of the Act.

2. Determining Current Compliance Status

The following summarizes the process generally followed by the Agency in assessing compliance with section 303(c)(2)(B). As with other aspects of this rule, EPA invites comments on the compliance determination process.

A State was determined to be in full compliance with the requirements of section 303(c)(2)(B) if,

a. The State had submitted a water quality standards package for EPA review since enactment of the 1987 Clean Water Act amendments or was determined to be already in compliance, and,

b. The adopted State water quality standards are effective under State law and consistent with the CWA and EPA's implementing regulations (EPA's December 1988 guidance described three Options, any one, or a combination of which EPA suggested States could adopt for compliance with the CWA and EPA regulations), and

c. EPA has issued a formal approval determination to the State.

States meeting these criteria are not included in this proposed rulemaking.

States which adopted standards following Option 1 generally have been found to satisfy section 303(c)(2)(B). An exception exists for selected States which attempted to follow Option 1 by adopting all EPA section 304(a) criteria by reference. EPA has withheld approval for a few States which have adopted such references into their standards because the adopted standards did not specify application factors necessary to implement the criteria (e.g., a risk level for carcinogens). Other States have achieved full compliance following options 1, 2, 3, or some combination of these options.

As of the date of signature of today's proposal, the Agency has determined that 35 States and Territories are in full compliance with the requirements of section 303(c)(2)(B). Compliance status for all States and Territories is set forth in Table 1.

TABLE 1.—PRELIMINARY ASSESSMENT OF STATE COMPLIANCE WITH CWA SECTION 303(C)(2)(B)

State	Is State in compliance with section 303(c)(2)(B)?
Alabama	Yes.
Alaska	No.
Arizona	No.
Arkansas	No.
California	No.
Colorado	No.
Connecticut	No.
Delaware	Yes.
Florida	No.
Georgia	Yes.
Hawaii	No.
Idaho	No.
Illinois	Yes.
Indiana	Yes.
Iowa	Yes.
Kansas	No.
Kentucky	Yes.
Louisiana	No.
Maine	Yes.
Maryland	Yes.
Massachusetts	Yes.
Michigan	No.
Minnesota	Yes.
Mississippi	Yes.
Missouri	Yes.
Montana	Yes.
Nebraska	Yes.
Nevada	No.
New Hampshire	No.
New Jersey	No.
New Mexico	Yes.
New York	Yes.
North Carolina	Yes.
North Dakota	Yes.
Ohio	Yes.
Oklahoma	Yes.
Oregon	Yes.
Pennsylvania	Yes.
Rhode Island	No.
South Carolina	Yes.
South Dakota	Yes.
Tennessee	Yes.
Texas	Yes.
Utah	Yes.
Vermont	No.
Virginia	No.
Washington	No.
West Virginia	Yes.
Wisconsin	Yes.
Wyoming	Yes.
American Samoa	Yes.
Commonwealth of the Northern Marianas Islands.	No.
District of Columbia	No.
Guam	Yes.
Puerto Rico	No.
Tr. Territories	Yes.
Virgin Islands	Yes.

Section III of appendix 1 provides a State-by-State summary of how compliance was achieved for the EPA-approved States, and what has been, and yet needs to be, accomplished in States included in this proposed rule.

E. Rationale and Approach for Developing Today's Proposed Rulemaking

The addition of section 303(c)(2)(B) to the Clean Water Act was an unequivocal signal to the States that Congress wanted toxics criteria in the State's water quality standards. The legislative history notes that the "beyond BAT" program (i.e., controls necessary to comply with water quality standards that are more stringent than technology-based controls) was the cornerstone to the Act's toxic pollution control requirements.

The major innovation of the 1972 Clean Water Act Amendments was the concept of effluent limitation guidelines which were to be incorporated into NPDES permits. In many cases, this strategy has succeeded in halting the decline in the quality of the Nation's waters and, often, has provided improvements. However, the effluent limitation guidelines for industrial discharges and the similar technology-based secondary treatment requirements for municipal discharges are not capable, by themselves, of ensuring that the fishable-swimmable goals of the Clean Water Act will be met.

The basic mechanism to accomplish this in the Act is water quality standards. States are required to periodically review and revise these standards to achieve the goals of the Act. In the 1987 CWA amendments, Congress focused on addressing toxics in several sections of the Act, but special attention was placed on the section 303 water quality standards program requirements. Congress intended that the adoption of numeric criteria for toxics would result in direct improvements in water quality by forcing, where necessary, effluent limits more stringent than those resulting from technology-based effluent limitations guidelines.

As the legislative history demonstrates, Congress was dissatisfied with the piecemeal, slow progress being made by States in setting standards for toxics. Congress reacted by legislating new requirements and deadlines directing the States to establish toxics criteria for pollutants addressed in EPA Section 304(a) criteria guidance, especially for those priority toxic pollutants that could reasonably be expected to interfere with designated uses. In today's action, EPA is exercising its authority under section 303(c)(4) to propose criteria where States have failed to act in a timely manner.

For those States not in compliance with section 303(c)(2)(B) four and one-half years after enactment, EPA now begins the process that will culminate in the promulgation of appropriate toxics criteria and the determination of the necessary parametric coverage and stringency of such criteria. While the previous section of this preamble explains EPA's approach to evaluating the adequacy of State actions in response to section 303(c)(2)(B), this section explains EPA's legal basis for issuing today's proposed rulemaking, discusses EPA's general approach for developing the proposed State-specific requirements in § 131.36(d).

In addition to the Congressional directive and the legal basis for this proposed action, there are a number of environmental and programmatic reasons why further delay in establishing water quality standards for toxic pollutants is no longer acceptable.

Prompt control of toxic pollutants in surface waters is critical to the success of a number of Clean Water Act programs and objectives, including permitting, enforcement, fish tissue quality protection, coastal water quality improvement, sediment contamination control, certain nonpoint source controls, pollution prevention planning, and ecological protection. The decade-long delay in State adoption of water quality standards for toxic pollutants has had a ripple effect throughout EPA's water programs. Without clearly established water quality goals, the effectiveness of many water programs is jeopardized.

Failure to take prompt action at this juncture would also undermine the continued viability of the current statutory scheme to establish standards. Continued delay subverts the entire concept of the triennial review cycle which is to combine current scientific information with the results of previous environmental control programs to direct continuing progress in enhancing water quality.

Finally, another reason to proceed expeditiously is to bring closure to this long-term effort and allow State attention and resources to be directed towards important, new national program initiatives. Until standards for toxic pollutants are in place, neither EPA nor the States can fully focus on the emerging, ecologically based water quality activities such as wetlands criteria, biological criteria and sediment criteria.

1. Legal Basis

Clean Water Act section 303(c) specifies that adoption of water quality standards is primarily the responsibility of the States. However, section 303(c) also describes a role for EPA of overseeing State actions to ensure compliance with CWA requirements. If the Agency's review of the State's standards finds flaws or omissions, then the Act authorizes EPA to initiate promulgation to correct the deficiencies (see section 303(c)(4)). The water quality standards promulgation authority has been used by EPA to issue final rules on nine separate occasions. These actions have addressed both insufficiently protective State criteria and/or designated uses and failure to adopt needed criteria. Thus, today's action is not unique, although it would affect more States and pollutants than previous actions taken by the Agency.

The Clean Water Act in section 303(c)(4) provides two bases for promulgation of Federal water quality standards. The first basis in paragraph (A) applies when a State submits new or revised standards that EPA determines are not consistent with the applicable requirements of the Act. If, after EPA's disapproval, the State does not promptly amend its rules so as to be consistent with the Act, EPA must promulgate appropriate Federal water quality standards for that State. The second basis for EPA's action is paragraph (B), which provides that EPA shall promptly initiate promulgation "* * * in any case where the Administrator determines that a revised or new standard is necessary to meet the requirements of this Act." EPA is relying on both section 303(c)(4)(A) and section 303(c)(4)(B) as the legal basis for this proposed rulemaking.

Section 303(c)(4)(A) supports today's action for several States. These States have submitted criteria for some number of priority toxic pollutants and EPA has disapproved the State's adopted standards. The basis for EPA's disapproval generally has been the lack of sufficient criteria or particular criteria that were insufficiently stringent. In these cases, EPA has, by letter to the State, noted the deficiencies and specified the need for corrective action. (See section III of appendix 1 for a summary description of each State's section 303(c)(2)(B) history.) Not having received an appropriate correction within the statutory time frame, EPA is today proposing the needed criteria. The action in today's proposal pursuant to section 303(c)(4)(A) may differ from those taken pursuant to section 303(c)(4)(B) by being limited to criteria for specific priority toxic pollutants, particular geographic areas, or particular designated uses.

Section 303(c)(4)(B) is the basis for EPA's proposed requirements for most States. For these States, the Administrator proposes criteria that would bring the States into compliance with the requirements of the CWA. In these cases, EPA is proposing, at a minimum, criteria for all priority toxic pollutants not addressed by approved State criteria. EPA is also proposing criteria for priority toxic pollutants where any previously-approved State criteria do not reflect current science contained in revised criteria documents and other guidance sufficient to fully protect all designated uses or human exposure pathways, or where such previously-approved State criteria are not applicable to all appropriate designated uses. EPA's action pursuant to section 304(c)(4)(B) may include several situations.

In some cases, the State has failed to adopt and submit for approval any criteria for those priority toxic pollutants for which EPA has published criteria. This includes those States that have not submitted triennial reviews. In other cases, the State has adopted and EPA has approved criteria for either aquatic life or human health, but not both. In yet a third siuation, States have submitted some criteria but not all necessary criteria. Lastly, one State has submitted criteria that do not apply to all appropriate geographic sections of the waters of the State. (See section III of appendix 1.)

The use of section 303(c)(4)(B) requires a determination by the Administrator "* * * that a revised or new standard is necessary to meet the requirements of * * *" the Act. The Administrator's determination could be supported in different ways.

One approach would be for EPA to undertake a time-consuming effort to research and marshall data to demonstrate the need for promulgation for each criteria for each stream segment or waterbody in each State. This would include evidence for each section 307(a) priority toxic pollutant for which EPA has section 304(a) criteria and that there is a "discharge or presence" which could reasonably "be expected to interfere with" the designated use. This approach would not only impose an enormous administrative burden, but would be contrary to the statutory scheme and the compelling Congressional directive for swift action reflected in the 1987 addition of section 303(c)(2)(B) to the Act.

An approach that is more reasonable and consistent with Congressional intent focuses on the State's failure to complete the timely review and adoption of the necessary standards required by section 303(c)(2)(B) despite information that priority toxic pollutants may interfere with designated uses of the State's waters. This approach is consistent with the fact that in enacting section 303(c)(2)(B) Congress expressed its determination of the necessity for prompt adoption and implementation of water quality standards for toxic pollutants. Therefore, a State's failure to meet this fundamental 303(c)(2)(B) requirement of adopting appropriate standards constitutes a failure "to meet the requirements of the Act." That failure to act can be a basis for the Administrator's determination under section 303(c)(4)(B) that new or revised criteria are necessary to ensure designated uses are adequately protected. Here, this determination is buttressed by the existence of evidence of the discharge or presence of priority toxic pollutants in a State's waters for which the State has not adopted numeric water quality criteria. The Agency has compiled an impressive volume of information in the record for this rulemaking (See appendix 1) on the discharge or presence of toxic pollutants in State waters. This data supports the Administrators's proposed determination pursuant to section 303(c)(4)(B).

The Agency's choice to base the proposed determination on the second approach is supported by both the elicit language of the statutory provision and by the legislative history. Congress added subsection 303(c)(2)(B) to section 303 with full knowledge of the existing requirements in section 303(c)(1) for triennial water quality standards review and submission to EPA and in section 303(c)(4)(B) for EPA promulgation. There was a clear expectation that these provisions be used in concert to overcome the programmatic delay that many legislators criticized and achieve the Congressional objective of the rapid availability of enforceable water quality standards for toxic pollutants. As quoted earlier, chief Senate sponsors, including Senators Stafford, Chafee and others, wanted the provision to eliminate State and EPA delays and force aggressive action.

In normal circumstances, it might be argued that to exercise section 303(c)(4)(B) the Administrator might have the burden of marshalling conclusive evidence of "necessity" for Federally promulgated water quality standards. However, in adopting section 303(c)(2)(B), Congress made clear that the "normal" procedure had become inadequate. The specificity and deadline in section 303(c)(2)(B) were layered on top of a statutory scheme already designed to achieve the adoption of toxic water quality standards. Congressional action to adopt an essentially redundant provision was driven by their impatience with the lack of State progress. The new provision was essentially a Congressional "determination" of the necessity for new or revised comprehensive toxic water quality standards by States. In deference to the principle of State primacy, Congress, by linking section 303(c)(2)(B) to the section 303(c)(1) three-year review period, gave States a last chance to correct this deficiency on their own. However, this Congressional indulgence does not alter the fact that section 303(c)(2)(B) changed the nature of the CWA State/EPA water quality standard relationship. The new provision and its legislative background indicate that the Administrator's determination to invoke his section 303(c)(4)(B) authority in this circumstance can be met by a generic finding of inaction on the part of a State and without the need to develop data for individual stream segments. Otherwise, the Agency would face the heavy data gathering burden of justifying the need for each Federal criterion, the process could stretch for years and never be realized. To interpret the combination of subsections (c)(2)(B) and (c)(4) as an effective bar to prompt achievement of statutory objectives would be a perverse conclusion and render section 303(c)(2)(B) essentially meaningless.

A second strong argument against requiring EPA to shoulder a heavy burden to exercise section 303(c)(4)(B) authority is that it would invert the traditional statutory scheme of EPA as national overseer and States as the entity with the greatest local expertise. The CWA provides States the flexibility to tailor water quality standards to local conditions and needs based upon their wealth of first-hand experience, knowledge and data. However, this allowance for flexibility is based on an assumption of reasoned and timely State action, not an abdication of State responsibility by failure to act. EPA does not possess the local expertise or resources necessary to successfully tailor State water quality standards. Therefore, the fact that the CWA allows States flexibility in standards development does not impose an inappropriate burden on EPA in the exercise of its oversight promulgation responsibilities. A broad Federal promulgation based on a showing of State inaction coupled with basic information on the discharge and presence of toxic pollutants meets the statutory objective of having criteria in place that are protective of public health and the environment. Without local expertise to help accurately narrow this list of pollutants and segments requiring criteria, there is no assurance of comparable protection. Nothing in the overall statutory water quality standards scheme anticipates EPA would develop this expertise in lieu of the States. EPA's lack of familiarity with local conditions argues strongly for a simple "determination" test to trigger section 303(c)(4)(B) promulgations. It also supports the concept of an across-the-board rulemaking for all priority toxic pollutants with section 304(a) criteria.

A final major reason supporting a simple determination to trigger 303(c)(4)(B) action is that comprehensive

Federal promulgation imposes no undue or inappropriate burden on States or dischargers. It merely puts in place standards for toxic pollutants that are utilized in implementing Clean Water Act programs. Under this rulemaking, a State still retains the ability to adopt alternative water quality standards simply by completing its standards adoption process. Upon EPA approval of those standards, EPA would take actions to withdraw the Federally-promulgated criteria.

Federal promulgation of State water quality standards should be a course of last resort. It is symptomatic of something awry with the basic statutory scheme. Yet, when it is necessary to exercise this authority, as the evidence suggests is this case, there should be no undue impediments to its use. Section 303(c)(4) is replete with deadlines and Congressional directives for the Administrator to act "promptly" in these cases. The statute indicates that the Administrator of EPA, is to "* * * promptly prepare and publish proposed regulations setting forth a revised or new water quality standard * * *" and "* * * shall promulgate any revised or new standard * * * not later than 90 days after he published such proposed standards, unless prior to such promulgation, such State has adopted a revised or new standard which the Administrator determines to be in accordance with the Act." EPA intends to make every effort to meet the 90 day schedule. The adoption of section 303(c)(2)(B) reinforced this emphasis on expeditious actions. EPA has demonstrated extensive deference to State primacy and a willingness to provide broad flexibility in their adoption of State standards for toxics. However, to fulfill its statutory obligation requires that EPA's deference and flexibility cannot be unlimited.

For the reasons just discussed, EPA does not believe it is necessary to support the criteria proposed today on a pollutant specific, State-by-State, waterbody-by-waterbody basis. Nonetheless, over the course of the past several years in working with and assisting the States, the Agency has reviewed the readily-available data on the discharge and presence of priority toxic pollutants. While this data is not necessarily comprehensive, it constitutes a substantial record to support a *prima facie* case for the need for numeric criteria for most priority toxic pollutants with section 304(a) criteria guidance in most States. In the absence of final State actions to adopt criteria pursuant to either Option 2 or 3 which meet the requirements for EPA approval, this evidence strongly supports EPA's decision to propose, pursuant to Section 303(c)(4)(B), criteria for all priority toxic pollutants not fully addressed by State criteria. The EPA data supporting this assertion is discussed more fully in the next section.

2. Approach for Developing Today's Proposed Rulemaking

The proposed State-specific requirements in § 131.36(d) were developed using one of two approaches. In the formal review of the adopted standards for certain States, EPA has determined that specific numeric toxics criteria are lacking. For some, criteria were omitted from the State standards, even though in EPA's judgment, the pollutants can reasonably be expected to interfere with designated uses. In these cases where EPA has specifically identified deficiencies in a State submission, today's proposed rule would establish Federal criteria for that limited number of priority toxic pollutants necessary to correct the deficiency.

For the balance of the States, EPA proposes to apply, to all appropriate State waters, the section 304(a) criteria for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria do not reflect current science contained in revised criteria documents and other guidance sufficient to fully protect all designated uses or human health exposure pathways, where such previously-approved State criteria do not protect against both acute and chronic aquatic life effects, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA encourages public comments regarding any data which demonstrate that specific priority pollutants or water bodies may not require Federal criteria to protect State designated uses.

Absent a State-by-State pollutant specific analysis to narrow the list, existing data sources strongly support a comprehensive rulemaking approach. Information in the rulemaking record from a number of sources indicates the discharge, potential discharge or presence of virtually all priority toxic pollutants in all States. The data available to EPA has been assembled into a "strawman" analysis designed to identify priority toxic pollutants that potentially require the adoption of numeric criteria. Information on pollutants discharged or present was identified by accessing various national data sources:

—Final section 304(l) short lists identifying toxic pollutants likely to impair designated uses;
—Water column, fish tissue and sediment observations in the Storage Retrieval (STORET) data base (i.e., where the pollutant was detected);
—The National Pollutant Discharge Elimination System's (NPDES) Permit Compliance System data base to identify those pollutants limited in direct dischargers' permits;
—Pollutants included on Form 2(c) permit applications which have been submitted by wastewater dischargers;
—Information on discharges to surface waters or POTWs from the Toxics Release Inventory required by the Emergency Planning and Community Right-To-Know Act of 1986 (title III, Pub. L. 99-499);
—Pollutants predicted to be in the effluent of NPDES dischargers based on industry-specific analyses conducted for the Clean Water Act effluent guideline program.

The extent of this data supports a conclusion that promulgation of Federal criteria for all priority toxic pollutants with section 304(a) criteria guidance documents is appropriate for those States that have not completed their standards adoption process. This conclusion is supported by several other factors.

First, many of the available data sources have limitations which argue against relying on them solely to identify all needed water quality criteria. For example, the section 304(l) short lists only identified water bodies where uses were impaired by point source discharges; State long lists did not generally identify pollutants causing use impairment by nonpoint sources. Other available data sources (i.e., NPDES permit limits) have a similar narrow scope because of their particular purposes. Even the value of those data bases designed to identify ambient water problems is restricted by the availability of monitoring data.

In many States, the quantity, spatial and temporal distribution, and pollutant coverage of monitoring data is severely limited. For example, the most recent Water Quality Inventory Report to Congress included an evaluation of use attainment for only one-third of all river miles and less than one-half of lake acres. Even for those waters where use attainment status was reported, many assessments were based on data which did not include the chemical-specific information necessary to identify the priority toxic pollutants which pose a threat to designated uses. After evaluating this data, EPA concluded that it most likely understates the adverse presence or discharge of priority toxic pollutants.

Further evidence justifying a broad promulgation rulemaking can be found in the State actions to date in their standards adoption process. While many have not come to completion, the initial steps have led many States to develop or propose rulemaking packages with extensive pollutant coverage. The nature of these preliminary State determinations argues for a Federal promulgation of all section 304(a) criteria pollutants to ensure adequate public health and environmental protection against priority toxic pollutant insults.

EPA's strawman analysis for each State is described in greater detail in part III of appendix 1 and the complete record is available for public review.

The detailed assumptions and "rules" followed by EPA in writing the proposed § 131.36(d) requirements for all jurisdictions are listed below. Comment is invited on the details of these determinations.

(1) No criteria are proposed for States which have been fully approved by EPA as complying with the section 303(c)(2)(B) requirements.

(2) For States which have not been fully approved, if EPA has not previously determined which specific pollutants/criteria/waterbodies are lacking from a State's standards (i.e., as part of an approval/disapproval action only), all of the criteria in columns B, C, and D of the proposed § 131.36(b) matrix are proposed for statewide application to all appropriate designated uses, except as provided for elsewhere in these rules. That is, EPA proposes to bring the State into compliance with section 303(c)(2)(B) via an approach which is comparable to option 1 of the December 1988 national guidance for section 303(c)(2)(B).

(3) If EPA has previously determined which specific pollutants/criteria/waterbodies are needed to comply with CWA section 303(c)(2)(B) (i.e., as part of an approval/disapproval action only), the criteria in proposed section 131.36(b) are proposed for only those specific pollutants/criteria/waterbodies (i.e., EPA proposes to bring the State into compliance via an approach which is comparable to option 2 of the December 1988 national guidance for section 303(c)(2)(B)).

(4) For aquatic life, except as provided for elsewhere in these rules, all waters with designated aquatic life uses providing even minimal support to aquatic life are included in the proposed rule (i.e., fish survival, marginal aquatic life, etc.).

(5a) For human health, except as provided for elsewhere in these rules, all waters with designated uses providing for public water supply protection (and therefore a potential water consumption exposure route) or minimal aquatic life protection (and therefore a potential fish consumption exposure route) are included in the proposed rule.

(5b) Where a State has determined the specific aquatic life segments which provide a fish consumption exposure route (i.e., fish or other aquatic life are being caught and consumed) and EPA approved this determination as part of standards approval/disapproval action, the proposed rule includes the fish consumption (Column D(II)) criteria for only those aquatic life segments, except as provided for elsewhere in these rules. In making a determination that certain segments do not support a fish consumption exposure route, a State must have completed, and EPA approved, a use attainability analysis consistent with the provisions of 40 CFR 131.10(j). In the absence of such an approved State determination, EPA has proposed fish consumption criteria for all aquatic life segments.

(6) Uses/Classes other than those which support aquatic life or human health are not included in the proposed rulemaking (e.g., livestock watering, industrial water supply), unless they are defined in the State standards as also providing protection to aquatic life or human health (i.e., unless they are described as protecting multiple uses including aquatic life or human health). For example, if the State standards include a use such as industrial water supply, and in the narrative description of the use the State standards indicate that the use includes protection for resident aquatic life, then this use is included in the proposed rulemaking.

(7) For human health, the "water+fish" criteria in Column D(I) of § 131.36(b) are proposed for all waterbodies where public water supply and aquatic life uses are designated, except as provided for elsewhere in these rules (e.g., rule 9).

(8) If the State has public water supplies where aquatic life uses have not been designated, or public water supplies that have been determined not to provide a potential fish consumption exposure pathway, the "water only" criteria in Column D(I) of § 131.36(b) are proposed for such waterbodies, except as provided for elsewhere in these rules (e.g., rule 9).

(9) EPA is generally not proposing criteria for priority toxic pollutants for which a State has adopted criteria and received EPA approval. The exceptions to this general rule are described in rules 10 and 11.

(10) For priority toxic pollutants where the State has adopted human health criteria and received EPA approval, but such criteria do not fully satisfy section 303(c)(2)(B) requirements, the proposed rule includes human health criteria for such pollutants. For example, consider a case where a State has a water supply segment that poses an exposure risk to human health from both water and fish consumption. If the State has adopted, and received approval for, human health criteria based on water consumption only (e.g., Safe Drinking Water Act Maximum Contaminant Levels (MCLs)) which are less stringent than the "water+fish" criteria in Column D(I) of proposed § 131.36(b), the Column D(I) criteria are proposed for those water supply segments. The rationale for this is to ensure that both water and fish consumption exposure pathways are adequately addressed and human health is fully protected. If the State has adopted water consumption only criteria which are more stringent or equal to the Column D(I) criteria, the "water+fish" criteria in Column D(I) criteria are not proposed.

(11) For priority toxic pollutants where the State has adopted aquatic life criteria and previous to the 1987 CWA Amendments received EPA approval, but such criteria do not fully satisfy section 303(c)(2)(B) requirements, the proposed rule includes aquatic life criteria for such pollutants. For example, if the State has adopted not-to-be-exceeded aquatic life criteria which are less stringent than the 4-day average chronic aquatic life criteria in § 131.36(b) (i.e., in Columns B(II) and C(II)), the acute and chronic aquatic life criteria in Section 131.36(b) are proposed for those pollutants.

The rationale for this is that the State-adopted criteria do not protect resident aquatic life from both acute and chronic effects, and that Federal criteria are necessary to fully protect aquatic life designated uses. If the State has adopted not-to-be-exceeded aquatic life criteria which are more stringent or equal to the chronic aquatic life criteria in § 131.36(b), the acute and chronic aquatic life criteria in § 131.36(b) are not proposed for those pollutants.

(12) Under certain conditions discussed in rules 9, 10, and 11, criteria listed in § 131.36(b) are not proposed for specific pollutants; however, EPA made such exceptions only for pollutants for which criteria have been adopted by the State and approved by EPA, where such criteria are currently effective under State law the appropriate EPA Region

concluded that the State's criteria fully satisfy section 303(c)(2)(B) requirements.

3. Approach for States That Fully Comply Subsequent to Issuance of Today's Proposed Rulemaking

As discussed in prior sections of this preamble, the water quality standards program has been established with an emphasis on State primacy. Although this proposed rule has been developed to Federally promulgate toxics criteria for States, EPA prefers that States maintain primacy, revise their own standards, and achieve full compliance. EPA is hopeful that today's proposed rulemaking will provide additional impetus for non-complying States to adopt the criteria for priority toxic pollutants necessary to comply with section 303(c)(2)(B).

For States that achieve full compliance before publication of the final rulemaking, EPA will not include such States in the final rulemaking. At any point in the process prior to final promulgation, a State can ensure that it will not be affected by this action by adopting the necessary criteria pursuant to State law and receiving EPA approval. The content of the adopted standards must be within the boundaries of the several acceptable approaches described earlier in this preamble.

Following a final promulgation of this rule, removal of a State from the rule will require rulemaking by EPA according to the requirements of the Administrative Procedure Act (5 U.S.C. 551 *et seq.*). EPA will withdraw the Federal rule without a notice and comment rulemaking when the State adopts standards no less stringent than the Federal rule (i.e., standards which provide, at least, equivalent environmental protection). For example, see 51 FR 11580, April 4, 1986, which finalized EPA's removal of a Federal rule for the State of Mississippi.

However, if a State adopts standards for toxics which are less stringent than the Federal rule but, in the Agency's judgment, fully meet the requirements of the Act, EPA will propose to withdraw the rule with a notice of proposed rulemaking and provide for public participation. This procedure would be required for partial or complete removal of a State from this rulemaking. A State covered by the final rule could adopt the necessary criteria using any of the three options or combinations of those Options described in EPA's 1989 guidance.

EPA cautions States and the public that promulgation of a Federal rule removes most of the flexibility available to States for modifying their standards on a discharger-specific or stream-specific basis. For example, variances, site-specific criteria and schedules of compliance actions pursuant to State law for federally promulgated criteria are precluded. Each of these types of modifications would require Federal rulemaking on a case-by-case basis to change the Federal rule for that State.

F. Derivation of Proposed Criteria

1. Sections 304(a) Criteria Process

Under the authority of CWA section 304(a) EPA has developed methodologies and specific criteria to protect aquatic life and human health. These methodologies are intended to provide protection for all surface water on a national basis. As described below, there are site specific procedures for more precisely addressing site specific conditions for an individual water body. However, these site-specific criteria procedures are infrequently used because the section 304(a) criteria recommendations have proven themselves to be appropriate for the vast majority of water bodies. The methodologies have been subject to public review, as have the individual criteria documents. Additionally, the methodologies have been reviewed and approved by EPA's Science Advisory Board.

EPA incorporates by reference into the record of this proposed rulemaking the aquatic life methodology as described in "Appendix B—Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses" (45 FR 79341, November 28, 1980) as amended by "Summary of Revisions to Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (50 FR 30792, July 29, 1985). EPA also incorporates by reference into the record of this proposed rulemaking the human health methodology as described in "Appendix C—Guidelines and Methodology Used in the Preparation of Health Effects Assessment Chapters of the Consent Decree Water Criteria Documents" (45 FR 79347, November 28, 1980). EPA also recommends that the following be reviewed for information: "Appendix D—Response to Comments on Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses," (45 FR 79357, November 28, 1980); "Appendix E—Responses to Public Comments on the Human Health Effects Methodology for Deriving Ambient Water Quality Criteria" (45 FR 79368, November 28, 1980); and "Appendix B—Response to Comments on Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (50 FR 30793, July 29, 1985). EPA also is placing into the record the most current individual criteria documents for the priority toxic pollutants included in today's proposal.

The primary focus of this rule is the inclusion of the water quality criteria for pollutant(s) in State standards as necessary to support water quality-based control programs. The Agency is accepting comment on the criteria proposed in today's rule. However, Congress has established a very ambitious schedule for the promulgation of the final criteria. The statutory deadline in section 303(c)(4) clearly indicates that Congress intended the Agency to move very expeditiously when Federal action is warranted. The Agency believes that the limited time available for promulgation of the regulation can be used most efficiently and effectively by addressing those issues that have not already come before the Agency.

The methodology used to develop the criteria and the criteria themselves (to the extent not updated through IRIS) have previously undergone scientific peer review and public review and comment, and have been revised as appropriate. For the most part, this review occurred before Congress amended the Act in 1987, to require the inclusion of numeric criteria for certain toxic pollutants in State standards. Congress acted with full knowledge of the EPA process for developing criteria and the Agency's recommendations under section 304(a). EPA believes it is consistent with Congressional intent to rely in large part on existing criteria rather than engage in a time-consuming reevaluation of the underlying basis for water quality criteria. Accordingly, the Agency does not intend in this rulemaking to address the issues that have already been addressed by the Agency in response to previous comments. It is the Agency's belief that this approach will best achieve the purpose of moving forward in promulgating criteria for States not in compliance with section 303(c)(2)(B) so that environmental controls intended by Congress can be put into place to protect public health and welfare and enhance water quality.

It should be noted that the Agency is initiating a review of the basic guidelines for developing criteria and that comments received in this rulemaking may be of value in that effort as well. Future revisions to the criteria guidelines will be reviewed by the Agency's Science Advisory Board and submitted to the public for review and comment following the same process that was used in issuing the existing methodological guidelines. Subsequent revisions of criteria documents and the issuance of any new criteria documents will also be subject to public review.

2. Aquatic Life Criteria

Aquatic life criteria may be expressed in numeric or narrative forms. EPA's guidelines describe an objective, internally consistent and appropriate way of deriving chemical-specific, numeric water quality criteria for the protection of the presence of, as well as the uses of, both fresh and marine water aquatic organisms.

An aquatic life criterion derived using EPA's section 304(a) method represents an estimate of the highest concentration of a pollutant in water that does not present a significant risk to aquatic organisms *per se* or to their use. EPA's guidelines are designed to derive criteria that protect aquatic communities by protecting most of the species and their uses most of the time, but not necessarily all of the species all of the time. Aquatic communities can tolerate some stress and occasional adverse effects on a few species so that total protection of all species all of the time is not necessary. EPA's guidelines attempt to provide a reasonable and adequate amount of protection with only a small possibility of substantial overprotection or underprotection. As discussed in detail below, there are several individual factors which may make the criteria somewhat overprotective or underprotective. Clearly, addressing them all is probably infeasible and, in any case, would make the criteria derivation process unduly resource intensive and time consuming. The approach EPA is using is believed to be as well balanced as possible, given the state of the science.

Numerical aquatic life criteria derived using EPA's most recent guidelines are expressed as short-term and long-term numbers, rather than one number, in order that the criteria more accurately reflect toxicological and practical realities. The combination of a criteria maximum concentration (CMC), a one-hour average acute limit, and a criteria continuous concentration (CCC), a four-day average concentration chronic limit, provide protection of aquatic life and its uses from acute and chronic toxicity to animals and plants, and from bioconcentration by aquatic organisms, without being as restrictive as a one-number criterion would have to be.

The two number criteria are intended to identify average pollutant concentrations which will produce water quality generally suited to maintenance of aquatic life and their uses while restricting the duration of excursions over the average so that total exposures will not cause unacceptable adverse effects. Merely specifying an average value over a time period is insufficient unless the time period is short, because excursions higher than the average can kill or cause substantial damage in short periods.

EPA's guidelines were developed on the assumption that the results of laboratory tests are generally useful for predicting what will happen in field situations. Certain ambient waters may have some capacity to bind pollutants and make them less bioavailable. The site-specific criteria process provides a means of addressing this effect (i.e., by allowing development and use of a "water effect ratio" that quantifies the difference in toxicity of a pollutant in site water versus the toxicity of the pollutant in the laboratory water used to develop the section 304(a) criteria recommendation). However, in the absence of such an approach, the criteria may be somewhat overprotective in some situations.

A minimum data set of eight specified families is required for criteria development (details are given in the methodology cited above). The eight specific families are intended to be representative of a wide spectrum of aquatic life. For this reason it is not necessary that the specific organisms tested be actually present in the water body. States may develop site-specific criteria using native species, provided that the broad spectrum represented by the eight families is maintained. All aquatic organisms and their common uses are meant to be considered, but not necessarily protected, if relevant data are available.

EPA's application of guidelines to develop the criteria matrix in the proposed rule is judged by the Agency to be applicable to all waters of the United States, and to all ecosystems. There are waters and ecosystems where site-specific criteria could be developed, as discussed below, but it is up to States to identify those waters and develop the appropriate site-specific criteria.

Fresh water and salt water (including both estuarine and marine waters) have different chemical compositions, and freshwater and saltwater species rarely inhabit the same water simultaneously. To provide additional accuracy, criteria developed recently are developed for fresh water and for salt water.

Assumptions which may make the criteria underprotective include the use of criteria on an individual basis, with no consideration of additive or synergistic effects, and the general lack of consideration of impacts on wildlife, due principally to a lack of data.

3. Criteria for Human Health

As with aquatic life, EPA's guidelines for human health criteria attempt to provide a reasonable and adequate amount of protection with only a small possibility of substantial overprotection or underprotection. EPA's section 304(a) criteria for human health are based on two types of biological endpoints:

(1) Carcinogenicity and (2) systemic toxicity (i.e., all other adverse effects other than cancer). Thus, there are two procedures for assessing these health effects: One for carcinogens and one for non-carcinogens.

EPA's guidelines assume that carcinogenicity is a "non-threshold phenomenon," that is, there are no "safe" or "no-effect levels" because even extremely small doses are assumed to cause a finite increase in the incidence of the response (i.e., cancer). Therefore, EPA's water quality criteria for carcinogens are presented as pollutant concentrations corresponding to increases in the risk of developing cancer.

For pollutants that do not manifest any apparent carcinogenic effects in animal studies (i.e., systemic toxicants), EPA assumes that the pollutant has a threshold below which no effects will be observed. This assumption is based on the premise that a physiological mechanism exists within living organisms to avoid or overcome the adverse effects of the pollutant below the threshold concentration.

The human health risks of a substance cannot be determined with any degree of confidence unless dose-response relationships are quantified. Therefore, a dose-response assessment is required before a criterion can be calculated. The dose-response assessment determines the quantitative relationships between the amount of exposure to a substance and the onset of toxic injury or disease. Data for determining dose-response relationships are typically derived from animal studies, or less frequently, from epidemiological studies in exposed populations.

The dose-response information needed for carcinogens is an estimate of the carcinogenic potency of the compound. Carcinogenic potency is defined here as a general term for a chemical's human cancer-causing potential. This term is often used loosely to refer to the more specific carcinogenic or cancer slope factor which is defined as an estimate of carcinogenic potency derived from animal studies or epidemiological data of human exposure. It is based on extrapolation from test exposures of high dose levels over relatively short periods of time to more realistic low dose levels over a lifetime exposure period by use of linear extrapolation models. The cancer slope factor, q1*, is EPA's estimate of carcinogenic potency and is intended to be a conservative upper bound estimate (e.g. 95% upper bound confidence limit).

For non-carcinogens, EPA uses the reference dose (RfD) as the dose response parameter in calculating the criteria. The RfD was formerly referred to as an "Acceptable Daily Intake" or ADI. The RfD is useful as a reference point for gauging the potential effects of other doses. Doses that are less than the RfD are not likely to be associated with any health risks, and are therefore less likely to be of regulatory concern. As the frequency of exposures exceeding the RfD increases and as the size of the excess increases, the probability increases that adverse effects may be observed in a human population. Nonetheless, a clear conclusion cannot be categorically drawn that all doses below the RfD are "acceptable" and that all doses in excess of the RfD are "unacceptable." In extrapolating non-carcinogen animal test data to humans to derive an RfD, EPA divides a no-observed-effect dose observed in animal studies by an "uncertainty factor" which is based on professional judgment of toxicologists and typically ranges from 10 to 10,000.

For section 304(a) criteria development, EPA typically considers only exposures to a pollutant that occur through the ingestion of waters and contaminated fish and shellfish. Thus the criteria are based on an assessment of risks related to the surface water exposure route only.

The assumed exposure pathways in calculating the criteria are the consumption of 2 liters per day at the criteria concentration and the consumption of 6.5 grams per day of fish/shellfish contaminated at a level equal to the criteria concentration but multiplied by a "bioconcentration factor." The use of fish consumption as an exposure factor requires the quantification of pollutant residues in the edible portions of the ingested species. Bioconcentration factors (BCFs) are used to relate pollutant residues in aquatic organisms to the pollutant concentration in ambient waters. BCFs are quantified by various procedures depending on the lipid solubility of the pollutant. For lipid soluble pollutants, the average BCF is calculated from the weighted average percent lipids in the edible portions of fish/shellfish, which is about 3%; or it is calculated from theoretical considerations using the octanol/water partition coefficient. For non-lipid soluble compounds, the BCF is determined empirically. The assumed water consumption is taken from the National Academy of Sciences publication "Drinking Water and Health" (1977). The 6.5 grams per day contaminated fish consumption value is equivalent to the average per-capita consumption rate of all (contaminated and non-contaminated) freshwater and estuarine fish for the U.S. population.

EPA also assumes in calculating water quality criteria that the exposed individual is an average adult with body weight of 70 kilograms. The issue of concern is dose per kilogram of body weight. EPA assumes 6.5 grams per day of contaminated fish consumption and 2 liters per day of contaminated drinking water consumption for a 70 kilogram person in calculating the criteria. Persons of smaller body weight are expected to ingest less contaminated fish and water, so the dose per kilogram of body weight is generally expected to be roughly comparable. There may be subpopulations within a State, such as subsistence fishermen, who as a result of greater exposure to a contaminant, are at greater risk than the hypothetical 70 kilogram person eating 6.5 grams per day of maximally contaminated fish and shellfish and drinking 2 liters per day of maximally contaminated drinking water. (EPA is in part addressing the potential that highly exposed subpopulations exist by selecting a relatively stringent cancer risk level (10^{-6}) for use in deriving State-wide criteria for carcinogens. Individuals that ingest ten times more of a pollutant than is assumed in derivation of the criteria will be protected to a 10^{-5} level, which EPA has historically considered to be adequately protective. There may, nevertheless, be circumstances where site-specific numeric criteria that are more stringent than the State-wide criteria are necessary to adequately protect highly exposed subpopulations. Although EPA intends in this initial promulgation to focus on promulgation of appropriate State-wide criteria that will reduce risks to all exposed individuals, including highly exposed subpopulations, site specific criteria may be developed subsequently by EPA or the States where warranted to provide necessary additional protection.)

For non-carcinogens RfDs are developed based on pollutant concentrations that cause threshold effects. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime.

Criteria are calculated for individual chemicals with no consideration of additive, synergistic or antagonistic effects in mixtures. If the conditions within a State differ from the assumptions EPA used, the States have the option to perform the analyses for their conditions.

EPA has a process to develop a scientific consensus on oral reference doses and carcinogenic slope factors. Reference doses and slope factors are validated by two Agency work groups (i.e., one work group for each) which are composed of senior Agency scientists from all of the program offices and the Office of Research and Development. These work groups develop a consensus of Agency opinion for Rfds and slope factors which are then used throughout the Agency for consistent regulation and guidance development. EPA maintains an electronic data base which contains the official Agency consensus for Rfd's and slope factors which is known as the Integrated Risk Information System (IRIS). It is available for use through EPA's electronic mail system, and also available through the Public Health Network of the Public Health Foundation, and on the National Institutes of Health National Library of Medicine's TOXNET system. For the criteria included in today's proposal, EPA used the criteria recommendation from the appropriate section 304(a) criteria document. (The availability of EPA's criteria documents has been announced in various **Federal Register** notices. These documents are also placed in the record for today's proposed rule.) However, if the Agency has changed in IRIS any parameters used in criteria derivation since issuance of the criteria guidance document, EPA recalculated the criteria recommendation with the latest information. (This information is included in the record.) Thus, there may be differences between the original recommendation, and those in today's proposal, but today's proposal presents the Agency's most current section 304(a) criteria recommendation. The recalculated human health numbers are denoted by an "a" in the criteria matrix in subsection 131.36(b) of today's proposed rule.

In order to base its regulatory decisions on the best available science, EPA continuously updates its assessment of the risk from exposure to contaminants. On September 11, 1991, EPA's Office of Research and Development (ORD) began reassessing the scientific models and exposure scenarios used to predict the risks of biological effects from exposure to low levels of dioxin. This reassessment has the potential to alter the risk assessment for dioxin and accordingly the Agency's regulatory decisions related to dioxin. At this time, EPA is unable to say with any certainty what the degree or directions of any changes in risk estimates might be. This rulemaking includes a proposed Agency action with regard to dioxin that may be affected by the reassessment. The Agency will be carefully monitoring ORD's efforts in order to ensure that appropriate actions are taken during the course of this rulemaking to reflect any necessary changes resulting from the reassessment. If a final Agency action on this rulemaking occurs prior to completion of ORD's work, the Agency will consider revisiting that decision.

4. Section 304(a) Human Health Criteria Excluded

Today's proposal does not contain certain of the Section 304(a) criteria for priority toxic pollutants because those criteria were not based on toxicity. The basis for these particular criteria are organoleptic effects (e.g., taste and odor) which would make water and edible aquatic life unpalatable but not toxic. Because the basis for this proposed rulemaking is to protect the public health and aquatic life from toxicity consistent with the language in section 303(c)(2)(B), EPA is proposing criteria only for those priority toxic pollutants whose criteria recommendations are based on toxicity. The Section 304(a) human health criteria based on organoleptic effects for copper, zinc, 2.4-dimethylphenol, and 3-methyl-4-chlorophenol are excluded for this reason.

5. Cancer Risk Level Proposed

EPA's Section 304(a) criteria guidance documents for priority toxic pollutants which are based on carcinogenicity present concentrations for upper bound risk levels of 1 excess cancer per 100,000 people (10^{-5}), per 1,000,000 people (10^{-6}), and per 10,000,000 people (10^{-7}). However, the criteria documents do not recommend a particular risk factor as EPA policy.

In the April, 1990, **Federal Register** notice of preliminary assessment of State compliance, EPA announced the intention to include in the proposed rulemaking an incremental cancer risk level of one in a million (10^{-6}) for all priority toxic pollutants regulated as carcinogens. That cancer risk level is reflected in this proposed rule. The reasons supporting this decision are discussed below. However, EPA's Office of Water's guidance to the States has consistently reflected the Agency's policy of accepting cancer risk policies from the States in the range of 10^{-6} to 10^{-4}. EPA reviews individual State policies as part of its water quality standards oversight function and determines if States have appropriately consulted its citizens and applied good science in adopting water quality criteria.

First, EPA's human health criteria have been developed based on a number of exposure assumptions. Many of these assumptions are based on the exposure for an average individual. For example, EPA's criteria assumes exposure of a 70 kilogram (154 pound) adult who consumes 2 liters (2.1 quarts) of water per day and 6.5 grams of fish per day (less than 7 ounces per month). These assumptions are based on approximate national averages, but considerably understate the exposure that would occur for certain segments of the population that have high fish consumption or depend on fish consumption for subsistence. Similarly, it would overstate the exposure of those who consume less fish than the National average amount. Therefore, although EPA would accept a lower State adopted risk level, in the range of 10^{-4} to 10^{-6}, EPA has chosen a 10^{-6} risk level to protect the average exposed individual at a conservative incremental lifetime cancer risk.

A second strong reason is that a 10^{-6} risk level is consistent with what most States have selected, or are expected to select, as their risk level. A recent EPA status report on State compliance with section 303(c)(2)(B) found that 36 of the 57 States and Territories will select 10^{-6} as their risk level (12 States have selected or are expected to select 10^{-5} and 9 of the remaining States are undecided). EPA's proposal is therefore consistent with the majority of the States, does not contradict those States choosing a 10^{-6} risk level and does not preclude States from eventually choosing a risk level below 10^{-6}.

Third, by selecting a risk level of 10^{-6} for the average exposed individual, some assurance is provided against the possibility that current section 304(a) criteria are not sufficiently stringent. The various parameters used in deriving the Section 304(a) criteria (e.g. cancer potency slopes, reference doses, bioaccumulation factors, etc.) are based on the state of present science. With additional research and experience, EPA may find that one or more of these factors understates the actual public risk. In addition, in many cases, EPA's criteria are based upon a single health effect. As the science evolves and available information expands, there is the potential that EPA will determine that other endpoints or effects are more sensitive than those currently considered. This risk level also reflects a recognition that certain factors are not considered in the current criteria methodology.

A proposed 10^{-6} risk level does not preclude State alternatives. If a State decides that a different risk level is more appropriate, it may avoid Federal promulgation by completing its standards adoption process in compliance with section 303(c)(2)(B). As discussed earlier, this would be the case both in advance of or subsequent to final promulgation.

6. Applying EPA's Nationally Derived Criteria to State Waters

To assist States in modifying EPA's water quality criteria, the Agency has provided guidance on developing site specific criteria for aquatic life and human health (see Water Quality Standards Handbook and the Guidelines for Deriving Numerical National Water Quality Criteria). This guidance can be used by the appropriate regulatory authority to develop alternative criteria Where such criteria are more stringent than the criteria finally developed pursuant to this proposed rulemaking, section 510 of the Clean Water Act (33 U.S.C. 1370) provides authority for their implementation and enforcement in lieu of today's proposed criteria.

EPA's experience with such site-specific criteria has verified that the national criteria are generally protective and appropriate for direct use by the States.

G. Description of the Proposed Rule

EPA's final rule would establish a new § 131.36 in 40 CFR part 131 entitled. "Toxics Criteria for Those States Not Fully Complying With Clean Water Act section 303(c)(2)(B)."

1. Scope

Subsection (a), entitled "Scope", clarifies that this section is not a general promulgation of the section 304(a) criteria for priority toxic pollutants but is restricted to specific pollutants in specific States.

2. EPA Criteria for Priority Toxic Pollutants

Subsection (b) presents a matrix of the applicable EPA criteria for priority toxic pollutants. Section 303(c)(2)(B) of the Act addresses only pollutants listed as "toxic" pursuant to section 307(a) of the Act. As discussed earlier in this preamble, the section 307(a) list of toxics contains 65 compounds and families of compounds, which potentially include thousands of specific compounds. The Agency uses the list of 126 "priority toxic pollutants" for administrative purposes (see 40 CFR part 423, appendix A). Reference in this proposed rule to priority toxic pollutants, toxic pollutants, or toxics refers to the 126 priority toxic pollutants.

However, EPA has not developed both aquatic life and human health section 304(a) criteria for all of the 126 priority toxic pollutants. The matrix in paragraph (b) contains human health criteria in Column D for 102 priority toxic pollutants which are divided into criteria (Column I) for water consumption (i.e., 2 liters per day) and aquatic life consumption (i.e., 6.5 grams per day of aquatic organisms), and Column II for aquatic life consumption only. The term aquatic life includes fish and shellfish such as shrimp, clams, oysters and mussels. The total number of priority toxic pollutants with criteria proposed today differs from the total number of priority toxic pollutants with section 304(a) criteria because EPA has developed and is proposing chromium criteria for two valence states. Thus, although chromium is a single priority toxic pollutant, there are two criteria for chromium. See numbers 5a and 5b in proposed § 131.36(b).

The matrix contains aquatic life criteria for 30 priority pollutants. These are divided into freshwater criteria (Column B) and saltwater criteria (Column C). These columns are further divided into acute and chronic criteria. The aquatic life criteria are considered by EPA to be protective when applied under the conditions described in the section 304(a) criteria documents and in the "Technical Support Document for Water Quality-based Toxics Control." For example, waterbody uses should be protected if the criteria are not exceeded, on average, once every three year period. It should be noted that the criteria maximum concentrations (the acute criteria) are one-hour average concentrations and that the criteria continuous concentrations (the chronic criteria) are four-day averages. It should also be noted that for certain of the metals, the actual criteria are equations which are included as footnotes to the matrix. The toxicity of these metals are water hardness dependent. The values shown in the table are based on a hardness expressed as calcium carbonate of 100 mg/l. Finally, the criterion for pentachlorophenol is pH dependent. The equation is the actual criterion and is included as a footnote. The value shown in the matrix is for a pH of 7.8 units.

Several of the freshwater aquatic life criteria are incorporated into the matrix in the format used in the 1980 criteria methodology. This distinction is noted in footnote (g) to the table. EPA has not updated these criteria for various reasons. Footnote (g) describes an approximate method to translate these 1980 criteria to the equivalent criteria by the 1985 methodology. EPA could make this translation in a final rule and solicits public comment on which approach is better.

The matrix also includes toxicity-based human health criteria for copper, 2-chloroethylvinyl ether, 1,2-trans-dichloroethylene, 2-chlorophenol, acenaphthene, butylbenzyl phthalate, and N-nitrosodi-n-propylamine. The criteria for these substances are shown in parentheses and are *not* being proposed today but are included for informational purposes and as notice for consideration in all future State triennial reviews. Although sufficient information on these compounds was previously unavailable to calculate a section 304(a) criterion based on carcinogenicity or systemic toxicity, Agency-approved information in IRIS now allow calculation of these criteria using the EPA criteria guidelines. EPA has assembled another matrix which provides all of the factors used to calculate the proposed human health criteria. This supplementary matrix is included in the record for this proposal.

3. Applicability

Section 131.36(d) establishes the applicability of the criteria proposed for each included State. It provides that the criteria promulgated for each State supersede and/or complement any State criteria for that toxic pollutant. EPA believes it has not proposed to supersede any State criteria for priority toxic pollutants unless the State-adopted criteria are disapproved or otherwise insufficient. The approach followed by the Agency in preparing proposed § 131.36(d) is described in section E.2, and further rationale is provided in section E.3 of this preamble. EPA invites comment on the accuracy of the Agency's decisions to include or exclude particular priority toxic pollutant criteria.

EPA's principal purpose today is to propose the toxics criteria necessary to comply with section 303(c)(2)(B). However, in order for such criteria to achieve their intended purpose the implementation scheme must be such that the final results protect the public health and welfare. In section F of this preamble a discussion focused on the factors in EPA's assessment of criteria for carcinogens. For example, fish consumption rates, bioaccumulation factors, and cancer potency slopes were discussed. When any one of these factors is changed, the others must also be evaluated so that, on balance, resulting criteria are adequately protective.

Once an appropriate criterion is selected for either aquatic life or human health protection, then appropriate conditions for calculating water quality-based effluent limits for that chemical must be established in order to maintain the intended stringency and achieve the necessary toxics control. EPA has included in this proposal appropriate implementation factors necessary to maintain the level of protection intended. These proposals are included in subsection (c).

For example, most States have low flow values for streams and rivers which establish flow rates below which numeric criteria may be exceeded. These low flow values became design flows for sizing treatment plants and developing water quality-based effluent limits. Historically, these so-called "design" flows were selected for the purposes of waste load allocation analyses which focused on instream dissolved oxygen concentrations and protection of aquatic life. With the publication of the 1985 Technical Support Document for Water Quality Based Toxics Control (TSD), EPA introduced hydrologically and biologically based analyses for the protection of aquatic life and human health.[1] EPA recommended either of two methods for calculating acceptable low flows, the traditional hydrologic method developed by the U.S. Geological Survey and a biological based method developed by EPA. The

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[1] These concepts have been expanded subsequently in guidance entitled "Technical Guidance Manual for Performing Wasteload Allocations, Book 6, Design Conditions," USEPA, Office of Water Regulations and Standards, Washington, DC (1986). These new developments are included in appendix D of the revised TSD. The discussion here is greatly simplified and is provided to support EPA's decision to propose baseline application values for instream flows and thereby maintain the intended stringency of the criteria for priority toxic pollutants.

results of either of these two methods may be used.

Some States have adopted specific low flow requirements for streams and rivers to protect designated uses against the effects of toxics. Generally these have followed the guidance in the TSD. However, EPA believes it is essential to include proposed design flows in today's proposed rule so that, where States have not yet adopted such design flows, the criteria proposed today would be implemented appropriately. Clearly, if the proposed criteria were implemented using inadequate design flows, the resulting toxics controls would not be fully effective, because the resulting ambient concentrations would exceed EPA's recommended levels.

In the case of aquatic life, more frequent violations than the once in 3 years assumed exceedences would result in diminished vitality of stream ecosystems characteristics by the loss of desired species such as sport fish. The low flow values proposed are:

Aquatic Life:	
Acute criteria (CMC).	1 Q 10 or 1 B 3.
Chronic criteria (CCC).	7 Q 10 or 4 B 3
Human Health:	
Non-carcinogens	30 Q 5.
Carcinogens	harmonic mean flow.

Where:

1 Q 10 is the lowest one day flow with an average recurrence frequency of once in 10 years determined hydrologically;

1 B 3 is biologically based and indicates an allowable exceedence of once every 3 years. It is determined by EPA's computerized method (DFLOW model);

7 Q 10 is the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years determined hydrologically;

4 B 3 is biologically based and indicates an allowable exceedence for 4 consecutive days once every 3 years. It is determined by EPA's computerized method (DFLOW model);

30 Q 5 is the lowest average 30 consecutive day low flow with an average recurrence frequency of once in 5 years determined hydrologically; and

The harmonic mean flow is a long term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows.

EPA is proposing the harmonic mean flow to be applied with human health criteria. The concept of a harmonic mean is a standard statistical data analysis technique. EPA's model for human health effects assumes that such effects occur because of a long-term exposure to low concentration of a toxic pollutant. For example, two liters of water per day for seventy years. To estimate the concentrations of the toxic pollutant in those two liters per day by withdrawal from streams with a high daily variation in flow, EPA believes the harmonic mean flow is the correct statistic to use in computing such design flows rather than other averaging techniques.[2]

All waters, whether or not suitable for such hydrologic calculations but included in this proposed rule (including lakes, estuaries, and marine waters), must contain the criteria proposed today. Such attainment must occur at the end of the discharge pipe, unless the State has an EPA approved mixing zone regulation. If the State has an EPA approved mixing zone regulation, then the criteria would apply at the locations stated in that regulation. For example, the chronic criteria (CCC) must apply at the geographically defined boundary of the mixing zone. Discussion and guidance of these factors are included in the revised TSD in chapter 4.

EPA is aware that the criteria proposed today for some of the priority toxic pollutants are at concentrations less than EPA's current analytical detection limits. Detection limits have never been an acceptable basis for setting standards since they are not related to actual environmental impacts. The environmental impact of a pollutant is based on a scientific determination, not an arbitrary measuring technique which is subject to change. Setting the criteria at levels that reflect adequate protection tends to be a forcing mechanism to improve analytical detection methods. As the methods improve, limits closer to the actual criteria necessary to protect aquatic life and human health are measurable. The Agency does not believe it is appropriate to promulgate insufficiently protective criteria (e.g., criteria equal to the current analytical detection limits).

EPA does believe, however, that the use of analytical detection limits are appropriate for determining compliance with NPDES permit limits. This historical view of the role of detection limits was recently articulated in guidance for translating dioxin criteria into NPDES permit limits which is the principal method used for water quality standards enforcement.[3] This guidance presents a model for addressing toxic pollutants which have criteria recommendations less than current detection limits. This guidance is equally applicable to other priority toxic pollutants with criteria recommendations less than current detection limits. The guidance explains that detection limits may be used for purposes of determining compliance with permit limits, but not for purposes of establishing water quality criteria or permit limits. Because under the Clean Water Act analytical detection limits are appropriately used only in connection with NPDES permit limit compliance determinations, EPA has not considered analytical detection limits in deriving the criteria proposed today.

EPA has added provisions in paragraph (c)(3) to determine when fresh water or saltwater aquatic life criteria apply. The structure of the paragraph is to establish presumptively applicable rules and to allow for site-specific determinations where the rules are not consistent with actual field conditions. Because a distinct separation generally does not exist between fresh water and marine water aquatic communities, EPA is proposing the following: (1) The fresh water criteria apply at salinities of 1 part per thousand and below; (2) marine water criteria apply at 10 parts per thousand and above; and (3) at salinities between 1 and 10 parts per thousand the more stringent of the two apply unless EPA approves another site specific criterion for the pollutant. This proposed assignment of criteria for fresh, brackish and marine waters was developed in consultation with EPA's research laboratories at Duluth, Minnesota and Narragansett, Rhode Island. The Agency believes such an approach is consistent with field experience.

In paragraph (c)(4)(i) EPA has included a limitation on the amount of hardness that EPA can allow to antagonize the toxicity of certain metals (see footnote (e) in the criteria matrix in paragraph (b) of the rule). The data base used for the Section 304(a) criteria documents for metals do not include data supporting the extrapolation of the hardness effects on metal toxicity beyond a range of hardness of 25 mg/l to 400 mg/l (expressed as calcium carbonate). Thus, the aquatic life values for the CNC (acute) and CCC (chronic) criteria for these metals in waters with a hardness less than 25 mg/l, must nevertheless use 25 mg/l when calculating the criteria; and in waters with a hardness greater than 400 mg/l, must nevertheless use 400 mg/l when calculating the criteria.

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[2] For a description of harmonic means see "Design Stream Flows Based on Harmonic Means," Lewis A. Rossman, J. of Hydraulics Engineering, Vol. 116, No. 7, July, 1990. This article is contained in the record for this proposal.

[3] Strategy for the Regulation of Discharges of PHDDs and PHDFs from Pulp and Paper Mills to Waters of the United States," memorandum from the Assistant Administrator for Water to the Regional Water Management Division Directors and NPDES State Directors, May 21, 1990.

Subsection (d) lists the States for which rules are being proposed. For each identified State, the water uses impacted (and in some cases the waters covered) and the criteria proposed are identified.

H. Specific Issues for Public Comment

As is the Agency's custom, EPA would like to request that particular public review be directed to the issues and alternatives presented in this section. Although the issues presented below are particularly notable and worthy of comment, EPA encourages public comment on any aspect of this proposed rule.

1. In section D of this preamble, EPA has presented a discussion of how EPA determines State compliance with section 303(c)(2)(9). The process described has been the Agency's general practice since the beginning of the water quality standards program, although the requirements specific to toxics criteria have evolved over the years. Briefly stated, EPA's ten Regional offices review the State-adopted standards to ascertain compliance with the Clean Water Act using the information developed by the State and other relevant and available data and information.

For compliance with section 303(c)(2)(B), EPA's focus in many cases was on the process the State used to assemble the criteria for those priority toxic pollutants which could reasonably be expected to interfere with the State's designated uses. For example, EPA's review of individual State water quality standards had to balance a need for national consistency with the need to implement the CWA scheme that provides for State primacy and State-specific approaches. If EPA had information on a toxic pollutant sufficient to satisfy the test that the pollutant can reasonably be expected to interfere with designated uses, and the State did not adopt sufficient, scientifically defensible criteria for that pollutant, EPA disapproved the State action as being inconsistent with Section 303(c)(2)(B). Alternative approaches could have had either a narrower focus on fewer priority toxic pollutants (for example, relying only on the results of the section 304(l) short list process) or might have been broader, (for example, requiring most States to adopt criteria for the complete list of priority toxic pollutants addressed in EPA section 304(a) criteria recommendations). EPA solicits comment on whether the Agency's traditional review process should have been changed.

2. EPA's approach and rationale for deciding which criteria to propose for a State is discussed in section E of this Preamble. Briefly stated, EPA either: (1) Proposed to promulgate Federal criteria for all priority toxic pollutants not acceptably addressed by approved State criteria (this approach is used for most States), or (2) proposed to promulgate Federal criteria only for specific priority pollutants for which State criteria are lacking or insufficient (this approach is used for only a few States). EPA could have used other approaches and solicits public comment. For example, EPA could have relied totally on the State's own determination pursuant to section 304(l) and 305(b), or entirely on an Option 1 approach of promulgating all Federal criteria for all State waters.

3. This proposed rulemaking includes proposed minimum implementation factors for the criteria, such as flow conditions. As proposed, these factors are dependent on existing State rules but subject to base values which are those used in developing the criteria. EPA's revised TSD explains more fully the details of these base values. EPA could rely entirely on existing State rules or establish the proposed Federal rules.

4. The conditions under which States will be removed from the rule, either before or after final promulgation, are described in section E.4 of this preamble. EPA could make the conditions for removing the applicability of the rule to a State more or less stringent. A difficult aspect of this issue is a definition of what the State must adopt for EPA to withdraw the applicability of its rule entirely. As currently stated, EPA's policy is that if the State's standards are judged to meet the requirements of the Act and thereby provide adequate environmental protection, EPA will withdraw the applicability of the Federal Rule as to that State. In the context of this proposal, the State would have to demonstrate that the criteria it adopted meet the statutory test of protecting the public health and would protect designated uses. State compliance could be by any one or a combination of the 3 options described in EPA's guidance. Once such a showing were made EPA would propose to withdraw the applicability of its rule entirely. However, if a State fails to make such a demonstration for all pollutants, partial withdrawals for certain pollutants could occur, leaving applicable parts of the Federal rule.

5. EPA must also decide whether it should pick a uniform cancer risk level of, for example, 10^{-6}, for all States included in a final rule, or whether different risk levels for different States are appropriate. EPA today proposes the human health criteria at a cancer risk level of 10^{-6} because such a risk level is conservative for the general population and in the generally applied risk range. However, as noted in section F.5., EPA has approved human health risk levels of 10^{-5} in 10 States, and for some criteria and uses risk levels of 10^{-4}. EPA's review of the explanations provided by the States supporting State-adopted risk levels of less than 10^{-5} focuses on public participation and the supportability of the risk factors included in the State's analysis.

While today's proposed action is predicated on a 10^{-6} risk level for carcinogens, another option that the public should consider in responding to this rule is the application of the proposed criteria at a 10^{-5} risk level. EPA's rationale for proposing at a 10^{-6} risk level was articulated earlier in the preamble. However, there are several arguments to support a less protective 10^{-5}level. The model used to calculate the criteria for carcinogens is a conservative one and has a very low probability of underestimating the potency of a carcinogen. As a result, a higher level of accepted risk as the endpoint for criteria calculations may be reasonable. For "Class C" carcinogens, i.e., those for which the data demonstrating oncogenicity in animal studies are most limited, a 10^{-5} risk level is closer to the criteria values calculated as Rfds (non-cancer endpoints of toxicity) for these chemicals. Use of RfDs reduces the likelihood that EPA is over-regulating chemicals of less definitive cancer potency. A 10^{-5} risk is within the range of accepted risks for other major EPA rulemakings which aim to protect the general public, such as national drinking water standards.

Similarly, EPA must decide what a State must adopt in the way of a risk level for EPA to withdraw a final rule. The question to be addressed is whether EPA can accept less stringent risk levels (applied statewide; by individual chemicals, or by geographical sub-area) than contained in EPA's final rule if such less stringent risk levels were adopted following State administrative procedures and adequately supported by the administrative record.

6. Today's proposed rulemaking includes an Agency proposal to establish criteria for only those EPA priority toxic pollutant criteria which are based on toxic effects. The Agency could include other section 304(a) priority toxic pollutant criteria

recommendations which are based on organoleptic (i.e., taste and odor) effects. The logic would be that the congressional reference to "toxic pollutants" in section 303(c)(2)(B) was the generic list of 126 priority toxic pollutants and EPA should include all such criteria developed for these pollutants rather than just those based on toxicity. Organoleptic effects cause taste and odor problems in drinking water which may increase treatment costs or the selection by the public of alternative but less protective sources of drinking water; and may cause tainting or off flavors in fish flesh and other edible aquatic life reducing their marketability, thus diminishing the recreational and resource value of the water. EPA believes that because the Section 303(c)(2)(B) focuses on toxicity of the priority toxic pollutants, EPA's proposal should likewise focus on toxicity.

7. EPA also invites public comment on the merits of promulgating a translator procedure (that could support derivation of new or revised chemical-specific criteria for those priority toxic pollutants for which EPA has not issued section 304(a) criteria guidance) for States in this rule to enhance State and EPA implementation of section 303 (c)(2)(B). Such a procedure would supplement the specific numeric criteria included in this proposal. The rationale for, and specifics of, such an approach are described below.

As discussed in previous sections of this preamble, CWA section 303(c)(2)(B) represents a clear congressional mandate for State adoption of chemical-specific numeric criteria for priority toxic pollutants where EPA has issued section 304(a) criteria guidance. However, where no such criteria exist, section 303(c)(2)(B) went on to direct States that, " * * * Where such numerical criteria are not available, whenever a State reviews water quality standards * * * or revises or adopts new standards * * *, such State shall adopt criteria based on biological monitoring or assessment methods * * *.

EPA's December 1988 national guidance provided States with three options for satisfying the chemical-specific criteria requirements. Option 3 of the guidance allows States to adopt and apply translator procedures. As described in section B-3 of this preamble, such translator procedures are defined as the methods, equations, and protocols by which a State calculates derived chemical-specific numeric criteria for priority toxic pollutants to ensure that the State's narrative toxics criterion is fully satisfied.

There are several alternative approaches for establishing a translator procedure. All approaches would utilize EPA's criteria guidelines (i.e., for aquatic life and human health as described in section F.1. of this preamble) as the basis for deriving chemical-specific criteria. They could also require EPA to periodically issue an updated list of derived numeric criteria and notice the availability of the list in the **Federal Register**.

One alternative would be to promulgate a mechanism for State usage only for the pollutants where EPA has not issued a section 304 (a) criteria guidance document.

Another alternative would be to allow criteria revisions in specific situations where EPA determines that a revised criterion is necessary. For example, if EPA issued a final revised estimate of the cancer potency slope of a priority toxic pollutant (i.e., by adding it to IRIS), such cancer slopes would be available for use in deriving new human health criteria for that pollutant following the translator procedure. Another example would be situations where additional data on the toxicity of a pollutant to aquatic life becomes available such that the minimum database requirements in the EPA criteria guidelines are satisfied. In such situations, the data could be applied to the translator procedure to derive new or revised aquatic life criteria more rapidly than the current method of proposing for comment and then publishing a final section 304(a) recommendation for subsequent consideration by States. This alternative would apply to criteria for both aquatic life and human health protection and could apply to pollutants for which a section 304(a) criteria recommendation exists or to those pollutants where no such recommendation exists.

A third approach would limit the applicability of the translator procedure to the priority toxic pollutants for which numeric criteria are contained in today's proposed rulemaking. Under this alternative, criteria could not be derived for pollutants without a section 304(a) criteria recommendation using the translator procedure, even where: (1) Formal Agency estimates of the parameters necessary to support derivation are issued, or (2) the data necessary to satisfy the minimum database requirements become available.

A final alternative providing only limited flexibility would be to limit use of the translator procedure to human health criteria where the Agency issues a final revised risk assessment for the parameter in IRIS. Such IRIS estimates are subject to extensive intra-Agency review. This alternative would limit revisions to situations where EPA makes a formal determination that a revised human health risk assessment is appropriate.

The Agency invites public comment on the environmental, programmatic and legal aspects of including a promulgation of a criteria translator mechanism for each State in the final issuance of this rulemaking. Comment is also invited on the scope and details of such an approach as described above.

8. EPA solicits comment on the section 304(a) assessment methodology (cancer and non-cancer) used to derive human health criteria for section 307(a) priority toxic pollutants. This methodology is discussed in section F of the Preamble but is derived in the criteria methodology published in the **Federal Register** on November 26, 1980 (45 FR 79347). For example, EPA has included proposed criteria for 3 PAHs (acenaphthylene, benzo(ghi)perylene and phenanthrene). The included criteria treat these PAHs as carcinogens and are based on data for benzo(a)pyrene. The section 304(a) criteria methodology does not distinguish between classes of carcinogens and allows the use of closely related chemicals of similar structure to carry the same criteria recommendation. This methodology is basic to the development of the human health criteria proposed today.

I. Executive Order 12291

Executive Order 12291 requires EPA and other agencies to perform regulatory impact analyses for major regulations. Major regulations are those that impose an annual cost to the economy of $100 million or more, or meet other criteria. This is a major regulation, however, a regulatory impact analyses has been waived by the Office of Management and Budget for this proposal for the reasons discussed below.

This rulemaking establishes a legal minimum standard where States have failed to comply with the statutory mandate to adopt numeric criteria for toxic pollutants. The impacts to dischargers are no different than what would occur if States had acted to adopt their own standards. There will be a cost to dischargers for complying with these proposed new standards as the standards are translated into specific NPDES permit limits for individual dischargers. However, for reasons discussed in more detail below, a meaningful cost estimate is difficult to develop. The increased costs incurred will depend upon the type and amount of pollutants discharged and the extent to which additional treatment needs to be installed beyond that which is required to meet the generally applicable technology-based limit regulations. As discussed earlier in the Preamble, the control of toxic pollutants is expected to provide societal benefits by reducing risk to human health and to reduce ecological impacts on aquatic life.

The general impacts on point source dischargers, publicly owned treatment works (POTWs) and nonpoint sources may be described. By establishing new goals for a waterbody, the addition of criteria for toxic pollutants into State water quality standards will affect the wasteload allocations developed for each waterbody segment to the extent the pollutant is actually discharged into the stream. If the pollutant is not present in the wastestream, the addition of criteria has no impact. Revised wasteload allocations may result in adjustments to individual NPDES permit limits for point source dischargers which could result in increased incremental treatment costs required to meet the revised water quality standards. These costs will vary depending on the types of treatment involved, the number and kind of pollutant(s) being treated, and the controls necessary to meet the technologically based effluent limits for a given industry.

Compliance costs for indirect industrial dischargers will be reflected in increased incremental costs for POTWs assuming that industrial sources are the primary source of toxics discharged by POTWs and that the incremental treatment costs incurred by POTWs will be passed along to their industrial dischargers. Possible areas where the addition of criteria for toxic pollutants into State standards may have a cost impact include: (1) POTW expansion, (2) operational changes, and (3) increased operator training costs.

Increased costs may also be incurred by nonpoint sources of toxic pollutants to the extent that best management practices need to be modified to reflect the revised standards. Although there is no comparable Federal permit program for nonpoint sources as there is to control point source discharges, there are existing State regulatory programs to control nonpoint sources.

Monitoring programs to generate information on the existing quality of water and the kinds and amount of pollutants being discharged are likely to be affected by this proposed rulemaking. However, the addition of criteria for toxic pollutants into State standards does not require the State to engage in a program to monitor for all such pollutants unless there is some reasonable expectation that the pollutants are manufactured or actually used in the State with the likelihood that they will be discharged into surface waters.

While recognizing that the application of criteria for toxic pollutants will result in increased treatment costs and that such costs are appropriately considered in several areas of the standards to permits process, it is important to consider the difficulties and the large potential uncertainties involved in developing meaningful cost estimates for purposes of this proposed rulemaking. The development of compliance cost estimates would require numerous assumptions about pollutant loadings, impacts of technology-based regulations on loadings, combinations of pollutants handled by a given treatment approach, the costs of each treatment train and the variables for each pollutant in each waterbody in each State. There are many sources of uncertainty in making these assumptions, and the resulting estimates could contain such significant estimation errors that the figures would have questionable value.

This proposed rule, including the above determination, has been reviewed by the Office of Management and Budget. Any written comments from OMB to EPA and any EPA response to those comments are included in the public record and are available for inspection.

J. Regulatory Flexibility Act

The Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*, Pub. L. 96–354) requires EPA to assess whether its regulations create a disproportionate effect on small entities. According to the provisions of the Act, EPA must prepare an initial regulatory flexibility analysis for all proposed regulations that have a significant impact on a substantial number of small entities. There will be a cost to dischargers for complying with these standards as they are translated into permit limits for individual dischargers. However, for the reasons discussed in the previous section, a meaningful estimate of the total cost or impact on small entities cannot be meaningfully computed.

This proposed regulation fills a regulatory void left by States not fully complying with the statute; thus, the impact on small entities is not different than what would have occurred if States had acted to adopt standards. In addition, the water quality standards regulation provides several means (such as adjusting designated uses, setting site-specific criteria, or granting variances) to consider costs and adjust standards to account for the impacts on dischargers.

K. Paperwork Reduction Act

The information collection requirements associated with this proposed rule have been submitted for approval to the Office of Management and Budget (OMB) under the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.* An Information Collection Request (ICR) document has been prepared by EPA (ICR No. 0988.04) and a copy may be obtained from Sandy Farmer, Information Policy Branch; EPA; 401 M St., SW. (PM-223Y); Washington, DC 20460 or by calling (202) 382–2740.

Public reporting burden for this collection of information is estimated to average 745 hours per respondent, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information.

Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Chief, Information Policy Branch, PM-223Y, U.S. EPA, 401 M St., SW., Washington, DC 20460; and to the Office of Information and Regulatory Affairs; Office of Management and Budget, Washington, DC 20503, marked "Attention: Desk Officer for EPA." The final rule will respond to any OMB or public comments on the information collection requirements contained in this proposal.

List of Subjects

Water quality standards, Toxic pollutants.

Dated: November 6, 1991.

William K. Reilly,

Administrator.

For the reasons set out in the preamble, part 131 of title 40 of the Code of Federal Regulations is proposed to be amended as follows:

PART 131—WATER QUALITY STANDARDS

1. The authority citation for part 131 continues to read as follows:

Authority: Clean Water Act, Pub. L. 92-500, as amended; 33 U.S.C. 1251 *et seq.*

2. Section 131.36 is added to subpart D to read as follows:

§ 131.36 Toxics criteria for those states not complying with Clean Water Act section 303(c)(2)(B)

(a) *Scope.* This section is not a general promulgation of the section 304(a) criteria for priority toxic pollutants but is restricted to specific pollutants in specific States.

(b) *EPA's Section 304(a) Criteria for Priority Toxic Pollutants*

A		B		C		D	
		Freshwater		Saltwater		Human health (10⁻⁶ risk for carcinogens)	
						For consumption of:	
(#) Compound	CAS No.	Criterion maximum concentration d (µg/L) B1	Criterion continuous concentration d (µg/L) B2	Criterion maximum concentration d (µg/L) C1	Criterion continuous concentration d (µg/L) C2	Water and organisms (µg/L) D1	Organisms only (µg/L) D2
1 Antimony	7440360					14 a	4300 a
2 Arsenic	7440382	360	190	69	36	0.018 bc	0.14 bc
3 Beryllium	7440417					0.0077 ac	0.13 ac
4 Cadmium	7440439	3.9 e	1.1 e	43	9.3	16	170 aj
5a Chromium (III)	16065831	1700 e	210 e			33000 a	670000 a
b Chromium (VI)	18540299	16	11	1100	50	170 a	3400 a
6 Copper	7440508	18 e	12 e	2.9	2.9	(1300) b	
7 Lead	7439921	82 e	3.2 e	220	8.5	50	
8 Mercury	7439976	2.4	0.012 i	2.1	0.025 i	0.14	0.15
9 Nickel	7440020	1400 e	160 e	75	8.3	610 a	4600 a
10 Selenium	7782492	20	5	300	71	100 b	6800 bj
11 Silver	7440224	4.1 e		2.3		105 a	65000 aj
12 Thallium	7440280					1.7 a	6.3 a
13 Zinc	7440666	120 e	110 e	95	86		
14 Cyanide	57125	22	5.2	1	1	700 a	220000 aj
15 Asbestos	1332214					7,000,000 fibers/L k	
16 2,3,7,8-TCDD (Dioxin)	1746016					0.000000013 c	0.000000014 c
17 Acrolein	107028					320	780
18 Acrylonitrile	107131					0.059 ac	0.66 ac
19 Benzene	71432					1.2 ac	71 ac
20 Bromoform	75252					4.3 ac	360 ac
21 Carbon Tetrachloride	56235					0.25 ac	4.4 ac
22 Chlorobenzene	108907					680 a	21000 aj
23 Chlorodibromomethane	124481					0.41 ac	34 ac
24 Chloroethane	75003						
25 2-Chloroethylvinyl Ether	110758						
26 Chloroform	67663					5.7 ac	470 ac
27 Dichlorobromomethane	75274					0.27 ac	22 ac
28 1,1-Dichloroethane	75343						
29 1,2-Dichloroethane	107062					0.38 ac	99 ac
30 1,1-Dichloroethylene	75354					0.057 ac	3.2 ac
31 1,2-Dichloropropane	78875					(0.52) kc	(39) kc
32 1,3-Dichloropropylene	542756					10 a	1700 a
33 Ethylbenzene	100414					3100 a	29000 a
34 Methyl Bromide	74839					48 a	4000 a
35 Methyl Chloride	74873					5.7 ac	470 ac
36 Methylene Chloride	75092					4.7 ac	1600 ac
37 1,1,2,2-Tetrachloroethane	79345					0.17 ac	11 ac
38 Tetrachloroethylene	127184					0.8 c	8.85 c
39 Toluene	108883					6800 a	200000 a
40 1,2-Trans-Dichloroethylene	156605					(700) a	(140000) a
41 1,1,1-Trichloroethane	71556					3100 a	(170000) a
42 1,1,2-Trichloroethane	79005					0.60 ac	42 ac
43 Trichloroethylene	79016					2.7 c	81 c
44 Vinyl Chloride	75014					2 c	525 c
45 2-Chlorophenol	95578					(120) a	(400) a
46 2,4-Dichlorophenol	120832					93 a	790 aj
47 2,4-Dimethylphenol	105679					(540) a	(2300) a
48 2-Methyl-4,6-Dinitrophenol	534521					13.4	765
49 2,4-Dinitrophenol	51285					70 a	14000 a
50 2-Nitrophenol.	88755						
51 4-Nitrophenol.	100027						
52 3-Methyl-4-Chlorophenol.	59507						
53 Pentachlorophenol	87865	20 f	13 f	13	7.9	0.28 ac	8.2 acj
54 Phenol	108952					21000 a	4600000 aj
55 2,4,6-Trichlorophenol	88062					2.1 ac	6.5 ac
56 Acenaphthene	83329					(1200) a	(2700) a
57 Acenaphthylene	208968					0.0028 c	0.031 c
58 Anthracene	120127					9600 a	110000 a
59 Benzidine	92875					0.00012 ac	0.00054 ac
60 Benzo(a)Anthracene	56553					0.0028 c	0.031 c
61 Benzo(a)Pyrene	50328					0.0028 c	0.031 c
62 Benzo(b)Fluoranthene	205992					0.0028 c	0.031 c

A		B		C		D	
		Freshwater		Saltwater		Human health (10^{-6} risk for carcinogens)	
						For consumption of:	
(#) Compound	CAS No.	Criterion maximum concentration d (μg/L) B1	Criterion continuous concentration d (μg/L) B2	Criterion maximum concentration d (μg/L) C1	Criterion continuous concentration d (μg/L) C2	Water and organisms (μg/L) D1	Organisms only (μg/L) D2
63 Benzo(ghi)Perylene	191242					0.0028 c	0.031 c
64 Benzo(k)Fluoranthene	207089					0.0028 c	0.031 c
65 Bis(2-Chloroethoxy)Methane	111911						
66 Bis(2-Chloroethyl)Ether	111444					0.031 ac	1.4 ac
67 Bis(2-Chloroisopropyl)Ether	108601					1400 a	170000 a
68 Bis(2-Ethylhexyl)Phthalate	117817					1.8 ac	5.9 ac
69 4-Bromophenyl Phenyl Ether	101553						
70 Butylbenzyl Phthalate	85687					(3000) a	(5200) a
71 2-Chloronaphthalene	91587					(1700) a	(4300) a
72 4-Chlorophenyl Phenyl Ether	7005723						
73 Chrysene	218019					0.0028 c	0.031 c
74 Dibenzo(a,h)Anthracene	53703					0.0028 c	0.031 c
75 1,2-Dichlorobenzene	95501					2700 a	17000 a
76 1,3-Dichlorobenzene	541731					400	2600
77 1,4-Dichlorobenzene	106467					400	2600
78 3,3'-Dichlorobenzidine	91941					0.04 ac	0.077 ac
79 Diethyl Phthalate	84662					23000 a	120000 a
80 Dimethyl Phthalate	131113					313000	2900000
81 Di-n—Butyl Phthalate	84742					2700 a	12000 a
82 2,4-Dinitrotoluene	121142					0.11 c	9.1 c
83 2,6-Dinitrotoluene	606202						
84 Di-n-Octyl Phthalate	117840						
85 1,2-Diphenylhydrazine	122667					0.040 ac	0.54 ac
86 Fluoranthene	206440					300 a	370 a
87 Fluorene	86737					1300 a	14000 a
88 Hexachlorobenzene	118741					0.00075 ac	0.00077 ac
89 Hexachlorobutadiene	87683					0.44 ac	50 ac
90 Hexachlorocyclopentadiene	77474					240 a	17000 aj
91 Hexachloroethane	67721					1.9 ac	8.9 ac
92 Indeno(1,2,3-cd)Pyrene	193395					0.0028 c	0.031 c
93 Isophorone	78591					8.4 ac	600 ac
94 Naphthalene	91203						
95 Nitrobenzene	98953					17 a	1900 aj
96 N-Nitrosodimethylamine	62759					0.00069 ac	8.1 ac
97 N-Nitrosodi-n-Propylamine	621647					(0.005) ac	(1.4) ac
98 N-Nitrosodiphenylamine	86306					5.0 ac	16 ac
99 Phenanthrene	85018					0.0028 c	0.031 c
100 Pyrene	129000					960 a	11000 a
101 1,2,4-Trichlorobenzene	120821						
102 Aldrin	309002	3 g		1.3 g		0.00013 ac	0.00014 ac
103 alpha-BHC	319846					0.0039 ac	0.013 ac
104 beta-BHC	319857					0.014 ac	0.046 ac
105 gamma-BHC	58899	2 g	0.08 g	0.16 g		0.019 c	0.063 c
106 delta-BHC	319868						
107 Chlordane	57749	2.4 g	0.0043 g	0.09 g	0.004 g	0.00057 ac	0.00059 ac
108 4-4'-DDT	50293	1.1 g	0.001 g	0.13 g	0.001 g	0.00059 ac	0.00059 ac
109 4,4'-DDE	72559					0.00059 ac	0.00059 ac
110 4,4'-DDD	72548					0.00083 ac	0.00084 ac
111 Dieldrin	60571	2.5 g	0.0019 g	0.71 g	0.0019 g	0.00014 ac	0.00014 ac
112 alpha-Endosulfan	959988	0.22 g	0.056 g	0.034 g	0.0087 g	0.93 a	2.0 a
113 beta-Endosulfan	33213659	0.22 g	0.056 g	0.034 g	0.0087 g	0.93 a	2.0 a
114 Endosulfan Sulfate	1031078					0.93 a	2.0 a
115 Endrin	72208	0.18 g	0.0023 g	0.037 g	0.0023 g	0.76 a	0.81 aj
116 Endrin Aldehyde	7421934					0.76 a	0.81 aj
117 Heptachlor	76448	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00021 ac	0.00021 ac
118 Heptachlor Epoxide	1024573	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00010 ac	0.00011 ac
119 PCB-1242	53469219		0.014 g		0.03 g	0.000044 ac	0.000045 ac
120 PCB-1254	11097691		0.014 g		0.03 g	0.000044 ac	0.000045 ac
121 PCB-1221	11104282		0.014 g		0.03 g	0.000044 ac	0.000045 ac
122 PCB-1232	11141165		0.014 g		0.03 g	0.000044 ac	0.000045 ac
123 PCB-1248	12672296		0.014 g		0.03 g	0.000044 ac	0.000045 ac
124 PCB-1260	11096825		0.014 g		0.03 g	0.000044 ac	0.000045 ac
125 PCB-1016	12674112		0.014 g		0.03 g	0.000044 ac	0.000045 ac
126 Toxaphene	8001352	0.73	0.0002	0.21	0.0002	0.00073 ac	0.00075 ac
Total No. of Criteria (h) =		24	29	33	27	103	102

Footnotes:

a. Criteria revised to reflect current agency q_1^* or RfD, as contained in the Integrated Risk Information System (IRIS). The fish tissue bioconcentration factor (BCF) from the 1980 criteria documents was retained in all cases. Values in parentheses indicate that no health based criteria appeared in the 1980 documents. The criteria in parentheses are not being proposed today but are presented as notice for inclusion in future state triennial reviews.

b. EPA in the Office of Research and Development's Environmental Criteria and Assessment Office prepared draft updates of criteria documents for arsenic, copper and selenium which are used instead of IRIS for this rulemaking. Each document was entitled as an "Addendum" to the prior criteria documents. These documents are available in the record for this proceeding.

c. Criteria based on carcinogenicity (10^{-6} risk).

d. Criteria Maximum Concentration=the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time (1-hour average) without deleterious effects.

Criteria Continuous Concentration=the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (4-days) without deleterious effects.

µg/L=micrograms per liter

e. Freshwater aquatic life criteria for these metals are expressed as a function of total hardness (mg/L), as follows (where exp represents the base e exponential function). (Values displayed above in the matrix correspond to a total hardness of 100 mg/L.)

	CMC=exp{m_A [ln(hardness)] + b_A}		CCC=exp{m_C [ln(hardness)] + b_C}	
	m_a	b_A	m_C	b_C
Cadmium	1.128	−3.828	0.7852	−3.490
Copper	0.9422	−1.464	0.8545	−1.465
Chromium (III)	0.8190	3.688	0.8190	1.561
Lead	1.273	−1.460	1.273	−4.705
Nickel	0.8460	3.3612	0.8460	1.1645
Silver	1.72	−6.52		
Zinc	0.8473	0.8604	0.8473	0.7614

f. Freshwater aquatic life criteria for pentachlorophenol are expressed as a function of pH, and are calculated as follows. (Values displayed above in the matrix correspond to a pH of 7.8.)

CMC=exp(1.005(pH)−4.830) CCC=exp(1.005(pH)−5.290)

g. Aquatic life criteria for these compounds were issued in 1980 utilizing the 1980 Guidelines for criteria development. The acute values shown are final acute values (FAV). According to the 1980 Guidelines, the acute values were intended to be interpreted as instantaneous maximum values, and the chronic values shown were interpreted as 24-hour average values. EPA has not updated these criteria pursuant to the 1985 Guidelines. However, as an approximation, dividing the final acute values in columns B1 and C1 by 2 yields a Criterion Maximum Concentration: No numeric changes are required for columns B2 and C2, and EPA suggests using these values directly as Criterion Continuous Concentration.

h. These totals simply sum the criteria in each column. For aquatic life, there are 30 priority toxic pollutants with some type of freshwater or saltwater, acute or chronic criteria proposed. For human health, there are 102 priority toxic pollutants with either "water + fish" or "fish only" criteria proposed. Note that these totals count chromium as one pollutant even though EPA has developed criteria based on two valence states. In the matrix, EPA has assigned numbers 5a and 5b to the proposed criteria for chromium to reflect the fact that the list of 126 priority toxic pollutants includes only a single listing for chromium. Criteria enclosed in parentheses are also *not* included in the totals.

i. Applies to methyl mercury.

j. No criteria for protection of human health from consumption of aquatic organisms (excluding water) was presented in the 1980 criteria document or in the 1986 Quality Criteria for Water. Nevertheless, the criterion value has not been placed in parentheses, because sufficient information was presented in the 1980 document to allow a calculation of a criterion, even though the results of such a calculation were not shown in the document.

k. The criterion for asbestos is the MCL (56 FR 3526, January 30, 1991). The criteria for 1,2-dichloropropane have been derived using MCL (56 FR 3526, January 30, 1991).

General notes:

(1) This chart lists all of EPA's priority toxic pollutants whether or not criteria recommendations are available. Blank spaces indicate the absence of criteria recommendations. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in appendix A of 40 CFR part 423. EPA has added the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

(2) The following chemicals have organoleptic based criteria recommendations that are not included on this chart (for reasons which are discussed in the preamble): copper, zinc, chlorobenzene, 2-chlorophenol, 2,4-dichlorophenol, acenaphthene, 2,4-dimethylphenol, 3-methyl-4-chlorophenol, hexachlorocyclopentadiene, pentachlorophenol, phenol

(3) For purposes of this rulemaking, freshwater criteria apply at salinity levels equal to or less than 1 part per thousand (ppt); saltwater criteria apply at salinity levels equal to or greater than 10 ppt; for waters with salinity between 1 and 10 ppt, the applicable criteria are the more stringent of the freshwater or saltwater criteria.

(c) *Applicability.* (1) The criteria in paragraph (b) of this section apply to the States' designated uses cited in paragraph (d) of this section and supersede any criteria adopted by the State, except when State regulations contain criteria which are more stringent for a particular use in which case the State's criteria will continue to apply;

(2) The criteria established in this section are subject to the State's general rules of applicability in the same way and to the same extent as are the other numeric toxics criteria when applied to the same use classifications including mixing zones, and low flow values below which numeric standards can be exceeded in flowing fresh waters, but only if these State general policies have been reviewed and approved previously by EPA after November 8, 1983.

(i) For all waters with approved EPA mixing zone regulations or implementation procedures, the criteria apply at the appropriate locations within or at the boundary of the mixing zones; otherwise the criteria apply throughout the waterbody including at the end of any discharge pipe, canal or other discharge point.

(ii) A State shall not use a low flow value below which numeric standards can be exceeded that is less stringent than the following for waters suitable for the establishment of low flow return frequencies (i.e., streams and rivers):

Aquatic Life
  acute criteria (CMC): I Q 10 or I B 3
  chronic criteria (CCC): 7 Q 10 or 4 B 3
Human Health
  non-carcinogens; 30 Q 5
  carcinogens; harmonic mean flow

where:

CMC—criteria maximum concentration=the water quality criteria to protect against acute effects in aquatic life and is the highest instream concentration of a priority toxic pollutant consisting of a one-hour average not to be exceeded more than once every three years on the average.

CCC—criteria continuous concentration=the water quality criteria to protect against chronic effects in aquatic life is the highest instream concentration of a priority toxic pollutant consisting of a 4-day average not to be exceeded more than once every three years on the average.

1 Q 10 is the lowest one day flow with an average recurrence frequency of once in 10 years determined hydrologically;

1 B 3 is biologically based and indicates an allowable exceedence of once every 3 years. It is determined by EPA's computerized method (DFLOW model);

7 Q 10 is the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years determined hydrologically:

4 B 3 is biologically based and indicates an allowable exceedence for 4 consecutive days once every 3 years. It is determined by EPA's computerized method (DFLOW model);

30 Q 5 is the lowest average 30 consecutive day low flow with an average recurrence frequency of once in 5 years determined hydrologically and, the harmonic mean flow is a long term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows.

(iii) If a State does not have such a low flow value for numeric standards compliance, then none shall apply and the criteria included in paragraph (d) of this section herein apply at all flows.

(3) The aquatic life criteria in the matrix in paragraph (b) of this section apply as follows:

(i) For waters in which the salinity is equal to or less than 1 part per thousand, the applicable criteria are the freshwater criteria in Column B.

(ii) For waters in which the salinity is equal to or greater than 10 parts per thousand, the applicable criteria are the saltwater criteria in Column C;

(iii) For waters in which the salinity is between 1 and 10 parts per thousand, the applicable criteria are the more stringent of the freshwater or saltwater criteria. However, the Regional Administrator may approve the use of alternative criteria if scientifically defensible information and data demonstrate that on a site-specific basis the biology of the waterbody is dominated by freshwater aquatic life and that freshwater criteria are more appropriate; or conversely, the biology of the waterbody is dominated by saltwater aquatic life and that saltwater criteria are more appropriate.

(4) Application of metals criteria. (i) For purposes of calculating freshwater aquatic life criteria for metals from the equations in footnote (e) in the criteria matrix in paragraph (b) of this section, the minimum hardness allowed for use in those equations shall not be less than 25 mg/l, as calcium carbonate, even if the actual ambient hardness is less than 25 mg/l as calcium carbonate. The maximum hardness value for use in those equations shall not exceed 400 mg/l as calcium carbonate, even if the actual ambient hardness is greater than 400 mg/l as calcium carbonate.

(ii) The hardness values used shall be consistent with the design discharge conditions established in pararaph (c)(2) of this section for flows and mixing zones.

(d) *Criteria for Specific Jurisdictions.*—(1) *Connecticut, Region 1*

(i) All waters assigned to the following use classifications in the "State of Connecticut Water Quality Standards" adopted pursuant to section 22a-426 of the Connecticut General Statutes are subject to the criteria in paragraph (d)(1)(ii) of this section, without exception:

II.5.(A)—Class AA Surface Waters
II.5.(B)—Class A and SA Surface Waters
II.5.(C)—Class B and SB Surface Waters

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(1)(i) of this section:

Use classification	Applicable criteria
Class AA; Class A; Class B waters where water supply use is designated.	Each of these classifications is assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(I)—all.
Class B waters where water supply use is not designated.	This classification is assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(II).
Class SA; Class SB	Each of these classifications is assigned the criteria in: Column C(I)—all. Column C(II)—all. Column D (II)—all.

(2) *New Hampshire, Region 1*

(i) All waters assigned to the following use classifications in the New Hampshire Revised Statutes Annotated Chapter 149:3 are subject to the criteria in paragraph (d)(2)(ii) of this section, without exception:

149:3.I Class A
149:3.II Class B
149:3.III Class C

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(a)(i) of this section:

Use classification	Applicable criteria
Class A; Class B waters where water supply use is designated.	Each of these classifications is assigned the criteria in: Column D (I)—#16. Column D(II)—#16.
Class B waters where water supply use is not designated Class C.	

(3) *Rhode Island, Region 1*

(i) All waters assigned to the following use classifications in the Water Quality Regulations for Water Pollution Control adopted under chapters 46-12, 42-17.1, and 42-35 of the General Laws of Rhode Island are subject to the criteria in paragraph d(3)(ii) of this section without exception:

6.21 Freshwater
  Class A
  Class B
  Class C
6.22 Saltwater
  Class SA
  Class SB
  Class SC

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(3)(i) of this section:

Use classification	Applicable criteria
Class A; Class B waters where water supply use is designated.	These classifications are assigned the criteria in: Column D (I)—all.
Class B waters where water supply use is not designated Class C; Class SA; Class SB; Class SC.	Each of these classifications is assigned the criteria in: Column D (II)—all.

(4) *Vermont, Region 1*

(i) All waters assigned to the following use classifications in the Vermont Water Quality Standards adopted under the authority of the Vermont Water Pollution Control Act (10 V.S.A., Chapter 47) are subject to the criteria in paragraph (d)(4)(ii) of this section, without exception:

Class A
Class B
Class C

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(4)(i) of this section:

Use classification	Applicable criteria
Class A; Class B waters where water supply use is designated.	This classification is assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(I)—all.
Class B waters where water supply use is not designated; Class C.	These classifications are assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(II)—all.

(5) *New Jersey, Region 2*

(i) All waters assigned to the following use classifications in the New Jersey Administrative Code (N.J.A.C.) 7:9-4.1 et seq., Surface Water Quality Standards, are subject to the criteria in paragraph (d)(5)(ii) of this section, without exception:

N.J.A.C. 7:9-4.12(c): Class FW2
N.J.A.C. 7:9-4.12(d): Class SE1
N.J.A.C. 7:9-4.12(e): Class SE2
N.J.A.C. 7:9-4.12(f): Class SE3
N.J.A.C. 7:9-4.12(g): Class SC

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(5)(i) of this section:

Use classificatior	Applicable criteria
FW2	This classification is assigned the criteria in: Column B(1)—all except #102, 105, 107, 108, 111, 112, 113, 115, 117, and 118. Column B(2)—all except #105, 107, 108, 111, 112, 113, 115, 117, 118, 119, 120, 121, 122, 123, 124, and 125. Column D(1)—all except #4, 5a, 5b, 7, 10, and 11. Column D(2)—all.
SE1, SE SE3, SC.	These classifications are each assigned the criteria in: Column C(1)—all except #102, 105, 107, 108, 111, 112, 113, 115, 117, and 118. Column C(2)—all except #105, 107, 108, 111, 112, 113, 115, 117, 118, 119, 120, 121, 122, 123, 124, and 125. Column D(2)—all.

(6) *Puerto Rico, Region 2*

(i) All waters assigned to the following use classifications in the Puerto Rico Water Quality Standards (promulgated by Resolution Number R-83-5-2) are subject to the criteria in paragraph (d)(6)(ii) of this section, without exception.

Article 2.2.2—Class SB
Article 2.2.3—Class SC
Article 2.2.4—Class SD

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(6)(i) of this section:

Use classification	Applicable criteria
Class SD	This classification is assigned criteria in: Column B(1)—all, except: 10, 102, 105, 107, 108, 111, 112, 113, 115, 117, and 126. Column B(2)—all, except: 105, 107, 108, 112, 113, 115, and 117. Column D(1)—all, except: 4, 5a, 5b, 6, 7, 10, 11, 14, 105, 112, 113, and 115. Column D(2)—all, except: 4, 5a, 5b, 10, 14, 105, 112, 113, and 115.
Class SB, Class SC.	These classifications are assigned criteria in: Column C(1)—all, except: 4, 5b, 7, 8, 10, 11, 13, 102, 105, 107, 108, 111, 112, 113, 115, 117, and 126. Column C(2)—all, except: 4, 5b, 10, 13, 108, 112, 113, 115, and 117. Column D(2)—all, except: 4, 5a, 5b, 10, 14, 105, 112, 113, and 115.

(7) *Virginia, Region 3*

(i) All waters assigned to the following use classifications in the Virginia Water Quality Standards, VR680-21 are subject to the criteria in paragraph (d)(6)(ii) of this section without exception:

VR680-21-08 Classes I-VII and PWS

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(7)(i) of this section:

Use classification	Applicable criteria
Class I	This classification is assigned the criteria in: Column C(I)—all. Column C(II)—all. Column D(II)—all, except #16.
Class II	This classification is assigned the criteria in: Column B(I)—all. Column B(II)—all. Column C(I)—all. Column C(II)—all. Column D(II)—all, except #16.
Class III-VII	Each of these classifications is assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(II)—all, except #16.
PWS	This classification is assigned the additional criteria in: Column D(I)—all, except #16.

(8) *District of Columbia, Region 3*

(i) All waters assigned to the following use classifications in Chapter 11 Title 21 DCMR, Water Quality Standards of the District of Columbia are subject to the criteria in paragraph (d)(8)(ii) of this section without exception:

1101.2 Class C waters

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classification identified in paragraph (d)(8)(i) of this section:

Use classification	Applicable criteria
Class C	This classification is assigned the additional criteria in: Column B(II)—#10, 118, 126. Column D(I)—#7, 15, 16, 44, 67, 68, 79, 80, 81, 88, 114, 116, 118. Column D(II)—all.

(9) *Florida, Region 4*

(i) All waters assigned to the following use classifications in Chapter 17-301 of the Florida Administrative Code (i.e., identified in Section 17-302.600) are subject to the criteria in paragraph (d)(9)(ii) of this section, without exception:

Class I
Class II
Class III

(ii) The following criteria from the matrix paragraph (b) of this section apply to the use classifications identified in paragraph (d)(9)(i) of this section:

Use classification	Applicable criteria
Class I	This classification is assigned the criteria in: Columns B1 and B2—5(b), 6, 7, 8, 9, 10, 11, 107, 111, 115, 118, and 126; and Column D1—all.
Class II; Class III (marine).	This classification is assigned the criteria in: Columns C1 and C2—2, 6, 7, 8, 9, 11, 13, 14, 111, 115, 118, and 126; and Column D2—all.
Class III (freshwater).	This classification is assigned the criteria in: Columns B1 and B2—5(b), 6, 7, 8, 9, 10, 11, 107, 111, 115, 118, and 126; and Column D2—all.

(10) *Michigan, Region 5*

(i) All waters assigned to the following use classifications in the Michigan Department of Natural Resources Commission General Rules, R 323.1043 Definitions; A to N, (i.e., identified in Section (g) "Designated use") are subject to the criteria in paragraph (d)(10)(ii) of this section, without exception:

(A) Industrial water supply
(B) Agricultural water supply
(C) Public water supply
(D) Recreation
(E) Fish, other aquatic life, and wildlife
(F) Navigation

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(10)(i) of this section:

Use classification	Applicable criteria
Public water supply	This classification is assigned the criteria in: Column B (I)—all, Column B (II)—all, Column D (I)—all.
All other designations.	These classifications are assigned the criteria in: Column B (I)—all, Column B (II)—all, and Column D (II)—all.

(11) *Arkansas, Region 6*

(i) All waters assigned to the following use classification in Section 4C (Waterbody uses) identified in Arkansas Department of Pollution Control and Ecology's Regulation No. 2 as amended and entitled, "Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas" are subject to the criteria in paragraph (d)(11)(ii) of this section, without exception:

(A) Extraordinary Resource Waters
(B) Ecologically Sensitive Waterbody
(C) Natural and Scenic Waterways
(D) Fisheries:
(*1*) Trout
(*2*) Lakes and Reservoirs
(*3*) Streams
(*i*) Ozark Highlands Ecoregion
(*ii*) Boston Mountains Ecoregion
(*iii*) Arkansas River Valley Ecoregion
(*iv*) Ouachita Mountains Ecoregion
(*v*) Typical Gulf Coastal Ecoregion
(*vi*) Spring Water-influenced Gulf Coastal Ecoregion
(*vii*) Least-altered Delta Ecoregion
(*viii*) Channel-altered Delta Ecoregion
Domestic Water Supply

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classification identified in paragraph (d)(11)(i) of this section:

Use classification	Applicable criteria
Extraordinary resource waters	
Ecologically sensitive waterbody	
Natural and scenic waterways	
Fisheries:	
(1) Trout	
(2) Lakes and reservoirs	
(3) Streams	
(a) Ozark highlands ecoregion	
(b) Boston mountains ecoregion	
(c) Arkansas river valley ecoregion	
(d) Ouachita mountains ecoregion	
(e) Typical gulf coastal Ecoregion	
(f) Spring water-influenced gulf coastal ecoregion	
(g) Least-altered Delta ecoregion	
(h) Channel-altered Delta ecoregion.	These uses are each assigned the criteria in Column B1—# 2, 4, 5a, 5b, 6, 7, 8, 9, 10, 11, 13, 14. Column B2—# 2, 4, 5a, 5b, 6, 7, 8, 9, 10, 13, 14. Column D2—all.
Domestic water supply.	This use is assigned the criteria in: Column D1—all.

(12) *Louisiana, Region 6*

(i) All waters assigned to the following use designations in the Louisiana Administrative Code, Title 33—Environmental Quality, Part IX—Water Quality Regulations, Chapter 11 (i.e., identified in Section 1111 Water Use Designations) are subject to the criteria in paragraph (d)(12)(ii) of this section, without exception:

(A) Public Water Supply
(B) Fish and Wildlife Propagation
(C) Oyster Propagation

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(12)(i) of this section:

Use classification	Applicable criteria
Public water supply	This classification is assigned the criteria in: Column D(I)—#16.
Fish and wildlife propagation.	These classifications are assigned the criteria in: Column D(II) #16.
Oyster propagation	Column D(II) #16.

(13) *Kansas, Region 7*

(i) All waters assigned to the following use classification in the Kansas Department of Health and Environment regulations, K.A.R. 28–16–28b through K.A.R. 28–16–28f, are subject to the criteria in paragraph (d)(13)(ii) of this section, without exception.

Section 28–16–28d:
Section (2)(A)—Special Aquatic Life Use Waters
Section (2)(B)—Expected Aquatic Life Use Waters
Section (2)(C)—Restricted Aquatic Life Use Waters
Section 3—Domestic Water Supply
Section (6)(c)—Consumptive Recreation Use.

(ii) The following criteria from the matrix is paragraph (b) of this section apply to the use classifications identified in paragraph (d)(13)(i) of this section:

Use classification	Applicable criteria
Sections (2)(A), (2)(B), (2)(C), 6(C).	These classifications are each assigned all criteria in: Column B(I), except #9, 13, 102, 105, 107, 108, 111–113, 115, 117, and 126; Column B(II), except #9; 13, 105, 107, 108, 111–113, 115, 117, 119–125, and 126; and Column D(II), except #9, 10, 112, 113, and 115.
Section (3)	This classification is assigned all criteria in: Column D(I), except #9, 10, 12, 112, 113, and 115.

(14) *Colorado, Region 8*

(i)(A) All waters assigned to the following use classifications in the Colorado Classifications and Numeric Standards for the following Basins:

(*1*) Arkansas River Basin—3.2.0 (5CCR 1002–8);

(*2*) Upper Colorado River Basin and North Platte River Basin (Planning Region 12)—3.3.0 (5CCR 1002–8);

(*3*) San Juan and Dolores River Basins—3.4.0 (5CCR 1002–8);

(*4*) Gunnison and Lower Dolores River Basins—3.5.0 (5CCR 1002–8);

(*5*) Rio Grande River Basin 3.6.0 (5CCR 1002–8);

(*6*) Lower Colorado Basin—3.7.0 (5CCR 1002–8);

(*7*) South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin—3.8.0 (5CCR 1002–8);

are subject to the criteria in paragraph (d)(14)(ii) of this section, except where only particular segments require criteria as delineated in paragraph (d)(14)(ii) of this section.

The following are the use classifications:

(*1*) Domestic Water Supply
(*2*) Class 1—Cold Water Aquatic Life
(*3*) Class 2—Cold Water Aquatic Life
(*4*) Class 1—Warm Water Aquatic Life
(*5*) Class 2—Warm Water Aquatic Life

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications in paragraph (d)(14)(i) of this section:

Use classification	Applicable criteria
Domestic water supply.	All waters assigned to this use classification are subject to the criteria in: Column D(I)—all except #4, 5a, 5b, 6, 7, 10, 11, 22, 33, 39, 41, 44, 53, 66, 77, 90, 95, 115.
Class 1 Cold Water A.L.	
Class 2 Cold Water A.L.	
Class 1 Warm Water A.L.	
Class 2 Warm Water A.L..	All waters assigned to these use classifications are subject to the criteria in: Column B(I)—#10. Column B(II)—#10. Column D(II)—all and the following specific segments (which have been assigned one of these aquatic life uses) are further assigned the criteria set forth below.

1. The criteria in: B(I)—#2, 4, 5a, 5b, 6, 7, 8, 9, 11, 13, 14; B(II)—#2, 4, 5a, 5b, 6, 7, 8, 9, 13, 14 are assigned to the following specific segments:

- Basin 3.2.0

Upper Arkansas River Basin: segments 14, 26
Middle Arkansas River Basin: segments 4, 13, 18
Fountain Creek Basin: segments 3a, 8
Lower Arkansas River Basin: segments 2, 6b, 13
Cimarron River Basin: segment 1

- Basin 3.3.0
  Blue River Basin (14010002): segments 5, 20
  Eagle River Basin (14010003): segment 11
  North Platte River Basin (1018001, 10180002): segment 7
  Yampa River Basin (14050001, 14050002): segment 12
- Basin 3.4.0
  San Juan River Basin: segments 3, 10, 11
  Piedra River Basin: segment 6
  Los Pinos River Basin: segment 6
  Animas and Florida River Basin: segment 13b
  La Plata River, Mancos River, McElmo Creek and San Juan River Basin in Montezuma County and Dolores Counties: segments 3, 6, 8
  Dolores River Basin: segment 11
- Basin 3.5.0
  Upper Gunnison River Basin: segments 6b, 16, 28, 32
  North Fork of the Gunnison River Basin: segment 6, 10
  Upcomphgre River Basin: segments 10, 12.
  Lower Gunnison River Basin: segment 4
  San Miguel River Basin: segment 12
  Lower Dolores River Basin: segment 4
- Basin 3.6.0
  Rio Grande River Basin: segments 15b, 25
  Closed Basin—San Luis Valley: segment 3
- Basin 3.7.0
  Lower Yampa River/Green River Basin: segments 3a, 3b, 6, 14, 17, 20
  White River Basin: segments 5, 9, 13a, 22
  Lower Colorado River Basin: segments 11b, 11e, 13
- Basin 3.8.0
  Republican River Basin: segments 6, 7
  South Platte River Basin (Region 1): segment 2
  Cache La Poudre River Basin: segments 8, 13
  Big Thompson River Basin: segments 6, 10
  South Platte River Basin (Region 2): segment 3
  St. Vrain Creek Basin: segment 6
  Boulder Creek Basin: segments 8, 11
  Big Dry Creek Basin: segment 1
  Clear Creek Basin: segments 8, 16, 18
  Cherry Creek Basin: segment 4
  South Platte River Basin (Regions 2, 3, 4): segments 7a, 11a, 16
  South Platte River Basin (Region 3 and 4): segment 7

2. The criteria in: Column B(I)—#9; Column B(II)—#9 are assigned to the following specific segments:

- Basin 3.3.0
  Blue River Basin (14010002): segment 12
- Basin 3.4.0
  Animas and Florida River Basin: segment 15
  La Plata River, Mancos River, McElmo Creek and San Juan River Basin in Montezuma County and Dolores Counties: segment 9
- Basin 3.8.0
  Big Thompson River Basin: segment 13
  Boulder Creek Basin: segments 4c, 6
  Clear Creek Basin: segment 12
  Bear Creek Basin: segments 4a, 5
  South Platte River Basin (Region 2, 3, and 4): segment 7b

3. The criteria in: Column B(I)—#8; Column B(II)—#8 are assigned to the following specific segments:

- Basin 3.7.0—Lower Colorado River Basin: segment 4
- Basin 3.8.0—South Platte River Basin (Region 2, 3, and 4): segment 11b

4. The criteria in: Column B(I)—#14; Column B(II)—#14 are assigned to the following specific segment:

- Basin 3.2.0—Upper Arkansas River Basin: segment 8b

5. The criterion in: Column B(I)—#11 is assigned to the following specific segment:

- Basin 3.7.0—Lower Colorado River Basin: segment 4.

(15) *Arizona, Region 9*

(i) All waters assigned the use classifications in chapter 21 of the Arizona Administrative Code (AAC) which are referred to in paragraph (d)(15)(ii) of this section, are subject to the criteria in paragraph (d)(15)(ii) of this section, without exception. These criteria amend the existing State standards contained in chapter 21 of the AAC sections R9–21–101 through 304, Water Quality Standards for Waters of the State, for the toxic pollutants identified in paragraph (d)(15)(ii) of this section. For purposes of this action, the specific standards to be applied are based on the following selected use designations as defined in chapter 21, AAC §§ R9–21–101 through R9–21–304:

(A) DWS—Domestic Water Source
(B) A&W—Aquatic & Wildlife (including any aquatic life designation)

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the water and use classifications defined in paragraph (d)(15)(i) of this section and identified below:

Water and use classification	Applicable criteria
Waters of the State with A&W but without DWS.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column D2—all pollutants.
Waters of the State with A&W and DWS.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column D1—all pollutants.
Waters of the State with DWS but without A&W.	These waters are assigned the criteria in: Column D1—all pollutants.

(16) *California, Region 9*

(i) All waters assigned any aquatic life or human health use classifications in the Water Quality Control Plans for the various Basins of the State ("Basin Plans"), as amended, adopted by the California State Water Resources Control Board ("SWRCB"), except for ocean waters covered by the Water Quality Control Plan for Ocean Waters of California ("Ocean Plan") adopted by the SWRCB with resolution Number 90–27 on March 22, 1990, are subject to the criteria in paragraph (d)(16)(ii) of this section, without exception. These criteria amend the portions of the existing State standards contained in the Basin Plans. More particularly these criteria amend water quality criteria contained in the Basin Plan Chapters specifying water quality objectives (the State equivalent of federal water quality criteria) for the toxic pollutants identified in paragraph (d)(16)(ii) of this section. Although the State has adopted several use designations for each of these waters, for purposes of this action, the specific standards to be applied in paragraph (d)(16)(ii) of this section are based on the presence in all waters of some aquatic life designation and the presence or absence of the MUN use designation (Municipal and domestic supply). (See Basin Plans for more detailed use definitions).

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the water & use classifications defined in paragraph (d)(16)(i) of this section and identified below:

Water and use classification	Applicable criteria
Waters of the state defined as bays or estuaries except the Sacramento-San Joaquin Delta and San Francisco Bay.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column C1—all pollutants. Column C2—all pollutants. Column D2—all pollutants

Water and use classification	Applicable criteria
Waters of the Sacramento-San Joaquin Delta and waters of the state defined as inland (i.e., all surface waters of the state not bays or estuaries or ocean) that include a MUN use designation except the San Joaquin River from the mouth of the Merced River to Vernalis and the Sacramento River and its tributaries upstream from Hamilton City.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column D1—all pollutants.
Waters of the state defined as inland without an MUN use designation except waters flowing to Grasslands Water District, San Luis National Wildlife Refuge and Los Banos State Wildlife Area.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column D2—all pollutants.
Waters of the San Joaquin River from the mouth of the Merced River to Vernalis.	These waters are assigned the criteria in: Column B1—all pollutants except #10. Column B2—all pollutants. Column D1—all pollutants except #10.
Waters of the Sacramento River and its tributaries upstream from Hamilton City.	These wates are assigned the criteria in: Column B1—all pollutants except #4, 6, 13. Column B2—all pollutants except #4, 6, 13. Column D1—all pollutants except #4.
Waters flowing to Grasslands Water District, San Luis National Wildlife Refuge, and Los Banos State Wildlife Area.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column D2—all pollutants except #10.
Waters of San Francisco Bay.	These waters are assigned the criteria in: Column B1—all pollutants. Column B2—all pollutants. Column C1—all pollutants except #10. Column C2—all pollutants except #10. Column D2—all pollutants.

(17) *Nevada, Region 9*

(i) All waters assigned the use classifications in chapter 445 of the Nevada Administrative Code (NAC), Nevada Water Pollution Control Regulations, which are referred to in paragraph (d)(17)(ii), of this section, are subject to the criteria in paragraph (d)(17)(ii) of this section, without exception. These criteria amend the existing State standards contained in the Nevada Water Pollution Control Regulations. More particularly, these criteria amend or supplement the table of numeric standards in NAC 445.1339 for the toxic pollutants identified in paragraph (d)(17)(ii) of this section.

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the waters defined in paragraph (d)(16)(i) of this section and identified below:

Water and use classification	Applicable criteria
Waters that the State has included in NAC 445.1339 where municipal or domestic supply is a designated use.	These waters are assigned the criteria in: Column B1—pollutant #118. Column B2—pollutant #118. Column D1—pollutants 15, 16, 18, 19, 20, 21, 23, 26, 27, 29, 30, 34, 35, 36, 37, 38, 42, 43, 55, 57-64, 66, 73, 74, 78, 82, 85, 87-89, 91, 92, 96, 98-100, 103, 104, 105, 114, 116, 117, 118.
Waters that the State has included in NAC 445.1339 where municipal or domestic supply is not a designated use.	These waters are assigned the criteria in: Column B1—pollutant #118. Column B2—pollutant #118. Column D2—all pollutants except #2.

(18) *Hawaii, Region 9*

(i) All waters assigned the use classifications in the existing State standards ("State Standards") which are referred to in paragraph (d)(18)(ii) of this section, are subject to the criteria in paragraph (d)(18)(ii) of this section, without exception. These criteria amend the existing State standards. Specifically, these criteria supplement the table of numeric standards for toxic pollutants applicable to all of Hawaii's waters in section 11-54-04(b)(3).

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the waters defined in paragraph (d)(18)(i) of this section and identified below:

Water and use classification	Applicable criteria
Waters of the State assigned to Classes AA, A, 1, and 2.	These waters are assigned the criteria in: Column D2—pollutants #3, 8.
Waters of the State assigned to Classes AA and A.	These waters are assigned criteria in: Column C1—pollutant #6. Column C2—pollutants #6, 7, 8.

(19) *Commonwealth of the Northern Mariana Islands, Region 9*

(i) All waters assigned the use classifications in the existing Commonwealth of the Northern Mariana Islands Marine and Fresh Water Quality Standards ("Standards") which are referred to in paragraph (d)(19)(ii) of this section, are subject to the criteria in paragraph (d)(19)(ii) of this section, without exception. These criteria amend the existing standards. Specifically, these criteria supplement the table of numeric standards in part 7.10 of the Standards.

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the waters defined in paragraph (d)(19)(i) of this section and identified below:

Water and use classification	Applicable criteria
Fresh surface waters of the Commonwealth assigned to classes 1 and 2.	These waters are assigned the criteria in: Column D1—all pollutants. Column B1—pollutants #53, 108, 118. Column B2—pollutants #53, 108, 118.
Marine waters of the Commonwealth to classes AA and A..	These waters are assigned the criteria in: Column D2—all pollutants. Column C1—pollutants #53, 108, 118. Column C2—pollutants #53, 108, 118.

(20) *Alaska, Region 10*

(i) All waters assigned to the following use classifications in the Alaska Administrative Code (AAC), chapter 18 (i.e., identified in 18 AAC 70.020) are subject to the criteria in paragraph(d)(20)(ii) of this section, without exception:

70.020.(1)(A)	Fresh water. Water supply. (i) Drinking, culinary, and food processing, (ii) Aquaculture;
70.020.(1)(B)	Water recreation. (i) Contact recreation, (ii) Secondary recreation;
70.020.(1)(C)	Growth and propagation of fish, shellfish, other aquatic life, and wildlife.

70.020.(2)(A)	Marine water. Water supply. (i) Aquaculture, (ii) Seafood processing,
70.020.(2)(B)	Water recreation. (i) Contact recreation, (ii) Secondary recreation;
70.020.(2)(C)	Growth and propagation of fish, shellfish, other aquatic life, and wildlife;
70.020.(2)(D)	Harvesting for consumption of raw mollusks or other raw aquatic life.

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(20)(i) of this section:

Use classification	Applicable criteria
(1)(A)i	This classification is assigned tho criteria in: Column D(I)—#'s 9, 10, 53. Column D(I)—human health carcinogens: #'s 2, 3, 16, 18, 19, 20, 21, 23, 26, 27, 29, 30, 35, 36, 37, 42, 43, 44, 55, 57-64, 66, 68, 73, 74, 78, 82, 85, 87, 88, 89, 91, 92, 96, 97, 98, 99, 100, 102-111, 117-126.
(1)(A)iii	This classification is assigned the criteria in: Same as for (1)(A)i (above) plus: Column B(I)—all. Column B(II)—#'s 9, 10, 13, 53.
(1)(B)i	This classification is assigned the criteria in: Same as for (1)(A)i above.
(1)(B)ii	This classification is assigned the criteria in: Column B(I)—all. Column B(II)—#'s 9, 10, 13, 53. Column D(II)—#'s 9, 10, 53. Column D(II) human health carcinogens: #'s 2, 3, 16, 18, 19, 20, 21, 23, 26, 27, 29, 30, 35, 36, 37, 42, 43, 44, 55, 57-64, 66, 68, 73, 74, 78, 82, 85, 87, 88, 89, 91, 92, 96, 97, 98, 99, 100, 102-111, 117-126
(1)(C) This classification is assigned the criteria in:. Same as for (1)(B)(ii).	
(2)(A)i	This classification is assigned the criteria in: Column C(I)—all. Column C(II)—#'s 9, 10, 13, 53. Column D(II)—#'s 9, 10, 53. Column D(II)—human health carcinogens: #'s 2, 3, 16, 18, 19, 20, 21, 23, 26, 27, 29, 30, 35, 36, 37, 42, 43, 44, 55, 57-64, 66, 68, 73, 74, 78, 82, 85, 87, 88, 89, 91, 92, 96, 97, 98, 99, 100, 102-111, 117-126
(2)(A)i	This classification is assigned the criteria in: Column C(I)—all. Column C(II)—only for #'s 9, 10, 13, 53.
(2)(B)i & ii	These classifications are assigned the criteria in: Column D(II) for #'s 9, 10, 53. Column D(II)—human health carcinogens: #'s 2, 3, 16, 18, 19, 20, 21, 23, 26, 27, 29, 30, 35, 36, 37, 42, 43, 44, 55, 57-64, 66, 68, 73, 74, 78, 82, 85, 87, 88, 89, 91, 92, 96, 97, 98, 99, 100, 102-111, 117-126.
(2)(C) and (2)(D)	These classifications are assigned the criteria in: Same as for (2)(A)i.

(21) *Idaho, Region 10*

(i) All waters assigned to the following use classifications in the Idaho Administrative Procedures Act (IDAPA), chapter 16 (i.e., identified in IDAPA 16.01.2100,02-16.01.2100,07) are subject to the criteria in paragraph (d)(21)(ii) of this section, without exception:

16.01.2100,02.	Domestic Water Supplies.
16.01.2100,03.	Cold Water Biota.
16.01.2100,04.	Warm Water Biota.
16.01.2100,05.	Salmonid Spawning.
16.01.2100,06.	Primary Contact Recreation.
16.01.2100,07.	Secondary Contact Recreation.

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(21)(i) of this section:

Use classification	Applicable criteria
02	This classification is assigned the criteria in: Column D(I)—all except #'s 4, 5, 7, 10, 11, 14, 115.
03, 04 and 05	These classifications are assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(II)—all.
06	This classification is assigned the criteria in: Column B(I)—all. Column B(II)—all.
07	This classification is assigned the criteria in: Column B(I)—all. Column B(II)—all. Column D(II)—all.

(22) *Washington, Region 10*

(i) All waters assigned to the following use classifications in the Washington Administrative Code (WAC), chapter 173-201 (i.e., identified in WAC 173-201-045) are subject to the criteria in paragraph (d)(22)(ii) of this section, without exception:

173-201-045.	Class AA water supplies. Class A. Class B. Class C. Lake class.

(ii) The following criteria from the matrix in paragraph (b) of this section apply to the use classifications identified in paragraph (d)(22)(i) of this section:

Use classification	Applicable criteria
AA and A	These classifications are assigned the criteria in: Column D(I)—all. Column D(II)—all. Columns B(I), B(II), C(I), and C(II): all except #'s 4, 5a&b, 7, 8, 9, 11, 13, 53, 108, 109, 110, 115, 117, 119-126
B and C	These classifications are assigned the criteria in: Same as for AA and A except do not include Column D(I).
Lake class	This classification is assigned the criteria in: Same as for AA and A except do not include Columns C(I), C(II) or D(I).

(Note.—The following appendix will not appear in the Code of Federal Regulations.)

Appendix to Preamble of Today's Proposal

I. Introduction

The purpose of this appendix is to provide background information and further explanation of today's proposed rulemaking. Two major topics are discussed. The first topic concerns the detailed assumptions and rules followed by EPA in writing the State-specific proposed regulatory requirements (i.e., the water quality uses and criteria) contained in proposed section § 131.36(d). The second topic concerns EPA's rationale for proposing the § 131.36(d) requirements. Separate, customized rationales are provided for each jurisdiction included in the water quality standards program (i.e., as defined by 40 CFR 131.3(j)).

II. Assumptions and Rules Followed by EPA in Writing the Proposed Section 131.36(d) Requirements for all Jurisdictions

The "rules" followed by EPA in writing the proposed § 131.36(d) requirements for all jurisdictions are as follows:

1. No criteria are proposed for States which have been fully approved by EPA as complying with the section 303(c)(2)(B) requirements.

2. For States which have not been fully approved, if EPA has not previously determined which specific pollutants/criteria/waterbodies are lacking from a State's standards (i.e., as part of an approval/disapproval action only), all of the criteria in Columns B, C, and D of the proposed § 131.36(b) matrix are proposed for statewide application to all appropriate designated uses, except as provided for elsewhere in these rules. That is, EPA proposes to bring the State into compliance with section 303(c)(2)(B) via an approach which is comparable to option 1 of the December 1988 national guidance for section 303(c)(2)(B).

3. If EPA has previously determined which specific pollutants/criteria/waterbodies are needed to comply with CWA section 303(c)(2)(B) (i.e., as part of an approval/disapproval action only), the criteria in proposed § 131.36(b) are proposed for only those specific pollutants/criteria/waterbodies (i.e., EPA proposes to bring the State into compliance via an approach which is comparable to option 2 of the December 1988 national guidance for section 303(c)(2)(B)).

4. For aquatic life, except as provided for elsewhere in these rules, all waters with designated aquatic life uses providing even minimal support to aquatic life are included in the proposed rule (i.e., fish survival, marginal aquatic life, etc.).

5(a). For human health, except as provided for elsewhere in these rules, all waters with designated uses providing for public water supply protection (and therefore a potential water consumption exposure route) or minimal aquatic life protection (and therefore a potential fish consumption exposure route) are included in the proposed rule.

5(b). Where a State has determined the specific aquatic life segments which provide a fish consumption exposure route (i.e., fish or other aquatic life are being caught and consumed) and EPA approved this determination as part of a standards approval/disapproval action, the proposed rule includes the fish consumption (Column D(II)) criteria for only those aquatic life segments, except as provided for elsewhere in these rules. In making a determination that certain segments do not support a fish consumption exposure route, a State must complete and EPA must have previously approved, a use attainability analysis consistent with the provisions of 40 CFR part 131.10(j). In the absence of such an approved State determination, EPA has proposed fish consumption criteria for all aquatic life segments.

6. Uses/Classes other than those which support aquatic life or human health are not included in the proposed rulemaking (e.g., livestock watering, industrial water supply), unless they are defined in the State standards as also providing protection to aquatic life or human health (i.e., unless they are described as protecting multiple uses including aquatic life or human health). For example, if the State standards include a use such as industrial water supply, and in the narrative description of the use the State standards indicate that the use includes protection for resident aquatic life, then this use is included in the proposed rulemaking.

7. For human health, the "water + fish" criteria in Column D(I) of § 131.36(b) are proposed for all waterbodies where public water supply and aquatic life uses are designated, except as provided for elsewhere in these rules (e.g., rule 9).

8. If the State has public water supplies where aquatic life uses have not been designated, or public water supplies that have been determined not to provide a potential fish consumption exposure pathway, the "water + fish" criteria in Column D(I) of § 131.36(b) are proposed for such waterbodies, except as provided for elsewhere in these rules (e.g., rule 9).

9. EPA is generally not proposing criteria for priority toxic pollutants for which a State has adopted criteria and received EPA approval. The exceptions to this general rule are described in rules 10 and 11.

10. For priority toxic pollutants where the State has adopted human health criteria and received EPA approval, but such criteria do not fully satisfy section 303(c)(2)(B) requirements, the proposed rule includes human health criteria for such pollutants. For example, consider a case where a State has a water supply segment that poses an exposure risk to human health from both water and fish consumption. If the State has adopted, and received approval for, human health criteria based on water consumption only (e.g., Safe Drinking Water Act Maximum Contaminant Levels (MCLs)) which are less stringent than the "water + fish" criteria in Column D(I) of proposed § 131.36(b), the Column D(I) criteria are proposed for those water supply segments. The rationale for this is to ensure that both water and fish consumption exposure pathways are adequately addressed and human health is fully protected. If the State has adopted water consumption only criteria which are more stringent or equal to the Column D(I) criteria, the "water + fish" criteria in Column D(I) criteria are not proposed.

11. For priority toxic pollutants where the State has adopted aquatic life criteria and received EPA approval, but such criteria do not fully satisfy section 303(c)(2)(B) requirements, the proposed rule includes aquatic life criteria for such pollutants (e.g., because previously approved State criteria do not reflect current science contained in revised criteria documents and other guidance sufficient to protect all designated uses or human health exposure pathways). For example, if the State has adopted not-to-be-exceeded aquatic life criteria which are less stringent than the 4-day average chronic aquatic life criteria in § 131.36(b) (i.e., in Columns B(II) and C(II)), the acute and chronic aquatic life criteria in § 131.36(b) are proposed for those pollutants. The rationale for this is that the State-adopted criteria do not protect resident aquatic life from both acute and chronic effects, and that federal criteria are necessary to fully protect aquatic life designated uses. If the State has adopted not-to-be-exceeded aquatic life criteria which are more stringent or equal to the chronic aquatic life criteria in § 131.36(b), the acute and chronic aquatic life criteria in § 131.36(b) are not proposed for those pollutants.

12. Under certain conditions discussed in rules 9, 10, and 11, criteria listed in § 131.36(b) are not proposed for specific pollutants; however, EPA made such exceptions only for pollutants for which criteria have been adopted by the State and approved by EPA, where such criteria are currently effective under State law and fully satisfy section 303(c)(2)(B) requirements.

III. State-by-State Summary Information and Rationale

EPA's jurisdiction-specific rationale for the § 131.36(d) requirements is described below. In addition, all proposed § 131.36(d) requirements conform to the rules specified in the previous section of this appendix.

Region 1

Connecticut is included in today's proposal because the State has not adopted any criteria for priority toxic pollutants, either before or in response to the statutory requirement, and EPA has reason to believe that at least some criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Connecticut's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows.

—August, 1990. Draft WQS revisions were submitted to EPA by the State. In this draft revision the State proposed adopting criteria for all priority pollutants for fresh water aquatic life and human health protection. No criteria were proposed for marine waters.

—December, 1990. EPA Region I notified Connecticut that adoption of criteria for marine waters is necessary to achieve compliance with section 303(c)(2)(B).

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State Section 304(1) short list for which State criteria have not been adopted and approved.

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 34 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

—Long Island Sound study conducted as part of the National Estuaries Program which indicates presence of priority pollutants in Long Island Sound.

Maine has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—June 1990. Legislative adoption of all EPA issued section 304(a)(1) criteria by reference.

—December 20, 1990. EPA approved the adopted State criteria.

EPA fully approved the criteria for priority toxic pollutants adopted by Maine in June of 1990 as being consistent with option 1 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Massachusetts has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

Massachusetts' actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—Massachusetts adopted revised standards on July 23, 1990. The State adopted the section 304(a)(1) criteria for aquatic life protection in fresh and marine waters.

—Massachusetts toxicity control policy adopted with the standards incorporates a 10^{-6} risk level.

—December 20, 1990. EPA fully approved the Massachusetts toxics criteria as fully satisfying the requirements of section 303(c)(2)(B).

EPA fully approved the criteria for priority toxic pollutants adopted by Massachusetts as being consistent with option 1 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

New Hampshire is included in today's proposal because although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, the State has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirement and EPA has reason to believe that at least some additional criteria are necessary to comply with section

303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

New Hampshire's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—August 1990. The State adopted water quality standards revisions following an option 1 approach using EPA national criteria for all pollutants. New Hampshire used a 10^{-6} risk assumption for human health protection for all pollutants except 2,3,7,8–TCDD for which a risk level of 10^{-5} was assumed.

—December 19, 1990. The revised toxics criteria adopted by the State were approved with the exception of the human health criteria for dioxin, which was disapproved.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 126 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory data base and/or the Permit Compliance System data base.

Rhode Island is included in today's proposal because although the State has completed a review and adopted numeric criteria for some priority pollutants in response to the statutory requirement, EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Rhode Island's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—October 1989. The State adopted revised WQS incorporating an option 1 approach for all section 304(a)(1) criteria for aquatic life protection in fresh and marine waters. No criteria were adopted for the protection of human health.

—March 30, 1989. EPA approved the water quality standards and informed Rhode Island that to come into full compliance with Section 303(c)(2)(B) that the State would have to adopt human health criteria.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State section 304(1) short list for which State toxics criteria have not been adopted and approved.

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric

criteria for an as yet undetermined number of priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.
—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.
—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.
—Superfund monitoring data indicating presence of priority pollutants at hazardous waste sites that may enter surface water through surface drainage and ground water migration.
—The Narragansett Bay Study conducted under the National Estuaries Program which indicated presence of priority pollutants in fish and shellfish tissue.

Vermont is included in today's proposal because the State has not adopted any criteria for priority toxic pollutants, either before or in response to the statutory requirement, and EPA has reason to believe that at least some criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Vermont's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—April 1990. Vermont proposed draft water quality standards revisions following an option 1 approach for all section 304(a)(1) pollutants for aquatic life and human health protection.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 126 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.
—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.
—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

Region 2

New Jersey is included in today's proposal because although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, the State has not completed a review/revision of their numeric criteria for priority toxic pollutants in response to the statutory requirement and EPA has reason to believe that additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

New Jersey adopted criteria for some priority toxic pollutants prior to passage of section 303(c)(2)(B) on April 29, 1985 (N.J.A.C 7:9–4.1 et seq.). EPA approved these criteria on July 8, 1985. Some of these criteria are not affected by today's proposed rulemaking.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—June 20, 1988: the State published a public notice of proposed revisions to the State Surface Water Quality Regulation, including new numeric criteria for toxic pollutants.
—July 14, 1989: The State adopted revisions to the State Surface Water Quality Standards Regulation. Numeric criteria were not included in the adopted revisions.
—July 16, 1990: The State informed EPA that it would be proposing numeric criteria for all EPA priority pollutants.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State section 304(1) list for which appropriate State criteria have not been adopted and approved, including metals.

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 16 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

—Correspondence from the State indicating that the adoption of criteria for all EPA priority pollutants would be proposed for adoption.

Puerto Rico is included in today's proposal because although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, the State has not completed a review/revision of their numeric criteria for priority toxic pollutants in response to the statutory requirement and EPA has reason to believe that additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Puerto Rico adopted criteria for some priority pollutants prior to passage of section 303(c)(2)(B) on February 28, 1983 (Puerto Rico Water Quality Standards Regulation, as amended, promulgated by Environmental Quality Board Resolution Number R–83–5–2). Some of these criteria are not affected by today's proposed rulemaking.

Puerto Rico's actions to respond to the 1987 Section 303(c)(2)(B) requirement can be summarized as follows:

—March 15, 1990: The Commonwealth submitted draft water quality standards revisions to EPA for review prior to issuing proposed standards for public comment.

—May 2–3, 1990 and July 12–13, 1990: The Commonwealth held public hearings on its proposed water quality standards revisions.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the Commonwealth into full compliance with section 303(c)(2)(B). To fully protect Puerto Rico's designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate Commonwealth waters, the criteria in proposed § 231.36(b) for all priority toxic pollutants which are not the subject of approved Commonwealth criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved Commonwealth criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved Commonwealth criteria are not applicable to all appropriate Commonwealth designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect Puerto Rico's designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with Puerto Rico's designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the Commonwealth's section 304(l) short list for which appropriate state criteria have not been adopted and approved, including metals and organic compounds.

—The Commonwealth's efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The Commonwealth has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 9 priority toxic pollutants. These efforts represent evidence of the Commonwealth's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the Commonwealth's priority pollutants for which sufficient Commonwealth numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient Commonwealth numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

—Previously proposed revisions to Puerto Rico's Water Quality Standards Regulation indicating that numeric criteria for additional priority pollutants are necessary.

New York has not been included in today's proposed rulemaking because the State has water quality standards which meet the requirements of section 303(c)(2)(B). The State has met the requirements of section 303(c)(2)(B) of the Act through a combined Option 2 and Option 3 approach, as described in

EPA's December 12, 1988 guidance document.

State actions in response to the Clean Water Act requirement to adopt criteria may be summarized as follows:

—September 1985: The State adopted numeric criteria for 95 substances or classes of substances, including aquatic life and/or human health criteria. The State also adopted procedures, in regulation, for developing both aquatic life and human health based criteria. The procedures are used for developing the numeric criteria in the standards as well as for developing guidance values to be used for all purposes for which numeric criteria are used. The State has applied these procedures to develop aquatic life or human health based criteria for a total of 215 substances or classes of substances.

—September 30, 1985: EPA approved the State Water Quality Standards submittal.

—June 8, 1990: EPA approved State section 304(l) lists. No segments were included on the "short list" under Section 304(l) due to the presence of EPA priority pollutants for which the State did not have either a numeric criterion or derived guidance value.

—New York State had begun a triennial review prior to the 1987 amendments to the Clean Water Act. A notice of a public hearing and public information meetings was issued on May 25, 1990. The State has proposed the adoption of a limited number of aquatic life and human health based criteria for EPA priority pollutants. Public hearings and meetings were conducted in August 1990. A number of the proposed aquatic life and human based criteria were formerly included as guidance values. The State may be expected to convert additional guidance values during the next triennial review.

EPA approved the criteria for priority toxic pollutants adopted by New York on September 27, 1990, as being consistent with options 2 and 3 of the December 12, 1988 section 303(c)(2)(B) guidance document. In this letter, EPA directed the State to adequately address three issues: the need for greater public participation in the use of guidance values; the need for additional bioconcentration/bioaccumulation-based criteria and guidance values; and participation in the process to identify appropriate water quality criteria for use in developing TMDLs/WLAs for the waters of the New York/New Jersey Harbor Complex. EPA believes that the State has established standards which include or provide for the derivation of, numeric criteria for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses".

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

The U.S. Virgin Islands has not been included in today's rulemaking. No EPA priority pollutants have been identified as impairing designated uses in the U.S. Virgin Islands through water quality monitoring and assessment activities. Further, EPA believes that there are no priority toxic pollutants present or discharged to surface waters which "may reasonably be expected to interfere with designated uses."

The following information supports EPA's conclusion:

—June 4, 1989: The U.S. Virgin Islands submitted lists of impaired waters pursuant to section 304(l). No waters were included on the section 304(l) "short list." No EPA priority pollutants were identified as impairing uses on other section 304(l) lists.

—May 9, 1990: EPA approved section 304(l) lists submitted by the U.S. Virgin Islands.

EPA has determined that the Water Quality Standards of the U.S. Virgin Islands fully meet the requirements of CWA section 303(c)(2)(B).

If additional information is submitted during the public comment period asserting that the U.S. Virgin Islands has not fully complied with section 303(C)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 3

Virginia is included in today's proposal because although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, such criteria are not mandatory in application and, furthermore, the State has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirement. EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—September 29, 1987. The State Water Control Board adopted a resolution to adopt numerical criteria for toxic pollutants immediately after EPA issuance of CWA section 303(c)(2)(B) guidance.

—November 29, 1988. The State held a public meeting to receive comments on the adoption of criteria for toxic pollutants.

—December 30, 1988. EPA sent the State final "Guidance for State Implementation of Water Quality Standards for CWA section 303(c)(2)(B)."

—January 10, 1989. EPA submitted formal comments from the public meeting.

—October 23, 1989. Virginia requested EPA to submit recommendations for its triennial review.

—November 21, 1989. EPA responded to Virginia's request for triennial review recommendations.

—December 14, 1989. Virginia began public meetings to receive comments on issues to be included in the triennial review.

—February 12, 1990. Virginia began public hearings on a water quality standard for dioxin.

—February 16, 1990. EPA informed the State of EPA's intent to include the State in the national rule to promulgate numeric water quality criteria for priority toxic pollutants for those States which failed to meet the requirements of section 303(c)(2)(B).

—March 5, 1990. EPA submitted comments on Virginia's proposed dioxin standard.

—April 9, 1990. The EPA Assistant Administrator for the Office of Water informed the State that it was going to be included in a proposed national rule to establish numeric, surface water criteria for toxic pollutants designed to bring all States into full compliance with the requirements of section 303(c)(2)(B).

—July 25, 1990. Virginia began public hearings on proposed water quality standards, including criteria for toxics.

—August 7, 1990. EPA submitted comments on Virginia's proposed standards.

—August 17, 1990. Virginia reproposed changes to the water quality standards for public comment.

—September 14, 1990. EPA submitted comments on the revisions to the proposed water quality standards.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed section 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State section 304(l) short list for which mandatory State criteria have not been adopted and approved.

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has adopted a human health criterion for dioxin and has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 67 other priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

Delaware has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—December 30, 1988. EPA sent the State final "Guidance for State Implementation of Water Quality Standards for CWA Section 303(c)(2)(B)."

—November 18, 1988. First draft revisions to water quality standards, including toxics.

—January 25, 1989. Second draft revisions to water quality standards.

—March 1, 1989. Third draft revisions to standards.

—June 1, 1989. Workshop draft of water quality standards, including development documents.

—June 12, 1989. Delaware began public workshops on standards revisions.

—July 10, 1989. EPA provided preliminary comments on the workshop draft revisions.

—July 28, 1989. Delaware submitted revised standards for EPA review.

—September 6, 1989. Delaware held a public hearing on the triennial review revisions to the water quality standards.

—September 6, 1989. EPA provided comments at the public hearing.

—February 2, 1990. Delaware adopted revisions to the water quality standards.

—February 5, 1990. Delaware submitted revised standards to EPA.

—February 16, 1990. EPA informed the State of EPA's intent to include the State in the national rule to promulgate numeric water quality criteria for priority toxic pollutants for those States which failed to meet the requirements of section 303(c)(2)(B).

—March 13, 1990. Delaware completed a responsiveness summary for its standards review.

—March 21, 1990. Delaware's Attorney General certified the revised standards.

—April 9, 1990. The EPA Assistant Administrator for the Office of Water informed the State that it was going to be included in a proposed national rule to establish numeric, surface water criteria for toxic pollutants designed to bring all States into full compliance with the requirements of section 303(c)(2)(B).

—August 24, 1990. EPA approved Delaware's revised standards for toxics.

EPA fully approved the criteria for priority toxic pollutants adopted by Delaware on February 2, 1990 as being consistent with option 2 of the December 12, 1988 section 303(c)(2)(B) guidance document. As part of its submittal of revised standards for EPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Maryland has not been included in today's proposed rulemaking, because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(C)(2)(B) requirement and received Environmental Protection Agency (EPA) approval for the criteria portion of the water quality standards.

The State's response to the 1987 section 303(C)(2)(B) requirement can be summarized as follows:

—December 30, 1988. EPA sent the State final "Guidance for State Implementation of Water Quality Standards for CWA section 303(c)(2)(B)."

—February 16, 1990. EPA informed the State of EPA's intent to include the State in the national rule to promulgate numeric water quality criteria for priority toxic pollutants for those States which failed to meet the requirements of section 303(c)(2)(B).

—March 21, 1990. The State adopted revised water quality standards which included numeric criteria for priority toxic pollutants.

—April 9, 1990. The EPA Assistant Administrator for the Office of Water informed the State that it was going to be included in a proposed national rule to establish numeric, surface water criteria for toxic pollutants designed to bring all States into full compliance with the requirements of section 303(c)(2)(B).

—April 30, 1990. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.

—May 4, 1990. The State proposed in the Maryland Register to adopt maximum contaminant levels (MCLs) for selenium and silver as drinking water criteria, which corrects a printing error resulting in the criteria being placed in the wrong column in the regulations proposed on November 3, 1989.

—June 12, 1990. Maryland submitted for EPA review the public hearing record for the toxic substances regulations proposed November 3, 1989.

—September 12, 1990. EPA approved the revised State numeric criteria for priority toxic pollutants.

EPA approved the criteria for priority toxic pollutants adopted by Maryland on March 21, 1990, as being consistent with option 2 of the December 12, 1988 section 303(c)(2)(B) guidance document. As part of its submittal of final revised standards for EPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses".

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Pennsylvania has not been included in today's proposed rulemaking because the State has adopted a translator procedure to derive numeric criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA-approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—August 26, 1987. The State submitted to EPA a proposed list of issues to be addressed during the triennial water quality standards review.

—April 5, 1988. EPA submitted comments on the draft proposed revisions to the water quality standards.

—June 16, 1988. The State held a public hearing on its proposed water quality standards revisions, at which EPA provided verbal testimony.

—June 20, 1988. EPA submitted written comments to the State regarding the proposed water quality standards revisions.

—November 15, 1988. The State adopted revised water quality standards which included a translator procedure (option 3) for deriving numeric criteria for priority toxic pollutants.

—December 30, 1988. EPA sent the State final "Guidance for State Implementation of Water Quality Standards for CWA section 303(c)(2)(B)."

—April 17, 1989. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.

—July 21, 1989. EPA requested clarification on the enforceability of the procedure adopted to derive criteria for priority toxic pollutants.

—July 28, 1989. The State responded to EPA's clarification request.

—September 29, 1989. EPA conditionally approved the State's water quality standards due to concerns regarding the enforceability and public participation of the translator procedure and the derived criteria.

—November 15, 1989. The State responded to EPA's conditional approval.

—January 18, 1990. EPA requested additional clarification regarding the State's response to the conditional approval.

—February 16, 1990. EPA informed the State of EPA's intent to develop a national rule to promulgate numeric water quality criteria for priority toxic pollutants for those States which failed to meet the requirements of section 303(c)(2)(B).

—February 20, 1990. The State provided additional clarification, in response to EPA's January 18, 1990, letter.

—April 9, 1990. The EPA Assistant Administrator for the Office of Water informed the State that it was going to be included in a proposed national rule to establish numeric, surface water criteria for toxic pollutants designed to bring all States into full compliance with the requirements of section 303(c)(2)(B).

—April 11, 1990. EPA approved the translator procedure for developing criteria for priority toxic pollutants.

EPA fully approved the procedure for developing numeric criteria for priority toxic pollutants which was adopted by Pennsylvania on November 15, 1988 as being consistent with option 3 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

West Virginia has not been included in today's proposal because the State has adopted criteria for priority toxic pollutants in response to the statutory requirement and will receive full EPA approval by September 13, 1990.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—June 23, 1988. The State submitted a draft list of toxic pollutants for criteria development to EPA for review prior to issuing proposed standards for public comment.

—July 25, 1988. EPA provided written comments on the draft list of toxic pollutants for criteria development.

—September 12, 1988. The State held a public hearing on its proposed water quality standards revisions, at which EPA provided verbal testimony.

—September 21, 1988. EPA provided written comments on the proposed revisions to the water quality standards.

—October 18, 1988. The State submitted proposed revisions to EPA for review and approval.

—December 30, 1988. EPA sent the State final "Guidance for State Implementation of Water Quality Standards for CWA section 303(c)(2)(B)."

—April 27, 1989. The State adopted final revisions to the water quality standards.

—September 29, 1989. EPA disapproved criteria for seven priority pollutants. Aquatic life criteria were disapproved for arsenic, cadmium, mercury, nickel, lead, selenium, and silver. Human health criteria were disapproved for arsenic, mercury and nickel. In addition, EPA disapproved site-specific toxics criteria (cyanide, hexavalent chromium, and copper) for two waterbody segments (Little Scary Creek and Turkey Run).

—November 13, 1989. The State responded to EPA's disapproval of the final revisions to the water quality standards.

—January 30, 1990. The State sent a letter to EPA which stated that the permittee discharging to Turkey Run was relocating its outfall to another water body.

—January 31, 1990. EPA responded to the State's November 13, 1989 reply to EPA's disapproval of the water quality standards revisions.

—February 16, 1990. EPA informed the State of EPA's intent to develop a national rule to promulgate numeric water quality criteria for priority toxic pollutants for those States which failed to meet the requirements of section 303(c)(2)(B).

—March 12, 1990. EPA granted the State an extension to address EPA's disapproval.

—April 9, 1990. The EPA Assistant Administrator for the Office of Water informed the State that it was going to be included in a proposed national rule to establish numeric, surface water criteria for toxic pollutants designed to bring all States into full compliance with the requirements of section 303(c)(2)(B).

—April 1990. The State submitted rejustification for a disapproved site-specific criterion for copper.

—June 13, 1990. The State submitted emergency revisions to the water quality standards to address EPA's disapproval.

—July 16, 1990. The State held a public hearing on its emergency rulemaking, at which EPA provided verbal testimony.

—July 25, 1990. The State submitted comments received on the standards revisions by industrial representatives and requested EPA's reaction to the comments.

—July 27, 1990. EPA held a conference call with the State and discharger to Little Scary Creek to discuss the site-specific copper criteria rejustification submitted in April, 1990.

—August 2, 1990. EPA sent the State recommended revised site-specific copper criteria for Little Scary Creek.

—August 13, 1990. EPA replied to the State's July 25, 1990 request to respond to comments received by industrial representatives.

—August 20, 1990. The State adopted final emergency revisions to the water quality standards to address EPA's remaining concerns.

—August 27, 1990. The State submitted the adopted final emergency revisions to the water quality standards with a State Attorney General certification to EPA for approval/ disapproval.

—September 18, 1990. EPA fully approved the State's revised State water quality standards, including full approval of the revised numeric criteria for priority toxic pollutants.

EPA fully approved the criteria for priority toxic pollutants adopted by West Virginia on August 20, 1990 as being consistent with option 2 of the December 12, 1988 section 303(c)(2)(B) guidance document. As part of its submittal of final revised standards for EPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

The District of Columbia is included in today's proposal because although the District adopted numeric criteria for most priority toxic pollutants before the 1987 amendments, the District has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirement, and EPA has reason to believe that at least some additional criteria are necessary and some criteria need to be revised to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the District is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

On August 26, 1985, prior to the passage of section 303(c)(2)(B), the District of Columbia adopted under emergency powers some criteria for priority toxic pollutants, chapter 11 of title 21 DCMR, "Water Quality Standards of the District of Columbia." EPA approved these criteria on October 31, 1985. The District made the emergency rules final on December 27, 1985.

The District's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—August 26, 1988. EPA sent comments to the District as to what issues should be addressed for the upcoming triennial water quality standards review.

—December 30, 1988. EPA sent the State final "Guidance for State Implementation of Water Quality Standards for CWA section 303(c)(2)(B)."

—February 15, 1989. The District submitted draft water quality standards revisions to EPA for review prior to issuing proposed standards for public comment.

—May 30, 1989. EPA sent the District a letter which emphasized the need for expediting the triennial water quality standards review.

—June 26, 1989. The District submitted proposed water quality standards revisions to EPA for review.

—July 5, 1989. The District held a public hearing on the proposed water quality standards revisions.

—September 15, 1989. The District submitted revised proposed water quality standards revisions to EPA for review.

—September 25, 1989. EPA submitted comments on the proposed water quality standards revisions and indicated that the District must adopt human health criteria for the consumption of fish.

—October 3, 1989. The District responded to EPA's comments.

—November 3, 1989. EPA provided additional comments on the proposed water quality standards revisions.

—December 11, 1989. EPA telephoned the District to inquire about a response to EPA's November 3, 1989, letter and the status of the water quality standards revisions.

—February 16, 1990. EPA informed the District of EPA's intent to develop a national rule to promulgate numeric water quality criteria for priority toxic pollutants for those States which failed to meet the requirements of section 303(c)(2)(B).

—April 9, 1990. The EPA Assistant Administrator for the Office of Water informed the State that it was going to be included in a proposed national rule to establish numeric, surface water criteria for toxic pollutants designed to bring all States into full compliance with the requirements of section 303(c)(2)(B).

—September 7, 1990. The District public noticed for comment proposed water quality standards revisions.

—October 5, 1990. EPA submitted comments on the proposed water quality standards revisions.

The District has adopted aquatic life criteria for 120 priority toxic pollutants and human health criteria for 107 priority toxic pollutants. The aquatic life criteria for two of the pollutants (selenium and toxaphene) and the human health criterion for one of the pollutants (hexachlorobenzene) exceed EPA's section 304(a)(1) criteria recommendations. Therefore, EPA believes that revised criteria for these pollutants are necessary. The District did not adopt human health criteria applicable to public water supplies for nine priority toxic pollutants (lead, asbestos, 2,3,7,8-tetrachlorodibenzo-p-dioxin, vinyl chloride, bis(2-chloroisopropyl) ether, bis(2-ethylhexyl) phthalate, diethyl phthalate, dimethyl phthalate, and di-n-butyl phthalate) and has not provided justification that the discharge or presence of these pollutants cannot reasonably be expected to interfere with designated uses in the District's surface waters. Therefore, EPA believes that human health criteria for the consumption of water are necessary for these pollutants.

The District has not adopted any criteria for the protection of humans from the consumption of fish. Since the District's 1989 State Clean Water Strategy identifies that fishing does occur on District waters, EPA believes it is necessary to propose human health criteria for fish consumption for all priority toxic pollutants for which EPA has issued section 304(a)(1) criteria recommendations.

This proposed rulemaking would federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 12 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient numeric criteria have not been adopted, based on surface water monitoring data in STORET.

Region 4

Alabama has not been included in today's proposed rulemaking because the State has adopted criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—January 24, 1990. The Alabama Environmental Management Commission adopted the triennial review of water quality standards.

—May 23, 1990. The State Attorney General notified EPA that the adopted water quality standards would not be certified.

—June 1, 1990. The State sent EPA a copy of the revised standards without a request for formal EPA review and approval.

—November 26, 1990. The State submitted draft water quality standards revisions for EPA review. These revisions include: (1) Criteria for protection of aquatic life based on an Option I approach as described in EPA's December 12, 1988 guidance document, (2) numeric criteria for protection of human health for 17 priority toxic pollutants based on Option II of the guidance, and (3) proposed criteria equations based on Option III of the guidance for the protection of human health for the remaining priority toxic pollutants.

—January 17, 1991. The State held public hearings on the proposed revisions to water quality standards.

—February 20, 1991. The State adopted revisions to water quality standards including the numeric criteria for priority toxic pollutant based on an Option I approach as described in EPA's December 12, 1988 guidance document.

—April 18, 1991. EPA received the State's request for formal review of the adopted water quality standards.

—May 24, 1991. The State Attorney General submitted information relating to the legal certification of the adopted water quality standards.

—July 3, 1991. The State Attorney General submitted further information relating to the legal certification of the adopted water quality standards.

—July 18, 1991. EPA approved the revised State water quality standards.

EPA fully approved the criteria for priority toxic pollutants adopted by Alabama on July 18, 1991 as being consistent with Option I of the December 12, 1988 guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Florida is included in today's proposal because although the State has adopted numeric criteria for priority toxic pollutants in response to the statutory requirement, the State has not yet requested or obtained EPA approval of the adopted criteria. In addition, EPA has reason to believe that criteria for at least one other priority toxic pollutant is necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

On September 24, 1987 EPA approved the previous triennial review of Florida Water quality standards with the exception of three areas of the water quality standards which were disapproved. Included in the water quality standards which were approved by EPA were several numeric criteria for toxic priority pollutants derived for the protection of aquatic life. These criteria were initially adopted by the State as water quality standards in adoption proceedings prior to 1985. These criteria were not revised in the State's triennial review completed in 1987.

These criteria included criteria values which are less stringent in value than several of the national ambient water quality criteria included in the proposed rulemaking. Data used to develop the national ambient water quality criteria were not available for consideration by the State at the time of the initial adoption of these criteria by the State.

In the letter approving revisions to water quality standards, EPA instructed the State "to initiate a review of existing criteria at the earliest possible date." This review was necessary to address the 1987 requirements of section 303(c)(2)(B) for adoption of numeric criteria for toxic priority pollutants.

In directing the State to complete this review, EPA stated, "Recent changes in federal law relating to water quality standards will make it necessary for the State to complete an extensive review of water quality criteria during the next triennial review of water quality standards. The Water Quality Act of 1987 mandates that each state adopt numerical criteria for all 307(a) toxics for which national criteria are available or adopt procedures which will result in numeric limitations in National Pollutant Discharge Elimination System permits for these contaminants.

Considering the above, EPA is including the national ambient aquatic life-based water quality criteria values for these toxic priority pollutants in this proposed rulemaking.

In addition, the criteria adopted by the State in 1990 for the protection of human health have not been formally submitted and certified to EPA with a request for approval. Therefore, EPA is including all national ambient water quality criteria for protection of human health (as a class of criteria).

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—December 27, 1989. The State submitted draft water quality standards revisions to EPA for review. These revisions include proposed criteria for protection of human health based on an Option II approach as described in EPA's December 12, 1988 guidance document as well as updates to adopted criteria for protection of aquatic life.

—February 7 and May 1, 1990. The State held public workshops on its proposed water quality standards revisions.

—December 7, 1990. The State adopted revisions to water quality standards which include 66 numeric criteria for priority toxic pollutants.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed section 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—priority toxic pollutants on the section 304(1) lists;

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has adopted new or revised chemical-specific, numeric criteria for 66 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Priority toxic pollutants for which there exist water quality-based limits in an NPDES permit or where NPDES permit screening shows that the Federal 304(a) criteria may be exceeded instream;

—Priority toxic pollutant ambient monitoring data or site specific data which show that the Federal 304(a) criteria in the water column or in fish tissue may be exceeded;

—Priority toxic pollutant data in the Toxics Release Inventory under section 313 of SARA title III or in the National Bioaccumulation Study which show that the Federal 304(a) criteria in the water column or in fish tissue may be exceeded;

—Priority toxic pollutant data for which there are reasonable expectations that the Federal 304(a) criteria will be exceeded in the water column or fish tissue as a result of impacts from Superfund or RCRA sites; and

—Consideration of other data such as sediment data and location of storage facilities of priority toxic pollutants where these pollutants could reasonably be expected to interfere with designated uses.

Georgia has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 Section 303(c)(2)(B) requirement can be summarized as follows:

—December 7, 1988. The State adopted revisions to water quality standards which included 12 criteria for 307(a) toxics.

—December 8, 1988. The State submitted the adopted revisions to water quality standards for review and approval.

—March 29, 1989. EPA disapproved the adopted 307(a) criteria adopted by the State.

—December 6, 1989. The State adopted water quality standards which included an Option I approach for the section 303(c)(2)(B) requirement with the exception of 2,3,7,8 TCDD (dioxin) and PCBs.

—December 14, 1989. The State submitted the adopted revisions to water quality standards for review and approval.

—March 28, 1990. The State adopted water quality criteria for dioxin and PCBs.

—April 3, 1990. EPA approved the priority toxic pollutant criteria adopted by the State on December 6, 1989.

—May 29, 1990. The State submitted the adopted criteria for dioxin and PCBs for EPA review and approval.

—October 29, 1990. The State submitted draft revisions to water quality standards including revised criteria for dioxin.

—November 27, 1990. EPA disapproved the adopted criteria for dioxin and approved the adopted criteria for PCBs.

—January 23, 1991. The State adopted revised criteria for dioxin.
—April 2, 1991. The State submitted the revised water quality standard for dioxin with a State Attorney General certification to EPA for approval.
—June 3, 1991. EPA approved the dioxin criteria, thus bringing the State into full compliance with section 303(c)(2)(B).

EPA fully approved the criteria for priority toxic pollutants on June 3, 1991 as being consistent with Option 1 of the December 12, 1988 guidance.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Kentucky has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—May 31, 1990. The State adopted revised water quality standards which included numeric criteria for priority toxic pollutants based on Option I approach for the section 303(c)(2)(B) requirement.
—June 29, 1990. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval.
—October 5, 1990. EPA approved the revised State water quality standards, including full approval of the revised numeric criteria for priority toxic pollutants.

EPA fully approved the criteria for priority toxic pollutants adopted by Kentucky on October 5, 1990 as being consistent with Option I of the December 12, 1988 guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Mississippi has not been included in today's proposed rulemaking because the State has adopted criteria for priority toxic pollutants in response to the section 303(c)(2(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—March 22, 1990. The State adopted revisions to water quality standards in response to the section 303(C)(2)(B) requirement. The adopted revisions did not include criteria for dioxin.
—May 14, 1990. The State submitted the adopted revisions to water quality standards for review and approval.
—October 5, 1990. EPA approved the water quality criteria adopted by the State with the exception of the absence of criteria for dioxin, which was disapproved.
—January 29, 30 and 31, 1991. The State held public hearings to receive comments on the proposed dioxin criteria.
—March 28, 1991. The State adopted dioxin criteria of 1.0 ppq for protection of human health from the exposure routes of consumption of fish and shellfish and consumption of water.
—July 12, 1991. The State submitted the adopted dioxin criteria for EPA review and approval.
—July 15, 1991. The State submitted the adopted dioxin criteria for EPA review and approval.
—July 24, 1991. EPA approved the State-adopted water quality criteria for dioxin.

EPA fully approved the criteria for priority toxic pollutants adopted by Mississippi on July 24, 1991, as being consistent with Options I and III of the December 12, 1988 guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

North Carolina has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—July 13, 1989. The State adopted revisions to water quality standards in response to the section 303(C)(2)(B) requirement.
—October 27, 1989. The State submitted the adopted revisions to water quality standards for review and approval.
—April 12, 1990. EPA approved the water quality criteria adopted by the State with the exception of the criteria for arsenic (saltwater), chromium (freshwater), copper, lead, pentachlorophenol and zinc.
—October 5, 1990. EPA approved the adopted criteria for chromium (freshwater) and decided that no criteria were required for pentachlorophenol to meet the 303(c)(2)(B) requirement. In addition, EPA conditionally approved the criteria for arsenic (saltwater), copper, lead and zinc based on a commitment by the State that revisions to these criteria would be adopted by the State by December 13, 1990.
—December 13, 1990. The State adopted revised criteria for arsenic, copper, chromium, lead and zinc.
—January 18, 1991. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval.
—February 7, 1991. EPA approved the revised North Carolina water quality standards, including full approval of the revised criteria for priority toxic pollutants.

On February 7, 1991, EPA fully approved the criteria for priority toxic pollutants adopted by North Carolina as being consistent with Options II and III of the December 12, 1988 guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

South Carolina has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—April 27, 1990. The State Legislature adopted revisions to water quality standards in response to the section 303(c)(2)(B) requirement.
—May 26, 1990. The State submitted the adopted revisions to water quality standards for review and approval.
—June 14, 1990. The State submitted for EPA review draft water quality standards revisions including numeric human health-based criteria based on Option I of the December 12, 1988 guidance document.
—August 1 and 2, 1990. The State held public hearings on proposed revisions to water quality standards which included 103 water quality criteria for protection of human health.
—October 5, 1990. EPA approved the water quality criteria adopted by the State with the exception of the criteria for protection of human health as a

class of criteria. The human health criteria for arsenic and lead were approved by EPA.

—October 11, 1990. The South Carolina Board of Health and Environmental Control promulgated the proposed revisions to water quality standards which included 103 criteria for the protection of human health.

—December 7, 1990. Promulgation by the Board of the South Carolina Department of Health and Environmental Control.

—March 13, 1991. Attorney General certification made.

—April 26, 1991. Revisions to South Carolina Water Classifications and Standards, Regulation 61–68, pertaining to numeric human health criteria for Clean Water Action section 307(a) toxics became effective upon publication in the State Register.

—May 8, 1991. The State submitted the adopted human health criteria for EPA review and approval.

—July 9, 1991. EPA approved the adopted standards, thus bringing the State into full compliance with section 303(c)(2)(B).

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Tennessee has not been included in today's proposed rulemaking because the State has adopted criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—May 1, 1989. The State submitted draft water quality standards revisions to EPA for review.

—December 15, 1989. The State submitted draft water quality standards revisions to EPA for review. The proposal included revisions to the draft water quality standards based on comments made by EPA and the public.

—December 15, 1989. The State held a public hearing on proposed revisions to water quality standards.

—July 30, 1990. The State submitted draft water quality standards revisions to EPA for review. The proposal included revisions to the draft water quality standards based on comments made by EPA and the public.

—November 15, 1990. The State held a second public hearing on proposed revisions to the water quality standards.

—January 17, 1991. The State adopted revised water quality standards which included numeric criteria for priority toxic pollutants based on Option II of EPA's December 12, 1988 guidance.

—August 14, 1991. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval.

—September 28, 1991. EPA approved the revised State water quality standard, including full approval of the criteria for toxic pollutants.

EPA fully approved the criteria for toxic pollutants adopted by Tennessee on September 28, 1991 as being consistent with Option II of the December 12, 1988 guidance.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 5

Wisconsin has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—February 1987. The Natural Resources Board authorized public hearings on Chapter NR 105.

—December 1987. The Natural Resources Board authorized public hearings on Chapter NR 106.

—Thirteen public hearings were held on the water quality standards revisions in 1987 and 1988.

—November 17, 1988 and December 15, 1988. The State adopted revised water quality standards (Chapter NR 106 and Chapter NR 105, respectively) which included numeric criteria for priority pollutants.

—February 3, 1989. Wisconsin Department of Natural Resources submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.

—March 1, 1989. Water quality standards became effective.

—May 15, 1989. USEPA approved the revised State water quality standards, including full approval of the revised numeric criteria for priority toxic pollutants.

USEPA fully approved the criteria for priority toxic pollutants adopted by Wisconsin on November 17 and December 15, 1988 as being consistent with option 2 of the December 12, 1988 section 303(c)(2)(B) guidance document As part of its submittal of final revised standards for USEPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Illinois has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—January 25, 1990. The State adopted revised water quality standards which included criteria for priority toxic pollutants.

—February 2, 1990. The State submitted the adopted water quality standards with a State Attorney General certification to USEPA for approval/disapproval.

—February 13, 1990. Water quality standards rules became effective.

—February 15, 1990. USEPA approved the revised water quality standards (Docket A), including full approval of the revised criteria for priority pollutants.

USEPA fully approved the criteria for priority toxic pollutants adopted by Illinois on January 25, 1990 as being consistent with a combination of options 2 and 3 of the December 12, 1988 section 303(c)(2)(B) guidance document. As part of its submittal of final revised standards for USEPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the

Agency's determination of full compliance.

Indiana has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—March 1, 2, and 7, 1989. The State conducted public hearings for the water quality standards rules revisions.

—December 13, 1989. The State adopted revised water quality standards which included criteria for priority toxic pollutants. The Governor signed the revised standards on January 31, 1990.

—March 3, 1990. Water quality standards rules became effective.

—April 5, 1990. The State submitted the adopted water quality standards with a State Attorney General certification to USEPA for approval/disapproval.

—May 7, 1990. USEPA approved the revised water quality standards including full approval of the revised numeric criteria for priority pollutants.

USEPA fully approved the criteria for priority toxic pollutants adopted by Indiana on December 15, 1989 as being consistent with a combination of options 2 and 3 of the December 12, 1988 section 303(c)(2)(B) guidance document. As part of its submittal of final revised standards for USEPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Ohio has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—November 28, 29 and 30, 1989. Ohio EPA conducted public hearings addressing water quality standards revisions.

—December 18, 1989 Public record closed.

—February 1, 1990. The State adopted revised water quality standards which included criteria for priority toxic pollutants.

—February 12, 1990. The State submitted the adopted water quality standards to USEPA for approval/disapproval.

—March 13, 1990. The State submitted the required Attorney General certification of the water quality standards.

—April 25, 1990. USEPA approved the revised water quality standards including full approval of the revised numeric criteria for priority pollutants.

—May 1, 1990. Water quality standards rules became effective.

USEPA fully approved the criteria for priority toxic pollutants adopted by Ohio on February 1, 1990 as being consistent with a combination of options 2 and 3 of the December 12, 1988 section 303(c)(2)(B) guidance document. As part of its submittal of final revised standards for USEPA review, the State included information which demonstrated that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Michigan is included in today's proposal because although the State adopted criteria for priority pollutants before the 1987 amendments, the State has not completed a review of their criteria for priority toxic pollutants in response to the statutory requirement and USEPA has reason to believe that modification of the water quality standards is necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Michigan adopted criteria for priority toxic pollutants consistent with option 3 of the December 12, 1988 section 303(c)(2)(B) guidance document prior to actual passage of section 303(c)(2)(B) on November 14, 1986 (General Rules of the Michigan Water Resources Commission, Part 4, Water Quality Standards, R 323 of the Michigan Administrative Code). USEPA approved these criteria on August 4, 1987. However, the translator mechanism guidelines implementing Rule 57 were not included within the water quality standards regulation itself and, therefore, the criteria calculated through the implementation of this procedure were not binding upon the Water Resources Commission but instead are considered to be recommendations to the Commission. The State's efforts in response to section 303(c)(2)(B) have consisted of bringing the existing option 3 procedure within Rule 57 itself, thereby making implementation of the procedure-generated criteria in permits mandatory.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—July 21, 1988. MDNR staff presented and the Michigan Water Resources Commission approved a proposed water quality standards review process and schedule.

—August, September and October 1988. Informal public comment on requests for changes in the water quality standards taken in Water Resources Commission meetings at Houghton, Lansing and Tawas, Michigan, respectively.

—February 28, 1989. Scoping session held by MDNR staff with interested parties prior to development of water quality standards package.

—August 20, 1989. Draft proposed water quality standards package as presented to the Commission and was approved for informal public comment through September 29, 1989.

—October 20, 1989. Staff presented a draft proposed standards package to the Commission which the Commission approved for formal public hearings.

—December 31, 1989. The proposed water quality standards were published in the November, 1989 Michigan Register along with a Notice of Public Hearing.

—February 20, 21 and 22, 1990. Public Hearings on the proposed standards were held in Lansing, Traverse City and Marquette, respectively.

—April 2, 1990. Public comment period ended.

—May 1990. Water Resources Commission approved revised water quality standards.

—September 1990. Revised water quality standards are to go before Joint Committee on Administrative Rules (JCAR) for approval/disapproval. The JCAR dropped this item from its agenda and did not address it during 1990. The Michigan

DNR has again submitted the existing revisions to JCAR for its review during February 1991.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the Michigan Section 304(l) short list (February 3, 1989) for which State criteria consistent with Section 303(c)(2)(B) have not been adopted and approved, including metals, dioxin, and polynuclear aromatic hydrocarbons.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

—1990 Michigan 305(b) Report.

—Current implementation of Michigan's Rule 57 in the State's NPDES program (e.g., Form 2c data, presence of water quality-based effluent controls in existing NPDES permits).

Minnesota has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—December 1989. Minnesota Pollution Control Agency begins rulemaking proceedings on amendments to Minnesota Rules Chapter 7050.

—February 1 to March 16, 1990. Minnesota Pollution Control Agency holds nine public hearings addressing the revised standards.

—April 10, 1990. Public record for the standards revisions closed.

—May 10, 1990. Administrative Law Judge issued his report on the standards revisions.

—June 25, 1990. Minnesota Pollution Control Agency staff met with the Minnesota Pollution Control Agency Board—Water Quality Committee to discuss standards revision issues.

—July 24, 1990. Board approved and adopted the standards revisions.

—July 16, 1991. EPA approved the revised Minnesota water quality standards, including full approval of the revised criteria for priority toxic pollutants.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 6

Arkansas is included in today's proposal because although the State has completed a review and adopted numeric criteria for some priority toxic pollutants in response to the statutory requirement, EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Arkansas adopted some criteria for priority pollutants on November 1984 and January 1988. EPA approved these criteria on 1/28/85 and 5/6/88 and these criteria are not affected by today's rulemaking.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—November 1984. The State adopted revised water quality standards that included numeric criteria for 16 toxic substances to protect aquatic life. These were approved by EPA on January 28, 1985.

—January 1988. The State adopted revised water quality standards that included numeric criteria for 24 priority pollutants to protect aquatic life. These were approved by EPA on May 6, 1988.

—July 27, 1990. The State proposed revised water quality standards that included numeric criteria for 36 priority pollutants to protect aquatic life and for 13 priority pollutants to protect human health at a 10-6 risk.

—August 27, 1990. The State held a public hearing to receive public comment on the proposed revisions mentioned above.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). A list of the pollutants requiring criteria was included in letters to the State dated February 15, 1990 and June 11, 1990 (copies are contained in the record). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State section 304(l) short list for which State criteria consistent with Section 303(c)(2)(B) have not been adopted and approved,
—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 7 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.
—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET and the National Bioaccumulation Study.
—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

Louisiana is included in today's proposal because although the State has adopted criteria for some priority toxic pollutants in response to the statutory requirement, EPA disapproved the lack of criteria for dioxin and has reason to believe that some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with Section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

The State completed a triennial revision of its water quality standards since passage of the Clean Water Act (CWA) section 303(c)(2)(B) and adopted revised standards on September 20, 1989. The revised numeric criteria were approved by EPA on December 19, 1989 with the exception of dioxin (no criterion proposed). Since this revision, a review of several databases—STORET, TRI, State 305(b) reports, and NPS assessments—indicated the need for Louisiana to adopt additional numeric criteria for mercury, lead, cadmium, copper and nickel via an Option 2 approach.

On March 20, 1991 the State adopted numeric criteria for 5 metals (cadmium, copper, lead, mercury and nickel). EPA received these revisions for our review on June 20, 1991.

Today's rule would only promulgate numeric criteria for dioxin and the metals listed above. Criteria approved on December 19, 1989 by EPA are not affected by today's proposed rulemaking.

New Mexico has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—June 6, 1988. The State proposed revised water quality standards that included numeric criteria for 11 priority pollutants to protect aquatic life. Additionally, the State proposed a narrative statement about protecting against toxic substances in domestic water supplies that create more than a 10–5 cancer risk.
—June 13, 1990. The State held a public hearing to receive public comment on the proposed revisions mentioned above.
—May 22, 1991. The State adopted numeric criteria for 14 priority pollutants. EPA received these revisions for our review on June 7, 1991.
—August 19, 1991. EPA approved the revised New Mexico water quality standards, including full approval of the revised criteria for priority toxic pollutants.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Oklahoma has not been included in today's proposed rulemaking because the State has adopted criteria for priority pollutants in response to the section 303(c)(2)(B) requirement and received full approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—June 10, 1989. The State adopted revised water quality standards which included numeric criteria for priority toxic pollutants.
—November 1, 1989. The State submitted the adopted water quality standards with a State Attorney General's certification to EPA for approval/disapproval.
—January 18, 1990. EPA approved the revised State water quality standards, including full approval of the numeric criteria for priority toxic pollutants.

EPA fully approved the criteria for priority toxic pollutants adopted by Oklahoma on June 10, 1989 as being consistent with Option 1 for aquatic life criteria and Option 2 for human health criteria as described in the December 12, 1988 section 303(c)(3)(B) guidance document. EPA's review concluded that numeric criteria had been adopted for all priority toxic pollutants which "may reasonably be expected to interfere with designated uses."

If additional information is submitted during the public comment period asserting that the State is not in compliance with section 303(c)(2)(B), EPA will transmit these comments to Oklahoma and will reevaluate the Agency's determination of full compliance after Oklahoma's submittal of their 1992 revised water quality standards to EPA for our approval/disapproval.

Texas has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—April 7, 1988. The State adopted revised water quality standards that included numeric criteria for 30 toxic

substances to protect aquatic life. The numeric criteria adopted for mercury protected human health in addition to aquatic life.
—June 29, 1985. EPA approved the aquatic life criteria for 30 priority toxic pollutants and the human health criterion for mercury.
—December 24, 1990. The State issued proposed water quality standards revisions for public comment. The proposed revisions included numeric criteria for 29 priority pollutants.
—February 25, 1991. The State held a public hearing on the proposed revisions to the water quality standards mentioned above.
—June 12, 1991. The State adopted numeric criteria for 29 priority pollutants. EPA received these revisions for our review on July 1, 1991.
—September 25, 1991. EPA approved the revised Texas water quality standards, including full approval of the revised criteria for priority toxic pollutants.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 7

Iowa has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—March 19, 1990—The Iowa Environmental Protection Commission adopted aquatic life use protection criteria for several priority toxic pollutants.
—April 9, 1990—The State submitted the adopted aquatic life criteria to EPA with a proposed effective date of May 23, 1990.
—May 3, 1990—The State submitted draft human health criteria to EPA.
—June 1, 1990—The State resubmitted draft human health criteria to EPA.
—July 11, 1990—The State published a notice of intended action concerning standards revisions for human health criteria and scheduled public hearings
—August 1, 2, and 7, 1990—The State held public hearings at three locations in the State.
—September 17, 1990—The State scheduled adoption by the Environmental Protection Commission for October 15, 1990.
—December 19, 1990. Standards become effective.
—June 11, 1991. EPA approved the revised State water quality standards as satisfying the requirement of section 303(c)(2)(B).

EPA fully approved the criteria for priority toxic pollutants adopted by Iowa on June 11, 1991, as being consistent with Option 1 of the December 12, 1988 guidance.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

EPA has withheld approval of the aquatic life criteria revisions until the State completes and submits all of the revisions and documentation necessary under section 303 (c)(2)(B).

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State section 304 (l) short list including metals for which revised state criteria have not been adopted and approved.
—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for ____ priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.
—Regional Ambient Fish Tissue Monitoring data indicating elevated fish flesh concentrations of pesticides which are not currently covered with approved state criteria.
—STORET data indicating the presence in surface waters of priority toxic pollutants which are not currently covered with approved state criteria.

Kansas is included in today's proposal because although the state adopted numeric criteria for a few priority toxic pollution before the 1987 amendments, the state has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirements and the Environmental Protection Agency (EPA) has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Kansas adopted some criteria for priority toxic pollutants prior to the passage of section 303(c)(2)(B) on May 1, 1986 (State Regulation K.A.R. 28–16–28e). EPA approved these criteria on June 19, 1986, and most of these criteria are not affected by today's proposed rulemaking. (Those not affected are aquatic life criteria for nickel, silver, zinc, aldrin, chlordane, DDT, dieldrin, endosulfan, endrin, heptachlor, lindane, and PCBs).

The state's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—January 1990—The state submitted a preliminary draft of numeric criteria for EPA prior to starting an internal and external review of water quality standards revisions.
—July 1990—The state stopped all action on the standards revisions citing concerns over the costs of compliance.
—January 1991—The state submitted a draft package of standards revisions to EPA including numeric criteria to satisfy section 303(c)(2)(B) and set a date of June 1991 for final adoption.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the state section 304(1) short and mini lists for which State criteria have not been adopted and approved, including metals.
—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for ___ priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.
—STORET data indicating the presence in surface water of priority toxic pollutants which are not currently covered with approved state criteria.

Missouri has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—March 17, 1989—Missouri Clean Water Commission adopted additional numeric criteria for priority toxic pollutants for aquatic life use protection.
—April 15, 1989—The adopted criteria became effective under State law.
—October 13, 1989—EPA approved criteria with a recommendation that Missouri review the need for additional human health criteria.
—August 6, 1990—The State held a public meeting to discuss human health criteria revisions.
—August 23, 1990—The State scheduled a public hearing and adoption before the Missouri Clean Water Commission for October 23, 1990.
—December 12, 1990. Clean Water Commission adopts water quality standards.
—January 30, 1991. Standards sumbitted to EPA for review.
—March 4, 1991. Standards become effective in State.
—June 11, 1991. EPA approves standards as complying with section 303(c)(2)(B).

EPA fully approved the criteria for priority toxic pollutants adopted by Missouri on June 11, 1991 as being consistent with Option 1 of the December 12, 1988 guidance.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Nebraska has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—May 20, 1988—The state adopted numeric criteria for aquatic life protection for priority toxic pollutants.
—August 29, 1988—The adopted criteria became effective under state law.
—October 18, 1988—EPA approved Nebraska's Water Quality Standards noting that the need for additional human health criteria must be evaluated.
—December 1, 1989—The state adopted some numeric priority toxic pollutant criteria for a human health use (drinking water supply).
—February 20, 1990—The adopted criteria became effective under state law.
—January 17, 1990—DEC proposed human health fish consumption criteria for priority toxic pollutants.
—February 16, 1990—The state adopted the proposed human health fish consumption numeric criteria.
—June 27, 1990—The human health fish consumption numeric criteria became effective under state law.
—August 10, 1990—The state proposed revisions to mixing zone provisions of State Water Quality Standards which affect the application of numeric criteria.
—September 21, 1990—The state adopted proposed revisions to mixing zone policies.
—August 2, 1991. EPA approved the revised Nebraska water quality standards, including full approval of the revised criteria for priority toxic pollutants.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 8

Colorado is included in today's proposal because, although Colorado has completed a review and adopted numeric criteria for some priority toxic pollutants in response to the statutory requirement, EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Colorado's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—June 5, 1989—Region VIII notified the State that the priority pollutant standards under consideration for adoption would not fully satisfy the requirements of section 303(c)(2)(B).

—August 17, 1989—Colorado completed its triennial review and revised the State's Basic Standards and Methodologies. The revised Standards were submitted to EPA for review on October 6, 1989. The revised Basic Standards and Methodologies included new numeric criteria for some of the priority toxic pollutants; however, not all of the priority toxic pollutants for which EPA has developed 304(a) criteria were included in the revised State rule.

—January 17, 1990—Region VIII sent a letter to the State explaining the requirements for full compliance with section 303(c)(2)(B). The letter explained that where a State selected an option 2 approach to full compliance (i.e., option 2 as described in EPA's December 12, 1988 guidance and the Region's January 17, 1990 letter to the State), the burden was on the State to demonstrate that additional criteria beyond those already adopted were not needed.

—February 5, 1990—In a letter from the Colorado Water Quality Control Division to EPA Region VIII, Colorado notified EPA that it intended to meet the full compliance requirements by way of option 2. To date, however, the documentation supporting full compliance with option 2 has not been received.

—July 9, 1990—Region VIII sent a letter to the State commenting on what the Region considered to be needed revisions to the State's Basic Standards and Methodologies. In the letter, the Region again advised the State that the current toxics provisions of the Basic Standards and Methodologies were incomplete and subject to the federal promulgation. The letter explained the Agency's approach to the upcoming promulgation, and the proposed regulatory language and criteria values to be promulgated were enclosed for State review.

—July 12, 1990—In a memorandum to the State, Region VIII provided additional information on compliance with the toxic requirements and the upcoming federal promulgation. The memorandum included a listing of EPA published and modified toxics criteria which could be used in proposing needed amendments to the existing toxics provisions in the Basic Standards and Methodologies (modified criteria were based on the most recent information in IRIS).

—August 13, 1990—Region VIII sent an improved version of the toxics criteria chart to the State staff.

—September 19, 1990. Region VIII sent to the State a "strawman" data analysis which provided stream-specific information regarding the priority toxic pollutants that may require adoption of criteria to satisfy the option 2 full compliance requirements of section 303(c)(2)(B).

—February 21, 1991. The State proposed amendments to the Basic Standards and Methodologies for its July triennial review hearing. The proposed amendments include: (1) Revisions and additions to the existing aquatic life criteria, and (2) application of EPA's human health criteria to all class 1 waters and any class 2 waters which provide an exposure pathway via consumption of contaminated aquatic organisms and/or drinking water.

—May 21, 1991. Region VIII sent a letter to the State detailing three deficiencies in the State's February 21, 1991 proposed revisions to the Basic Standards and Methodologies: (1) Failure to explain why health-based standards applicable to water supply segments were not included for more than 40 priority toxic pollutants addressed by section 304(a) guidance, (2) failure to explain why health-based standards applicable to aquatic life segments were not included for more than 20 priority toxic pollutants addressed by section 304(a) guidance, and (3) failure to finally resolve within the Basic Standards and Methodologies the applicability of: (a) The numeric aquatic life and human health standards for inorganics, and (b) certain human health numeric standards (i.e., those that address human exposure from water and fish consumption) for organics. The Region VIII letter notified the State that these deficiencies would need to be addressed to satisfy the full compliance requirements and to ensure that Colorado would not be affected by the Federal section 303(c)(2)(B) promulgation.

—July 1, 1991. The State held a public hearing on the proposed standards revisions. At the hearing, EPA submitted written testimony that identified the specific issues and options related to section 303(c)(2)(B) compliance.

—August 20, 1991. In a letter to the State, EPA Region VIII approved the August 17, 1989 toxics criteria adopted by Colorado as partially fulfilling the requirements of section 303(c)(2)(B). The letter clearly indicated that additional State action would be required to achieve full compliance.

—October 8, 1991. The State Water Quality Control Commission adopted additional numeric criteria for priority toxic pollutants, including criteria for all such toxics addressed by EPA section 304(a) criteria guidance. The adopted standards were intended to resolve all issues related to section 303(c)(2)(B) compliance. Because EPA has not yet had sufficient opportunity to review and approve these standards, today's proposal is based on the standards previously adopted by the State on August 17, 1989.

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. For example, to fully protect aquatic life uses from the impacts of inorganic priority toxic pollutants (including metals), EPA proposes to promulgate aquatic life criteria for only those particular segments and inorganic substances for which State aquatic life criteria have not been applied. EPA invites public comment regarding any specific priority pollutants or water bodies for which

Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory data base and/or the Permit Compliance System data base.

North Dakota has not been included in today's proposed rulemaking because the State has adopted revised criteria in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—May 1, 1989. North Dakota completed its triennial review and revised the State's standards. The revised standards were submitted to EPA for review on September 20, 1989. The revised standards included new numeric criteria for some of the priority toxic pollutants; however, not all of the priority toxic pollutants for which EPA has developed 304(a) criteria were included in the revised State rule.

—January 17, 1990. Region VIII sent a letter to the State explaining the requirements for full compliance with section 303(c)(2)(B). The letter explained that the burden was on the State to demonstrate that additional criteria beyond those already adopted were not needed.

—February 7, 1990. In a letter from the North Dakota Water Supply and Pollution Control Division to EPA Region VIII, North Dakota notified EPA that it intended to meet the full compliance requirements by way of option 1 (i.e., an option 1 approach as described in EPA's December 12, 1988 guidance document and the Region's January 17, 1990 letter to the State).

—July 12, 1990. In a memorandum to the State, Region VIII provided additional information on compliance with the toxics requirements and the upcoming federal promulgation. The memorandum included a listing of EPA published and modified toxics criteria which could be used in proposing needed amendments to the existing toxics provisions in the State standards (modified criteria were based on the most recent information in IRIS).

—August 13, 1990. Region VIII sent an improved version of the toxics criteria chart to the State staff.

—October 16, 1990. The Region approved the previously adopted State standards as partially fulfilling the section 303(c)(2)(B) requirements and notified the State that the standards would be considered incomplete pending completion of the full compliance requirements. The Regional WQS review letter also notified the State that the incomplete portions of the State rule would be subject to the proposed federal promulgation.

—November 15, 1990. North Dakota adopted additional standards for the priority toxic pollutants. The amended standards include criteria for all of the priority pollutants for which EPA has published 304(a) criteria plus additional criteria based on the most recent information in EPA's IRIS data base. The amended standards meet the requirements for full compliance with section 303(c)(2)(B). The amended standards became effective February 1, 1991, and the standards were submitted by the State for EPA review and approval on February 25, 1991.

—March 8, 1991. Region VIII approved the amended State water quality standards and advised the State that the amended standards met the full compliance requirements of section 303(c)(2)(B).

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

South Dakota has not been included in today's proposed rulemakingbecause the State has adopted revised criteria for priority toxic pollutants in response to the section 393(c)(2)(B) requirement and received full EPA approval.

South Dakota's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—October 8, 1987. South Dakota completed its triennial review and revised the State's Standards. The revised Standards were submitted to EPA for review on May 5, 1989. The revised Standards included a reference to EPA's Water Quality Criteria, 1986 as the numeric criteria incorporated in State Standards; however, the State did not include or identify certain information needed to distinguish which specific EPA criteria had been adopted as State Standards.

—January 17, 1990. Region VIII sent a letter to the State explaining the requirements for full compliance with section 303(c)(2)(B). The letter explained that incorporation of EPA's national criteria into State Standards by reference to EPA's Quality Criteria for Water, 1986 was acceptable; however, such a reference would have to include sufficient information to identify the specific numeric criteria which comprised State Standards. The needed information was not provided prior to today's proposal.

—February 13, 1990. Region VIII sent a letter to the State further explaining the issues that would have to be clarified before the Region would be able to grant final approval of the toxics portion of the State water quality standards.

—March 8, 1990. South Dakota further amended the State Standards to clarify the role of the Department of Natural Resources in applying the criteria in Quality Criteria for Water, 1986; however, the new amendments did not address the specific information needed to satisfy the full compliance requirements for section 303(c)(2)(B).

—July 12, 1990. Region VIII sent additional information to the State on compliance with the toxics requirements and the upcoming federal promulgation. The memorandum included a listing of EPA published and modified toxics criteria which could be used in proposing needed amendments to the existing toxics provisions in the State standards (modified criteria were based on the most recent information in IRIS).

—August 13, 1990. Region VIII sent an improved version of the toxics criteria chart to the State staff.

—November 6, 1990. Region VIII sent additional information to the State further delineating the specific application information that would be needed to achieve approval of the toxics provisions of the water quality standards.

—March 6, 1991. In a letter from the Division of Environmental Regulation, South Dakota provided a complete interpretation of the toxics control provisions in section 74:03:02:14, the section of the South Dakota water quality standards which incorporates EPA's Quality Criteria for Water, 1986 by reference. The State's letter included a listing of the specific criteria which are considered to be standards of the State. The list included all of the published 304(a) criteria and identified the uses to which the criteria applied.

—March 13, 1991. The Region approved the adopted State criteria as fulfilling the section 303(c)(2)(B) requirements.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Utah has not been included in today's proposed rulemaking because the State has adopted revised criteria in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—April 21, 1988. Utah completed its triennial review and revised the State's standards. The revised standards were submitted to EPA for review on February 10, 1989. The revised standards included new numeric criteria for some of the priority toxic pollutants for which EPA has developed 304(a) criteria were included in the revised State rule.

—January 17, 1990. Region VIII sent a letter to the State enplaning the requirements for full compliance with section 303(c)(2)(B). The letter explained that the burden was on the State to demonstrate that additional criteria beyond those already adopted were not needed.

—January 31, 1990. In a letter from the Utah Bureau of Water Pollution Control to EPA Region VIII, Utah notified EPA that it intended to meet the full compliance requirements by way of option 1 (i.e., an option 1 approach as described in EPA's December 12, 1988 guidance document and the Region's January 17, 1990 letter to the State).

—July 12, 1990. In a memorandum to the State, Region VIII provided additional information on compliance with the toxics requirements and the upcoming federal promulgation. The memorandum included a listing of EPA published and modified toxics criteria which could be used in proposing needed amendments to the existing toxics provisions in the State standards (modified criteria were based on the most recent information in IRIS).

—August 13, 1990. Region VIII sent an improved version of the toxics criteria chart to the State staff.

—November 29, 1990. The Region approved the previously adopted State standards as partially fulfilling the section 303(c)(2)(B) requirements and notified the State that the standards would be considered incomplete pending completion of the full compliance requirements. The Regional water quality standards review letter also notified the State that the incomplete portions of the State rule would be subject to the provisions of the proposed federal promulgation.

—January 18, 1991. Utah adopted additional standards for the priority toxic pollutants. The amended standards include criteria for all of the priority pollutants for which EPA has published 304(a) criteria. The amended standards meet the requirements for full compliance with section 303(c)(2)(B). The amended standards were submitted by the State for EPA review and approval on February 13, 1991.

—March 8, 1991. Region VIII approved the amended State water quality standards and advised the State that the amended standards met the full compliance requirements of section 303(c)(2)(B).

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Wyoming has not been included in today's proposed rulemaking because the State has adopted revised criteria in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—January 17, 1990. Region VIII sent a letter to the State explaining the requirements for full compliance with section 303(c)(2)(B). The letter explained that the burden was on the State to demonstrate that additional criteria beyond those already adopted were not needed.

—February 12, 1990. In a letter from the Wyoming Water Quality Division of the Department of Environmental Quality, Wyoming notified EPA that it intended to meet the full compliance requirements by way of option 1 (i.e., an option 1 approach as described in EPA's December 12, 1988 guidance document and the Region's January 17, 1990 letter to the State).

—May 29, 1990. Region VIII provided written comments for the Wyoming Environmental Quality Council triennial review hearing. The Region's comments further explained the requirements for full compliance with section 303(c)(2)(B).

—July 12, 1990. In a memorandum to the State, Region VIII provided additional information on compliance with the toxics requirements and the upcoming federal promulgation. The memorandum included a listing of EPA published and modified toxics criteria which could be used in proposing needed amendments to the existing toxics provisions in the State standards (modified criteria were based on the most recent information in IRIS).

—July 19, 1990. Region VIII provided additional written comment to the Wyoming Environmental Quality Council. The Region's comments provided further information on the toxics requirements, including specific lists of published and modified criteria for the priority pollutants which would meet the full compliance requirements.

—August 13, 1990. Region VIII sent an improved version of the toxics criteria chart to the State staff.

—October 3, 1990. Wyoming adopted additional standards for the priority toxic pollutants. The amended standards include criteria for all of the priority pollutants for which EPA has published 304(a) criteria plus additional criteria based on the most recent information in EPA's IRIS data base. The amended standards meet the requirements for full compliance with section 303(c)(2)(B). The amended standards became effective November 29, 1990, and the standards were submitted by the State for EPA review and approval on December 24, 1990. Clarification of the legal standing of the newly adopted rule was provided with a memorandum from the State dated January 12, 1991.

—March 8, 1991. Region VIII approved the amended State water quality standards and advised the State that the amended standards met the full compliance requirements of section 303(c)(2)(B).

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary to respond to those comments and reevaluate the Agency's determination of full compliance.

Montana has not been included in today's proposed rulemaking because the State has adopted revised criteria in response to the section 303(c)(2)(B) requirement and received full EPA approval. The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—September 23, 1988. The State adopted final water quality standards which included numeric criteria for the priority toxic pollutants (by reference to EPA's Quality Criteria for Water, 1986 through update #2 1987 including supporting information).

—December 9, 1988. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.

—March 8, 1989. EPA approved the portion of the revised State water quality standards which responded to the requirements of section 303(c)(2)(B) (other portions of the revised standards were disapproved).

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 9

American Samoa has not been included in today's proposed rulemaking because it has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

American Samoa's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—January 1990. American Samoa submitted draft water quality standards revisions to EPA and the public for review.

—February 1990. American Samoa held a public hearing on its proposed water quality standards revisions.

—September 7, 1990. The American Samoa Environmental Commission adopted its proposed water quality standards revisions which include numeric criteria for priority toxic pollutants.

—September 20, 1990. American Samoa submitted the adopted water quality standards to EPA for approval/disapproval.

—September 25, 1990. American Samoa submitted the State Attorney General certification.

—September 27, 1990. EPA approved the revised American Samoa water quality standards, including full approval of the revised numeric criteria for priority pollutants.

EPA fully approved the criteria for priority toxic pollutants adopted by American Samoa on September 27, 1990 based on a determination that the criteria are consistent with option 1 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that American Samoa has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Arizona is included in today's proposal because, although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, the State has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirement and EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—Late 1988. The State submitted a series of discussion papers to EPA and the public.

—June 7, 1989. The State submitted draft water quality standards revisions to EPA for review prior to issuing proposed standards for public comment.

—December 11, 1989. The State transmitted a Surface Water Quality Standards Triennial Review Briefing Book, dated December 8, 1989, to EPA and the public.

—February 15, 1990. The State submitted, to EPA and the public, draft proposed revisions to its Surface Water Quality Standards.

—March 16, 1990. The State submitted Proposed Surface Water Quality Standards Rules to EPA and the public.

—During 1988–90, the State held several public meetings and roundtables regarding the proposed water quality standards.

—October 26, 1990. Arizona prepared revised draft water quality standards which were released for comment October 29, 1990.

—December 14, 1990. EPA provided written comments to the States.

—January 15, 1991. Arizona prepared a re-draft of the water quality standards for review and comment.

—February 13, 1991. EPA provided written comments to the States.

—May 8, 1991. Arizona approval by the Governor's Regulatory Review Council on May 7, 1991 of the Navigable Water Quality Standards proposed rules and the Economic Impact Statement.

Also announced the schedule of oral proceedings and availability of the proposed rules.

Today's proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not included in approved State criteria. EPA also proposes to promulgate the § 131.36(b) criteria where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all waters with relevant State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for section 303(c)(2)(B) criteria. For most priority toxic pollutants, however, available data on the discharge and presence of such pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that section 303(c)(2)(B) criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State Section 304(l) lists (as updated), and supporting documentation, for which State criteria have not been adopted and approved, including metals, dioxin, and some organics.

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 126 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—STORET data indicating the presence in surface waters of a majority of the priority toxic pollutants which are not covered with approved State criteria.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

California is included in today's proposal because, although the State has completed a review and adopted numeric criteria for some priority toxic pollutants for some waters in response to the statutory requirement, EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

For ocean waters, the State adopted revised criteria on March 22, 1990, and EPA fully approved those criteria on June 23, 1990. Regarding inland waters and bays and estuaries, the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments and a few site specific criteria since 1987. Included among these criteria are numeric criteria for copper, cadmium and zinc applicable to the Sacramento River and its tributaries upstream of Hamilton City adopted by the State on August 16, 1984, and approved by EPA on August 7, 1985. Since the 1987 amendments, the State adopted numeric monthly mean and maximum criteria for selenium in the San Joaquin River from the mouth of the Merced River to Vernalis and monthly mean criteria in flows to Grasslands Water District, San Luis National Wildlife Refuge, and Los Banos State Wildlife Area on September 21, 1989; EPA approved these criteria on April 13, 1990, and, at the same time, disapproved selenium criteria for other locations. These approved numeric criteria comply with section 303(c)(2)(B) and are not amended by today's proposed rulemaking. Subsequent to these specific efforts, the State completed a review of their numeric criteria for priority toxic pollutants for State inland waters and bays and estuaries and transmitted them to EPA. EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). In addition, several parties have petitioned State Court to restrain the SWRCB from utilizing the standards for inland waters and bays and estuaries.

The State's actions, regarding inland waters and bays and estuaries, to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—October 6, 1989. The State issued a staff report proposing methodologies for development of water quality criteria for statewide plans.

—December 1, 1989. EPA submitted written comments to State on its proposed methodology.

—January 29, 1990. The State issued draft water quality standards for inland surface waters and enclosed bays and estuaries for EPA and public review.

—February 28 and March 5, 1990. The State held public hearings on proposed standards revisions.

—March 29, 1990. EPA submitted written comments to the State on proposed standards revisions.

—August 16, 1990. The State held a public workshop on development and implementation of standards for agricultural drains and ephemeral streams. (EPA testified.)

—August 22, 1990. EPA submitted written comments to the State on development and implementation of standards for agricultural drains and ephemeral streams.

—November 2, 1990. The State issued revised draft water quality standards for EPA and public review.

—December 7, 1990. EPA submitted written comments on the revised draft water quality standards.

—December 10, 1990. The State held a hearing on the revised draft standards. (EPA testified.)

—February 8, 1991. EPA provided written comments to the State re: the agricultural drains section of the Inland Surface Waters Plan.

—March 26, 1991. The State issued drafts of the Statewide Water Quality Control Plans for Inland Surface Waters and Enclosed Bays and Estuaries.

—March 27, 1991. EPA provided written comments to the San Francisco Bay Regional Water Quality Control Board re: proposed interim objectives for toxic pollutants in the South Bay.

—April 10, 1991. EPA provided written comments to the State re: The Statewide Water Quality Control Plans for Inland Surface Waters and Enclosed Bays and Estuaries.

—April 10, 1991. EPA provided written comments to the State re: EPA's position on how to proceed with dioxin related programs.

—April 11, 1991. The State adopted the Statewide Waters Quality Control Plans for Inland Surface Water and Enclosed Bays and Estuaries.

—May 10, 1991. The State transmitted to EPA the Statewide Waters Quality Control Plans for Inland Surface Water and Enclosed Bays and Estuaries.

Today's proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all State inland waters and bays and estuaries, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not included in EPA approved State criteria. EPA also proposes to promulgate section 303(c)(2)(B) criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all waters with relevant State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some additional Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for section 303(c)(2)(B) criteria. For most priority toxic pollutants, however, available data on the discharge and presence of such pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that section 303(c)(2)(B) criteria are necessary may be summarized as follows:

—priority toxic pollutants discussed in the State Section 304(l) lists, and supporting documentation, for which State criteria have not been adopted and approved, including metals, dioxin, and some organics,

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants for inland waters and bays and estuaries, as described above. The State has completed efforts to adopt new or revised chemical-specific, numeric criteria for 68 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—STORET data indicating the presence in inland waters and bays and estuaries of priority toxic pollutants which are not covered with approved State criteria (e.g., detection of more than 40 priority toxic pollutants in the water column).

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

The Commonwealth of the Northern Mariana Islands (CNMI) is included in today's proposal because, although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, the State has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirement and EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

The Commonwealth's actions to respond to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—March 22, 1990. The Commonwealth transmitted a letter to EPA indicating that its water quality standards revision process had been delayed.

—March 28, 1991. CNMI submitted draft water quality standards revisions to EPA for review.

—May 22, 1991. EPA provided comments to CNMI re: the draft revised standards.

Today's proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not included in approved State criteria. EPA also proposes to promulgate the § 131.36(b) criteria where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all waters with relevant State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—CNMI efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. CNMI has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 108 priority toxic pollutants. These efforts represent evidence of the CNMI's recognition of the need for numeric criteria for these priority toxic pollutants.

—STORET data indicating the presence in CNMI waters of priority toxic pollutants which are not covered with approved CNMI criteria.

Guam has not been included in today's proposed rulemaking because Guam has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

Guam's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—July 2, 1987. Guam adopted revised water quality standards which include numeric criteria for priority toxic pollutants.

—August 1987. Guam submitted the adopted water quality standards with an Attorney General certification to EPA for approval/disapproval.
—September 30, 1987. EPA approved the revised Guam water quality standards, including full approval of the revised numeric criteria for priority toxic pollutants. EPA fully approved the criteria for priority toxic pollutants adopted by Guam on July 2, 1987. It has been determined since that time that the criteria are consistent with option 1 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that Guam has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Hawaii is included in today's proposal because, although the State has completed a review and adopted numeric criteria for some priority toxic pollutants in response to the statutory requirement, EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirements can be summarized as follows:

—January 8, 1990. The State adopted revised criteria.
—February 9, 1990. Hawaii submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.
—May 9, 1990. EPA approved Hawaii's water quality standards noting that omission of human health limits for five toxic metals precluded full satisfaction of the section 303(c)(2)(B) requirement.
—May 29, 1990. The State responded to the EPA approval indicating plans to adopt human health limits for the five toxic metals.
—July 13, 1990. EPA clarified portions of the May 1990 approval letter.

Because the State has adopted criteria for priority toxic pollutants using an option 1 approach as described in EPA's December 12, 1988 guidance document EPA is taking an approach of proposing criteria for all remaining priority toxic pollutants which have been the subject of section 304(a)(1) criteria recommendations. EPA believes that the discharge or presence of these priority toxic pollutants can reasonably be expected to interfere with designated uses in the State and that Federal criteria therefore are necessary to protect Hawaii designated uses. This conclusion is based on the following information in the record:

—priority toxic pollutants on the State section 304(l) lists for which State criteria have not been adopted and approved, including these metals,
—STORET data indicating the presence in surface waters of these priority toxic pollutants.

Nevada is included in today's proposal because, although the State has completed a review and adopted numeric criteria for some priority toxic pollutants in response to the statutory requirement, EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—May 24, 1988. The State held a public hearing on it's proposed water quality standards revisions.
—September 12, 1988. The State submitted draft water quality standards revisions to EPA and the public for review.
—September 20, 1988. EPA provided comments to Nevada regarding its proposed water quality standards for toxics.
—October 21, 1988. The State submitted revisions to the Nevada toxic material definition and bioassay procedures to EPA and the public for review.
—November 10, 1988. The State held a public hearing on its proposed water quality standards revisions.
—November 29, 1988. The State held a public hearing on its proposed water quality standards revisions. (Revisions to the definition of "toxic" were adopted following this hearing.)
—May 31, 1989. The State submitted draft water quality standards revisions to EPA and the public for review.
—June 22, 1989. EPA provided comments to Nevada regarding its proposed standards for toxics.
—August 9, 1989. The State submitted draft water quality standards revisions to EPA and the public for review.
—August 22, 1989. The State submitted draft water quality standards revisions and rationale to EPA.
—September 18, 1989. EPA provided comments on Nevada's proposed water quality standards for toxics.
—September 27, 1989. The State held a public hearing on its proposed water quality standards revisions. (Revisions to the bioassay requirements as part of the narrative toxics standard were adopted following this hearing.)
—February 26, 1990. The State submitted draft water quality standards revisions to EPA and the public for review.
—March 27, 1990. EPA provided comments on Nevada's proposed February 26, 1990 toxics standards.
—March 28, 1990. The State held a public hearing on its proposed water quality standards revisions.
—May 2, 1990. EPA provided comments regarding the latest proposed standards revisions.
—May 2, 1990. The State adopted water quality standards revision which included some numeric criteria for priority toxic pollutants.
—August 23, 1990. State transmitted approved water quality standards revisions without a State Attorney General Certification to EPA for approval/disapproval.
—September 28, 1990. The State Attorney General certified the May 2, 1990 adoption.
—January 16, 1991. EPA approved in part and disapproved in part standards adopted by the State and notified them of the actions they needed to take pursuant to the disapproval and that they had not fully satisfied section 303(c)(2)(B).
—March 14, 1991. The State responded to the January 1991 approval/disapproval of standards.

Today's proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not included in approved State criteria. EPA also proposes to promulgate the § 131.36(b) criteria where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all waters with relevant State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for criteria. For most priority toxic pollutants, however, available data on the discharge and presence of such pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that section 303(c)(2)(B) criteria are necessary may be summarized as follows:

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 108 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—Presence in surface waters of the State of priority pollutants for which sufficient State numeric criteria have not been adopted, based on surface water monitoring data in STORET.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

The Trust Territories of the Pacific Islands (Palau) has not been included in today's proposed rulemaking because Palau has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

Palau's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—November 7, 1990. Palau adopted revised water quality standards which include numeric criteria for priority toxic pollutants.

—December 12, 1990. Palau submitted the adopted water quality standards with an Attorney General certification to EPA for approval/disapproval.

—January 11, 1991. EPA approved the revised Palau water quality standards, including full approval of the revised numeric criteria for priority toxic pollutants.

EPA fully approved the criteria for priority toxic pollutants adopted by Palau on January 11, 1991 based on a determination that the criteria are consistent with option 1 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that Palau has not fully complied with section 303(c)(2)(B), it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Region 10

Alaska is included in today's proposal because although the State had previously adopted all section 304(a) criteria by reference, the State Attorney General has decided that the adoption by reference is invalid. Based on information in the record (see below), EPA has reason to believe that at least some criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Alaska's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—December 20, 1989. The State submitted draft water quality standards revisions to EPA and the public for review.

—April 6, 1990. The State held public hearings and accepted written comments on its proposed water quality standards revisions through this date.

—On November 4, 1991, Region 10 sent a letter to the State partially approving the State's incorporation by reference of EPA's toxic pollutant criteria; and noting the deficiencies which will be included in EPA's proposed rulemaking (e.g. Alaska's failure to adopt a human health criteria).

This proposed rulemaking would federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above.

The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 103 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—STORET data indicating the presence in surface waters of priority toxic pollutants which are not currently covered with approved State criteria.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

Idaho is included in today's proposal because although the State adopted some numeric criteria for human health protection for some priority toxic pollutants before the 1987 amendments, the State has not completed a review of their numeric criteria for priority toxic pollutants in response to the statutory requirement. Furthermore, the State's criteria protecting human health are based only on drinking water maximum contaminant levels; fish consumption is not protected, and EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Idaho's action to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—July 23, 1990. The State submitted draft water quality standards revisions to EPA and the public for review.

This proposed rulemaking would federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously aapproved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State Section 304(l) short list for which State criteria have not been adopted and approved, including metals and some organics.

—STORET data indicating the presence in surface waters of priority toxic pollutants which are not currently covered with approved State criteria.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

Oregon has not been included in today's proposed rulemaking because the State has adopted revised criteria for priority toxic pollutants in response to the section 303(c)(2)(B) requirement and received full EPA approval.

The State's response to the 1987 section 303(c)(2)(B) requirement can be summarized as follows.

—August 28, 1987. The State adopted revised water quality standards which included numeric criteria for priority toxic pollutants.

—January 26, 1988. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.

—March 9, 1988. EPA approved the revised State water quality standards, including full approval of the revised numeric criteria for priority toxic pollutants.

EPA fully approved the criteria for priority toxic pollutants adopted by Oregon on February 12, 1989 as being consistent with option 2 of the December 12, 1988 section 303(c)(2)(B) guidance document.

If additional information is submitted during the public comment period asserting that the State has not fully complied with section 303(c)(2)(B) it will be necessary at that time to respond to those comments and reevaluate the Agency's determination of full compliance.

Washington is included in today's proposal because although the State adopted numeric criteria for some priority toxic pollutants before the 1987 amendments, the State has not adopted numeric criteria for any human health based criteria for priority pollutants, and EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B). Therefore, EPA has determined for purposes of today's proposed rulemaking that the State is not currently in compliance with section 303(c)(2)(B) because it has not adopted water quality standards consistent with section 303(c)(2)(B) which have been fully approved by the appropriate EPA Regional Administrator.

Washington adopted 26 freshwater and marine criteria which EPA fully approved on March 4, 1988 (see below). The State has not completed a review of their criteria for priority toxic pollutants in response to the statutory requirement and EPA has reason to believe that at least some additional criteria are necessary to comply with section 303(c)(2)(B).

The State's actions to respond to the 1987 section 303(c)(2)(B) requirement can be summarized as follows:

—February 9, 1988. The State submitted the adopted water quality standards with a State Attorney General certification to EPA for approval/disapproval.

—March 4, 1988. EPA approved the revised State water quality standards.

—July 20, 1990. Washington released its proposed water quality standards with public comments accepted through this date..

This proposed rulemaking would Federally promulgate the criteria necessary to bring the State into full compliance with section 303(c)(2)(B). To fully protect State designated uses, and to ensure that the required criteria are adopted, EPA proposes to apply broadly the criteria in proposed § 131.36(b). At a minimum, EPA proposes to apply, to all appropriate State waters, the criteria in proposed § 131.36(b) for all priority toxic pollutants which are not the subject of approved State criteria. EPA also proposes to promulgate Federal criteria for priority toxic pollutants where any previously-approved State criteria are insufficiently stringent to fully protect all designated uses, or where such previously-approved State criteria are not applicable to all appropriate State designated uses. EPA invites public comment regarding any specific priority pollutants or water bodies for which Federal criteria may not be necessary to protect State designated uses.

For reasons which are fully discussed in the preamble, EPA has not attempted to determine the specific priority pollutants and water bodies that require criteria. However, EPA has determined that at least some Federal criteria are necessary to protect designated uses. This determination is supported by information in the record which demonstrates that priority toxic pollutants are discharged or present in surface waters at levels that can reasonably be expected to interfere with State designated uses. For some priority toxic pollutants, available data clearly demonstrate use impairment and the need for toxics criteria. For most priority toxic pollutants, however, available data on the discharge and presence of priority toxic pollutants are spatially and temporally limited. Nevertheless, EPA believes that the data for many of these pollutants are sufficient to satisfy the "reasonable expectation" test established in section 303(c)(2)(B). The information in the record which demonstrates that priority toxic pollutants are discharged or present and that Federal criteria are necessary may be summarized as follows:

—Priority toxic pollutants on the State Section 304(l) short list for which State criteria have not been adopted and approved, including metals and some organics.

—State efforts since 1987 to adopt additional numeric criteria for priority toxic pollutants, as described above. The State has initiated (but not completed) efforts to adopt new or revised chemical-specific, numeric criteria for 91 priority toxic pollutants. These efforts represent evidence of the State's recognition of the need for numeric criteria for these priority toxic pollutants.

—STORET data indicating the presence in surface waters of priority toxic pollutants which are not currently covered with approved State criteria.

—Discharge to surface waters of priority pollutants for which sufficient State numeric criteria have not been adopted, based on data in the Toxics Release Inventory database and/or the Permit Compliance System database.

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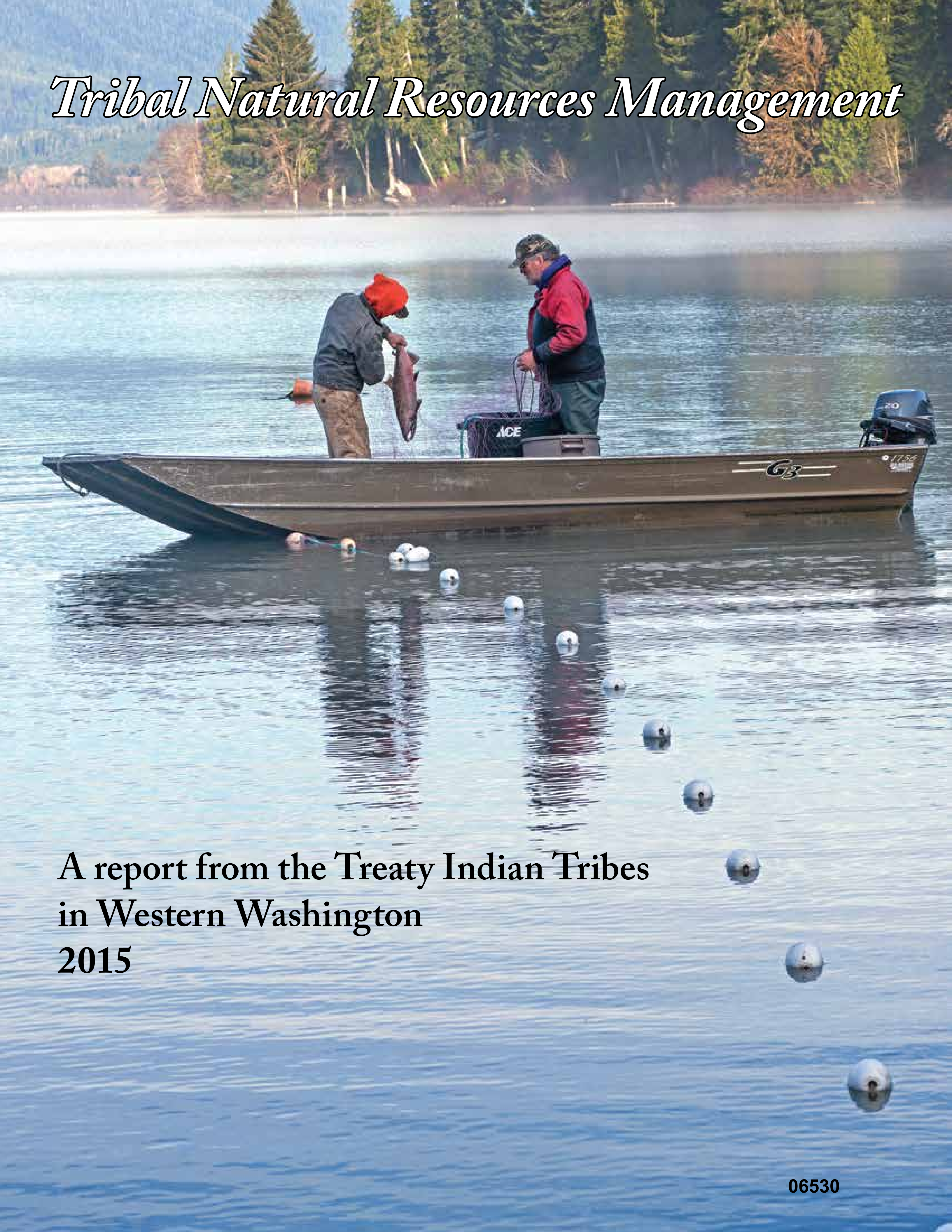
Tribal Natural Resources Management



A report from the Treaty Indian Tribes in Western Washington

2015

We, the Indians of the Pacific Northwest, recognize that our fisheries are a basic and important natural resource and of vital concern to the Indians of this state, and that the conservation of this natural resource is dependent upon effective and progressive management. We further believe that by unity of action, we can best accomplish these things, not only for the benefit of our own people, but for all of the people of the Pacific Northwest.

– PREAMBLE TO THE NWIFC CONSTITUTION

Member Tribes of the Northwest Indian Fisheries Commission

Cover: Shawn Johnstone, left, and Skip Pickett, Quinault Indian Nation hatchery technicians, pull a coho from a net as part of the Quinault Indian Nation's hatchery operations on Lake Quinault. *Photo: Debbie Preston. Map: Ron McFarlane.*

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Year in Review

Lorraine Loomis

As we celebrated the 40th anniversary of *U.S. v. Washington* (the Boldt decision) this year we also mourned the loss of Billy Frank Jr., our longtime chairman and good friend. Billy, 83, passed away on May 5, 2014.

From his first arrest at age 14, Billy spent his entire life fighting for the recognition of tribal rights reserved in treaties with the United States. The 1974 ruling by Judge George Boldt in *U.S. v. Washington* re-affirmed the tribal treaty right to harvest salmon and established the tribes as natural resources co-managers entitled to half of the harvestable salmon returning annually to western Washington waters.

Today tribes are leaders in the management of the region's salmon fisheries and other natural resources.

Billy Frank Jr.

I am honored and humbled to follow in Billy's footsteps as chair of the Northwest Indian Fisheries Commission. The tribes remain committed to Billy's legacy and direction to "stay the course" with salmon recovery. Our goal is to return all salmon populations to sustainable levels that can support harvest. We commit ourselves to this task with the recognition that we must act in the best interests of those who will follow us seven generations from now.

Treaty Rights at Risk

Sadly, ongoing loss and damage to salmon habitat has stalled salmon recovery and threatens tribal treaty rights. For those rights to have meaning, there must be salmon available for harvest. That is why we are continuing the Treaty Rights at Risk initiative begun in July 2011 by Billy and other tribal leaders.

Through this effort we are asking the federal government, our trustee, to align its agencies and programs and take charge of a more coordinated salmon recovery effort. We want the federal government to take charge of salmon recovery because it has the obligation and the authority to ensure both salmon recovery and protection of treaty rights.

We are disappointed with the federal government's slow response and lack of progress. There has been a lot of discussion, but little action by the federal government, in spite of its responsibility to protect tribes' treaty rights and recover salmon stocks listed as threatened under the federal Endangered Species Act (ESA).

We have requested that the Treaty Rights at Risk initiative be institutionalized in the U.S. government via President Obama's Council on Native American Affairs created several years ago. Addressing tribal natural resources concerns was supposed to be one of five main areas of work when the council was founded. Subgroups of the council already have been formed to focus on economic development, education, climate change and energy. We think a similar group should be formed to address tribal natural resources concerns, especially salmon recovery and treaty rights.

Importance of Hatcheries

Even as we struggle with the continual decline of salmon populations caused by lost and damaged habitat, hatcheries are under attack. Hatcheries were designed to make up for lost natural salmon production, and are essential to fulfilling tribal treaty rights, but federal funding has not kept pace with needed repairs and replacement of aging facilities. Tribes produce about 40 million salmon and steelhead annually.

The National Marine Fisheries Service has worsened the situation by delaying review and approval of permits required under the ESA for hatchery operations. The delays led to legal action that prevented the release last fall of nearly 1 million hatchery-raised steelhead in western Washington. Indian and non-Indian fishermen will feel the loss of those fish for years to come.

Hatcheries and the salmon they produce are absolutely necessary as long as lost and damaged habitat prevents salmon recovery. They deserve more support from all corners. Today, most of the chinook and coho harvested by Indian and non-Indian fishermen come from hatcheries.

Updated Water Quality Standards

Tribes continued their efforts to encourage the state of Washington to adopt a more realistic fish consumption rate as part of updating water quality standards. The higher the fish consumption rate, the cleaner the water must be.

For more than 20 years, the state has operated under water quality rules based on a fish consumption rate of 6.5 grams per day, or one 8-ounce serving a month. This was one of the lowest rates in the nation, even though Washington residents eat more fish and shellfish than people in other states, and most tribal members consume much more than that.

In July, Gov. Jay Inslee approved an increase to 175 grams per day, a compromise rate supported by the tribes, but still lower than the actual amount of fish and shellfish eaten by Indian people in western Washington. At the same time, Inslee increased the risk of getting cancer from water pollution from one in a million to one in 100,000. The tenfold increase in cancer risk effectively cancels out most of the benefits of the higher fish consumption rate.

As a result, the treaty tribes have approached their trustee, the U.S. Environmental Protection Agency, to step in and enact new water quality rules for the state. The 1972 federal Clean Water Act requires states to implement standards that ensure waters are clean enough to support fish that are safe to eat.

Fossil Fuel Transportation

Proposals to build coal and oil export terminals in western Washington continued as major concerns in 2014. The planned increases in train and ship traffic threaten the health and safety of tribal members as well as treaty-protected rights and resources.

Coal export terminals proposed for Cherry Point near Bellingham and Longview on the Columbia River would be fed by hundreds of trains daily from coal fields in Montana and Wyoming. Coal dust from each train would be spread all along its route.

Also proposed is a plan to use mile-long crude-oil trains to feed massive new oil terminals in Grays Harbor. As with increased coal train traffic, tribes are deeply concerned about health, safety and environmental issues associated with the trains and ships transporting the oil.

Disastrous Fraser Sockeye Season

A high diversion rate of Fraser River sockeye through Johnstone Strait around the northern part of Vancouver Island led to poor catches for treaty tribal and non-tribal fishers in 2014. Nine treaty Indian tribes in western Washington harvest sockeye returning to British Columbia's Fraser River.

Typically, about half of the returning sockeye swim around Vancouver Island and through the Strait of Juan de Fuca where treaty tribal and non-Indian commercial fishermen can harvest them when they enter U.S. waters. By the end of August, Canadian fishermen had caught about five million fish; non-Indian commercial and treaty tribal fishermen harvested about 275,000.

Tribes will be requesting a declaration of natural disaster under the Stafford Disaster Relief and Emergency Assistance Act, and a fisheries economic disaster under the Magnuson-Stevens Act, which would provide services and financial assistance to fishermen.

Culvert Repairs Begin

As part of the favorable ruling for the tribes in the Culvert Case, talks began in 2014 to prioritize repair of culverts under state roads that are barriers to fish passage. The state was ordered by the federal court in 2013 to repair more than 600 state-owned culverts over the next 17 years. Fish-blocking culverts deny salmon access to hundreds of miles of good habitat in western Washington streams, affecting the fish in all stages of their life cycle. The treaty tribes and the U.S. filed the initial Culvert Case litigation in 2001 under *U.S. v. Washington*. The state has appealed the ruling.

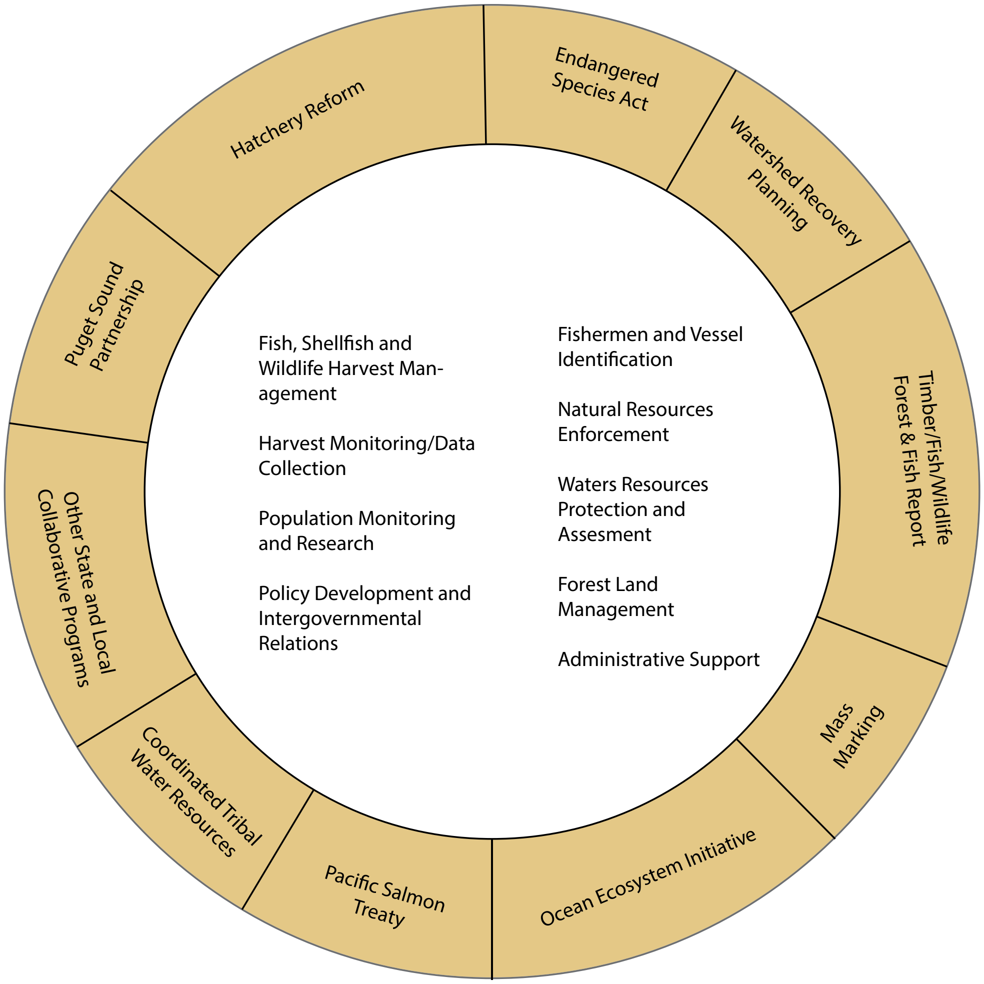
To find out more about these and other natural resources management issues important to the treaty tribes, visit the Northwest Indian Fisheries Commission website at *nwifc.org.*

Lorraine Loomis

Lorraine Loomis
NWIFC Chair

Tribal Natural Resources Management Core Program

Natural resources management functions and associated programs of the treaty tribes in western Washington:



Habitat Management

Habitat protection and restoration are essential for recovery of wild salmon in western Washington. Tribes are taking action to recover salmon in each watershed.

- The tribes continue to support the Treaty Rights at Risk initiative, calling on the federal government to align its agencies and programs to better meet salmon recovery goals, particularly those for habitat protection and restoration. The initiative calls on the federal government to lead a more coordinated salmon recovery effort because it has both the obligation and authority to recover salmon and protect tribal treaty rights.

- The NWIFC Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) provides a "living database" of local and regional habitat conditions. SSHIAP has launched an interactive map to track repairs to state-owned culverts; a tool to map potential steelhead habitat; and a data exchange for research about the nearshore environment.

- Tribes continue to address the habitat concerns identified in the 2012 State of Our Watersheds report. The report, which documents ongoing loss and damage of salmon habitat, can be viewed at *nwifc.org/sow*. It will undergo a comprehensive update in 2015.

- Tribes conduct extensive monitoring of water quality for pollution, and ensure factors such as dissolved oxygen and temperature levels are adequate for salmon and other fish. To make limited federal funding work to its fullest, tribes partner with state agencies, industries and property owners through collaborative habitat protection, restoration and enhancement efforts.

- In western Washington, the National Oceanic and Atmospheric Administration's Pacific Coastal Salmon Recovery Fund has supported projects that have restored thousands of acres of forest, protected hundreds of acres of habitat and removed hundreds of fish passage barriers.

Lower Elwha Klallam Tribe Monitors Restored River

Tiffany Royal

With the Glines Canyon and Elwha dams completely removed, the Elwha River now flows freely.

While two massive fish-blocking dams on the Elwha River were being torn down between 2011 and 2014, the Lower Elwha Klallam Tribe was studying how the river, salmon and wildlife were responding to dam removal.

After the 108-foot-tall Elwha and 210-foot-tall Glines Canyon dams were built in the early 1900s, millions of cubic yards of sediment built up behind the structures, creating lakes Aldwell and Mills.

As the dams were deconstructed, sediment flowed downriver, changing the dynamics of the river and restoring the river mouth from cobblestone to sandy beach. Scientists have found forage fish and shellfish, such as Dungeness crab, using the new habitat.

In the estuaries, tribal staff are seining the ponds to examine fish populations and study the stomach contents of juvenile salmon.

After the Elwha Dam was completely removed by spring 2013, salmon were found spawning above the former dam site. The second dam, Glines Canyon, was completely removed by end of September 2014 and soon after, bull trout and chinook were detected beyond that dam site.

Biologists have been counting adult fish through scuba surveys and a sonar camera in the lower river. Since 2013, biologists have counted nearly 9,000 chinook and steelhead returning to the river.

The tribe's new hatchery was finished in 2010 and regularly spawns and rears coho and chum salmon. It also operates steelhead and pink broodstock programs.

Since lakes Aldwell and Mills were drained, crews from the tribe, Washington Conservation Corps and Olympic National Park have been eradicating invasive plants and replacing them with native trees, shrubs and grasses within the new open riverbeds. More than 50 engineered logjams have been installed to help slow the river's velocity and create pools and other salmon habitat.

The tribe's wildlife staff studied river otters and American dippers, looking at how the animals used the river for food and habitat and how those needs were impacted by dam removal. Post-dam removal, the wildlife staff is monitoring how elk, deer and small mammals are using the newly exposed lakebeds as habitat.

Hatchery Management

Hatcheries must remain a central part of salmon management in western Washington as long as lost and degraded habitat prevents watersheds from naturally producing abundant, self-sustaining runs of sufficient size to meet tribal treaty fishing harvest rights.

- Treaty Indian tribes released more than 39 million salmon in 2013, including 10 million chinook, 16.5 million chum and 7.7 million coho.

- Most tribal hatcheries produce salmon for harvest by both Indian and non-Indian fishermen. Some serve as wild salmon nurseries that improve the survival of juvenile fish and increase returns of salmon that spawn naturally in our watersheds.

- Tribes conduct an extensive mass marking and coded-wire tag program. Young fish are marked by having their adipose fin clipped before release. Tiny coded-wire tags are inserted into the noses of young salmon. The tags from marked fish are recovered in fisheries, providing important information about marine survival, migration and hatchery effectiveness.

Tribal Programs Support Threatened Steelhead

Tribal hatcheries not only produce fish for harvest, but also provide a vital role in helping imperiled stocks. Some tribal facilities are the linchpin in restoring weak runs of steelhead. Puget Sound steelhead are listed as threatened under the federal Endangered Species Act.

Hatchery programs started by the Skokomish, Puyallup and Muckleshoot tribes in 2006 to rescue weak runs of steelhead have seen tremendous results.

The steelhead population in the Skokomish River has doubled since the Skokomish Tribe began its supplementation project as part of a 16-year-long project to boost the steelhead stocks in Hood Canal.

"The increase in the number of egg nests has given us an early indication that the project is working, but the long-term monitoring will be the true test of its success," said Matt Kowalski, the tribe's steelhead biologist.

The tribe spent the past eight years collecting 30,000 steelhead eggs annually from the Skokomish River. The eggs, collected between May and June, have been raised to smolts in a state hatchery. Most are released as juveniles, but 400 of the fish are transported to a federal hatchery where they are raised to 4-year-old adults before release to improve their chances of spawning in the river.

The Puyallup Tribe of Indians is continuing its successful steelhead broodstock program by releasing young steelhead from an acclimation pond in the upper White River.

"Acclimation ponds help ensure there are juvenile steelhead in the river each year to take advantage of the available habitat," said Blake Smith, the tribe's hatchery manager. The fish will be released at a pond on Huckleberry Creek, a tributary to the White River in the Puyallup watershed.

To help recover the declining run, the Muckleshoot and Puyallup tribes started the steelhead broodstock program eight years ago. Each year, the partners spawn up to 25 wild steelhead taken from an adult trap on the White River.

Up to 50,000 juvenile steelhead are produced annually at the Muckleshoot Tribe's White River hatchery. This year will mark the first release of hatchery steelhead from the acclimation ponds.


Tiffany Royal

Tribal and federal staff and volunteers collect steelhead eggs from the Skokomish River valley.

Harvest Management

Salmon

Treaty Indian tribes and the Washington Department of Fish and Wildlife co-manage salmon fisheries in Puget Sound, the Strait of Juan de Fuca and nearshore coastal waters.

- For decades, state and tribal salmon co-managers have reduced harvest in response to declining salmon runs. Tribes have cut harvest by 80-90 percent since 1985.
- Under *U.S. v. Washington* (the Boldt decision), harvest occurs only after sufficient fish are available to sustain the resource.
- The tribes monitor their harvest using the Treaty Indian Catch Monitoring Program to provide accurate, same-day catch statistics for treaty Indian fisheries. The program enables close monitoring of tribal harvest levels and allows in-season adjustments.
- Tribal and state managers work cooperatively through the Pacific Fishery Management Council and the North of Falcon process to develop fishing seasons. The co-managers also cooperate with Canadian and Alaskan fisheries managers through the U.S./Canada Pacific Salmon Treaty.

Fraser Sockeye Run Avoids U.S. Waters


Kari Neumeyer

Swinomish fisherman Landy James helps bring in Fraser sockeye during the tribes' ceremonial and subsistence fishery.

Tribal fishermen had high hopes for the 2014 Fraser River sockeye fishery, forecast to be more than 20 million fish.

The returning fish were the offspring of the record 2010 Fraser run of about 30 million fish.

Unfortunately, 96 percent of the sockeye were diverted into Canadian waters, out of reach for the nine tribes with treaty-reserved rights to harvest Fraser sockeye. The tribes are Jamestown S'Klallam, Lower Elwha Klallam, Lummi, Nooksack, Makah, Port Gamble S'Klallam, Suquamish, Swinomish and Tulalip.

This year's diversion rate was one of the highest on record. Usually, about half of the sockeye swim around Vancouver Island through the Strait of Juan de Fuca, where tribal fishermen can harvest them when they enter U.S. waters. But by the end of August, Canadian fishermen had caught about five million Fraser sockeye, while in the States, tribal and non-tribal fishermen had caught about 275,000 fish.

Tribes will be requesting a declaration of natural disaster under the Stafford Disaster Relief and Emergency Assistance Act, and a fisheries economic disaster under the Magnuson-Stevens Act, which would provide services and financial assistance to fishermen.

Before the commercial fishery opened in August, the Swinomish Tribe held a one-day ceremonial and subsistence fishery intended to harvest sockeye for both Swinomish and Tulalip tribal members to put away for the winter.

"The tribes take some of their quota to save for ceremonies, and to give to tribal members to cook or can," said Lorraine Loomis, fisheries manager of the Swinomish Tribe. "We don't have enough fish to get through the winter."

The tribes were targeting 35,000 sockeye to be caught for the nine sockeye tribes' ceremonial and subsistence use, but only 3,100 were caught.

Lummi Nation tribal members fished for Fraser sockeye with a traditional reef net in addition to their commercial purse seine and gillnet fleet.

"It's an imitation of the seafloor, like a reef," said Lummi fisherman Richard Solomon. "*Sxwole* is what our people called it."

The net is suspended from two canoes while tribal fishermen watch for salmon to swim into the simulated reef and then lift the net.

"We have to relive the path," said Lummi fisherman Troy Olsen. "Our journey back to the *sxwole*, our reef net, is in its infancy and we're just now starting."

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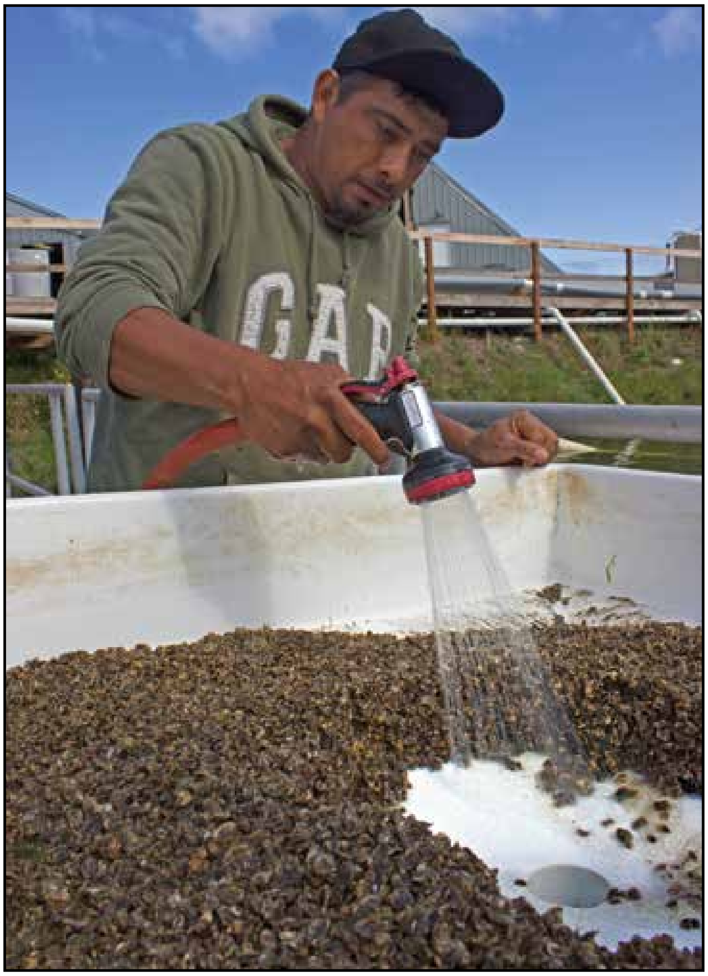
Shellfish

Treaty tribes harvest native littleneck, manila and geoduck clams, Pacific oysters, Dungeness crab, shrimp and other shellfish throughout the coast and Puget Sound.

- Shellfish from ceremonial and subsistence fisheries are for tribal use only, and are a necessary part of their culture and traditional diet.
- Tribal shellfish programs manage harvests with other tribes and the state through resource-sharing agreements. The tribes are exploring ways to improve management of other species, including sea cucumbers, Olympia oysters and sea urchins.
- Tribes continue to work with property owners to manage harvest on non-tribal tidelands.
- Tribal shellfish enhancement results in bigger and more consistent harvests that benefit both tribal and non-tribal diggers.
- Shellfish harvested in commercial fisheries are sold to licensed shellfish buyers. For the protection of public health, shellfish are harvested and processed according to strict state and national standards.
- In 2013, treaty tribes in western Washington commercially harvested nearly 900,000 pounds of manila and littleneck clams; more than 2.6 million pounds of geoduck clams; more than 4 million oysters; 8.5 million pounds of crab; nearly 271,000 pounds of sea cucumbers and more than 247,000 pounds of shrimp.

Jamestown S'Klallam, Partners Start Hatchery


Tiffany Royal

Hatchery technician Nicolas Rosales rinses oysters before placing them in a floating upwelling system.

The Jamestown S'Klallam Tribe is developing its own shellfish hatchery to benefit both tribal and non-tribal shellfish operations in Puget Sound.

The tribe plans to raise shellfish and grow seed to sell, said Kurt Grinnell, Jamestown S'Klallam Tribe vice-chair.

The tribe leased the former Washington Department of Fish and Wildlife shellfish hatchery in Quilcene in late 2013 and started rearing 800 Pacific oysters in March.

The tribe is working in partnership with Troutlodge, a private salmon and shellfish aquaculture company, and Jones Farm, a shellfish farm on Lopez Island. The tribe and its partners are working together because water chemistry has been an issue when sourcing seed from one location.

"We lower risk by partnering up with others," Grinnell said.

The primary focus will be growing manila clams, geoduck and oysters from seed to adult, plus the algae needed to feed everything, as well as selling seed to others.

"We want to create our own larvae and broodstock here and provide seed to others," Grinnell said. "We've had a need for something like this for a long time and to have it accessible to all the tribes. We're going to make this work, we just have a long ways to go. There is such a demand for seed and everything we grow will be sold."

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Harvest Management (continued)

Marine Fish

Treaty tribes are co-managers of the marine fish resource. They work closely with the state of Washington, federal agencies and in international forums to develop and implement species conservation plans for all groundfish stocks in Puget Sound and along the Pacific coast.

- The Pacific Fishery Management Council, which includes the tribal and state co-managers, regulates the catch of black cod, rockfish and other marine fish. Halibut are managed through the International Pacific Halibut Commission, established by the United States and Canada governments. Tribes are active participants in season-setting processes and the technical groups that serve those bodies.
- The state of Washington, Hoh Indian Tribe, Makah Tribe, Quileute Tribe and the Quinault Indian Nation are working with the National Oceanic and Atmospheric Administration to develop research goals that look at changing ocean conditions and managing ocean resources.
- The tribes and state support ocean monitoring and research leading to ecosystem-based management of fishery resources. In 2013, the Quinault Indian Nation developed a nearshore ocean-monitoring system that uses sensors in crab pots to gather water quality information.

Halibut Hook Links Generations


Debbie Preston

Makah elder Jesse Ides examines a modern day halibut hook designed to test traditional fishing methods.

A fish hook has tied history, culture and the Makah community together in unexpected ways.

The *čibu·d* (pronounced “cha bood”), or halibut hook, became the subject of a student project during an internship with Makah Fisheries Management.

“I had a student, Larry Buzzell, come to me wanting to do a project that related to historical fishing methods,” said Jonathan Scordino, marine mammal biologist for the Makah Tribe.

Historically the hooks were made of both wood and bone. As the tribe gained access to new materials, they also made hooks from metal.

“The goal of the project was to test if the *čibu·d* was more selective for catching halibut than contemporary circle hooks when fished on a longline,” Scordino said.

Setting up the experiment was challenging because the study required 200 *čibu·d* to be made by hand. The Makah Cultural and Research Center opened its exhibit preparation space for several weeks to allow community members to come in and help make the hooks.

Through trial and error, a group of volunteers learned it was better to bend the metal hooks cold rather than heat the metal.

Elder Jesse Ides (*Hushta*) watched as young people learned to make the hook he used in his youth.

“It’s terrific seeing them show the determination to make it and use it,” Ides said.

He recalled his father hauling canoes out to the halibut grounds to fish.

“You’d catch just halibut with that gear, nothing else,” he said.

“The *čibu·d* was known to not only fish selectively for halibut, but not catch too small or too big a halibut,” Scordino said. “From a management perspective, that’s exactly the size you want to catch so the older spawners remain and the young grow to be a harvestable size.”

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Wildlife Management

The treaty Indian tribes are co-managers of wildlife resources in western Washington, which include species such as deer, elk, bear and mountain goats.

- Western Washington treaty tribal hunters account for a small portion of the total combined deer and elk harvest in the state. In the 2013-14 season, treaty tribal hunters harvested a reported 432 elk and 567 deer, while non-Indian hunters harvested a reported 7,246 elk and 27,448 deer.
- Tribal hunters do not hunt for sport, but for sustenance. Most do not hunt only for themselves. Tribal culture in western Washington is based on extended family relationships with hunters sharing game with several families. Some tribes have designated hunters who harvest wildlife for tribal elders and others unable to hunt for themselves, as well as for ceremonial purposes.
- All tribes prohibit hunting for commercial purposes.
- As a sovereign government, each treaty tribe develops its own hunting regulations and ordinances for tribal members. Tribal hunters are licensed by their tribes and must obtain tags for animals they wish to hunt.
- Many tribes conduct hunter education programs aimed at teaching tribal youth safe hunting practices and the cultural importance of wildlife to the tribe.

Tracking Deer and Elk Predators: Bobcats, Cougars

Olympic Peninsula tribes are tracking bobcats and cougars to find out whether they are the primary predators of deer and elk on the peninsula. Until now, there hasn't been much scientific evidence supporting or disproving that theory.

Several tribes are putting radio-signal transmitting collars on cougars to better understand their home ranges, diet and other behavior. The Makah Tribe is the only entity collecting similar data on bobcats.

"There really has been no research done on bobcats in Washington," said Rob McCoy, Makah wildlife division manager. The tribe has been conducting research on cougars since December 2010 and started radio-collaring bobcats in January 2012.

"We have really good data on cougars and male bobcats," McCoy said. "We're working to get more females into the study to better understand reproduction and size of litters and survival."

The tribe now has four male and four female bobcats with collars.

When a collared cat makes a kill, the radio signals show that it has stopped moving while it feeds. Biologists walk in and note the kill species.

"We're still gathering data, but right now, we just aren't seeing elk in the bobcat diet at all," McCoy said. "It's early in the study, but we aren't seeing a significant number of deer being killed by bobcats either. There is evidence they scavenge on deer opportunistically after a cougar kill or natural cause of death."

McCoy said that bobcats may actually survive on smaller prey such as mountain beavers, birds, rabbits, moles and mice.

Adult male bobcats have little overlap of home ranges as they are quite territorial.

"One of the things we want to know about female cats is whether their home ranges are larger or smaller and how territorial they are, comparatively," McCoy said.

Coupled with extensive research of elk and deer within their traditional hunting area, the tribe will use the research on cats to manage them in the future.

Debbie Preston

Rob McCoy, wildlife division manager for the Makah Tribe, applies eyedrops to a bobcat prior to fitting it with a radio collar.

Regional Collaborative Management

Puget Sound Partnership

The Puget Sound Partnership (PSP) was created in 2007 to recover Puget Sound's health by 2020. Tribes are actively involved in leadership and participation in a wide range of projects to improve the health of Puget Sound.

- U.S. Reps. Derek Kilmer and Denny Heck formed the Puget Sound Recovery Caucus in 2013. The congressional caucus coordinates action at the federal level and collaborates with stakeholders on efforts to improve the health of Puget Sound.

- The 2014-15 Action Agenda update focused on revisions to recovery activities that should begin or be completed within two years. New initiatives, priorities and strategies are not included in this update, but will be considered when substantial review and updating takes place in 2016.

- Tribal representatives are active in partnership efforts to protect salmon habitat. One approach seeks improved habitat protection through review and improvements to current regulatory processes.

Tribes Collaborate on Salish Sea Survival


Emmett O'Connell

Jed Moore, salmon biologist for the Nisqually Indian Tribe, takes zooplankton samples to better understand the food available to migrating juvenile salmon.

Fisheries managers studying poor ocean survival of salmon are concentrating their research on juvenile fish and their preferred prey. Several tribes collaborated on studies in 2014.

The Tulalip, Nisqually, Port Gamble S'Klallam, Lummi, Swinomish and Sauk-Suiattle tribes are among the collaborators sampling zooplankton throughout the region.

Zooplankton and ichthyoplankton are the preferred prey for juvenile salmon. Researchers want to find out whether prey availability has changed in the Salish Sea during the critical period of juvenile salmon development, leading to poor growth and survival.

"This effort will fill critical knowledge gaps in understanding the lower levels of the marine food web that affect juvenile salmon," said Paul McCollum, director of natural resources for the Port Gamble S'Klallam Tribe. "The data will contribute to the development of ecosystem indicators that have already been demonstrated to greatly improve adult salmon return forecasting."

In Hood Canal and Admiralty Inlet, the Port Gamble S'Klallam Tribe has been conducting nearshore research and monitoring of juvenile salmon and forage fish, using acoustics, trawl and beach seine methods, as well as zooplankton sampling.

"The increasing inability in recent years to accurately estimate annual salmon returns is impacting tribal treaty rights and implementation of the U.S./Canada Pacific Salmon Treaty," said Terry Williams, commissioner of fisheries and natural resources for the Tulalip Tribes. "It also impairs the critical decision-making necessary to achieve salmon recovery goals and sustainable fisheries."

The Tulalip and Nisqually tribes are partnering on a study of juvenile salmon in the Snohomish and Nisqually river watersheds and adjacent nearshore and offshore marine areas.

The study will examine the entire community structure of competitors and predators, including plankton and other fish species. Smolt traps operate continuously on both rivers from winter through summer to collect timing, size and abundance data for out-migrating salmon. Both tribes also sample juvenile fish use of nearshore marine areas and pocket estuaries using fyke nets and beach seines.

This sampling data should allow researchers to identify the life stage, timing and locations where growth of juvenile salmon is limited.

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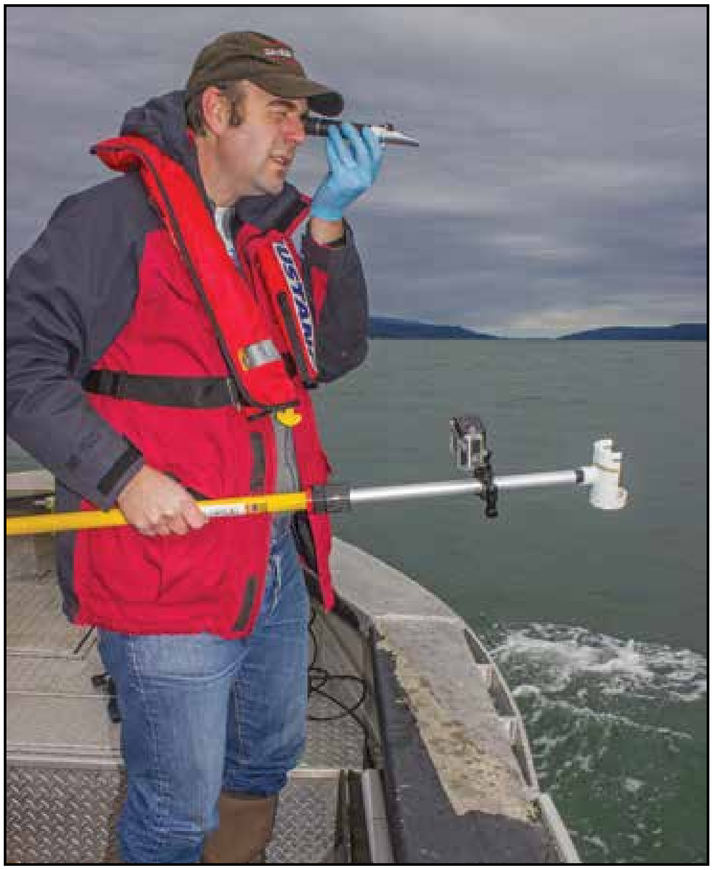
Ocean Ecosystem Management

The state of Washington, the Hoh, Makah and Quileute tribes and the Quinault Indian Nation work with the National Oceanic and Atmospheric Administration (NOAA) to integrate common research goals to understand changing ocean conditions and create the building blocks for managing these resources.

- In recognition of the challenges facing the Olympic Coast ecosystem, the tribes and state of Washington established the Intergovernmental Policy Council to guide management of Olympic Coast National Marine Sanctuary. Many of the research and planning goals established by tribes and the state mirror the recommendations of the U.S. Ocean Policy.
- Climate change and ocean acidification have been top priorities the past two years. Because of their unique vulnerability, coastal indigenous cultures are leaders in societal adaptation and mitigation in response to events driven by climate change.
- The tribes continue to work with the state of Washington and federal partners to respond to the findings of the state's blue ribbon panel on ocean acidification including prioritizing research to understand its effects on marine ecology and shared natural resources.

Tribal Environmental Protection and Water Resources Program



Tiffany Royal

Skokomish Tribe water quality biologist Seth Book measures the salinity of a water sample from Hood Canal near Hoodsport.

The Coordinated Tribal Water Quality Program was created by the Pacific Northwest tribes and the federal Environmental Protection Agency (EPA) to address water quality issues under the Clean Water Act.

- EPA's General Assistance Program (GAP) was established in 1992 to improve capacity for environmental protection programs for all tribes in the country. Many tribes are now participating in the pilot "Beyond GAP" project to build on the investments of the last 20 years by creating environmental implementation programs locally while supporting national environmental protection objectives.
- These programs are essential to combat the threats to tribal treaty resources such as declining water quality and quantity. In western Washington, climate change and urban development negatively affect water resources and aquatic ecosystems, and will get worse with a state population expected to rise by 1 million in the next 20 years.
- Tribal water quality resource program goals include establishing instream flows to sustain harvestable populations of salmon, identifying limiting factors for salmon recovery, protecting existing groundwater and surface water supplies, and participating in multi-agency planning processes for water quantity and quality management.

Regional Collaborative Management (continued)

Forest Management

Two processes, the Timber/Fish/Wildlife (TFW) Agreement and the Forests and Fish Report (FFR), provide the framework for an adaptive management process that brings together tribes, state and federal agencies, environmental groups and private forest landowners to protect salmon, wildlife and other species while providing for the economic health of the timber industry.

- Treaty tribes in western Washington manage their forestlands to benefit people, fish, wildlife and water.
- Reforestation for future needs is part of maintaining the healthy forests that are key to vibrant streams for salmon, and that enable wildlife to thrive.
- Forestlands are a source of treaty-protected foods, medicine and cultural items.
- A tribal representative serves on the state's Forest Practices Board, which sets standards for activities such as timber harvests, road construction and forest chemical applications. Tribes also are active participants in the FFR Cooperative Monitoring, Evaluation and Research Committee (CMER).

Upper Skagit Tribe Improves Elk Forage

Debbie Preston

Elk populations in the North Cascades have suffered as a result of degraded habitat. The Upper Skagit Tribe recently helped thin a forest and added mulch to the soil to improve forage quality.

The Upper Skagit Indian Tribe's natural resources department thinned and mulched forestland on Puget Sound Energy (PSE) property last fall to improve elk forage in the North Cascades mountains.

Degraded and disconnected habitat is one of the main causes of the decline in numbers of the Nooksack elk herd, which went from a population of more than 1,700 20 years ago to about 300 by 2003. Since then, tribal and state co-managers have improved elk habitat in the region. Annual population surveys indicate that the herd is showing signs of recovery.

"Elk need a corridor of habitat that is rich in forage to keep them from becoming nuisances in populated areas," said Scott Schuyler, natural resources director for the Upper Skagit Tribe.

PSE acquired the land from the Department of Natural Resources as part of the mitigation requirements of the 2008 relicensing agreement with the Federal Energy Regulatory Commission for the utility's Baker River Hydroelectric Project.

A crew used chainsaws to remove hundreds of trees on about 3 acres of land and 1,500 feet of road. The trees, mostly small Douglas fir, were then put through a wood chipper to mulch the dry, rocky soil.

"We needed to remove enough of the canopy to let light in so grasses can grow," said Upper Skagit timberland services manager Robert Schuyler. "The trees we left can be harvested later for a commercial crop."

The mulched ground was seeded with grasses, clover and small burnet.

"There's no forage out here, it's all knee-deep salal, Oregon grape and sword fern, which elk don't eat," said Tony Fuchs, PSE wildlife biologist. "Once we get grasses and clover established, elk will find a better place to forage."

NWIFC Functions, Programs and Activities

Tiffany Royal

NWIFC fish pathologist Marcia House, left, and Lower Elwha Klallam Tribe hatchery manager Larry Ward discuss coho that returned to the hatchery in November 2014.

The Northwest Indian Fisheries Commission (NWIFC) was created in 1974 by the 20 treaty Indian tribes in western Washington that were parties to the *U.S. v. Washington* litigation that affirmed their treaty-reserved salmon harvest rights and established the tribes as natural resources co-managers with the state.

The NWIFC is an inter-tribal organization that assists member tribes with their natural resources co-management responsibilities. Member tribes select commissioners who develop policy and provide direction for the organization. The commission employs about 70 full-time employees and is headquartered in Olympia, Wash., with satellite offices in Forks, Kingston and Burlington.

The NWIFC provides broad policy coordination as well as high-quality technical and support services for its member tribes in their efforts to co-manage the natural resources of western Washington. The NWIFC serves as a clearinghouse for information on natural resources management issues important to member tribes. The commission also acts as a forum for tribes to address issues of shared concern, and enables the tribes to speak with a unified voice.

The NWIFC has coordinated the tribal Treaty Rights at Risk initiative that seeks to encourage the federal government to align its agencies and programs with salmon recovery goals and to lead a more coordinated salmon recovery effort. Tribes are calling on the federal government for assistance because it has both the obligation and authority to recover salmon and protect tribal treaty rights.

Habitat Services

- Coordinate policy and technical discussion between tribes and federal, state and local governments, and other interested parties.
- Coordinate, represent and monitor tribal interests in the Timber/Fish/Wildlife Forests and Fish Report process, Coordinated Tribal Water Resources and Ambient Monitoring programs. Analyze and distribute technical information on habitat-related forums, programs and processes.
- Implement the Salmon and Steelhead Habitat Inventory and Assessment Project.

U.S./Canada Pacific Salmon Treaty

- Facilitate inter-tribal and inter-agency meetings, develop issue papers and negotiation options.
- Inform tribes and policy representatives about issues affected by the treaty implementation process.
- Serve on the pink, chum, coho, chinook, Fraser sockeye and data-sharing technical committees, and other work groups and panels.
- Coordinate tribal research and data-gathering activities associated with implementation of the Pacific Salmon Committee.

Quantitative Services

- Administer and coordinate the Treaty Indian Catch Monitoring Program.
- Provide statistical consulting services.
- Conduct data analysis of fisheries studies and developing study designs.
- Update and evaluate fishery management statistical models and databases.

Fisheries Management

- Long-range planning, wild salmon recovery efforts and federal Endangered Species Act implementation.
- Annual fisheries planning: developing pre-season agreements; pre-season and in-season run size forecasts; monitoring; and post-season fishery analysis and reporting.
- Marine fish management planning.
- Shellfish management planning.

Enhancement Services

- Coordinate coded-wire tagging of more than 4 million fish at tribal hatcheries to provide information critical to fisheries management.
- Analyze coded-wire data.
- Provide genetic, ecological and statistical consulting for tribal hatchery programs.
- Provide fish health services to tribal hatcheries in the areas of juvenile fish health monitoring, disease diagnosis, adult health inspection and vaccine production.

Information and Education Services

- Provide internal and external communication services to member tribes and NWIFC.
- Develop and distribute communication products such as news releases, newsletters, videos, photos and web-based content.
- Respond to public requests for information about the tribes and their tribal natural resources management activities.
- Work with state agencies, environmental organizations and others in cooperative communication efforts.

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nwifc.org

PCB/PBDE Loading Estimates for the Greater Lake Washington Watershed

September 2013

King County

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PCB/PBDE Loading Estimates for the Greater Lake Washington Watershed

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U.S. Environmental Protection Agency Region 10

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EXECUTIVE SUMMARY

King County was awarded a Puget Sound Action Agenda: Technical Investigations and Implementation Assistance Grant by the U.S. Environmental Protection Agency (USEPA) to estimate loading of polychlorinated biphenyls (PCBs) and polybrominated diphenylethers (PBDEs) to Lake Washington, Lake Union and Puget Sound; and model potential reduction in Lake Washington fish tissue concentrations associated with selected PCB loading reduction scenarios. A field study was designed and implemented to measure concentrations in key contaminant loading pathways to Lakes Washington and Union (i.e., rivers, streams, stormwater, combined sewer overflows, highway bridges and atmospheric deposition) and measure the PCB/PBDE concentrations in the export pathway leaving the lake system through the Ship Canal locks to Puget Sound. By combining contaminant concentration data with long term flow estimates for these pathways, mass loading estimates to Lakes Washington and Union and export to Puget Sound for total PCB (tPCB) and total PBDE (tPBDE) were developed. Details of the tPCB and tPBDE loading calculation approach and resulting estimates are presented in this report. Sampling details and results are the subject of a separate report.

This project is considered a first step toward understanding the relative importance of major contaminant loading pathways that contribute PCBs and PBDEs to these lakes as well as understanding their long term fate and the potential for recovery. The end result will be a more complete understanding of major pathways transporting PCBs and PBDEs to these lakes, processes controlling their ultimate fate and potential for management actions to reduce health risks from consuming contaminated fish from Lake Washington. The study will also provide a better understanding on which future monitoring and modeling efforts can be planned.

Some overall findings from the PCB and PBDE loading report are highlighted below:

PCB Loading Estimate Findings

- As much as 70 percent of the tPCB load to Lake Washington comes from local tributary watersheds around the lake.
- Three creeks (Thornton, Juanita and May) representing a range in the type and intensity of development were monitored.
    - Thornton Creek had the highest amount of commercial/industrial development that occurred prior to the ban on PCB manufacture and use limitations and the highest estimated tPCB loading.
    - May Creek had the lowest amount of older commercial/industrial development and the lowest estimated tPCB loading.
    - Juanita Creek had intermediate amount of older commercial/industrial development and an estimated tPCB loading that fell between the estimate for Thornton and May creeks.
- Loading estimates and additional analyses suggest that the predominant source of tPCBs is stormwater runoff from developed areas – possibly linked to older

commercial/industrial development. This is consistent with the conceptual model of tPCB sources and pathways emerging from other studies that suggest that PCB sources are concentrated in urban centers containing older commercial and industrial buildings in which paints, caulks, and sealants containing PCBs were used.

- Estimated total tPCB loading to Lake Washington is less than the estimated loading exported from the lake outlet. This is because the lake acts as a sink for PCBs, primarily as the result of sediment accumulation and burial, but also through volatilization through the lake surface. The relative importance of these fate processes will be evaluated in the next phase of this study.
- tPCB concentrations (and hence loading), increase from the outlet of Lake Washington to the outlet of Lake Union to Puget Sound. tPCB loading estimates for Lake Union suggest that this may be the result of loading from CSOs and runoff from local drainage basins.

PBDE Loading Estimate Findings

- In general, there was more uncertainty associated with tPBDE loading estimates and source pathways appeared to be more diffuse. This is consistent with an emerging conceptual model for PBDE sources and pathways based on the fact that PBDEs were introduced more recently into the environment and sources are more dispersed throughout the urban and suburban landscape (e.g., upholstery containing PBDE-based fire retardants).
- Loading estimates for the two major rivers to Lake Washington (Cedar and Sammamish) suggest a tPBDE load somewhat smaller than the tributary stream load, although there is a high degree of uncertainty in these estimates. Loadings from rivers include all pathways from upstream waterbodies.
- The contribution of atmospheric deposition to the surface of Lake Washington was also estimated to be relatively significant; close to 30 percent of the total loading estimate for PBDEs.
- tPBDE loading to Lake Union was dominated by input from Lake Washington. This input was estimated to contribute about 80 percent of the total tPBDE load.

The tPCB loading estimates documented in this report will be used in models that will be developed in the next phase of this study to simulate the response of Lake Washington to reductions in tPCB loading that might result from various management approaches and resulting changes in concentrations in resident fish.

1.0. INTRODUCTION

In 2010 King County was awarded a Puget Sound Action Agenda: Technical Investigations and Implementation Assistance Grant by the U.S. Environmental Protection Agency (USEPA) to estimate loading of polychlorinated biphenyls (PCBs) and polybrominated diphenylethers (PBDEs) to Lake Washington, Lake Union and Puget Sound; and model potential reduction in Lake Washington fish tissue concentrations associated with selected PCB loading reduction scenarios. A field study was designed and implemented to measure PCB and PBDE concentrations in key contaminant loading pathways to Lakes Washington and Union (i.e., rivers, streams, stormwater, combined sewer overflows, highway bridges and atmospheric deposition) and measure the concentrations in the export pathway leaving the lake system through the Ship Canal locks to Puget Sound (King County 2013). By combining contaminant concentration data with long term flow estimates for these pathways, mass loading estimates to Lakes Washington and Union and subsequent export to Puget Sound for total PCB (tPCB) and total PBDE (tPBDE) were developed. Details of the tPCB and tPBDE loading calculation approach and resulting estimates are presented in this report. Sampling details and results are the subject of a separate report (King County 2013).

This project is considered a first step toward understanding the relative importance of major contaminant loading pathways that contribute PCBs and PBDEs to these lakes as well as understanding their long term fate and the potential for recovery. The end result is expected to be a more complete understanding of pathways transporting PCBs and PBDEs to these lakes, processes controlling their ultimate fate and the potential for management actions to reduce health risks from consuming contaminated fish from Lake Washington. Knowing the relative importance of the loadings pathways will provide a better understanding on which future monitoring and modeling efforts can be planned.

1.1 Background

1.1.1 PCBs

PCBs are chlorinated organic compounds that were manufactured for uses that required chemical stability and low flammability. PCBs include 209 individual compounds known as congeners that vary to some degree in physical, chemical and toxicological properties based primarily on the degree of chlorination. Due to their chemical stability and low water solubility, PCBs are persistent in the environment, bind strongly to sediment and soil particles; and bioaccumulate in aquatic organisms, wildlife and humans.

Bioaccumulation of PCBs presents a potential health risk to aquatic life, terrestrial wildlife, and humans. The Washington Department of Health (WADOH) issued a fish consumption advisory for PCBs in Lake Washington which covers yellow perch, cutthroat trout, carp, and northern pikeminnow (WADOH 2004).[1] PCB concentrations in Lake Washington fish exceed both the National Toxics Rule[2] levels for protection of human health and the 95th-percentile of concentrations measured in fish collected statewide (Seiders and Deligeannis 2009).

Commercial production of PCBs began in the 1920s, initially for use as a dielectric fluid in electrical transformers, capacitors and electric motors. After World War II, production increased substantially and PCB use diversified to include heat transfer fluids, hydraulic fluids, plasticizers, carbonless copy paper, lubricants, inks, laminating agents, paints, adhesives, waxes, additives in cements and plasters, casting agents, sealing liquids, fire retardants, immersion oils and pesticides (De Voogt and Brinkman 1989). PCBs were voluntarily phased-out of production in the 1970s and manufacture and most uses were banned in 1979 in the United States (44 FR 31514).[3] While the sale and production of PCBs has been banned for over three decades, considerable amounts of PCBs remain in use – primarily as dielectric fluid in so-called closed sources like transformers and capacitors and in open sources such as building paints, caulks and sealants (Diamond et al. 2010b; Robson et al. 2010).

In general, halting the production of PCBs, elimination of many uses, and a declining inventory of PCBs in use has resulted in declining concentrations in environmental media, including fish tissue and aquatic sediments (Peterman et al. 1990; Van Metre and Mahler 2005). However, studies of fish tissue and sediment concentrations in many areas of the world indicate that the initial rate of decline appears to have slowed or halted completely (Van Metre et al. 1998; Hickey et al. 2006; Bhavsar et al. 2007).

Historical data on PCB levels in non-anadromous fish collected from Lakes Washington and Union are insufficient to evaluate long-term trends in PCB concentrations (McIntyre 2004). Studies have been conducted on anadromous fish; however, these fish generally spend only a portion of their life cycle in these lakes and the measured contaminant concentrations are generally lower than those observed in resident (non-anadromous) fish species (McIntyre 2004; Fletcher 2009).

Substantial declines in Lake Washington sediment PCB concentrations have been documented. Surface sediment PCB levels are now about a third of the peak concentrations measured at depth in sediment core horizons dated to the early 1970s (Yake 2001; Van Metre et al. 2004; Van Metre and Mahler 2005; Furl et al. 2009). The increase and subsequent decrease in sediment PCB concentrations coincide with national trends in production, use and subsequent use limitations and elimination of production. In the case of Lake Washington, the increase and decline also coincides generally with the development and growth of cities around the lake and subsequent diversion of inputs of

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[1] Washington State Department of Health Fish Consumption Advisories (see: http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx

[2] U.S. Environmental Protection Agency (USEPA) National Toxics Rule (see: http://water.epa.gov/scitech/swguidance/standards/wqsregs.cfm)

[3] U.S. Environmental Protection Agency (see: http://www.epa.gov/history/topics/pcbs/01.html)

treated wastewater from Lake Washington to Puget Sound that was completed in 1968 (Edmondson and Lehman 1981).

1.1.2 PBDEs

PBDEs are brominated organic compounds that have been in use, primarily as flame retardants in plastics and textiles, since 1965. Specific uses of PBDEs include incorporation into flexible polyurethane foams used in upholstery stuffing for furniture and car seats, electronic components, electrical components, and plastics used in the casings of televisions, personal computers, and other electronic equipment (USEPA 2010). PBDEs are manufactured as three primary formulations: "Penta," "Octa," and "Deca," which differ in the relative combination of specific PBDE congeners.

PBDEs have chemical, physical and toxicological properties similar to those of PCBs. However, only recently have PBDEs come under scrutiny for their potential for environmental harm due to their toxicity, persistence, and potential to bioaccumulate (Oram et al. 2008). These concerns led to the voluntary withdrawal of the Penta and Octa forms by U.S. manufacturers in 2004, leaving only the Deca formulation currently in commercial use in the United States (USEPA 2010). In 2007, Washington banned most PBDE uses (RCW 70.76) and the ban became effective for Penta and Octa containing products, and for mattresses containing Deca, in 2008. As a result of follow-up studies required in the new law, Washington banned the manufacture, sale and distribution of televisions, computers and residential upholstered furniture containing Deca by January 2011.[4] At the national level, USEPA announced a national phase-out of the Deca formulation in 2009, with production, importation, and sales for most uses in the United States to end by the end of 2012 and all uses to end in 2013 (USEPA 2010).

Data are insufficient to evaluate trends in PBDE concentrations measured in water, sediment, fish or other aquatic life in Lakes Washington or Union. A study of water and tissue concentrations of PBDEs in resident Lake Washington fish was conducted by WADOH and Ecology in 2005 (Johnson et al. 2006). Johnson et al. (2006) also compiled and compared fish tissue data collected from 44 sites representing 36 rivers/impoundments and lakes in the state. Lake Washington had the fifth highest level of tPBDE fish tissue concentrations.

1.2 Project Goals and Objectives

This project will fill data gaps and develop modeling tools to help answer three management questions:

1. Which types of loading pathways are the highest priorities for PCB/PBDE load reduction?
2. Will potential loading reductions from these pathways reduce fish bioaccumulation and contribute substantially towards lifting the fish consumption advisory on Lake Washington?

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[4] Washington Department of Ecology (see: http://www.ecy.wa.gov/news/2009news/2009-017.html)

3. How long might it take the system to respond to these hypothetical loading reductions?

This report presents the loading calculation approach and resulting estimates that will be used to address the first question above and provide key inputs for the development of models that will be used to address all three project management questions. The development and application of these models will be the subject of a future report.

1.3 Study Area

1.3.1 Greater Lake Washington Watershed

The study area encompasses the 1,590 km^2 (614 mi^2) Greater Lake Washington watershed (Figure 1) from its mouth at the Hiram M. Chittenden Locks (Locks).[5] The area experiences a generally mild maritime climate with heaviest precipitation occurring in winter months, primarily as rain at lower elevations and as snow at higher elevations. Elevations are generally less than 1,000 m (3,281 ft), but the total amount of annual rainfall is very dependent on elevation which ranges from about 6 m above mean sea level (msl) to 1,700 m (4,464 ft), and this results in a range of annual precipitation from almost 1,000 mm (39 in) at lake level to over 2,500 mm (100 in) at the highest elevations. Winds are highly variable, but during the winter, major storms and associated winds typically originate from the southwest.

Two major rivers drain to Lake Washington. The Sammamish River drains Lake Sammamish and tributaries in the Sammamish River valley and enters Lake Washington from the north, providing about 30 percent of the total inflow to lake. The Cedar River enters the south end of the lake and contributes about 50 percent of the total inflow (Edmondson 1977; King County 2003a; Cerco et al. 2004). Lake Washington then drains through the Montlake Cut to Lake Union, which drains through the Lake Washington Ship Canal (Ship Canal) and Locks to Puget Sound.

Historically, Lakes Washington and Union were not connected. By 1916 a canal was completed between the two lakes, the outlet of Lake Union was widened and deepened and a lock and dam system was in operation (Chrzastowski 1983). Prior to canal and lock construction, the main inflow to Lake Washington was from the Sammamish River and outflow was through the Black River at the southern end of the lake. To provide sufficient water for lock operation and to reduce flooding, the Cedar River, which had previously joined the Black River near the southern end of the lake, was diverted to Lake Washington (Chrzastowski 1983). These engineering changes resulted in the summer intrusion of saltwater from Puget Sound that enters through the Locks and Ship Canal into Lake Union, resulting in a layer of denser saline water in the lake, which is then entrained and flushed from the lake during winter high flows. The extent of intrusion of saline water is limited to Lake Union through various mitigation measures, including a salt water barrier at the upstream side of the larger of the two locks and a saltwater drain located in a depression at

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[5] This watershed area estimate includes the surfaces of all lakes, streams and wetlands in the watershed.

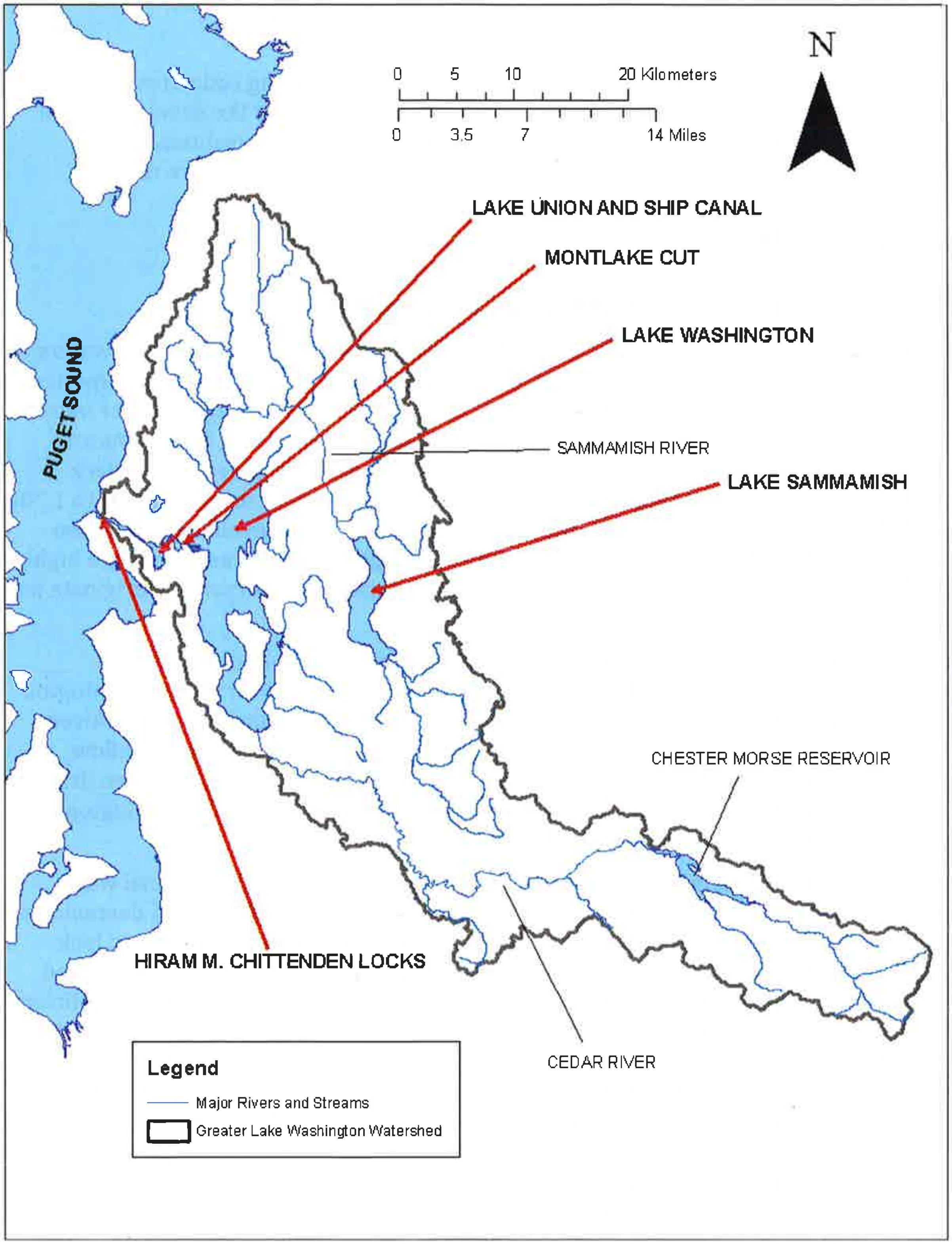

Figure 1. Greater Lake Washington Watershed.

the head of both locks. Salinity is monitored continuously in summer at the University Bridge and is not to exceed 1 ppt (173-201A WAC).

The immediate area around Lake Washington and Lake Union/Ship Canal (simply Lake Union hereafter) is highly developed and includes the major cities (i.e., >50,000 residents) of Seattle, Bellevue, and Renton. While Lake Washington received wastewater from a number of municipal treatment plants until 1968, there are still approximately 70 combined sewer overflows (CSOs) that intermittently discharge to locations along the Seattle shoreline of Lakes Washington and Union. In general, industrial activity around Lake Washington has been limited, while the Lake Union shoreline has historically experienced more intensive industrial uses that are transitioning to mixed use commercial/residential developments.

Approximately 40 sites in the study basin are listed for PCB contamination in Ecology's Confirmed and Suspected Contaminated Sites database (Figure 2).[6] Of these, the sites most often highlighted with respect to Lakes Washington and Union are the Boeing Renton and Quendall Terminals sites on Lake Washington (Era-Miller et al. 2010) and the Seattle Steam Plant site on Lake Union (Cubbage 1992).[7]

The lakes are each crossed by one state and one interstate highway. Lake Washington is crossed by two floating bridges – State Route 520 (SR 520) to the north and Interstate 90 (I-90) to the south. Lake Union is spanned by Interstate 5 (I-5) and State Route 99 (SR 99).

The study area also includes relatively undeveloped, primarily forested, areas in the headwaters of the two major river basins. The headwaters of tributaries along the southeast shoreline of Lake Washington are also relatively undeveloped. The headwaters of the Cedar River are in a protected watershed for the Chester Morse water supply reservoir that provides Seattle Public Utilities (SPU) with a portion of its potable water supply.

1.3.2 Lake Washington and Lake Union

Lake Washington is the second largest natural lake in the state. The lake is an elongated north-south trending glacial trough approximately 35 km (21.7 mi) long with an average depth of 32.9 m (108 ft), a maximum depth of 65.2 m (214 ft), a surface area of 87.6 km^2 (33.8 mi^2) and a volume of 2.884 x 10^9 m^3 (2,338,000 acre-ft) (Anderson 1954).[8] Edmondson and Lehman (1981) provide estimates of annual lake hydraulic renewal times, which indicate that on average the fraction of lake volume renewed each year with

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[6] Ecology Confirmed and Suspected Contaminated Sites list downloaded October 31, 2012: https://fortress.wa.gov/ecy/tcpwebreporting/

[7] The former site of the Shuffleton Power Plant in Renton that discharged cooling water to Lake Washington until 1989 has also been discussed (see Era-Miller et al. 2010), but this site was designated No Further Action by Ecology in 2000.

[8] King County geographic information system (GIS) data indicate a lake surface area (including Union Bay) closer to 89 km^2 (34.4 mi^2), but this may be due to the exclusion of Union Bay from the earlier estimate. Also, Edmondson and Lehman (1981) report a total lake volume of 2.885 x 10^9 m^3 (2,339,000 acre-ft).

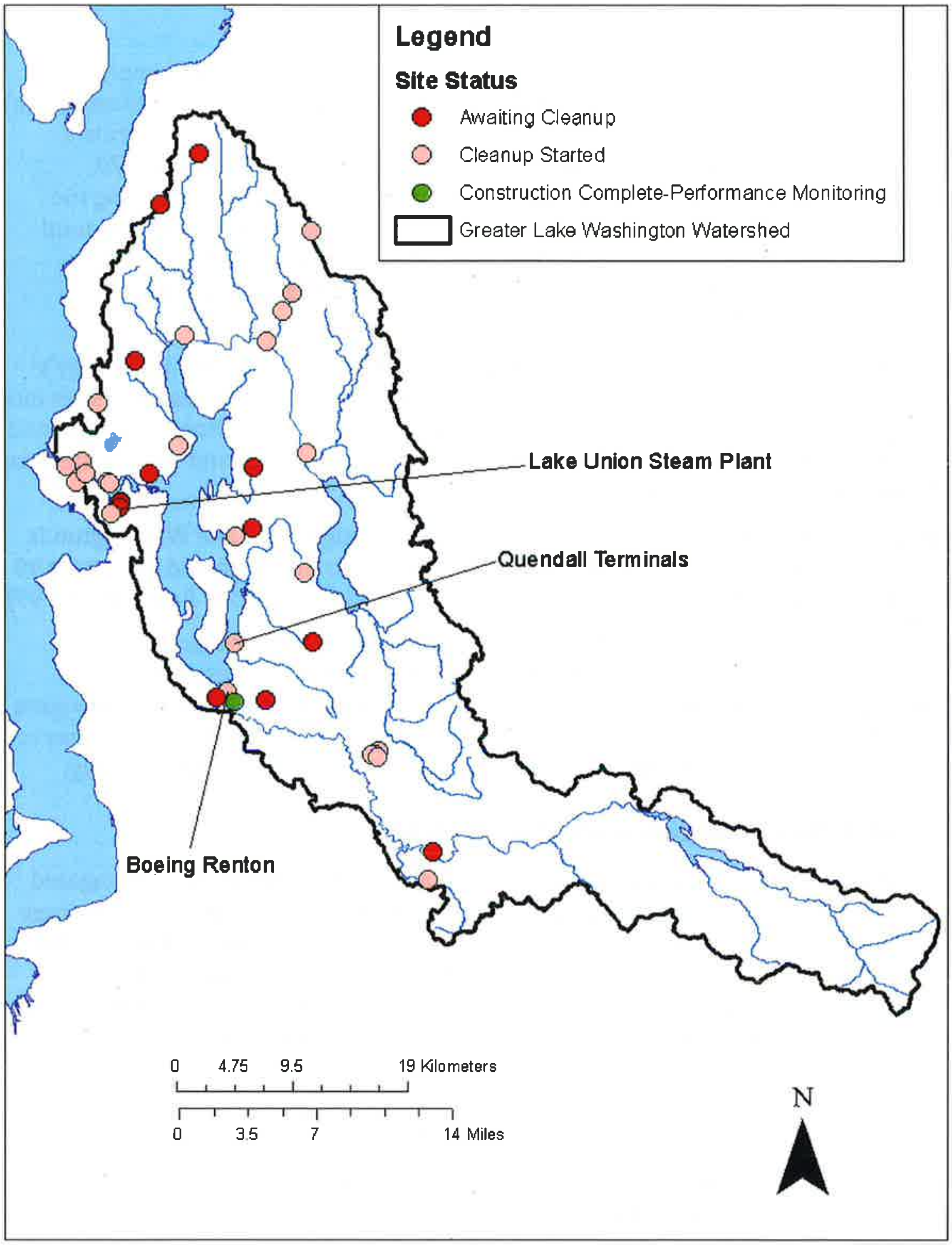

Figure 2. Sites within the Greater Lake Washington watershed with confirmed or suspected PCB contamination and their cleanup status, within the Greater Lake Washington watershed.

Source: Ecology's Confirmed and Suspected Contaminated Sites database.

incoming water (corrected for evaporation) is 0.43 per year. The reciprocal of this is 2.3 years – the average hydraulic residence time of water in the lake.

Lake Union is much smaller than Lake Washington with a total surface area of about 3.8 km^2 (1.5 mi^2) and a volume of approximately 2.5 x 10^7 m^3 (20,000 acre-ft).[9] A navigation channel is maintained to a depth of 9 m (30 ft) in the canals and bays between Union Bay in Lake Washington and the locks, while the lake itself is deeper and does not require dredging. The lake is separated by a sill into north and south basins with depths of 14 and 15 m (46 and 49 ft), respectively (Rattray et al. 1954). The contribution of water from the local watershed is small relative to the inflow from Lake Washington; it generally enters as surface runoff, through storm drains, or via CSOs. Due to the small volume of Lake Union relative to the watershed area, it is estimated that the entire volume of the lake is completely exchanged about once a week on average (Tomlinson et al. 1977).

1.4 Report Organization

The report is organized into an introduction (Section 1.0) to the issues of concern, the overall study goals and specific objective of the analyses presented in this report. General and study area specific background information on PCBs and PBDEs is also provided in Section 1.0. Section 2.0 presents a conceptual model for the hypothesized relationships among PCB sources, pathways, lake fate processes, and links to environmental impairments. PBDEs receive some limited treatment in this section. However, the main focus of the overall project is the collection of PCB data (and calculate loading) to support the development of a PCB fate and bioaccumulation model of Lake Washington. Section 3.0 describes the methods and data used to develop the PCB and PBDE loading estimates and Section 4.0 presents the results of those calculations. A discussion of the results is presented in Section 5.0 and Section 6.0 provides some general conclusions drawn from the results and discussion of the loading estimates.

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[9] This is likely the volume of Lake Union only and does not include the volume of the Ship Canal.

2.0. CONCEPTUAL MODEL

The conceptual model presented in this report is adapted from the one developed for San Francisco Bay (Davis et al. 2006). The conceptual relationships of PCB sources, major pathways, lake fate processes and bioaccumulation linkages to fish tissue contamination are shown in Figure 3. The sections below describe the PCB sources and pathways, fate processes and bioaccumulation linkages. Emphasis in these sections is on the conceptual model of PCB sources and pathways – the fate and bioaccumulation modeling components that are part of the next phase of this project will provide more details on the these components of the overall conceptual model. PBDE receives limited treatment in this section as the main focus of the overall study is on the sources, pathways, fate and bioaccumulation modeling of PCBs in Lake Washington.

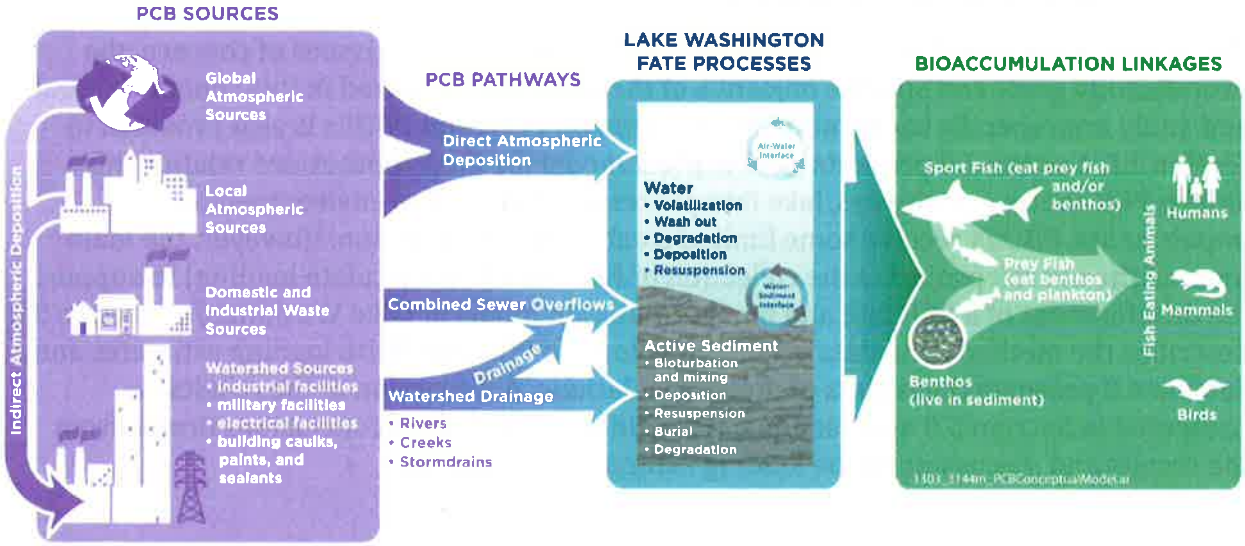

Figure 3. Conceptual relationships of important PCB sources, pathways, in-lake fate processes and bioaccumulation linkages.

Note: Adapted from Figure 18 in Davis et al. (2006)

2.1 Sources and Pathways

Current sources of PCBs in the Greater Lake Washington watershed include long-range transport of airborne contamination and local air emissions sources that are deposited directly on the lake surface (direct deposition) or are deposited on lake watersheds (indirect deposition) (EPA 2001, Totten et al. 2004, Wethington and Hornbuckle 2005, Totten et al. 2006, Persoon et al. 2010, Melymuk et al. 2012). The indirect deposition may be stored on the land surface (e.g., on buildings, rooftops, paved areas, in soils, on vegetation, or in ponds and wetlands) but some percentage of the deposited PCB can be mobilized and transported to the lake via volatilization or resuspension as dust and subsequent direct deposition or by rainfall washoff and transport via lake tributary streams, stormwater outfalls or through CSOs. Long-range atmospheric sources could include distant industrial and commercial centers, particularly those associated with activities such as coal combustion, steel smelting and waste incineration. Landfills with PCB-containing materials and former industrial sites contaminated with PCBs can also be an atmospheric source of PCBs. Commercial/Industrial areas can also be an atmospheric source of PCBs through volatilization of PCBs from open sources such as PCB-containing paints, caulks and sealants or leaking transformer oils.

Many of these potential local atmospheric sources can also be local runoff sources within the watershed via indirect deposition and subsequent mobilization (Rossi et al. 2004, Ecology 2007, Zgheib et al. 2010, Morace 2012). These sources include abrasion of exterior PCB-containing paint, caulks and sealants as well as capacitors and transformers.

Major pathways that PCBs take to reach the lake include direct atmospheric deposition to the lake surface, rivers, streams draining the urban and suburban watersheds around the lake, and runoff from urban areas along the Seattle shoreline that result from a highly developed stormwater and wastewater conveyance network. This network routes some of the runoff into a combined stormwater/wastewater conveyance system that delivers this combination to treatment plants that discharge the treated water to Puget Sound. A relatively small, portion of this combined stormwater/wastewater results in the CSO pathway to the lake when the conveyance capacity of this system is exceeded.

Based on a number of relatively recent studies, the emerging paradigm is that urban runoff is a major source of PCBs to receiving waters (Rossi et al. 2004, Davis et al. 2007, Ecology 2007, Diamond et al. 2010a, Morace 2012). For example, Davis et al. (2007) indicated that urban runoff from local watersheds is a particularly significant pathway for PCBs entering San Francisco Bay. Diamond et al. (2010a) found high concentrations of PCBs in air, soil and tributaries at urban vs. rural sites in and around Toronto, which pointed to urban areas as the main source of PCBs to nearshore Lake Ontario. This assessment was consistent with an inventory conducted of open and closed PCB sources in Toronto building stock (Diamond et al. 2007b, Robson et al. 2010). Another relevant finding is that organic films (soot) sampled from window surfaces in downtown Baltimore had higher concentrations of PCBs in downtown compared to more suburban sites (Liu et al. 2003). It appears that PCBs have an enhanced affinity for soot (Bucheli and Gustafsson 2003). Work has already begun to estimate stocks of PCB containing caulk in buildings in the San Francisco Bay area (Klosterhaus et al. 2011).

Urban runoff also appears to be a significant source of PBDEs to receiving waters (Oram et al. 2008, Diamond et al. 2010a), although sources appear to be more geographically dispersed than PCBs. PBDEs appear to follow a similar pathway of release to air, primarily from indoor air contaminated by volatilization from PBDE containing plastics and polyurethane foam used in furniture, and then deposited on land surfaces, which can be mobilized by stormwater runoff (Melymuk et al. 2012).

2.2 Fate Processes

Once PCBs (and PBDEs) are introduced the lake, a number of loss and recycling processes determine their mass (and concentration) in the water and sediments of the lake (Gobas et al. 1995, Davis 2004, Oram et al. 2008). These processes include gas exchange across the air-water interface, diffusion across the sediment-water interface, settling and resuspension, burial in deep sediments and washout through the lake outlet. Partitioning between dissolved and sorbed forms determines the amount of particulate-bound contaminant that settles to the bottom and the amount in dissolved form determines exchanges at the air-water and water-sediment interfaces.

2.3 Bioaccumulation Linkages

PCBs (and PBDEs) enter the lake foodweb through accumulation by phytoplankton at the base of the food web, uptake directly from the water and through accumulation by sediment dwelling organisms (benthos) (Gobas et al. 1995, Arnot and Gobas 2004, Kuo et al. 2010). Contaminant concentrations can then increase with each increase in trophic level (i.e., biomagnify) posing the greatest risk to fish eating animals, including humans, river otters and fish-eating birds.

3.0. METHODS

The method used to calculate surface runoff loading of tPCB and tPBDE from watersheds (drainage basins) to Lakes Washington and Union follows the approaches used in similar contaminant mass budget studies (Davis et al. 2007; Oram et al. 2008; Herrera 2011; Gries and Osterberg 2011) where specific basin inputs and pathways are monitored relatively intensively, including the largest fluvial sources, and loads from unmonitored sources are derived based on areal loading rates of the monitored basins. This approach is based on the assumption that monitored drainage basins are representative of the average loads from unmonitored basins, which is not absolutely correct but serves as a basis for a first order estimate of total contaminant loading (Oram et al. 2008).

In general, this approach is suitable for:

- identifying major land uses which are significant sources of these contaminants
- use as a planning tool to evaluate load reductions associated with managing inputs from major pathways
- identifying portions of a watershed where pollutant accumulation and delivery to receiving waters may be greatest
- use in a simple box mass budget model of lake water and sediment to understand how these lakes might respond to reductions in contaminant loading

Loading estimates were based on average hydrological conditions over the last decade (2002 to 2011 Oct-Sep Water Years) to provide a representative starting point for comparisons among pathways and as an appropriate time scale for use as input to the mass budget box model of Lake Washington that will be developed in the next phase of this study.

3.1 tPCB and tPBDE Data

The field study portion of this project was designed to provide adequate representation of the spatial and temporal variation in contaminant concentrations in various surface water loading pathways. These pathways included the two major rivers (Cedar and Sammamish), tributary inputs from three local watersheds (Thornton, Juanita and May creeks) representing a range of development intensity, highway runoff, stormwater, and CSOs (Figure 4). In addition to collection of samples from surface water pathways, the field study also measured bulk contaminant deposition[10] (atmospheric loading) at two locations within the study area (see Figure 4). Atmospheric deposition data are used directly from the associated project data report (King County 2013) to compare relative loadings from various surface water pathways to loading directly to the surface of the lakes. The reader is

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[10] This is also sometimes referred to as atmospheric flux, which can to refer to the downward flux, but also can refer to the net exchange across the air-water interface. Net exchange will be estimated in the modeling component of this study. The term *atmospheric deposition* is used in this report to avoid any confusion that might arise through the use of the term *flux*.

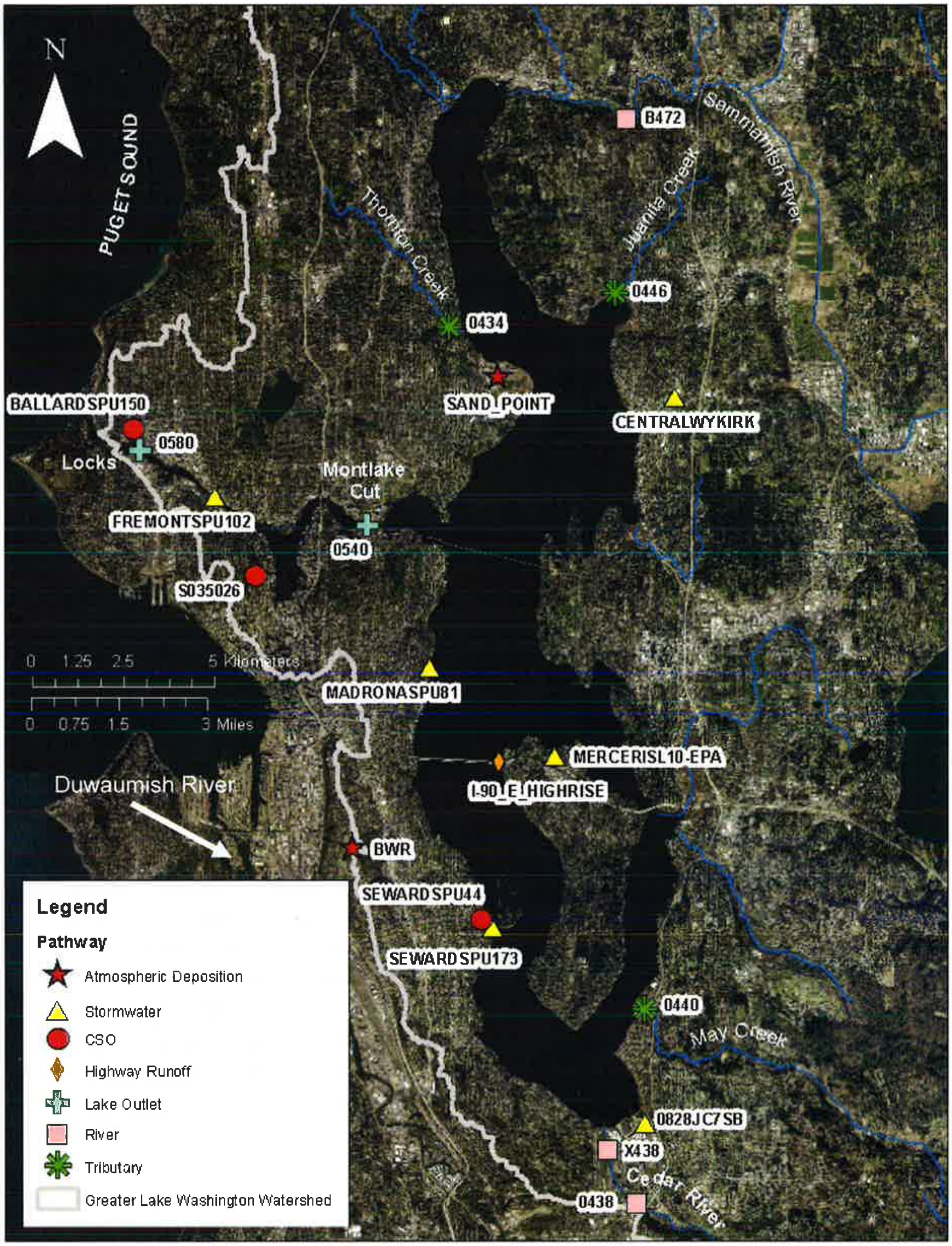

Figure 4. Locations sampled in this study categorized by loading pathway.

Table 1referred to the associated project data report for sampling details, results, and data handling rules (King County 2013).

Table 1 provides summary statistics for tPCB and tPBDE concentrations in surface water pathways measured at each sampling location. Note that all concentrations are reported here in ng/L (10^{-3} µg/L) to two significant figures. Summary statistics include the minimum, maximum, mean, median (i.e., 50th-percentile) and 25th- and 75th-percentile concentrations. In general, tPCB and tPBDE concentrations were highest in CSOs and lowest in the two major rivers and lake outlets. tPCB concentrations in stormwater runoff were much lower than concentrations in CSOs and somewhat higher than concentrations measured in tributary streams. tPBDE concentrations in stormwater were somewhat lower than those measured in CSOs and generally higher than concentrations measured in tributary streams.

An initial evaluation of the data indicated that the greatest amount of skew, and hence uncertainty in loading calculations, was observed in the CSO tPCB sampling data (King County 2013). This was partly due to the relatively small number of samples collected (8 CSO events from 3 CSOs were sampled), but was also likely due to other sources of as yet unexplained variation (e.g., PCB contamination hot spots in a particular CSO basin or dominance of older commercial/industrial buildings containing PCB contaminated materials).

Fortunately, additional tPCB data have been collected from CSOs discharging to the Duwamish River using similar sampling methods and laboratory analytical techniques (King County 2011). The Duwamish River empties into marine waters of Elliott Bay in Seattle just south of the outlet of the Greater Lake Washington watershed to Puget Sound (see Figure 1). A total of 45 samples were collected from seven individual CSO locations during the Duwamish River Basin CSO study (King County 2011). tPCB concentrations reported in the Duwamish study were similar to those measured in this study, although not nearly as positively skewed. Also, the mean concentration in the Duwamish study was somewhat lower (65.2 vs. 100 ng/L) and the median concentration was somewhat higher (47.7 vs. 23 ng/L) than in this study (Table 2).

The data from the Duwamish CSO study were combined with the data from this study to develop a more accurate estimate of the mean CSO tPCB concentration and more accurate statistical characterization to use in estimating tPCB loading uncertainty to Lakes Washington and Union from this pathway. The statistical summary of the combined CSO tPCB data are provided in Table 2.

Mean concentrations determined for each pathway were used to calculate tPCB and tPBDE loading, while the 25th- and 75th-percentile concentrations were used to establish the range of uncertainty in the estimates. Median concentrations were also used to estimate loading for comparison to loading estimates based on the mean concentration and to illustrate the amount of skew in observed pathway concentrations.

Table 1. tPCB and tPBDE results summary for surface water samples. Note that concentrations are all shown in ng/L and rounded to two significant figures.

		tPCB (ng/L)						tPBDE (ng/L)					
						Percentiles						Percentiles	
Pathway/Location [a]	n	mean	min	max	25th	50th [b]	75th	mean	min	max	25th	50th [b]	75th
Major Rivers/Lake Outlets													
Sammamish River	6	0.12	0.042	0.27	0.073	0.110	0.13	0.61	0.02	1.6	0.03	0.47	1.1
Cedar River[c]	6	0.091	0.022	0.23	0.043	0.066	0.11	0.60	0.003	3.2	0.02	0.058	0.25
Montlake Cut	6	0.11	0.051	0.26	0.059	0.085	0.11	0.65	0.18	1.6	0.27	0.53	0.76
Ship Canal Locks [d]	6	0.29	0.14	0.58	0.15	0.20	0.43	0.80	0.029	2.1	0.23	0.60	1.1
Tributaries [e]													
Thornton	4	4.2	1.1	11.0	1.5	2.7	5.4	7.5	1.9	21	2.3	3.6	8.8
Juanita	4	1.7	0.081	5.9	0.23	0.47	2.0	3.8	0.059	14	0.37	0.53	4.0
May	4	1.1	0.10	2.6	0.12	0.77	1.7	0.9	0.059	2.8	0.10	0.42	1.2
All combined	12	2.4	0.081	11	0.24	1.3	2.9	4.1	0.059	21	0.39	1.3	3.2
Highway Bridge (I-90)	4	9.3	3.3	16	5.6	8.9	13	60	2.0	220	4.2	6.2	62
Stormwater													
Renton	3	2.3	1.5	3.4	1.7	2.0	2.7	0.8	0.0091	2.4	0.026	0.043	1.2
Kirkland	4	1.2	0.0078	2.5	0.21	1.2	2.2	0.97	0.012	3.0	0.23	0.43	1.2
Fremont	3	18	3.9	39	7.3	11	25	57	1.8	170	3.1	4.5	85
Madrona	4	7.1	4.1	12	4.7	6.3	8.7	4.1	1.6	9.4	1.6	2.8	5.3
Mercer Island	4	1.9	0.55	3.6	0.87	1.8	2.9	0.79	0.0078	2.2	0.020	0.47	1.2
Seward Park	3	1.9	0.77	2.5	1.6	2.4	2.5	0.070	0.013	0.18	0.017	0.022	0.10
All Combined	21	5.1	0.0078	39	1.5	2.5	4.1	9.4	0.0078	170	0.024	0.93	2.4
CSOs													
Ballard	2	23	19	28	-	23	-	91	16	170	-	91	-
Dexter	3	250	28	570	93	160	360	140	74	210	110	150	180
Seward Park	3	4.3	2.3	6.2	3.4	4.5	5.3	16	6.7	21	14	20	21
All Combined	8	100	2.3	570	5.8	23	61	83	7	210	19	48	150

[a] ***Sample station locator IDs*****: Rivers/Lake Outlets*** *- Sammamish River (B472), Cedar River (0438), Montlake Cut (0540), Ship Canal Locks (0580;, Tributaries - Thornton Creek (0434), Juanita Creek (0446), May Creek (0440);* ***Highway Bridge I-90*** *– I-90_E_HIGHRISE;* ***Stormwater*** *– Renton (0828JC7SB), Kirkland (CENTRALWYKIRK), Fremont (FREMONTSPU102), Madrona (MADRONASPU81), Mercer Island (MERCERISL10-EPA), Seward Park (SEWARDSPU173),* ***CSOs*** *– Ballard (BALLARDSPU150), Dexter (S035026), Seward Park (SEWARDSPU44).*

[b] *The 50th percentile is synonymous with the median.*

[c] *Upper Cedar River station only.*

[d] *All PBDE congeners were qualified as non-detect in one sample at the Ship Canal Locks. The highest detection limit of all congeners in this sample was used to represent the tPBDE result.*

[e] *The tributary sample statistics represent one base flow and three storm event samples for each tributary (total of four samples per tributary).*

Table 2. Comparison of CSO tPCB concentrations (ng/L) measured in this study and a previous study of Duwamish River CSOs.

	Minimum	25th-percentile	Median	Mean	75th-percentile	Maximum
			tPCB (ng/L)			
This study (n = 8)	2.3	5.8	23.	100	61.	570
Duwamish River [a] (n = 45)	8.01	30.0	47.7	65.2	71.7	455
Combined data (n = 53)	2.3	28.	44.	71.	72.	570

[a] Source: King County (2011)

3.2 Hydrologic Data

In addition to the PCB/PBDE data collected as part of this study, available river and stream flow data provided by the U.S. Geological Survey (USGS), King County and Snohomish County were used to estimate contaminant loading from the monitored rivers and tributary streams (Figure 5).[11] Note that river and stream monitoring locations were intentionally selected to be co-located with continuous gauging locations.

Because discharge from the locks to Puget Sound is not directly measured, precipitation data were used in conjunction with daily flow, lake elevation and evaporation estimates to develop a lake water budget. The water budget provided an estimate of discharge to Puget Sound that was combined with contaminant concentrations measured just upstream of the locks to estimate contaminant loading to Puget Sound. Precipitation data were also used to estimate highway bridge runoff and contaminant loading to the lakes from this pathway.

Daily precipitation data for two stations near the Lake Washington shoreline were obtained from the National Climatic Data Center (Figure 5). Evaporation data were provided by the Washington State University (WSU) Puyallup Research and Extension Center in Puyallup, WA approximately 37 km (23 mi) to the south of Lake Washington.[12] This is the closest station reporting this type of continuous data over the period of interest.

Daily changes in the elevation of Lakes Washington and Union were based on a stage record at the locks obtained from the Seattle District U.S. Army Corps of Engineers (USACOE) (Figure 5).[13] Details of methods used to develop the lake water budget are described in Section 3.4.6 below.

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[11] Respectively, USGS: http://waterdata.usgs.gov/wa/nwis/dv/?referred_module=sw; King County: http://green.kingcounty.gov/wlr/waterres/hydrology/; Snohomish County: http://www1.co.snohomish.wa.us/Departments/Public_Works/Divisions/SWM/Library/Data/

[12] WSU Extension Puyallup AgWeatherNet station: http://weather.wsu.edu/awn.php

[13] U.S. Army Corps of Engineers, Northwestern Division dataquery: http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=%22lake+washington%22

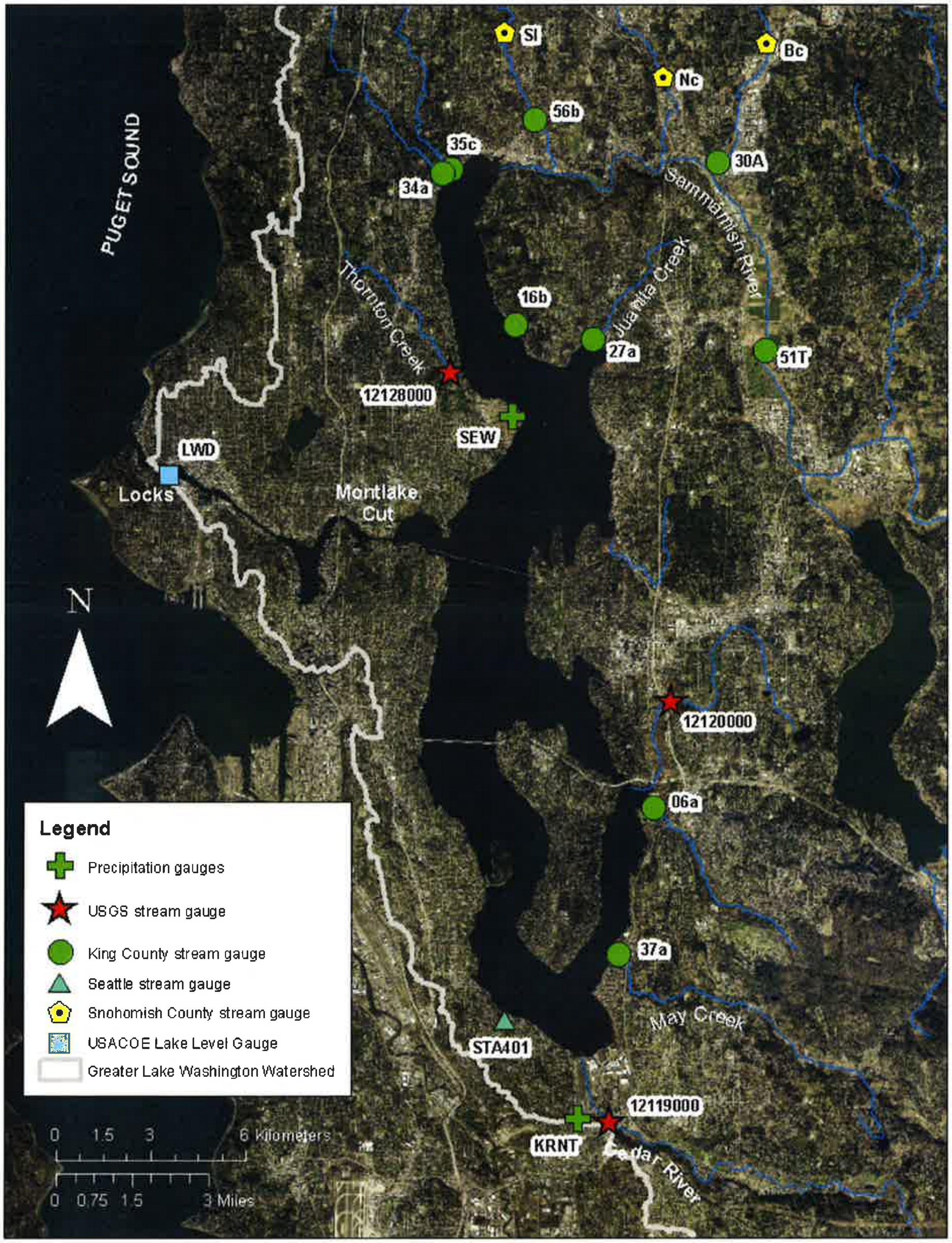

Figure 5. Locations where flow and precipitation were recorded and obtained for use in this study.

3.3 Extrapolation of Flow to Unmonitored Drainage Basins

It was not feasible to measure all inputs from every tributary stream and stormwater drainage basin to a lake system of this size. Therefore, extrapolation was necessary to estimate total contaminant loading from this pathway. Although hydrologic and water quality models (Hydrologic Simulation Program-FORTRAN [HSPF]) have been developed for tributary stream basins to Lake Washington (King County 2003b)[14], these models have not been updated to represent more recent land cover or meteorological data. In addition, these models have not been calibrated to flow data that are available for many of these tributary basins. One exception is Juanita Creek, which King County recently updated and calibrated for use in a stormwater retrofit study (King County 2012).

After updating the land cover represented in these models and calibration to available flow gauging data, extrapolation to ungauged basins would still be necessary, albeit via the sophistication of a continuous hydrologic model. It is uncertain that such an extrapolation approach would be more accurate considering the findings of Dinicola (2001) that calibrated HSPF models of Puget Lowland tributaries are not readily transferable to ungauged basins without additional calibration. Regardless, updating and calibrating these models was beyond the scope of this study.

Methods used to extrapolate flow to unmonitored drainage basins for use in the lake water budget are described below. The method used to extrapolate contaminant loading to unmonitored drainage basins is described in Section 3.4.2.

3.3.1 Definition of Terms

Before describing the methods used to extrapolate flow to unmonitored drainage basins, it may be helpful to define some terminology. For example, hydrologists use a variety of terms that are more or less synonymous, but may have more specific meaning for some readers.

For example, a *drainage basin* is an area of the land surface where rain (or melting snow) drains or runs to a single point defined at the discretion of a researcher or by geographic features, such as where a river, creek or stream enters a lake. Other terms that are synonymous with drainage basin are *catchment, tributary basin* or *watershed.* A *drainage basin* as defined here is a river, creek, stream or stormwater conveyance system that is flowing into another or larger water system (e.g., a stormwater conveyance system to a stream, a stream to a lake). Drainage basins within the Greater Lake Washington watershed defined for the purposes of this report are placed into four categories:

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[14] The Lake Union watersheds were not modeled as part of that project, nor were the combined and partially separated drainages to Lake Washington to the north and south of Union Bay.

- River basins: The Cedar and Sammamish basins are the largest and best defined drainage basins to Lake Washington with reliable flow measurements for the study period of interest.
- Tributary basins: Smaller drainages to Lake Washington with some remaining historical stream network that discharges to the lake. Several of these basins have reliable flow measurements for the study period of interest (e.g., Juanita Creek), but some do not (e.g., Forbes Creek).
- Partially separated basins: For lack of a better term, this is used to describe basins that no longer have much of an existing historical stream network and consist of partially separated stormwater and wastewater conveyance networks. These basins are found within the Central Seattle area and drain to the central western shore of Lake Washington and to Lake Union and the Ship Canal. For the most part, these basins do not have reliable flow data and the area of the basin that contributes to surface runoff that is ultimately delivered to the lakes is not well defined.
- Stormwater basins: These are relatively small, well defined drainage areas with little or no historical stream network that route precipitation runoff through a stormwater conveyance network that discharges directly to Lakes Washington or Union. These basins do not have reliable flow data for the study period of interest, although instantaneous flow measurements were made when study samples were collected for analysis.

Hopefully, these definitions will assist in more clearly describing the methods used to extrapolate flow and contaminant data from monitored to unmonitored drainage basins.

Definitions of various components of drainage basin flow or discharge hydrographs will hopefully provide necessary context for the description of methods used to separately calculate drainage basin loads from *base flow*, *storm flow* and *stormwater runoff* (see Figure 6). In typical Lake Washington tributary basins, there is a base level of flow (*base flow*) that is maintained through the release of shallow groundwater to the stream – more in winter and progressively less through the driest late summer and early fall period. During precipitation events, particularly in urbanized basins with stormwater drainage basins (i.e., stormwater conveyance systems) connected to the stream, *stormwater runoff* is delivered to the stream, which increases flow so that the stream carries a mixture of stormwater runoff and base flow that is defined here as *storm flow*. Base flow can also increase initially, in part due to the relatively rapid delivery of water passed laterally through the soil to the stream. Figure 6 provides a visual representation of the flow hydrograph definitions developed above.

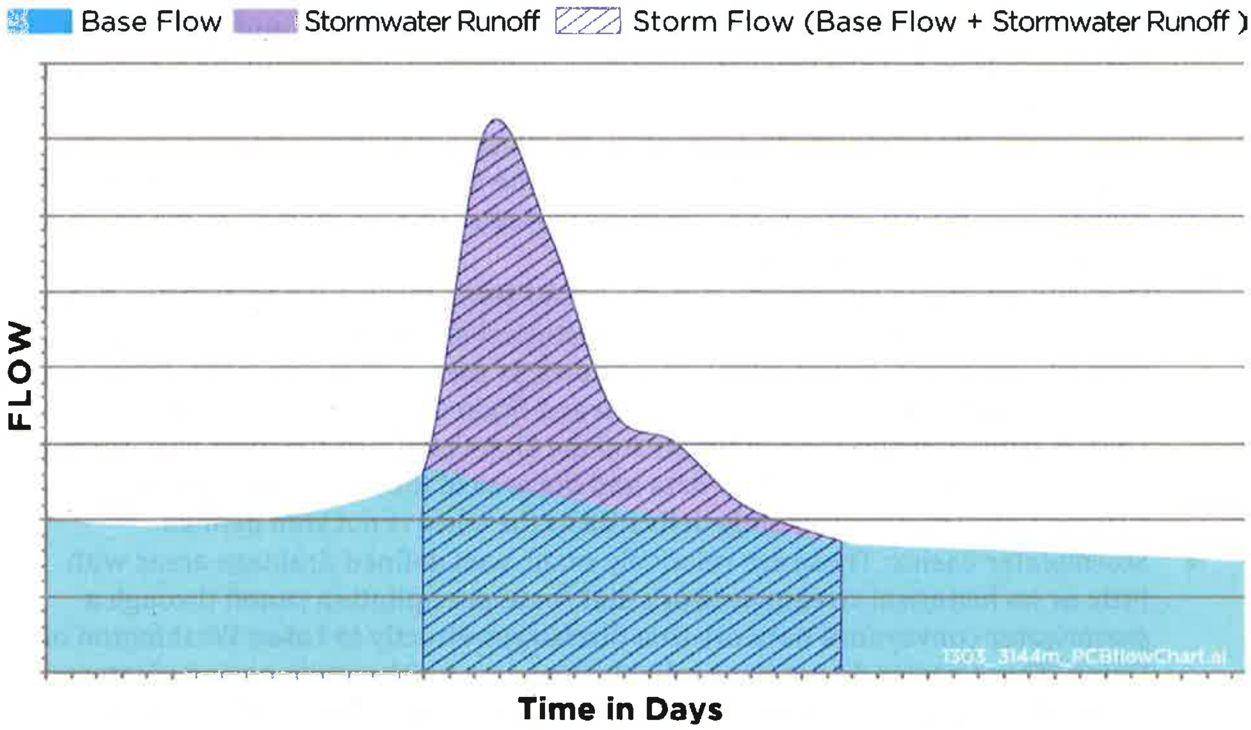

Figure 6. Conceptual storm and base flow hydrograph, including visual definitions of base flow, stormwater runoff and storm flow (Base Flow + Stormwater Runoff).

3.3.2 Estimating Ungauged Drainage Basin Flow

To estimate long-term average flow from ungauged drainage basins, the long-term mean annual flow (2002-2011) of gauged tributary basins around the lake was calculated and compared to the contributing basin area for each gauge.[15] A linear regression ($r^2 = 0.84$; $p < 0.0001$, SE = 30%) of basin area vs. mean annual flow indicated that basin area could be used as a reasonable first approximation of mean annual flow in other tributary basins around the lake (Figure 7). The slope of the linear regression line indicated an average water yield of 0.103 cms per km^2 (1.4 cfs per mi^2).

There appeared to be two outliers (Mercer/Kelsey Creek and Thornton Creek) in the relationship between mean annual flow and basin area. Mercer/Kelsey Creek yields more water and Thornton Creek yields less water per unit area than is typical of other gauged Lake Washington tributaries. The explanation for the lower yield of Thornton Creek is in part the result of the significant amount of flow that is diverted past the gauge via a direct discharge from Meadowbrook Pond to Lake Washington (City of Seattle 2007). The higher yield of Mercer/Kelsey is more difficult to explain, although it is believed that water is occasionally diverted to Mercer/Kelsey Creek from Phantom Lake in the Lake Sammamish drainage just east of the headwaters of the Mercer/Kelsey basin (City of Bellevue 2009). Regardless, removal of these two data points did not change the slope of the regression, but did increase the regression coefficient ($r^2 = 0.98$; $p < 0.0001$, SE = 13%). Therefore, 0.103

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[15] King County GIS Center. topo_basin: http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=topo_basin

cms per km² (1.4 cfs per mi²), the average water yield, is used to extrapolate gauged drainage basin flows to ungauged Lake Washington drainage basins.

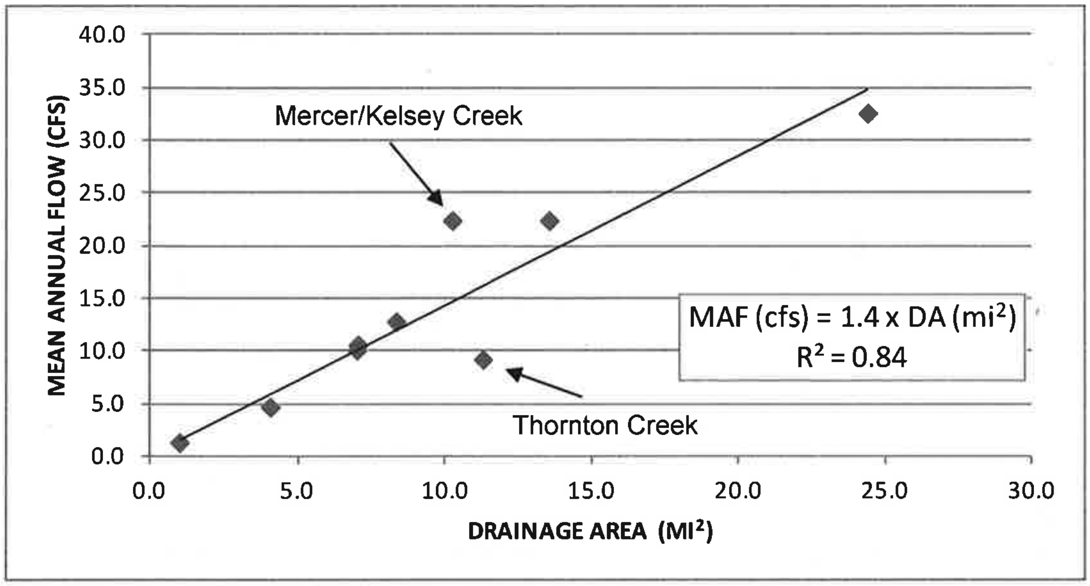

Figure 7. Scatter plot and linear regression best-fit line of mean annual flow vs. drainage area for gauged Lake Washington tributaries.

Note: MAF = Mean annual flow; DA = Drainage area; 1.4 cfs mi^{-2} *= annual areal water yield*

Because of a significant backwater effect of Lake Washington on the Sammamish River (King County 2009), the existing flow gauge is located upstream of three major tributaries (Little Bear, North and Swamp creeks) that enter the river below the gauge but before it discharges to Lake Washington. Swamp and Little Bear creeks have been gauged near their mouths in the past decade, but these gauges have been discontinued and, in the case of Swamp Creek, the gauge was operated for just a few years. Fortunately, Snohomish County has maintained gauges on all three creeks over the past decade.

Total flow from the three Sammamish River tributaries below the gauge was estimated by scaling the observed flow rate at the upstream tributary gauge by the ungauged lower tributary watershed area (Total Flow = Gauged Flow x Total Area/Gauged Area). Flow from the ungauged valley area to the river was based on the unit area flow rate of 0.025 cms per km² (0.9 cfs per mi²) derived from previous hydrologic modeling of the Sammamish River (King County 2009). This value is less than the unit area runoff rate used for the unmonitored Lake Washington basins because of low impervious cover and relatively flat terrain of the Sammamish River valley floor.

3.3.3 Estimating Flow from Central Seattle Basins

Extrapolation of flow to the most urbanized drainage basins in central Seattle, which do not have long-term gauging data, is made more challenging because a portion of these drainages are part of a combined sewer system that transfers stormwater runoff and domestic wastewater to treatment plants that discharge directly to Puget Sound. Some of these combined systems are responsible for episodic CSOs that discharge to the lake and canal system. The remainder of this area is served by a partially separated system, often with rooftop drains connected to the wastewater conveyance system, and street and parking lot runoff directed to a stormwater conveyance system. The stormwater conveyance system may eventually discharge to the lake or canal, but sometimes an initially separated stormwater conveyance ultimately empties into the wastewater conveyance system.

Although hydraulic models of the combined wastewater system exist, they are generally not integrated with stormwater conveyance system details that would readily provide an estimate of flow to the lake and ship canal system. It may be possible to develop partially separated basin flow estimates from the wastewater conveyance models; however, this approach is beyond the scope and resources for this project.

To provide a first approximation of the flow from the partially separated areas, a GIS coverage of the partially separated basin areas provided by the City of Seattle[16] was intersected with central Seattle tributary watershed boundaries (Figure 8) to estimate the drainage areas contributing flow to Lakes Washington and Union. This area was then used along with the approach described above for extrapolating flows to ungauged partially separated basins to estimate the average flow contribution from these areas. This provides a reasonable first approximation until better estimates of flow from these areas can be developed.

3.3.4 Estimating the Thornton Creek Flow Bypass

As mentioned above, a flow bypass on Thornton Creek diverts flow during high flow events via a diversion to Meadowbrook Pond located just below the confluence of the north and south branches of the creek. When storage in the pond is exceeded, flows are diverted to an outfall that discharges directly to Lake Washington (City of Seattle 2007). The amount of flow bypassed can be substantial relative to the total flow of Thornton Creek. The Thornton Creek Watershed Management Committee (2000) indicated that the bypass flow rate can be as high as 9.91 cms (350 cfs) with an annual average of approximately 0.147 cms (5.2 cfs). The average flow rate of 0.147 cms (5.2 cfs) was used to approximate the additional stormwater flow from Thornton Creek.

3.4 Loading Estimates

Loading is determined by multiplying a contaminant concentration in units of mass per volume by a flow rate in volume per time, resulting in an estimate of the mass delivered per some unit of time. For tPCBs and tPBDEs, contaminant loading is typically reported in grams per year (g yr^{-1}). Loading is also reported on a per unit area basis by dividing the

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[16] King County GIS Center. cse_dbasin: http://gisdw/intranet/sdc/nonkcgis/content/hydro_ext/cse_dbasin.htm (KC intranet access only)

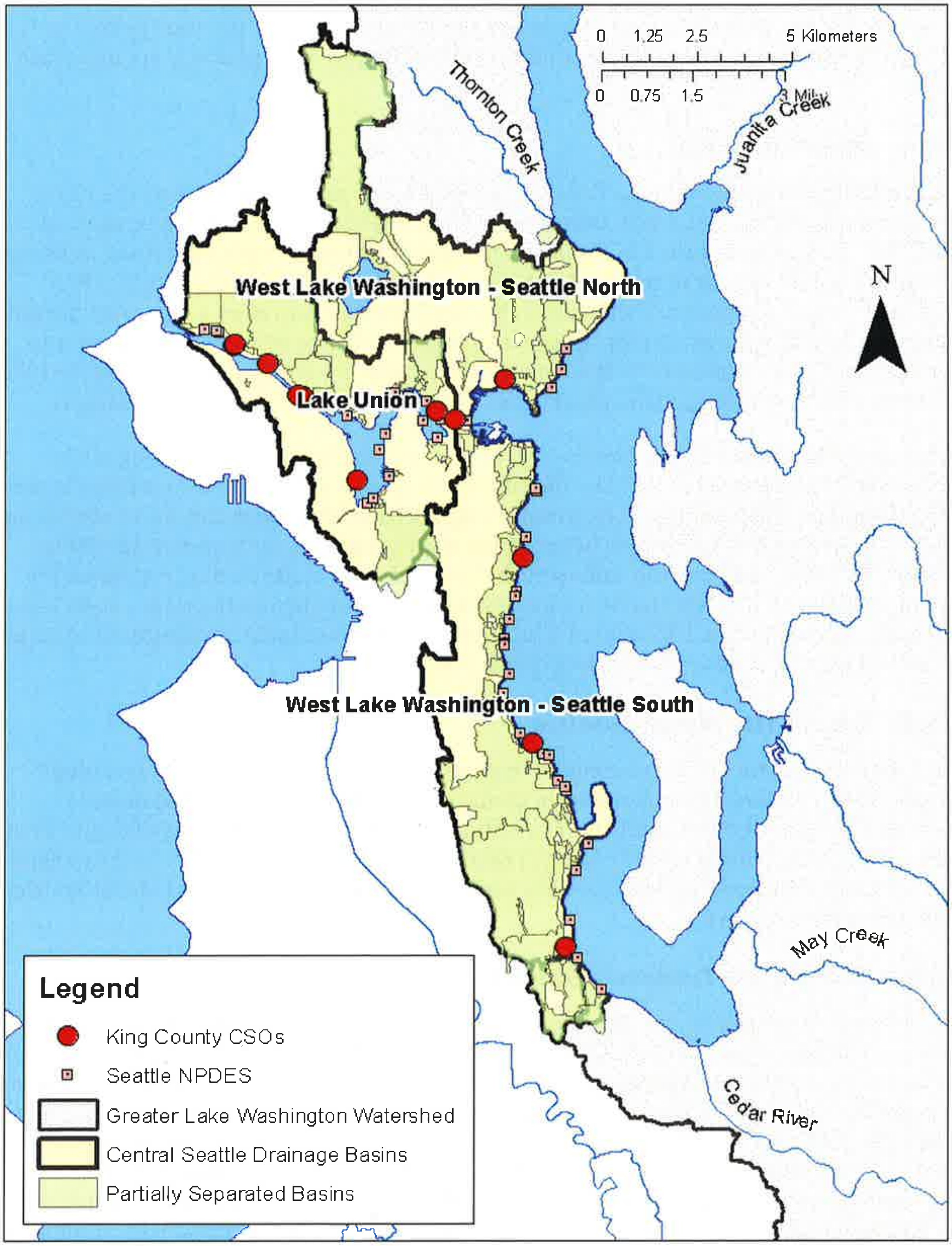

Figure 8. Location and extent of Central Seattle and Lake Union tributary basins and the contributing area of partially separated basins.

estimated load by the total watershed area above that point. Areal loads for these contaminants are typically reported in grams per square kilometer per year (g km^{-2} yr^{-1}). Details of methods used to estimate contaminant loading for each pathway are described below.

3.4.1 Major Rivers

tPCB and tPBDE loading from the Cedar River were calculated by multiplying the mean concentration of tPCB and tPBDE measured at Station 0438 by the annual average flow (2002-2011) observed at the USGS gauge (Station 12119000) on the Cedar River at Renton. Contaminant data were also collected at a station located closer to the mouth (Station X438) to evaluate the potential increase in contaminant concentration as the river passed through part of downtown Renton. Concentrations of tPCB and tPBDE did not appear to increase based on comparison of the four synoptic sampling events (see King County 2012 for more details regarding comparison of upstream and downstream concentrations).

Contaminant loading from the Sammamish River was calculated by multiplying mean concentrations measured at B472 by the sum of the annual average flow measured at the upstream gauge (King County 51T), tributary inputs from Little Bear and North creeks, and the flow from the river valley area between the river gauge and contaminant sampling location. Total loading from the Sammamish River did not include loading estimated for Swamp Creek, which enters the river below Station B472 but before the river enters Lake Washington (see Section 3.3.2 above). The method used to estimate unmonitored tributary watershed loading is described in the next section.

3.4.2 Local Drainage Basins

The approach to estimating contaminant loading from local drainage basins, including loading from tributary streams and from Central Seattle basins, is described below. Methods are described separately for estimating loading from local drainage basins (1) that were monitored during this study, and (2) that were unmonitored, for which extrapolation was used, including loading from partially separated drainages within the Central Seattle watersheds (see Figure 8).

3.4.2.1 Monitored Tributary Basins

Total loads from local tributary basins were estimated by assuming that unmonitored basins contribute comparable PCB loads as monitored tributary basins with similar overall land uses (i.e., Thornton, Juanita and May creeks). This approach is similar to that used to estimate PCB and PBDE loadings to the San Francisco Estuary (Davis et al. 2007; Oram et al. 2008). The method used to develop loading estimates for monitored tributary basins follows the approach used by Herrera (2011) to estimate areal contaminant loading rates from specific land use types monitored in several small watersheds located in two Puget Sound river basins (Puyallup and Snohomish). Details of calculating loads from monitored tributary basins and extrapolation to the remaining unmonitored drainage basins are described below.

Loading from monitored tributaries was calculated using gauged flow data and measured contaminant concentrations at the same location. One base flow and three storm flow samples were collected from each tributary basin. A stream flow hydrograph separation program based on the local-minimum method implemented in HYSEP (Sloto and Crouse 1996) was used to quantify mean base flow and storm event flow rate using decade-long (2002-2011) daily flow records available for each tributary contaminant sampling location. Base and storm flow loadings were calculated by multiplying base flow and mean storm flow contaminant concentrations by the respective mean flow rates. In the case of Thornton Creek, estimated average storm bypass flow of 0.147 cms (5.2 cfs) was added to mean storm flow from the base flow separation analysis before calculating the storm load. Base and storm flow loads were then summed to obtain the total loading rate in g yr^{-1} for each tributary. Total basin area of each tributary was then used to calculate the areal loading rate for tPCB and tPBDE.

Although hydrograph separation is a somewhat subjective process, computer algorithms allow for the consistent application of a certain set of rules to remove some of the subjectivity inherent in this type of analysis as noted by Soto and Crouse (1996). In addition to the stream flow time series, basin area above the gauge is used in the program to determine the appropriate time interval to use in flow separation analysis.

3.4.2.2 Extrapolation to Unmonitored Drainage Basins

Extrapolation of contaminant loading to ungauged watersheds in the San Francisco Estuary studies (Davis et al. 2007; Oram et al. 2008) used the average areal loading rate derived for monitored basins representing approximately 10 percent of the local drainage.[17] However, they note that their estimate may have been too low because inputs from small, historically industrial watersheds could contribute relatively large loads that might not have been well represented in their studies.

In this study, the three monitored tributary basins represent over 20 percent of the local drainage to Lake Washington (excluding estimated drainage to the combined system) and also have a range of land uses reflective of the local tributary drainages to the lake. These tributaries were selected for monitoring because they had operating continuous flow gauges. The three tributaries also represented historical and current development ranging from older high density residential and commercial development in Thornton Creek to somewhat lower intensity and younger development in Juanita Creek and more recent medium to low density and mixed commercial development in May Creek.

Rather than use average areal contaminant loading rates of the three basins to extrapolate loading to the remainder of the local drainages, hypotheses were developed based on the conceptual model presented above (see Section 2.1) and additional information presented below to estimate contaminant loading rates. Based on evaluation of these hypotheses, we identified unmonitored Thornton Creek-like, Juanita Creek-like and May Creek-like tributary basins as a first approximation for extrapolation. Our intent was to lay the

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[17] Local drainage refers to creeks and river drainages surrounding the estuary, excluding the Sacramento-San Joaquin Basin ("Delta" flow in their publications) which drains about a third of California.

foundation of a conceptual model to frame interpretation of the loading information generated in this study and generate hypotheses to guide future studies and management activities.

Previous studies have identified urban areas as significant sources of PCBs and PBDEs from atmospheric emission (Persoon et al. 2010; Wethington and Hornbuckle 2005; Melymuk et al. 2012) and urban runoff (Davis et al. 2007; Oram et al. 2008). For PCBs, this is consistent with Robson et al. (2010) who found that significant stocks of PCBs remain in urban areas in closed sources like transformers, capacitors and light ballasts and in open sources like caulks and sealants used in commercial and industrial buildings.

Melymuk et al. (2012) noted that atmospheric concentrations of PCBs and PBDEs were highest in the vicinity of the central business core of Toronto, Canada. This pattern is consistent with results of a recent Puget Sound contaminant deposition study that found highest deposition rates of PCBs and PBDEs at a highly urban and industrial site in Tacoma, WA (Brandenberger et al. 2010). One study has even suggested a link between linear distance from percent commercial land use and PCB contamination of perch sampled from sub-estuaries around Chesapeake Bay (King et al. 2004).

A recent Puget Sound contaminant loading study focused on small drainage basins with relatively consistent land use within each basin characterized as either commercial/industrial, residential, agricultural or forest/field/other (Herrera 2011). They found that highest areal loads of PCBs and PBDEs were delivered in storm flow from basins with predominantly commercial/industrial land use. Areal loading from base flow was similar among the four land use categories.

Based on the conceptual model and additional synthesis of previous studies, estimated areal loading rates from Thornton, Juanita and May creeks were compared to basin-scale population density, percent impervious cover, percent of basin built in or before 1979, and percent of basin area built as commercial or industrial property in or before 1979. This information was used to evaluate hypotheses to classify unmonitored drainage basins as similar to one of the monitored basins. Population density was based on the most recent census block data, percent impervious cover was based on the 2006 National Land Cover Database (Fry et al. 2011), and percent of land built in or before 1979 was based on analysis of the most recent King County parcel layer and assessor tables.

3.4.3 Highway Runoff

Contaminant loadings from highway bridges that cross Lakes Washington (SR 520 and I-90) and Union (I-5 and SR 99) were calculated by multiplying surface areas of these highways[18] by the average of long-term (2002-2011) mean annual precipitation reported at the Renton Airport located at the southern end of Lake Washington and Sand Point on the western shore of the lake (see Section 3.2 above). Annual surface runoff was then multiplied by mean tPCB and tPBDE concentrations measured in bridge runoff during the

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[18] Data based on bridge inspection reports provided by Archie Allen, Maintenance and Operations Bridge Superintendant, Washington State Department of Transportation, Bellevue, WA.

study to estimate total annual contaminant loads to each lake system from this pathway. It was assumed that there were no evaporative losses during runoff events.

3.4.4 Combined Sewer Overflows

Loading from combined sewer overflows was estimated by compiling the most recent and most reliable CSO flow estimates for King County and Seattle CSOs available from annual reports (e.g., King County 2012c; Seattle Public Utilities 2012). To represent flow conditions, the most recent reliable flow data were selected. For King County CSOs, flow data were available for 2007 through 2011; a five year period. Reliable flow data were available for Seattle CSOs only for three years (2009 through 2011). Total annual CSO flow was summed separately for CSO discharges to Lake Washington and to Lake Union. The mean annual flow rates to Lake Washington and to Lake Union were then multiplied by the average CSO concentrations based on the combination of data from this study and the data from the Duwamish River study (see Section 3.1 above) to estimate long-term annual contaminant loading from CSOs.

3.4.5 Atmospheric Deposition

Atmospheric loading was based on deposition data collected during this study. Field methods and details of deriving deposition rates are documented in a separate report (King County 2013). Reported contaminant deposition rates from the two stations were averaged and the mean areal deposition rate was multiplied by the surface area of each lake system to derive an estimate of annual loading from this pathway.

3.4.6 Loading to Puget Sound

Discharge from Lake Union and the locks to Puget Sound is not directly measured because of the complexity of the lock and dam system at the outlet of the Greater Lake Washington watershed. To estimate loading to Puget Sound, estimates of total outflow were derived using two slightly different approaches. One approach was based on a daily water balance approach that has been used in previous water quality modeling studies of the lake (Cerco et al. 2004).

The water balance equation solved for the system outflow is:

$$Q_{out} = (Q_{in} + Q_{prec}) - (Q_{\Delta S} + Q_{evap})$$

Where :

$Q_{out} \equiv$ Total outflow to Puget Sound

$Q_{in} \equiv$ Watershed inflows

$Q_{prec} \equiv$ Precipitation

$Q_{\Delta S} \equiv$ Storage

$Q_{evap} \equiv$ Evaporation

Watershed inflows were based on the sum of gauged river and tributary inflows and estimated ungauged tributary inflows between October 2002 and September 2011. Because daily flow from ungauged tributaries was needed for this approach, the annual average unit area flow estimate described above was unsuitable for this purpose. For the daily lake water balance, ungauged tributary flows were based on scaling daily flow from a representative gauged tributary. The daily flow record for May Creek was selected as the basis for extrapolation. May Creek was used because it has complete daily flow records for the period of interest (i.e., no missing daily values) and does not appear to be affected by significant flow diversions (see Section 3.3.2 above).

The remainder of inputs to the daily water balance included the average of daily precipitation measured at the Renton Airport and at Sand Point. Daily evaporation data was obtained from the WSU Experimental Station in Puyallup, WA. Storage changes in the lake were based on daily changes in lake level reported by the Seattle District USACOE and the surface area of Lakes Washington and Union. All inputs were converted to daily flow by multiplying the depth of rainfall, evaporation or lake level change by the total combined area of Lakes Washington and Union of 92.8 km^2 (35.8 mi^2).

The second approach was based on the knowledge that over a decade long period, lake storage changes become a relatively unimportant component of the water budget and can be omitted from the water balance equation. This is especially true for this system, considering that the level of the lake generally ranges no more than 0.61 m (2 ft) and is closely controlled to the same maximum level in summer and the same minimum level in winter.

Therefore, the water balance on a long-term basis becomes:

$$Q_{out} = \left(Q_{in} + Q_{prec}\right) - \left(Q_{evap}\right)$$

Where:

$Q_{out} \equiv$ Total outflow to Puget Sound

$Q_{in} \equiv$ Watershed inflows

$Q_{prec} \equiv$ Precipitation

$Q_{evap} \equiv$ Evaporation

Furthermore, daily flow inputs can be replaced with long-term average flows, which means that the unit area flow scaling approach (described in Section 3.3.2 above) can be used to estimate long-term mean flow from ungauged tributaries. Both approaches were applied using data for the Water Year (Oct-Sep) period 2002-2011.

3.5 Uncertainty Assessment

Understanding uncertainty in measured hydrologic and contaminant data is critical to appropriate water quality assessment, management and modeling (Harmel et al. 2009). Harmel et al. (2006) identified four procedural sources of uncertainty including streamflow measurement, sample collection, sample preservation/storage and laboratory analysis.

Herrera (2011) identified a slightly more expansive list of sources of uncertainty that included streamflow measurement and laboratory error, but also included extrapolation of sampling results as another source of uncertainty. Uncertainty from extrapolation includes extrapolation from instantaneous loads based on measured flow and concentration to longer periods (months to years) and extrapolation of loads estimated for a measurement location to unmonitored locations (Webb et al. 1997).

A quantitative uncertainty analysis based on propagation of all quantifiable sources of error is beyond the scope of this study.[19] In general, surface runoff estimates developed for this study are assumed to be relatively certain. An earlier water budget of Lake Washington that included first-order error analysis, determined that because much of the river and stream flow to the lake is measured relatively accurately, the total estimated discharge to the lake is associated with relatively little error (Edmondson and Lehman 1981). The greatest uncertainty is likely associated with estimated mean contaminant concentration in each loading pathway and associated extrapolation errors. To provide a first approximation of uncertainty in these loading estimates, the 25th- and 75th-percentile contaminant concentrations were used to calculate a likely upper and lower bound on the loading estimate based on the mean concentration measured in a particular loading pathway.

Contaminant loading estimated using the median concentration is also calculated and compared to the load estimated using the mean concentration to highlight the degree of skew in observed tPCB and tPBDE concentrations in each loading pathway. The skew in environmental contaminant data is typically positive; the tail on the right side of the data distribution is longer and the majority of concentration values lie to the left of the mean (i.e., the mean is higher than the median value).

Although relatively large differences between mean and median values suggest significant skew in the population of contaminant concentrations in a particular loading pathway, this does not imply that the loading estimate based on the median (or geometric mean) would be a more accurate estimate of loading. However, the relatively large skew in the small data sets generated for particular loading pathways in this study indicates that the current estimate of the mean concentration and subsequent loading estimate is highly uncertain. In the cases where skew appears to be relatively smaller, loading estimates have relatively less uncertainty.

To demonstrate that the mean concentration is the correct value to use in loading calculations, a simple example is presented here using an existing data set consisting of one year of daily flow and total phosphorus (TP) measurements made in Issaquah Creek (Birch 1976). Issaquah Creek is the main inflow to Lake Sammamish (see Figure 1). TP data are right-skewed with a mean and median concentration of 57.4 and 37.0 µg/L, respectively. The mean flow during the sampling period was 3.99 cms (141 cfs). Assuming that daily TP

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[19] Note that the terms "error" and "uncertainty" as used here are synonymous and refer to the uncertainty in (or error of) our measurements and estimations of total average flow and contaminant concentrations, which if known with absolute certainty for each pathway would provide the true contaminant load to the system.

values are an accurate representation of the concentration in the river each day[20], the actual load can be calculated by multiplying the daily concentration by the daily flow which yields an estimated loading of 7,200 kg TP yr^{-1}. One can arrive at very nearly the same result by multiplying the mean annual flow by the mean concentration. However, if one uses the median concentration, the estimated load is 4,700 kg TP yr^{-1} – about 35 percent less than the best estimate of total load based on the daily flow and concentration data.

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[20] Single daily grab samples collected in the study were probably not the best representation of daily average TP concentration, but this is mostly a separate sampling and statistical issue not being addressed explicitly here, but acknowledged as an issue in our study (i.e., procedural uncertainty).

4.0. RESULTS

Results for each loading pathway are summarized below and compared to data from other studies with a focus on studies conducted within the Puget Sound basin.

4.1 Major Rivers

Estimated tPCB and tPBDE loading from the two major rivers is summarized in Table 3. Estimated loads are based on the average (2002-2011) flow rate of 19.6 cms (692 cfs) for the Cedar River and 10.9 cms (384 cfs) for the Sammamish River. Even though the total flow from the Sammamish River is lower than that of the Cedar River, estimated loading from these rivers is similar in magnitude, although the contribution from the Sammamish River based on mean concentrations is somewhat lower than that from the Cedar for both tPCB and tPBDE. Note that the range of river loading estimates indicate positive skew in the concentration data, particularly for tPBDE concentrations measured in both rivers where the loading estimates using the mean are greater than those estimated using the 75th-percentile concentration.

Estimated areal loadings of tPCB and tPBDE from the Cedar and Sammamish rivers are summarized in Table 4. As with total loading, estimated loadings on an areal basis are similar for the two rivers. Because the drainage area represented by the Sammamish River estimate is somewhat larger than that represented by the Cedar River, areal loading rates based on mean concentrations are somewhat lower for the Sammamish River.

In general, areal tPCB loading estimates for the Cedar and Sammamish rivers are near the lower range reported by Gries and Sloan (2009) for the Green River just to the south of the Cedar River basin. Their estimate was based on analysis of contaminants sorbed to suspended particulate matter and ranged from 0.14 to 1.99 g km^{-2} yr^{-1}. Estimates of areal loading for the Cedar and Sammamish rivers reported here are also within the range of estimated areal loads of tPCB from the study of five major Puget Sound rivers, which ranged from 0.058 to 0.364 g km^{-2} yr^{-1} reported as the 25th and 75th percentile (Ecology and King County 2011; Greis and Osterberg 2011). Areal tPBDE loading from the same five rivers ranged from 0.118 to 0.230 g km^{-2} yr^{-1} again reported as the 25th and 75th percentile (Ecology and King County 2011; Greis and Osterberg 2011). Estimated areal loadings of tPBDE for the Cedar and Sammamish rivers are generally closer to the higher range of loading estimates for large Puget Sound rivers.

Table 3. Loading estimates of tPCB and tPBDE to Lake Washington from the Sammamish and Cedar rivers.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g yr^{-1})		
Cedar River	27	41	56	68
Sammamish River[a]	25	38	41	45
		tPBDE (g yr^{-1})		
Cedar River	9.9	36	370	150
Sammamish River[a]	11	160	210	380

[a] *Note that the estimated load from the Sammamish River is based on measured concentrations and estimated flow at B472, which is above the point where Swamp Creek enters the Sammamish River. Estimated loading from Swamp Creek is included in the unmonitored tributary loading estimate below.*

Table 4. Areal loading estimates of tPCB and tPBDE for the Sammamish and Cedar rivers.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g km^{-2} yr^{-1})		
Cedar River	0.054	0.082	0.11	0.14
Sammamish River[a]	0.045	0.068	0.074	0.081
		tPBDE (g km^{-2} yr^{-1})		
Cedar River	0.020	0.072	0.74	0.30
Sammamish River[a]	0.020	0.29	0.38	0.68

[a] *Note that the estimated load from the Sammamish River is based on measured concentrations and estimated flow at B472, which is above the point where Swamp Creek enters the Sammamish River. Estimated loading from Swamp Creek is included in the unmonitored tributary loading estimate below.*

4.2 Local Drainage Basins

4.2.1 Monitored Tributary Basins

The first step in the approach used to estimate loading from the three monitored tributaries was to conduct a base flow separation analysis in order to assign a concentration for days of base flow and another concentration representing days with storm flow. Example results for the analysis of the flow records from the three gauged basins are provided in Figure 9.

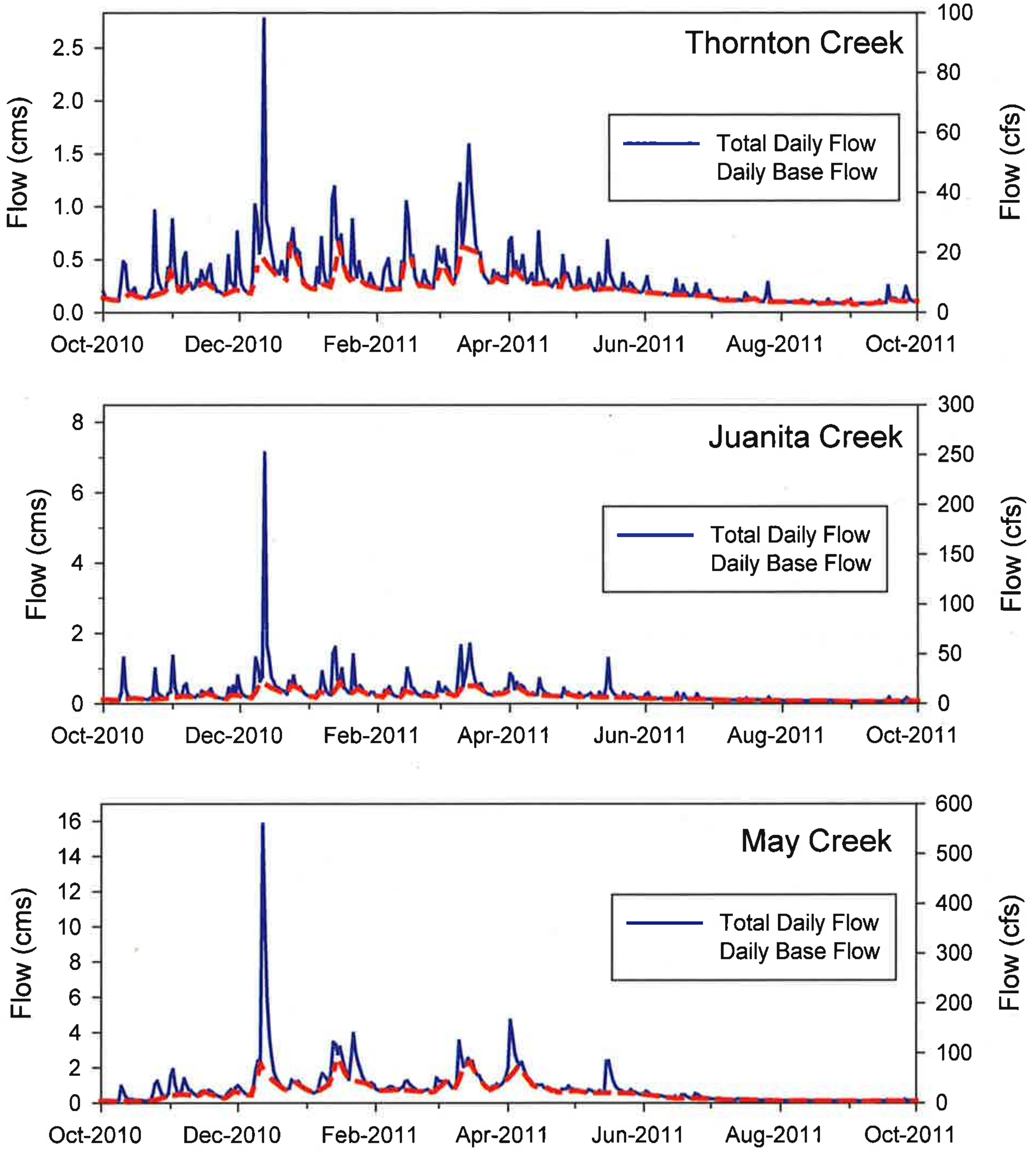

Figure 9. Time series graphs of daily average flow and estimated base flow for Water Year (Oct-Sep) 2011 discharge observed in Thornton (top graph), Juanita (middle graph) and May (bottom graph) creeks.

Note: The y-axis scale is different in each graph.

The mean base and storm flow (2002-2011) estimates derived from the base flow separation analysis are provided in Table 5. Flow (base, storm and mean) was highest in May Creek, which is consistent with its much larger basin area and higher elevation headwaters. The Juanita Creek drainage is about 40 percent smaller than Thornton Creek, but had similar base flow. Accounting for the flow that bypasses the Thornton Creek gauge at the mouth results in storm and mean flows that are higher than those in Juanita Creek, but not quite as much as would be expected based on basin area. It is possible that some of the runoff in the Thornton Creek basin remains unaccounted for, either as a result of error in the bypass flow estimate or as the result of diversion of storm drainage to another basin or to a combined sewer system.

Table 5. Base and storm flow estimates based on base flow separation analysis of Thornton, Juanita and May creeks.

	Base Flow	Storm Flow cms (cfs)	Mean Flow
Thornton Creek	0.068 (2.4)	0.317 (11.9) [a]	0.408 (14.4) [a]
Juanita Creek	0.068 (2.4)	0.232 (8.2)	0.300 (10.6)
May Creek	0.116 (4.1)	0.518 (18.3)	0.634 (22.4)

[a] *The storm flow and mean flow estimates for Thornton Creek include the estimate for the flow bypass from Meadowbrook Pond to Lake Washington. The observed mean flow (2002-2011) was 0.261 cms (9.2 cfs).*

Estimated tPCB and tPBDE loadings from the three monitored tributaries based on measured contaminant concentrations and the base and storm flow estimates provided above are summarized in Table 6. The range in observed storm flow concentrations was carried through to the estimate of total tPCB and tPBDE loadings from these tributary basins in Table 7. Note that the range of loading estimates generally indicate positive skew in the storm flow concentration data such that estimated mean loadings are greater than estimates based on the median storm flow concentrations, with the possible exception of May Creek. Estimated loadings from May Creek based on mean and median storm flow concentrations were the same for tPCB.

Areal loading estimates for these tributary basins are summarized in Table 8. On an areal basis, loading from these basins was higher than that observed for the Cedar and Sammamish rivers. Also, mean areal loading rates were consistently lowest for May Creek and highest for Thornton Creek.

Tributary basin areal loading rates shown in Table 8 are comparable to the median estimates for Puget Sound commercial/industrial land uses reported by Herrera (2011). Based on Puget Sound drainage areas for each land use type characterized in their study, the median loads provided in Table 15 of their report were converted to areal loading, which resulted in an estimated tPCB loading rate of 1.2 g km^{-2} yr^{-1} and a tPBDE loading rate of 1.9 g km^{-2} yr^{-1}. Areal loading rates for other land uses targeted in their study (residential,

Table 6. Base and storm flow loading estimates of tPCB and tPBDE to Lake Washington from Thornton, Juanita and May creeks.

	Base Flow (g yr^{-1})	Storm Flow			
		25th-percentile	Median	Mean	75th-percentile
			tPCB (g yr^{-1})		
Thornton Creek	2.5	28.	39.	56.	76.
Juanita Creek	0.17	3.5	4.9	17.	24.
May Creek	0.46	12.	23.	23.	33.
			tPBDE (g yr^{-1})		
Thornton Creek	4.0	38.	50.	99.	140.
Juanita Creek	1.3	2.0	3.5	36.	53.
May Creek	2.6	1.4	1.9	16.	23.

Table 7. Total loading estimates of tPCB and tPBDE to Lake Washington from Thornton, Juanita and May creeks.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g yr^{-1})		
Thornton Creek	31.	41.	59.	78.
Juanita Creek	3.7	5.1	17.	24.
May Creek	13.	23.	23.	34.
		tPBDE (g yr^{-1})		
Thornton Creek	42.	54.	100.	140.
Juanita Creek	3.3	4.8	37.	55.
May Creek	4.1	4.5	19.	26.

Table 8. Total areal loading estimates of tPCB and tPBDE for Thornton, Juanita and May creeks.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g km^{-2} yr^{-1})		
Thornton Creek	1.1	1.4	2.0	2.7
Juanita Creek	0.20	0.28	0.93	1.3
May Creek	0.37	0.67	0.66	0.95
		tPBDE (g km^{-2} yr^{-1})		
Thornton Creek	1.4	1.9	3.5	4.8
Juanita Creek	0.18	0.26	2.0	3.0
May Creek	0.12	0.13	0.53	0.74

agricultural, forest/field/other) were lower that estimates for Thornton, Juanita and May creeks by one or more orders of magnitude; 0.084 to 0.148 g km^{-2} yr^{-1} for tPCB and 0.064 to 0.163 g km^{-2} yr^{-1} for tPBDE based on median loads reported in Herrera (2011).

4.2.2 Extrapolation to Unmonitored Local Drainage Basins

Estimated areal loading from the three monitored tributary basins was consistent with the expectation that the range in character and degree of development among the monitored basins would result in a range of areal loading estimates – highest in Thornton Creek and lowest in May Creek. The areal loading estimates were compared to four basin characteristics to identify a plausible and somewhat objective means of extrapolating loading rates to unmonitored drainage basins around the lake. These characteristics were percent total impervious cover, population density, percent of basin developed in or before 1979 and percent of basin developed as commercial/industrial parcels in or before 1979.

Comparisons of tPCB and tPBDE areal loading rates (based on mean storm flow concentrations) to the four basin characteristics are shown in Figure 10. All comparisons suggest a positive relationship between the selected basin characteristics and areal tPCB and tPBDE loading rates. With only three points of comparison, the relationships cannot be evaluated statistically. The relationship between percent developed as commercial/ industrial in or before 1979 was chosen as the basis for extrapolation because it seemed to best fit the emerging conceptual model, at least for PCBs, that commercial/industrial land use may be a significant source of these types of contaminants. The relationship also indicated a convenient separation of areal loading rates among the basins. The rule selected for assigning areal loading rates to unmonitored basins was as follows:

- Less than or equal to 4 percent – use May Creek areal loading rates
- Greater than 4 percent but less than or equal to 8 percent – use Juanita Creek areal loading rates
- Greater than 8 percent – use Thornton Creek areal loading rates

The classification of each drainage basin with respect to percent developed as commercial/industrial in or before 1979 is shown in Figure 11. The range of estimated tPCB and tPBDE loading from local drainages to Lake Washington and Lake Union is provided in Table 9. The range of estimated tPCB and tPBDE areal loading from local drainage basins to Lake Washington and Lake Union is provided in Table 10. Estimated mean areal loading rates ranged from 1.2 to 2.0 and 2.2 to 3.5 g km^{-2} yr^{-1} for tPCB and tPBDE, respectively. These areal loading rates are comparable to the median estimates for Puget Sound commercial/industrial land uses reported by Herrera (2011), which is consistent with the moderate to high percentages of this type of land use in the watersheds surrounding these lakes.

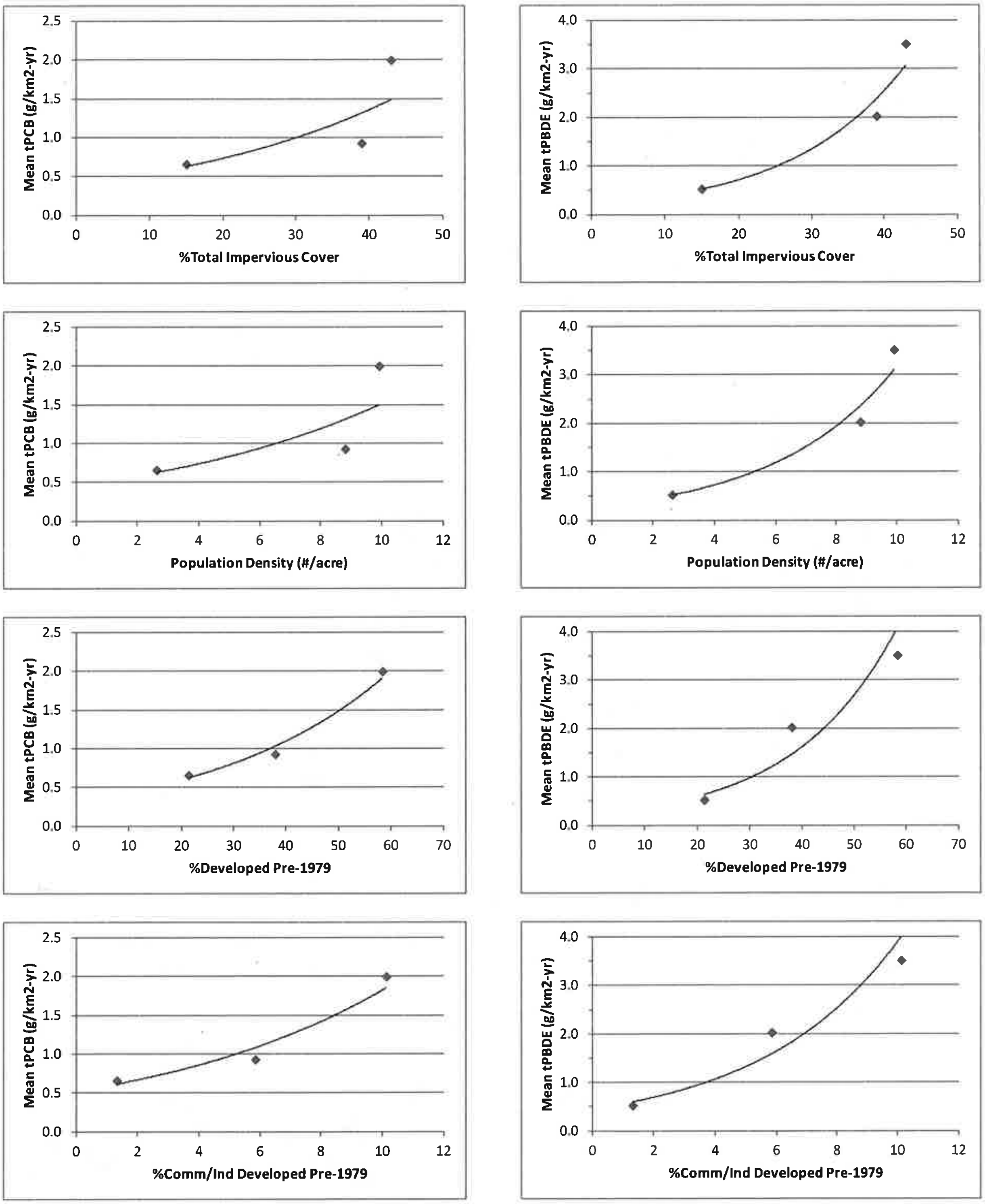

Figure 10. Scatterplots of areal loading of tPCB (left panel) and tPBDE (right panel) for percent total impervious cover, population density, percent developed in or before 1979, and percent developed as commercial/industrial land use in or before 1979.

Note: An exponential regression fit is shown only to illustrate the suggestive positive relationships between the four basin characteristics and areal contaminant loading.

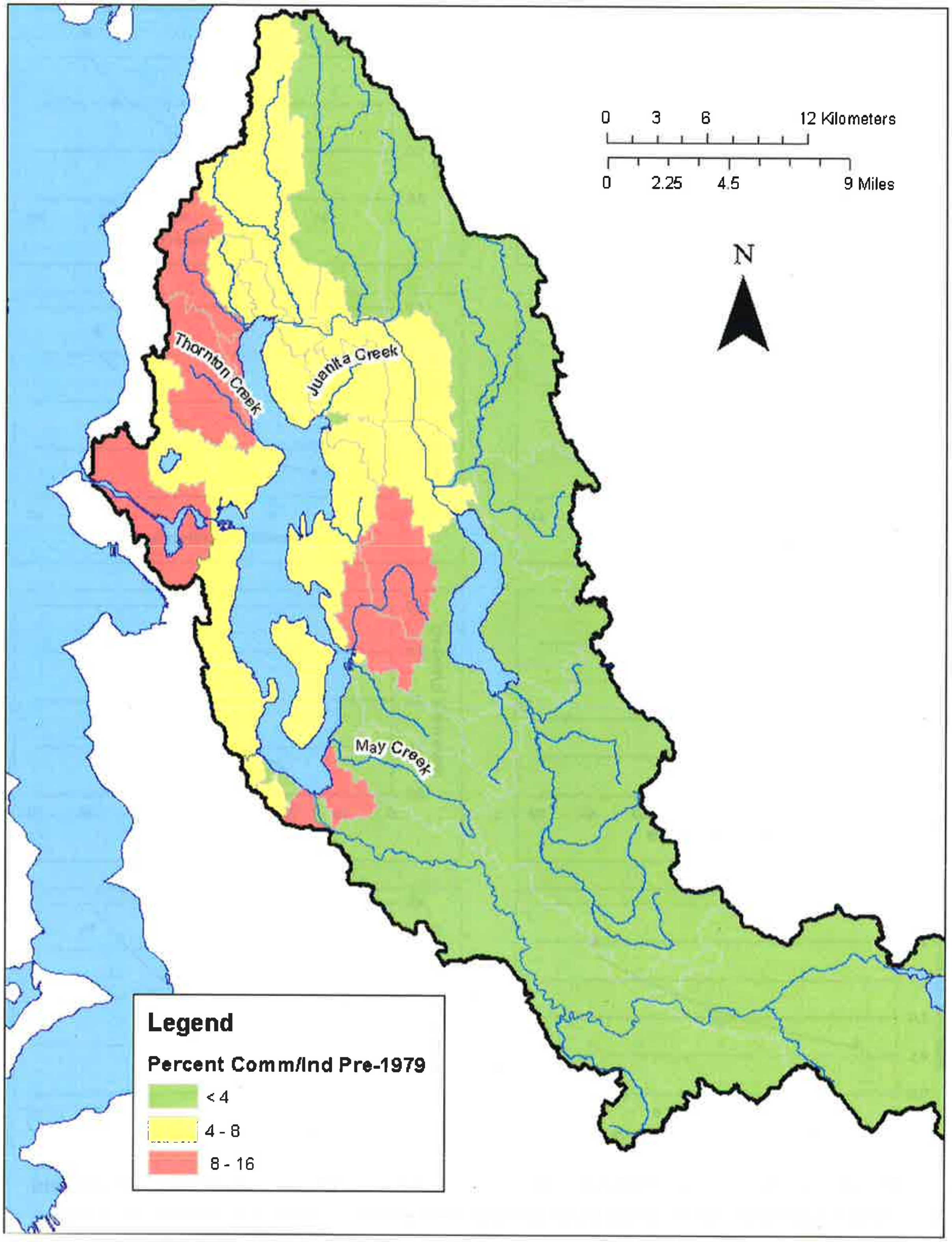

Figure 11. Lake Washington and Lake Union local drainage basins categorized by percent developed as commercial/industrial land use in or before 1979.

Table 9. Loading estimates of tPCB and tPBDE to Lakes Washington and Union from local drainage basins.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g yr^{-1})		
Lake Washington[a]	190	260	450	620
Lake Union	22	28	40	53
		tPBDE (g yr^{-1})		
Lake Washington[a]	200	280	820	1,200
Lake Union	28	38	69	95

[a] *Note that the estimated loads include inputs estimated for Swamp Creek, which enters the Sammamish River just upstream of where the river enters Lake Washington.*

Table 10. Areal loading estimates of tPCB and tPBDE to Lake Washington and Lake Union from local drainage basins.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g km^{-2} yr^{-1})		
Lake Washington[a]	0.51	0.70	1.2	1.7
Lake Union	1.1	1.4	2.0	2.7
		tPBDE (g km^{-2} yr^{-1})		
Lake Washington[a]	0.54	0.76	2.2	3.2
Lake Union	1.4	1.9	3.5	4.8

[a] *Note that the estimated loads include inputs estimated for Swamp Creek, which enters the Sammamish River just upstream of where the river enters Lake Washington.*

4.3 Highway Runoff

The estimated areas of state and interstate highway bridges that contribute runoff to Lakes Washington and Union are provided in Table 11. Table 12 presents the estimated loading from state and interstate highway bridges that contribute runoff to Lakes Washington and Union. These estimates were based on the contributing area of each bridge (Table 11), a long-term annual average precipitation amount of 940 mm (37 in), and tPCB and tPBDE concentrations measured in I-90 bridge runoff during this study (see Table 1). Estimated areal loading rates from bridge runoff are provided in Table 13. Currently, no studies have been identified that would provide a basis for comparison to these results, although a previous study of runoff from the SR 520 bridge indicated that high volume traffic surfaces can be a concentrated source of various contaminants (King County 2006).

Table 11. Contributing areas of state and interstate bridge crossings of Lakes Washington and Union.

		Contributing Bridge Deck Area	
		m^2	ft^2
Lake Washington			
	SR 520	134,438	1,447,076
	I-90	197,674	2,127,749
	Total	332,112	3,574,825
Lake Union			
	SR 520 (Portage Bay)	16,376	176,270
	I-5	64,777	697,258
	SR 99	18,201	195,916
	Total	99,355	1069444
	Grand Total	431,467	4,644,269

Table 12. Loading estimates of tPCB and tPBDE to Lakes Washington and Union from highway bridge runoff.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g yr^{-1})		
To Lake Washington	1.7	2.8	2.9	4.1
To Lake Union	0.52	0.83	0.87	1.2
		tPBDE (g yr^{-1})		
To Lake Washington	1.3	1.9	19.	19.
To Lake Union	0.39	0.58	5.6	5.8

Table 13. Areal loading estimates of tPCB and tPBDE from highway bridge runoff.

25th-percentile	Median	Mean	75th-percentile
	tPCB (g km^{-2} yr^{-1})		
5.3	8.4	8.7	12.
	tPBDE (g km^{-2} yr^{-1})		
3.9	5.8	56.	58.

4.4 CSOs

Estimated long-term CSO flow rates for Lakes Washington and Union are provided in Table 14. Estimated tPCB and tPBDE loading from CSOs to Lakes Washington and Union is summarized in Table 15. tPCB loading estimates are based on the average CSO discharge rate to each lake and the contaminant concentrations measured in data combined from this study and another recent study conducted on CSOs discharging to the Duwamish River in southeast Seattle (53 samples from 11 CSOs; see Section 3.1). tPBDE loading is based on the CSO discharge rates and the data collected in this study.

Note that the estimated tPCB loading rate based on the mean concentration is similar to the estimate based on the 75th-percentile concentration, which indicates positive skew in the CSO tPCB concentration results. This is due to consistently high concentrations measured in a CSO at the southern end of Lake Union and relatively high concentrations observed in a CSO that discharges to the Duwamish River. PCB concentrations measured in the two other CSOs that were monitored in this study and discharge to the Ship Canal in Ballard and to Lake Washington near Seward Park are lower and similar to concentrations measured in stormwater (see Table 1).

The positive skew in the limited number of CSO samples analyzed in the two recent studies, combined with the highly episodic nature of CSOs, suggest that the CSO loading estimates are relatively uncertain.

Table 14. Estimated long-term CSO flow rates for Lakes Washington and Union.

	cms	cfs
Lake Washington	0.0055	0.190
Lake Union	0.026	0.920

Table 15. Loading estimates of tPCB and tPBDE to Lakes Washington and Union from CSOs.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g yr^{-1})		
To Lake Washington	4.9	7.6	12.	12.
To Lake Union	23.	36.	58.	59.
		tPBDE (g yr^{-1})		
To Lake Washington	3.3	8.3	14.	26.
To Lake Union	16.	39.	68.	120.

4.5 Atmospheric Deposition

The bulk deposition of tPCB and tPBDE measured in this study are summarized in Table 16. tPCB and tPBDE areal deposition rates in ng m^{-2} d^{-1} were greatest at the Beacon Hill site to the southwest of the lake, although the difference for tPCB deposition was relatively small and may not be statistically significant. The range in the rates of tPCB deposition reported in this study (2.58-4.30 ng m^{-2} d^{-1}) were somewhat higher than that reported in a recent deposition study conducted at seven locations along the Puget Sound shoreline that used similar methods (Brandenberger et al. 2010). Mean deposition rates reported by Brandenberger et al. (2010) ranged from 0.75 to 2.54 ng m^{-2} d^{-1}, with the highest rate measured at a highly urban location in Tacoma, WA approximately 35 km (22 mi) to the south of the Beacon Hill site occupied in this study.

Table 16. Atmospheric deposition rate (ng m^{-2} d^{-1}) measured in this study, including a comparison to a recent Puget Sound study.

Sand Point	Beacon Hill	Puget Sound [a]
tPCB (ng m^{-2} d^{-1})		
2.58	4.30	0.75 - 2.54
tPBDE (ng m^{-2} d^{-1})		
5.95	30.3	6.2 - 30.4

[a] Brandenberger et al. 2010 (excluding results for Padilla Bay)

The range in tPBDE deposition measured in this study is very similar to mean deposition rates reported by Brandenberger et al. (2010) for locations around Puget Sound. The lower rate of 5.95 ng m^{-2} d^{-1} measured at Sand Point is similar to many of the more rural areas monitored by Brandenberger et al. (2010) and the higher rate measured at the Beacon Hill site (30.3 ng m^{-2} d^{-1}) is similar to the highest deposition rate reported by Brandenberger et al. (30.4 ng m^{-2} d^{-1}) at their highly urban Tacoma location.

Atmospheric loading estimates to Lakes Washington and Union are reported in Table 17. Estimated loading is based on the deposition rates measured at the two stations monitored in this study and the surface areas of each lake.

4.6 Loading to Puget Sound

The lake water balance yielded a long-term flow estimate of 36.9 cms (1,400 cfs) from the Greater Lake Washington drainage to Puget Sound. This is similar to a previous estimate provided by the USACOE (Lynne Melder, Hydraulic Engineer, Seattle District USACOE) of 40.4 cms (1,426 cfs) for the period 1995-2000. As a check, a second calculation was done that used the long-term average flow, evaporation and precipitation inputs which allowed daily changes in storage to be ignored. This method provided an estimated long-term discharge of 41.6 cms (1,470 cfs), which is within 10 percent of the estimate based on the daily water balance that included the effect of changes in storage.

Table 17. Atmospheric loading estimates of tPCB and tPBDE to the surface of Lake Washington and Lake Union.

	Minimum (Sand Point)	Mean/Median [a]	Maximum (Beacon Hill)
		tPCB (g yr^{-1})	
Lake Washington	84	110	140
Lake Union	3.6	4.8	6.0
		tPBDE (g yr^{-1})	
Lake Washington	190	590	980
Lake Union	8.3	25	42

[a] Range based on data collected at the two stations

Average concentrations of tPCB and tPBDE measured at Station 0580 just upstream of the Locks were 0.29 (range 0.14-0.58) and 0.80 (range 0.029-2.1) ng/L, respectively (see Table 1). The average concentration of tPCB is very similar to the concentrations estimated from seasonal semi-permeable membrane device (SPMD) deployments in the Lake Washington Ship Canal conducted by Ecology (Sandvik 2008; Sandvik 2009; Sandvik and Seiders 2011; Sandvik and Seiders 2012). The range of tPCB concentrations reported in Ecology's SPMD studies was 0.12 to 0.51 ng/L. tPBDE concentrations reported in those same studies were generally lower than measured in this study. tPBDE concentrations reported in their study ranged from below detection to 0.27 ng/L.

Ecology has also analyzed whole water samples from five major rivers discharging to Puget Sound (Skagit, Snohomish, Nooksack, Stillaguamish, and Puyallup) and reported tPCB concentrations ranging between 0.003 to 0.059 ng/L and tPBDE concentrations ranging between 0.011 and 0.265 ng/L (Gries and Osterberg 2011). These Puget Sound river tPCB and tPBDE concentrations are generally lower than those observed in our study, which is not unexpected as these rivers drain large relatively undeveloped areas.

tPCB and tPBDE loading to Puget Sound from the Greater Lake Washington watershed based on the estimated long-term flow and average concentrations are 360 and 990 g yr^{-1}, respectively (Table 18). Based on the total upstream drainage area of 1,590 km^2 (614 mi^2), the estimated areal loading rate is 0.23 and 0.62 g km^{-2} yr^{-1} for tPCB and tPBDE, respectively (Table 19). Loading estimates from Lake Washington to Lake Union via Montlake Cut are also provided in Table 18 and Table 19.

Based on the range in estimated tPCB and tPBDE loading rates it appears that Lake Union contributes a significant portion of PCBs and PBDEs to Puget Sound – the mean fluvial tPCB loading rate increases by about a factor of three and the tPBDE load doubles after water passes through Lake Union (see Table 18).

In general, the tPCB loading estimate for the Greater Lake Washington discharge to Puget Sound is within the range reported by Gries and Sloan (2009) for the Green River, which discharges to Elliott Bay/Puget Sound just to the south. Their estimate was based on analysis of contaminants sorbed to suspended particulate matter and ranged from 0.14 to 1.99 g km^{-2} yr^{-1}. Estimated areal loads of tPCB from the study of five major Puget Sound rivers mentioned above ranged from 0.058 to 0.364 g km^{-2} yr^{-1} reported as the 25th and 75th percentile (Ecology and King County 2011, Gries and Osterberg 2011). Areal tPBDE loading from the same five rivers ranged from 0.118 to 0.230 g km^{-2} yr^{-1} again reported as the 25th and 75th percentile (Ecology and King County 2011, Gries and Osterberg 2011).

Table 18. Loading estimates of tPCB and tPBDE to Puget Sound from the Greater Lake Washington watershed. Estimated loading to Lake Washington and from Lake Washington to Lake Union via Montlake Cut also shown.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g yr-1)		
To Lake Washington	333	459	672	889
From Lake Washington to Lake Union	73	110	140	140
From Lake Union to Puget Sound	190	250	360	540
		tPBDE (g yr-1)		
To Lake Washington	416	1,076	2,023	2,755
From Lake Washington to Lake Union	330	650	800	940
From Lake Union to Puget Sound	280	740	990	1,400

Table 19. Areal loading estimates of tPCB and tPBDE for the Greater Lake Washington watershed. Estimated areal loading to Lake Washington and from Lake Washington to Lake Union via Montlake Cut also shown.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g km^{-2} yr^{-1})		
To Lake Washington	0.21	0.30	0.43	0.57
From Lake Washington to Lake Union	0.047	0.068	0.088	0.088
From Lake Union to Puget Sound	0.12	0.16	0.23	0.34
		tPBDE (g km^{-2} yr^{-1})		
To Lake Washington	0.27	0.69	1.3	1.8
From Lake Washington to Lake Union	0.21	0.42	0.52	0.60
From Lake Union to Puget Sound	0.18	0.47	0.62	0.85

Also shown Table 18 and Table 19 are the estimated total load (mass and areal, respectively) of tPCB and tPBDE to Lake Washington from rivers, tributary drainages, bridge runoff, CSOs and atmospheric deposition. Comparison of loading to Lake Washington to the export from Lake Washington to Lake Union indicates that from about 75 to 85 percent of the tPCB input and 20 to 65 percent of the tPBDE input to Lake Washington is deposited in lake sediments, accumulated by lake biota and possibly lost through volatilization across the air-water interface. The next step of this study will be the development of tPCB fate and bioaccumulation models that will account for contaminant loss to sediments, contaminant exchange across the air-water interface and accumulation in biota. This tool will be used to evaluate the potential for management actions to reduce health risks from consuming contaminated fish from Lake Washington.

5.0. DISCUSSION

To synthesize and better illustrate the results presented above, a chart was prepared that shows the range of tPCB and tPBDE loading estimates for each pathway for Lakes Washington and Union. Figure 12 shows the range of tPCB loading estimates, which illustrates that loading from local drainages are likely the dominant source of tPCBs to Lake Washington (left panel). However, estimated local drainage basin inputs appear to have the greatest absolute uncertainty and range from 190 to 620 g yr^{-1}. The second largest source of tPCB appears to be direct deposition to the surface of the lake followed by inputs from the two major rivers.

Although the CSO load is uncertain due to the positive skew in the observed tPCB concentration data, the CSO contribution to Lake Washington as a whole is small relative to all but bridge runoff. However, the estimated relative contribution and uncertainty in tPCB loading to Lake Union (see right panel of Figure 12) highlights the potential contribution of CSOs and local stormwater runoff loading to the apparent increase in loading between Lake Washington at Montlake Cut and the discharge to Puget Sound at the locks.

Figure 13 shows the range of tPBDE loading estimates, which illustrates that tPBDE loading estimates for Lake Washington (left panel), with the exception of loading from CSOs and bridges which are relatively low, have a great deal of uncertainty. There is not a clearly dominant source pathway for tPBDEs for Lake Washington. It appears that loading from the outflow of Lake Washington to Lake Union is the dominant source of tPBDE to Lake Union, with much smaller contributions from local drainage and bridge runoff, CSOs and atmospheric deposition.

The suggestion that local drainage basins are the most significant source of tPCBs to Lake Washington warrants further discussion. The area around the lake is substantially developed for residential, commercial, and limited industrial uses. Development around the lake accelerated during and after World War II. Some of the materials associated with this development are known PCB sources and development has also traditionally been associated with increased impervious cover that collects and routes rainfall quickly and efficiently, along with contaminants that accumulate on these surfaces, to wastewater conveyance systems, stormwater outfalls, streams and lakes.

Although the highest tPCB concentrations in this study were measured in CSOs, the next highest concentrations were measured in stormwater outfalls sampled from the I-90 bridge and six other locations draining small areas (less than 4 km^2/1,000 acres) around the lakes. The samples collected from the three tributary basins included a base flow sample – significant base flow does not typically occur in stormwater drains – and samples collected during storms that contain a mixture of base and storm flow. In general, about 70 percent of stream flow in these tributaries is base flow and the remainder (30 percent) is stormwater runoff.[21] To illustrate the dominance of stormwater runoff on tPCB load in tributary streams, the base flow separation results, along with the measured base flow

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[21] Recall Figure 6 and the definitions provided in Section 3.3.1.

tPCB concentration, were used to calculate the stormwater runoff concentration needed to match the estimated tPCB load.

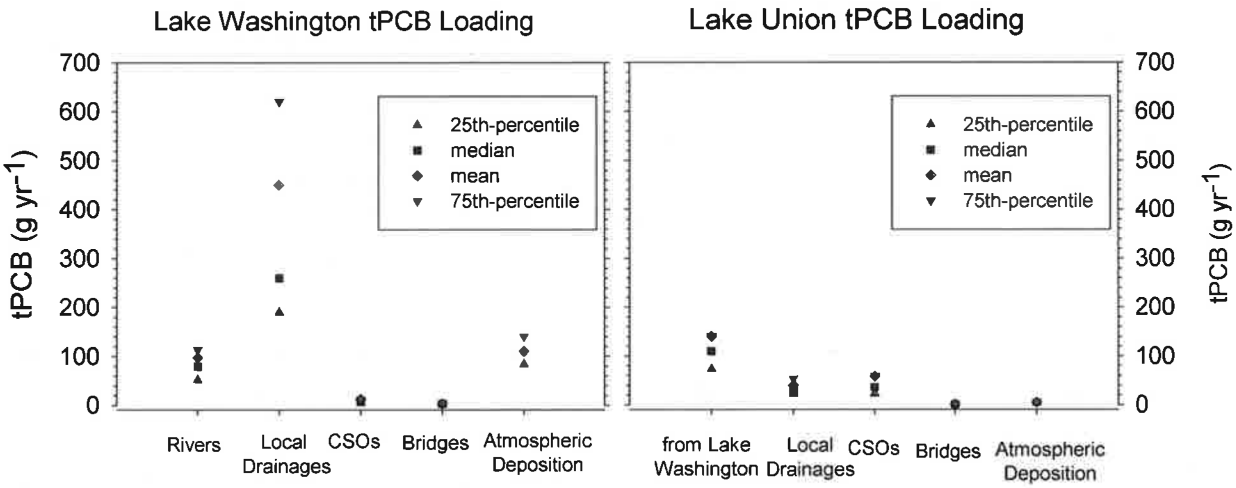


Figure 12. Range of tPCB loading estimates for Lake Washington and Lake Union.

Note: Ranges of loading from atmospheric deposition are minimum and maximum estimates based on the data from the two deposition sites monitored in this study.

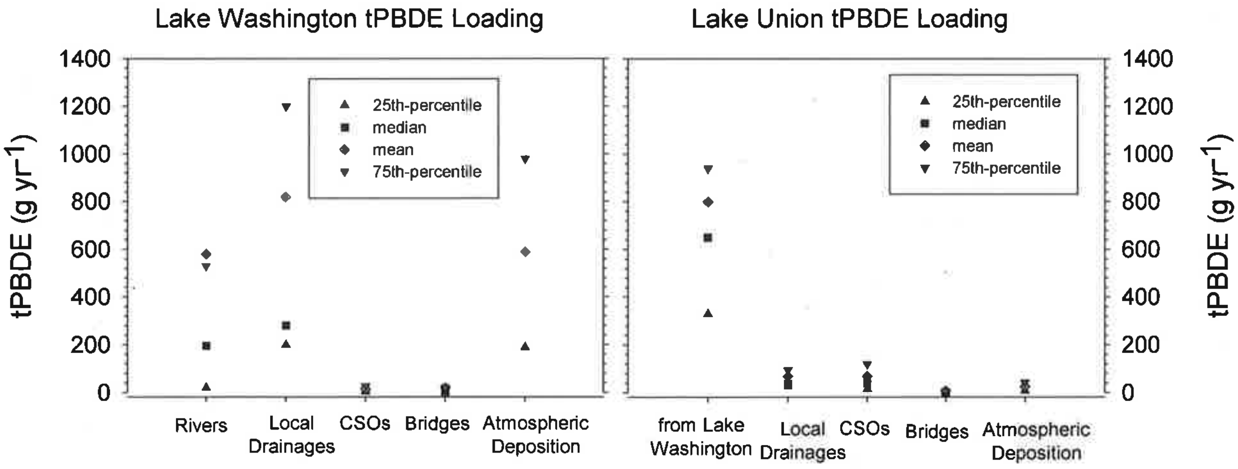


Figure 13. Range of tPBDE loading estimates for Lake Washington and Lake Union.

Note: Ranges of loading from atmospheric deposition are minimum and maximum estimates based on the data from the two deposition sites monitored in this study.

Table 20 presents a summary of these calculations, which indicate that the stormwater concentrations needed to match the estimated total tPCB loading estimate was highest for Thornton Creek and lowest for May Creek – consistent with the pattern observed in the tributary basin storm flow measurements. The estimated stormwater runoff concentrations are also generally consistent with measurements made in the stormwater outfalls sampled in this study. Based on the 18 storm events sampled from the stormwater outfalls in this study (see Table 22 in King County 2013), the 25th and 75th percentile tPCB concentrations were 1.6 and 4.7 ng/L, respectively.

The analysis presented in Table 20 also suggests that stormwater runoff contributes over 80 and perhaps even over 90 percent of the total local drainage basin load (Storm [Est]/Total Load), regardless of the level or type of development. This is in spite of the fact that stormwater runoff is only about 30 percent of the total annual tributary flow.

Table 20. Estimate of stormwater tPCB concentration needed to match estimated tPCB load from Thornton, Juanita and May creeks given base and storm flow and base flow tPCB concentration.

	Flow		tPCB Load (g yr^{-1})			tPCB Concentration	
						Observed Base Flow	Estimated Stormwater Runoff
	cms	cfs	Base Flow	Storm (Estimate)	Target Total Load	ng/L	
Thornton Creek[a]							
Base flow	0.190	6.7	6.9	52.	59.	1.1	7.6 [b]
Stormflow	0.217	7.7					(1.6 - 11) [c]
Juanita Creek							
Base flow	0.200	7.1	0.51	16.7	17.	0.081	5.4 [b]
Stormflow	0.099	3.5					(0.27-5.9) [c]
May Creek							
Base flow	0.429	15.	1.7	21.7	23.	0.13	3.4 [b]
Stormflow	0.205	7.3					(0.12-2.8) [c]

[a] *The analysis for Thornton Creek includes the estimate of stormwater bypass flow from Meadowbrook Pond to Lake Washington.*

[b] *The 75th-percentile storm flow tPCB concentrations in Thornton, Juanita and May creeks were 7.1, 3.3 and 2.0 ng/L, respectively.*

[c] *The minimum and maximum tPCB concentrations in the three storm flow samples collected from each creek during the study.*

To further evaluate the relative importance of urban stormwater runoff as significant source of tPCB to these lakes, the pooled storm event tPCB concentration statistics for the six stormwater outfalls provided in Table 22 of the companion data report (King County 2013) were used to estimate areal loading rates from a typical urban stormwater basin. Stormwater loading estimates were not calculated for each basin, primarily because flow was not measured continuously at each stormwater sampling location over the course of the study so that runoff flow could be accurately calculated. Unfortunately, it was not within the resources of this project to measure continuous flow at the stormwater outfalls.

Areal stormwater basin loading was estimated using two different precipitation runoff assumptions. The first assumption follows that used for the calculation of stormwater runoff from the bridges (i.e., all precipitation is translated into runoff) using the same estimated long term annual precipitation amount of 940 mm (37 in). This assumption may not be an unreasonable first approximation based on the results of flow gauging conducted on a small partially separated drainage basin (drainage area of 152 ac) in the University District, which is within the Central Seattle drainage basin and which drains to Lake Union (City of Seattle 2012).

The second assumption was that generated runoff would be less than the total precipitation amount. The estimated tributary basin yield of 1.4 cfs per mi^2 used for estimating ungauged drainage basin flow was used as a reasonable approximation of the second assumption. This translates to approximately 483 mm (19 in) of runoff per unit basin area. The result of these calculations and comparison to the areal loading estimates for Thornton, Juanita and May creeks is presented in Table 21. The estimated stormwater basin areal loading rates are similar to, but somewhat higher than the estimated areal loading rates for Thornton Creek and consistently higher than the estimated loadings from Juanita and May creeks. This pattern is consistent with stormwater runoff from urban drainage areas being a significant source of tPCB to urban tributary streams and to these lakes.

Table 21. Areal loading estimates of tPCB from a unit stormwater basin drainage area based on stormwater basin storm event sampling conducted for this study. Comparisons to the estimated areal loading rates for Thornton, Juanita and May creeks are also provided.

	25th-percentile	Median	Mean	75th-percentile
		tPCB (g km^{-2} yr^{-1})		
Composite Stormwater Basin	1.7	3.0	5.5	4.6
Thornton Creek	1.1	1.4	2.0	2.7
Juanita Creek	0.20	0.28	0.93	1.3
May Creek	0.37	0.67	0.66	0.95

Another potentially informative comparison is between atmospheric deposition rates measured in this study and the areal loading rates estimated for the monitored tributary drainage basins and major rivers (Table 22). It appears that atmospheric deposition rates based on measurements made near the lake in Seattle are generally similar to the areal loading rates from the more highly developed basins (Thornton and Juanita creeks) and are higher than the areal loading rates from the less developed May Creek basin. Areal loading rates from the major rivers are generally much lower than the observed atmospheric deposition rates.

There are at least two, not necessarily mutually exclusive explanations for these observations. It is possible that atmospheric deposition declines as a function of distance from highly developed commercial/industrial areas. May Creek and the two major river basins include less developed rural areas. This phenomenon has been suggested in other studies (Brandenberger et al. 2010, Melymuk et al. 2012). It is also possible that the greater area of soils and forests in less developed basins are more effective at retaining and storing deposited contaminants than developed areas with extensive impervious cover that is connected to stormwater conveyance networks that efficiently deliver water and associated contaminants directly to receiving streams and lakes.

Also note that even though atmospheric deposition rates are similar to areal loading rates in developed drainage basins, this does not preclude the possibility of significant direct inputs from local sources such as leaking transformers, abrasion of contaminant containing building materials, etc., since even in highly developed areas there are soils and often some trees that can sorb and store contaminants deposited or generated from within the drainage basin. In general, the emerging conceptual model, at least for PCBs, is that much of the current PCB load is primarily from local sources stored in building and construction materials containing PCBs and leakage from PCB containing electrical equipment (Diamond et al. 2010; Robson et al. 2010). The relative contribution from these sources in the Greater Lake Washington watershed remains unknown.

Table 22. Comparison of tPCB and tPBDE areal atmospheric deposition rates measured at Sand Point and Beacon Hill to mean areal loading rates estimated for the Thornton, Juanita and May creeks and the Cedar and Sammamish rivers.

Atmospheric Deposition						
Sand Point	Beacon Hill	Thornton Creek	Juanita Creek	May Creek	Sammamish River	Cedar River
		tPCB (g km^{-2} yr^{-1})				
0.94	1.6	2.0	0.93	0.66	0.052	0.074
		tPBDE (g km^{-2} yr^{-1})				
2.2	11.1	3.5	2.0	0.53	0.61	0.38

6.0. CONCLUSIONS

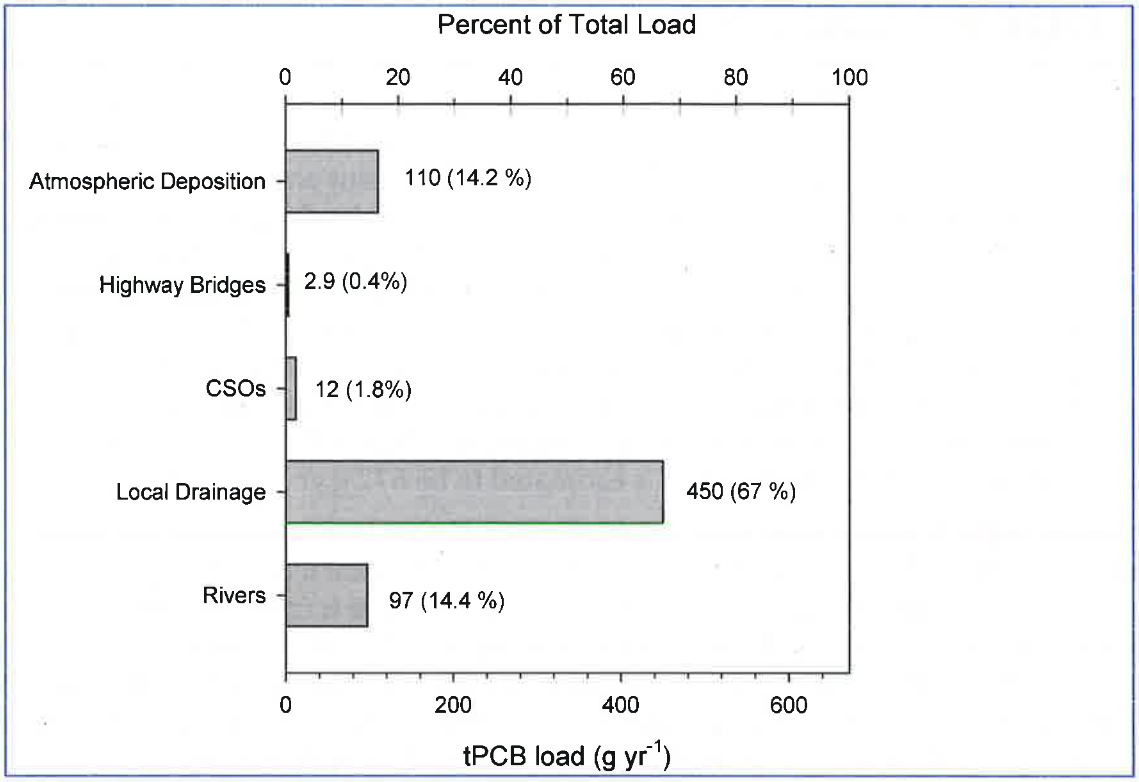
The current best estimates of tPCB loading to Lakes Washington and Union are shown in Figure 14. These estimates suggest that local drainage basins contribute about 67 percent of the total tPCB load to Lake Washington. The next most significant pathways appear to be atmospheric deposition to the surface of the lake and major river loading; each accounting for ~14 percent of the total loading. This suggests that over 95 percent of the loading to Lake Washington can be accounted for from these three pathways. Based on the analyses in this report, there appears to be a large range in the plausible estimates of local drainage basin loading, but even the lowest estimates are above the uncertainty range in the next highest loading estimate. Depending on the true local drainage tPCB loading contribution, local drainage basin loading may be more or less significant. Total tPCB loading from all of the assessed pathways to Lake Washington is estimated to be 672 g yr^{-1}.

For Lake Union, input (export) from Lake Washington (140 g yr^{-1}) appears to be the most significant source of tPCB, contributing about 57 percent of the total load (244 g yr^{-1}). CSOs appear to be the next highest contributor (~24 percent), but there is considerable uncertainty in this estimate. Local drainage basin loading, which is almost exclusively stormwater runoff, is estimated to contribute approximately 16 percent, so together these three pathways are estimated to deliver about 97 percent of the total load to Lake Union. CSOs and stormwater runoff from the local drainage basins, along with atmospheric deposition and bridge runoff, are the likely contributors to the apparent increase in tPCB concentration and loading between Lake Washington and the discharge through the locks to Puget Sound. Although tPCB load appears to increase between Lake Washington and Puget Sound, Lake Washington appears to be a sink for tPCBs based on the substantial reduction in tPCB load (~80 percent) observed between inputs to Lake Washington and export through the Lake Washington Ship Canal (see Table 18).

The current best estimates of tPBDE loading to Lakes Washington and Union are shown in Figure 15. tPBDE loading estimates for major rivers, local drainage basins and atmospheric deposition to Lake Washington are relatively uncertain, but the best current estimate is that they together contribute almost all of the tPBDE to the lake. Total tPBDE loading from all of the assessed pathways to Lake Washington is estimated to be 2,023 g yr^{-1}.

Lake Washington appears to be the largest source of tPBDE to Lake Union (800 g yr^{-1}), contributing about 80 percent of the total load (968 g yr^{-1}). CSO and local drainage runoff inputs have similar uncertainty, but are also estimated to contribute similar amounts – approximately 7 percent each so that most of the tPBDE loading to Lake Union is associated with those three pathways.

These tPCB loading estimates will be used in the models that will be developed in the next phase of this study to simulate the response of Lake Washington to reductions in tPCB loading that might result from various management approaches and resulting changes in concentrations in resident fish.



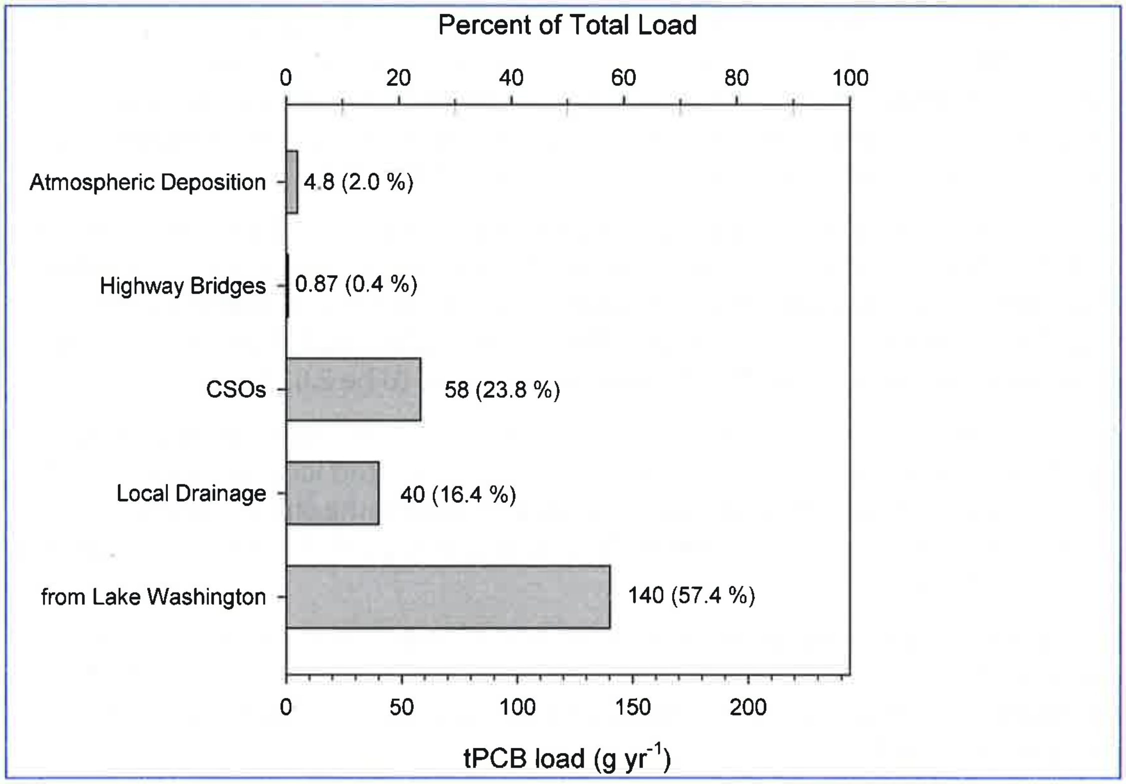
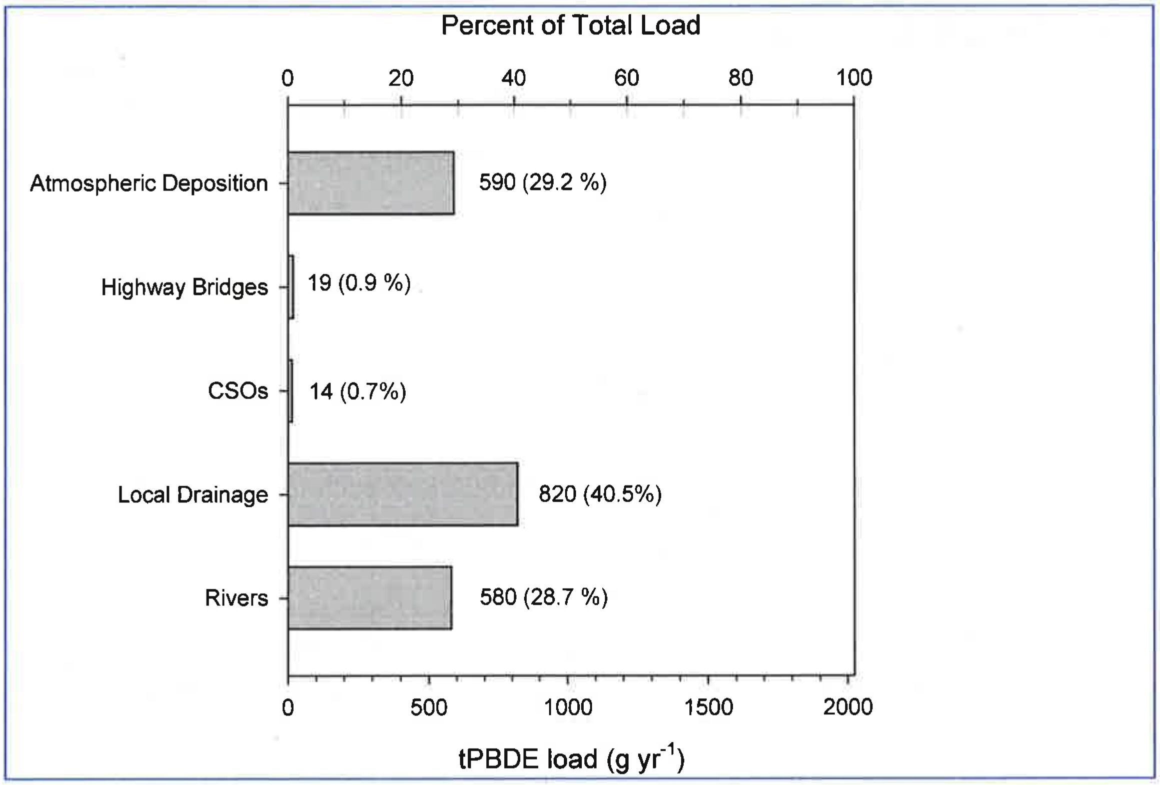


Figure 14. Bar charts showing current best estimates of the relative contribution of tPCB (g yr^{-1}, percent of total) from each pathway to Lake Washington (top) and to Lake Union (bottom).



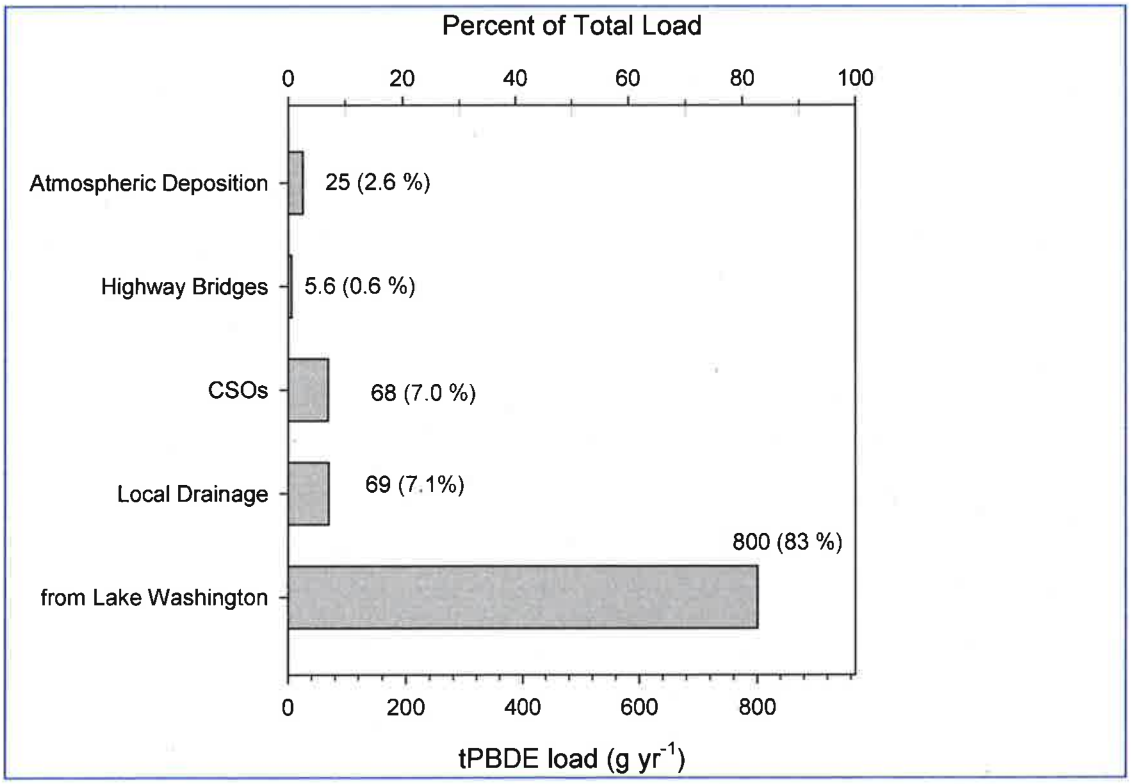


Figure 15. Bar charts showing current best estimate of the relative contribution of tPBDE (g yr^{-1}, percent of total) from each pathway to Lake Washington and to Lake Union.

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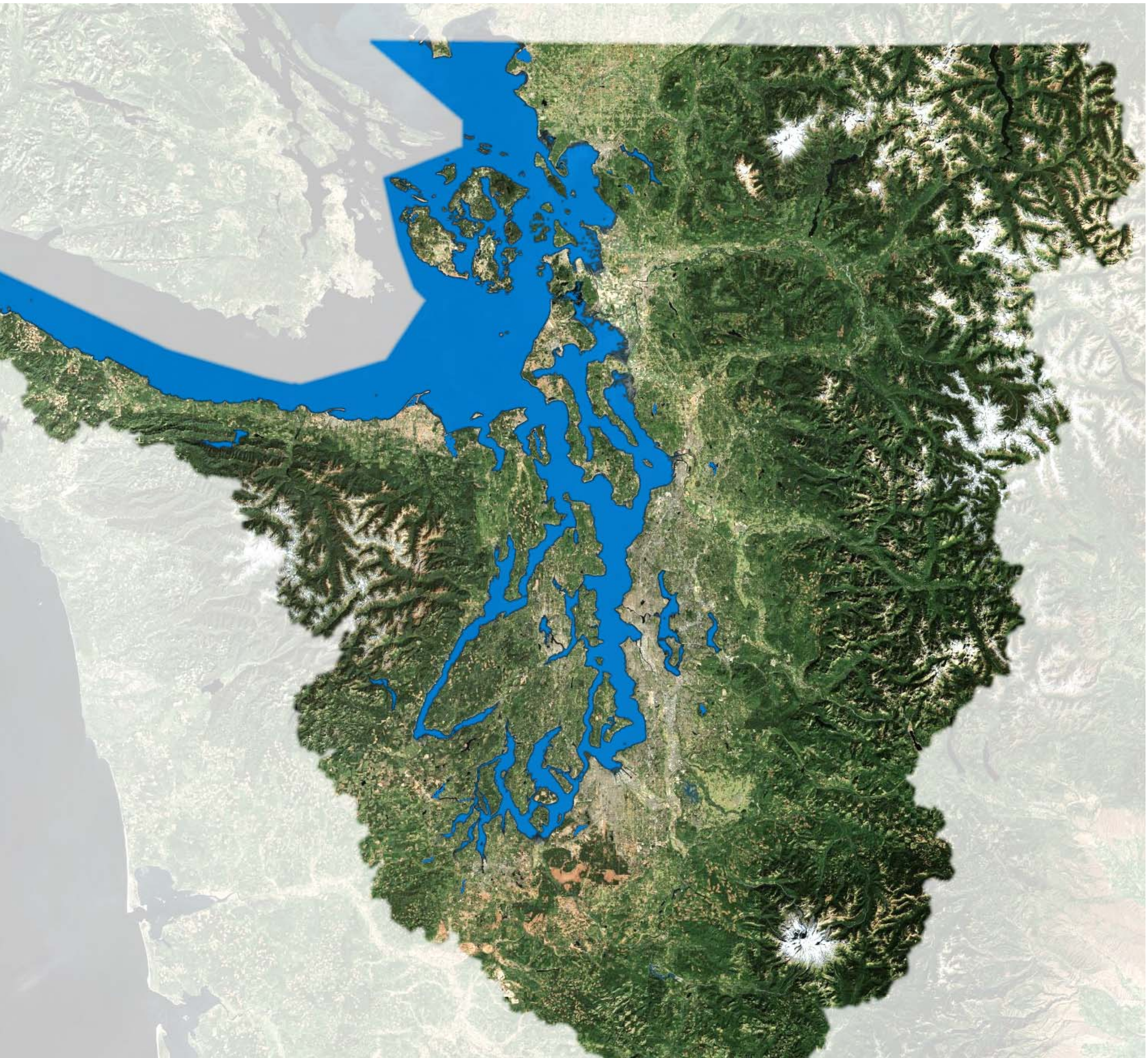

Control of Toxic Chemicals in Puget Sound

Quality Assurance Project Plan for Phase 3: Characterization of Toxic Chemicals in Puget Sound and Selected Major Tributaries

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

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WA-PS-0240
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WA-03-1010
WA-10-1020
WA-PS-0290
WA-02-0020
WA-05-1010
WA-06-0010
WA-PS-0250

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Quality Assurance Project Plan

Control of Toxic Chemicals in Puget Sound Phase 3: Characterization of Toxic Chemicals in Puget Sound and Selected Major Tributaries

August 2009

Approved by:

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Signatures are not available on the Internet version.
TSU = Toxics Studies Unit.
EAP = Environmental Assessment Program.
EIM = Environmental Information Management system.

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Abstract

The Puget Sound Partnership identified the control and reduction of toxic chemicals entering Puget Sound as vital to the ecosystem's recovery and maintenance. In a multi-phase effort to develop source-control strategies for toxic contaminants, the Puget Sound Toxics Loading Analysis (PSTLA) will quantify concentrations within, and loadings to, Puget Sound, ultimately guiding management decisions.

Existing data were used to estimate chemical loadings during Phase 1 of the PSTLA. Phase 2 efforts included development of the Puget Sound Toxics Box Model to simulate chemical fate, transport, and bioaccumulation. This numerical model gives managers the ability to evaluate impacts on water, sediment, and biota under different control strategies. Initial modeling exercises indicated that additional data on toxic chemical concentrations in the marine water column, oceanic boundary waters, and major rivers discharging to Puget Sound were needed to reduce uncertainty in the model outputs.

For the present study, the Washington State Department of Ecology (Ecology) will collect seasonal water samples (June, September, and December of 2009) at three oceanic boundary sites, in four Puget Sound basins, and at the mouths of the five largest rivers discharging to the Sound. Water samples will be collected above and below the halocline at marine stations, and above tidal influence at river sampling sites. Suspended particulates will be collected during one event from the four Puget Sound basin stations and the five major rivers.

Target analyses will include metals, semivolatile organics, chlorinated pesticides, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs). This information will fill identified data gaps, providing concentration and loading estimates for model input and calibration.

Each technical study conducted by Ecology must have an approved Quality Assurance Project Plan. The plan must describe the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a final report describing the study results will be posted to the Internet.

Background

Puget Sound Toxics Loading Analysis

The State of Washington enacted legislation in 2007 to advance efforts to restore and protect the health of the Puget Sound ecosystem by 2020. Charged with coordinating and overseeing these efforts, the Puget Sound Partnership (Partnership) identified the control and reduction of toxic chemical releases to the Sound as a priority action necessary to ensure recovery of the ecosystem.

To this end, the Washington Department of Ecology (Ecology) is working in collaboration with the Partnership, the U.S. Environmental Protection Agency (EPA), and other local, state, and federal agencies to study toxic chemical loadings to Puget Sound. This multi-year effort, the Puget Sound Toxics Loading Analysis (PSTLA), will quantify the sources of toxic contaminants that enter Puget Sound and improve understanding of how these chemicals move within the ecosystem. The collected information will guide management decisions about how to direct resources to effectively resolve toxic contamination issues.

Initial Phases

In Phase 1 of this effort, existing data were used to obtain quantitative estimates of loadings released to Puget Sound via surface runoff, atmospheric deposition, permitted wastewater discharges, combined sewer overflows, and direct spills (Hart Crowser et al., 2007).

Land use classifications were refined and roadway loadings were incorporated during Phase 2, yielding improved toxic chemical loading estimates for the entire Puget Sound Basin (EnviroVision et al., 2008).

Phase 2 also saw the expansion of numerical modeling efforts to provide insights about the relative importance of the various loading pathways. The Puget Sound Toxics Box Model is composed of three parts (Pelletier and Mohamedali, 2009):

1. Water circulation and transport box model.
2. Contaminant fate and transport mass balance model.
3. Food web transfer bioaccumulation model.

Seeded with the Phase 2 loading estimates, the Puget Sound Toxics Box Model allowed managers to investigate the response of contaminant concentrations in the water, sediment, and biota of Puget Sound under various source-control scenarios. Initial modeling exercises were performed for polychlorinated biphenyls (PCBs) due to the relative abundance of existing PCB data. Polybrominated diphenyl ethers (PBDEs) will be evaluated with the model during Phase 3.

Data Gaps and Recommended Actions

A review of readily available data collected since 1995 on selected toxic chemicals in Puget Sound and the Straits of Juan de Fuca and Georgia (Serdar, 2008) identified significant gaps and limitations in the existing data. With very few exceptions, the available data were inadequate for providing representative concentrations for model input and analyses.

Initial simulations run by the Puget Sound Toxics Box Model agreed, indicating that further data collection would improve the accuracy of model predictions. To address these data gaps, Pelletier and Mohamedali (2009) recommended the following targeted efforts:

- **Water column toxics.** Data on the concentrations of toxic chemicals in the water column throughout Puget Sound are very limited. While typical ambient concentrations are extremely low, the uptake of toxics by biota is sensitive to both the distribution and partitioning of toxics in this reservoir. Toxic chemical concentrations in the major basins of Puget Sound should be measured to facilitate improved calibration of the model.

- **Marine boundary.** Existing data from the marine waters bordering Puget Sound are scarce. The loading from the marine boundary is estimated to be comparable in magnitude to the loadings from each of the major land use types in the Puget Sound watershed, and therefore has the potential to significantly influence the concentrations of toxics in the Sound. Additional data should be collected in the Strait of Juan de Fuca and Haro Strait to improve the accuracy of the fluxes modeled through this boundary.

- **External loads.** While Phases 1 and 2 provided estimates of toxic chemical loadings to Puget Sound, surface runoff loading estimates for various land uses should be improved to reduce uncertainties in the model.

These data are needed to improve calibration of the Puget Sound Toxics Box Model and to reduce uncertainty in model predictions for the examination of toxic chemical fate and transport in Puget Sound.

Project Description

The present study is part of Phase 3 of the collaborative work on toxic chemicals in Puget Sound. The study is motivated by significant data gaps identified during the development of the Puget Sound Toxics Box Model. The study will provide an extensive set of data on toxic chemical concentrations in the water column of the major basins in Puget Sound, in the marine boundary waters of the Straits of Juan de Fuca and Haro Strait, and in the freshwater flows of five major rivers that discharge to the Sound.

Objectives

Objectives of the study are to:

- Quantify concentrations of target toxic chemicals and other water quality parameters above and below the halocline in four Puget Sound basins (Main, Whidbey, South Sound, and Hood Canal South) and in marine boundary waters (Strait of Juan de Fuca and Haro Strait).
- Measure freshwater loadings of target toxic chemicals and other water quality parameters in the five largest tributaries discharging to Puget Sound (Nooksack, Skagit, Stillaguamish, Snohomish, and Puyallup Rivers).
- Determine concentrations of toxic chemicals associated with suspended particulates in marine water and freshwater samples.
- Assess seasonal variability in concentrations and loadings of target toxic chemicals and other water quality parameters.

Parameters

Samples from the marine water column will be analyzed for an extensive suite of parameters, many of which have not historically been monitored in Puget Sound. These data will facilitate extension of the modeling framework to evaluate the fate, transport, and bioaccumulation of chemicals of concern beyond those presently used in model simulations. Target analytes will include PCB and PBDE congeners, chlorinated pesticides, polynuclear aromatic hydrocarbons (PAHs), semivolatile organics, and total and dissolved metals. Analyses will also measure total and dissolved organic carbon (TOC/DOC) and total suspended solids (TSS) to better understand partitioning and fate of the target analytes.

Freshwater (river) samples will be analyzed for the identical suite of analytes, but will incorporate additional analyses of several conventional water quality parameters. These will include water hardness and nutrients (ammonia nitrogen, nitrate and nitrite nitrogen, total persulfate nitrogen, orthophosphate phosphorus, and total phosphorus). Total petroleum hydrocarbons (TPH-gas and TPH-diesel) and hexane-extractable materials (HEM, or “oil and grease”) will also be measured to clarify and improve external loading estimates from surface runoff for oil and petroleum products.

Particulate samples from both marine waters and freshwaters will be analyzed for TOC, metals, semivolatile organics, chlorinated pesticides, and PCB and PBDE congeners.

Sampling Sites and Schedules

Marine water sampling locations will be established at the approximate centroid of each of the four Puget Sound basins of interest to represent ambient mean basin conditions. Water samples will be collected from above and below the halocline at each location. Sampling will not target or address acute localized impacts from contaminated nearshore environments. Boundary conditions for the model will be determined from the average of concentrations measured at two sites in the Strait of Juan de Fuca and one site in the Haro Strait.

Major rivers will be sampled at the first bridge crossing above marine saline influence with a companion gage station operated by the U.S. Geological Survey (USGS) or Ecology.

Water sampling at both marine and freshwater sites will be conducted on three occasions to estimate seasonal concentrations of the target parameters. Sampling will occur in June (after spring flushing), September (after first seasonal flush), and December (wet season), providing loading data for a wide range of discharge.

Suspended particulate samples will be collected from the surface and bottom waters of the four Puget Sound basins, and from the discharges of the five selected rivers. Marine particulate samples will be collected once, during the period of October to December 2009. Collection of particulate samples from the five river sites will also occur once, coinciding with the marine particulate collection.

Outcomes

The information generated by the present study will result in direct contributions to the creation and implementation of pollution-reduction strategies for toxic chemicals entering Puget Sound. Products of this study will include the following:

- **Water column toxics.** Marine water column samples from four Puget Sound basins will (1) yield baseline measurements of a large suite of toxic chemicals, and (2) provide a better understanding of present concentrations and seasonal variation. These data will be used as input and for calibration of the Puget Sound Toxics Box Model.
- **Marine boundary fluxes.** Measurements of toxic chemical concentrations in the Strait of Juan de Fuca and Haro Strait will facilitate estimation of the import and export of contaminants between Puget Sound and the ocean boundary waters. Incoming loadings from the boundary waters to Puget Sound will be estimated using bottom layer concentrations of the target contaminants and flow information generated from the circulation component of the Puget Sound Toxics Box Model. Outgoing loads will be estimated in a similar way using surface layer concentrations and flow information.

- **External loading estimates.** Water samples from the major rivers discharging to Puget Sound will support improved estimates of toxic chemical loadings to the Sound from surface runoff. Study data on contaminant concentrations and flow from the freshwater discharges will be provided electronically to Herrera Environmental Consultants for their use in the development of overall contaminant loading estimates for Puget Sound.
- **Partitioning.** Determinations of dissolved- and particulate-phase concentrations of toxic chemicals in Puget Sound waters, oceanic boundary waters, and major freshwater inputs will improve the accuracy of model predictions of chemical transport and fate.
- **Additional chemicals of concern.** Concentration measurements for an extensive suite of contaminants will allow extension of the Puget Sound Toxics Box Model beyond the initial PCB simulations to additional contaminants of concern. Preliminary exercises will be run to simulate the transport and fate of PCBs and PBDEs in Puget Sound and to estimate the net flux at the oceanic boundary.

Organization and Schedule

The following people are involved in this project. All are employees of the Washington State Department of Ecology.

Table 1. Organization of Project Staff and Responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
James M. Maroncelli Water Quality Program Phone: (360) 407-6588	Client	Clarifies scope of the project, provides internal review of the QAPP, and approves the final QAPP.
Randy Coots Toxics Study Unit, SCS Phone: (360) 407-6690	Project Manager	Writes the QAPP, conducts QA review of data, and analyzes and interprets data.
Tom Gries Toxics Study Unit, SCS Phone: (360) 407-6327	Principal Investigator	Analyzes and interprets data. Writes the draft report and final report.
David Osterberg Toxics Study Unit, SCS Phone: (360) 407-6446	Field Lead	Oversees field sampling and transportation of samples to the laboratory, records field information, and enters data into EIM.
Dale Norton Toxics Study Unit, SCS Phone: (360) 407-6765	Unit Supervisor for Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra SCS Phone: (360) 407-6698	Section Manager for Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Robert F. Cusimano Western Operations Section Phone: (360) 407-6688	Section Manager for Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Stuart Magoon Manchester Environmental Laboratory Phone: (360) 871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP = Environmental Assessment Program.
SCS = Statewide Coordination Section.
QAPP = Quality Assurance Project Plan.
QA = Quality Assurance.
EIM = Environmental Information Management system.

Table 2. Proposed Schedule for Completing Field and Laboratory Work, Data Entry into EIM, and Reports.

Field and laboratory work	Due date	Lead staff
Field work completed	December 2009	David Osterberg
Laboratory analyses completed	February 2010	
Environmental Information System (EIM) database		
EIM user study ID	RCOO0010	
Product	Due date	Lead staff
EIM data loaded	July 2010	David Osterberg
EIM QA	August 2010	Dale Norton
EIM complete	September 2010	David Osterberg
Final report		
Author lead and support staff	Tom Gries	David Osterberg
Schedule		
Draft due to supervisor	May 2010	
Draft due to client/peer reviewer	June 2010	
Draft due to external reviewer(s)	Not applicable	
Final (all reviews done) due to publications coordinator (Joan)	August 2010	
Final report due on web	September 2010	

Quality Objectives

Manchester Environmental Laboratory (MEL) and their contractors are expected to meet quality control requirements of methods selected for the project. Quality control (QC) procedures used during field sampling and laboratory analyses will provide data for determining the accuracy of the monitoring results. Tables 3 and 4 show the measurement quality objectives (MQO) for the methods selected for water and particulate sample analysis.

Analytical precision and bias will be evaluated and controlled by use of laboratory check standards, duplicates, spikes, and blanks analyzed along with study samples.

Precision is a measure of the ability to consistently reproduce results. Precision will be evaluated by analysis of check standards, duplicates/replicates, spikes, and blanks. Results of duplicate (split) analyses will be used to estimate laboratory precision. Overall precision of the entire sampling and analysis process is estimated by analysis of field replicates. Field precision is the difference between laboratory precision estimates and overall precision estimates.

Bias is the systematic error due to contamination, sample preparation, calibration, or the analytical process. Most sources of bias are minimized by adherence to established protocols for the collection, preservation, transportation, storage, and analysis of samples. Check standards (also known as laboratory control standards) contain a known amount of an analyte and indicate bias due to sample preparation or calibration.

Blanks are particularly important quality control samples for low level analyses where results are expected near detection limits. Method blanks will be analyzed along with all samples to measure any response in the analytical system for target analytes. Method blanks have an expected theoretical concentration of zero. Field blanks are used to detect bias from contamination. This may include contamination from containers, sample equipment, environmental surroundings, preservatives, transportation or storage, other samples, or laboratory analysis.

Surrogates will be added to all organic samples prior to extraction. Surrogates have similar characteristics to target compounds. The recovery of surrogate spikes is used to estimate the recovery of target compounds in samples.

The lowest concentrations of interest in Tables 3 and 4 are from reporting limits MEL and their contractors have reported for water and sediment analyses from previous studies.

Table 3. Measurement Quality Objectives for Water Samples.

Parameter	Lab Control Samples (% Recovery)	Duplicate Samples (RPD[5])	Matrix Spike (% Recovery)	Matrix Spike Dups (RPD)	Surrogate Recoveries (% Recovery)	Lowest Concentration of Interest
TSS	80 - 120%	≤20%	NA[6]	NA	NA	1 mg/L
TOC	80 - 120%	≤20%	NA	NA	NA	0.10%
DOC	80 - 120%	≤20%	NA	NA	NA	0.10%
Hardness	80 - 120%	≤20%	75 - 125%	20%	NA	1 mg/L
PO_4^{-3}	80 - 120%	≤20%	80 - 120%	≤20%	NA	3 *u*g/L
TP	80 - 120%	≤20%	80 - 120%	≤20%	NA	5 *u*g/L
$NO_2 + NO_3$	80 - 120%	≤20%	80 - 120%	≤20%	NA	10 *u*g/L
NH_3	80 - 120%	≤20%	80 - 120%	≤20%	NA	10 *u*g/L
TPN	80 - 120%	≤20%	80 - 120%	≤20%	NA	25 *u*g/L
Metals – Marine Water						
Arsenic	85 - 115%[1]	≤20%	80 - 120%	20%	NA	0.05 *u*g/L
Cadmium	85 - 115%[1]	≤20%	75 - 125%	20%	NA	0.01 *u*g/L
Copper	75 - 125%[1]	≤20%	70 - 130%	20%	NA	0.05 *u*g/L
Lead	80 - 120%[1]	≤20%	75 - 125%	20%	NA	0.05 *u*g/L
Zinc	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.25 *u*g/L
Metals – Freshwater						
Arsenic	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.1 *u*g/L
Cadmium	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.1 *u*g/L
Copper	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.4 *u*g/L
Lead	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.1 *u*g/L
Zinc	65 - 135%[1]	≤20%	65 - 135%	20%	NA	0.5 *u*g/L
TPH-diesel	50 - 150%	≤50%	25 - 150%	50%	50 - 150%	0.15 mg/L
TPH-gas	50 - 150%	≤50%	25 - 150%	50%	50 - 150%	0.14 mg/L
HEM (“oil and grease”)	50 - 150%	≤50%	25 - 150%	50%	50 - 150%	5 mg/L
Semivolatiles (BNA)	40 - 150%	≤50%	40 - 150%	40%	10 - 150%[2]	1 - 5 *u*g/L
PAHs	40 - 150%	≤50%	40 - 150%	40%	10 - 150%[2]	0.01 *u*g/L
Chlorinated Pesticides	50 - 150%	≤50%	50 - 150%	40%	30 - 150%[2]	0.07 ng/L
PCB Congeners	50 - 150%	≤50%	NA	NA	25 - 150%[3]	10 pg/L
PBDE Congeners	50 - 150%	≤50%	50 - 150%	40%	25 - 150%[3,4]	10 pg/L

[1] = Blank spike recovery.
[2] = Surrogate recoveries are compound specific.
[3] = Labeled congeners.
[4] = BDE 209 recovery between 20 – 200%.
[5] = Relative percent difference.
[6] = Not applicable.

Table 4. Measurement Quality Objectives for Particulate Samples

Parameter	Lab Control Samples (% Recovery)	Duplicate Samples (RPD[2])	Matrix Spike (% Recovery)	Matrix Spike Dupes (RPD)	Surrogate Recoveries (% Recovery)	Lowest Concentration of Interest
TOC	75 - 125%	≤20%	NA[3]	NA	NA	0.1 *u*g/Kg
Metals[1]	80 - 120%	≤20%	70 - 130%	30%	NA	0.1-5 mg/Kg
Semivolatiles (BNA)	40 - 150%	≤50%	40 - 150%	40%	10 - 150%	1 *u*g/Kg
PAHs	40 - 150%	≤50%	40 - 150%	40%	10 - 150%	1 *u*g/Kg
Chlorinated Pesticides	50 - 150%	≤50%	50 - 150%	40%	50 - 150%	1 *u*g/Kg
PCB Congeners	25 - 150%	≤50%	NA	NA	25 - 150%[4]	0.05 *u*g/Kg
PBDE Congeners	NA	≤50%	NA	NA	25 - 150%[4-5]	0.05 *u*g/Kg

1 = Total recoverable for particulate metals.
2 = Relative percent difference.
3 = Not applicable.
4 = Labeled compounds.
5 = BDE 209 recovery between 20 – 200%.

Sampling Design

This study will generate baseline data for a suite of organic chemicals, metals, and conventionals in the marine and freshwaters of Puget Sound. The data are needed to (1) provide representative concentrations of chemicals of concern in the major basins of Puget Sound, (2) estimate the flux of toxic chemicals at the ocean boundary of Puget Sound, and (3) improve loading estimates from surface runoff to the Sound. An overview of sample collection for the study can be found in Table 5.

Table 5. Summary of Sample Collection at Marine and Freshwater Sites.

Marine Site	Water[1]		Particulates[2]	
	Below Halocline	Above Halocline	Below Halocline	Above Halocline
Hood Canal South	3	3	1	1
Puget Sound Main Basin	3	3	1	1
Whidbey Basin	3	3	1	1
South Sound Basin	3	3	1	1
Haro Strait	3	3	NA[3]	NA
Strait of Juan de Fuca North	3	3	NA	NA
Strait of Juan de Fuca at Sill	3	3	NA	NA
Total =	42		8	

Freshwater Site	Water[1]	Particulates[2]
Nooksack River	3	1
Skagit River	3	1
Stillaguamish River	3	1
Snohomish River	3	1
Puyallup River	3	1
Total =	15	5

[1] Samples collected June, September, and December.
[2] Samples collected from October to December only.
[3] Not applicable.

Marine Sampling

Marine water samples will be collected from above and below the halocline at seven locations throughout Puget Sound and its ocean boundary waters. The latitudes and longitudes of the marine sampling sites are listed in Appendix A (Table A1) and shown on Figure 1.

Marine sampling sites were selected to correspond to basin cells in the Puget Sound Toxics Box Model. Four basins were selected based on geographic distribution across Puget Sound, with priority given to basins having greater size and depth. The sampling site in each of the selected basins represents the deepest location in the approximate centroid of the corresponding model basin cell.

For the purposes of the model, the sills at Admiralty Inlet and Deception Pass were defined as the boundary for Puget Sound. Two sampling sites in the Strait of Juan de Fuca and one in Haro Strait represent the ocean boundary waters of Puget Sound. These sites in the Straits coincide with monitoring station locations established by the Joint Effort to Monitor the Strait of Juan de Fuca (JEMS).

Contaminant movements between Puget Sound basins and fluxes between ocean boundary waters and Puget Sound will be simulated using the water circulation and transport component of the Puget Sound Toxics Box Model (Babson et al., 2006; Pelletier and Mohamedali, 2009). Incoming loads at the ocean boundary will be estimated using bottom layer concentrations of target chemicals, while contaminant exports from the Sound at the ocean boundary will be similarly estimated using surface layer concentrations.

Suspended particulates will be collected by moored sediment traps in the four selected Puget Sound basins. Traps will be moored above and below the halocline, and located as near as possible to water sampling sites where water depth does not exceed 50 meters. Bottom traps will be at least 10 meters above the sediment to avoid collection of re-suspended material, and surface traps will be roughly 10 meters below the surface. Sediment traps have been used successfully in other Ecology studies measuring contaminants associated with particulates in marine waters (Norton, 2001, 1996, and 1995).

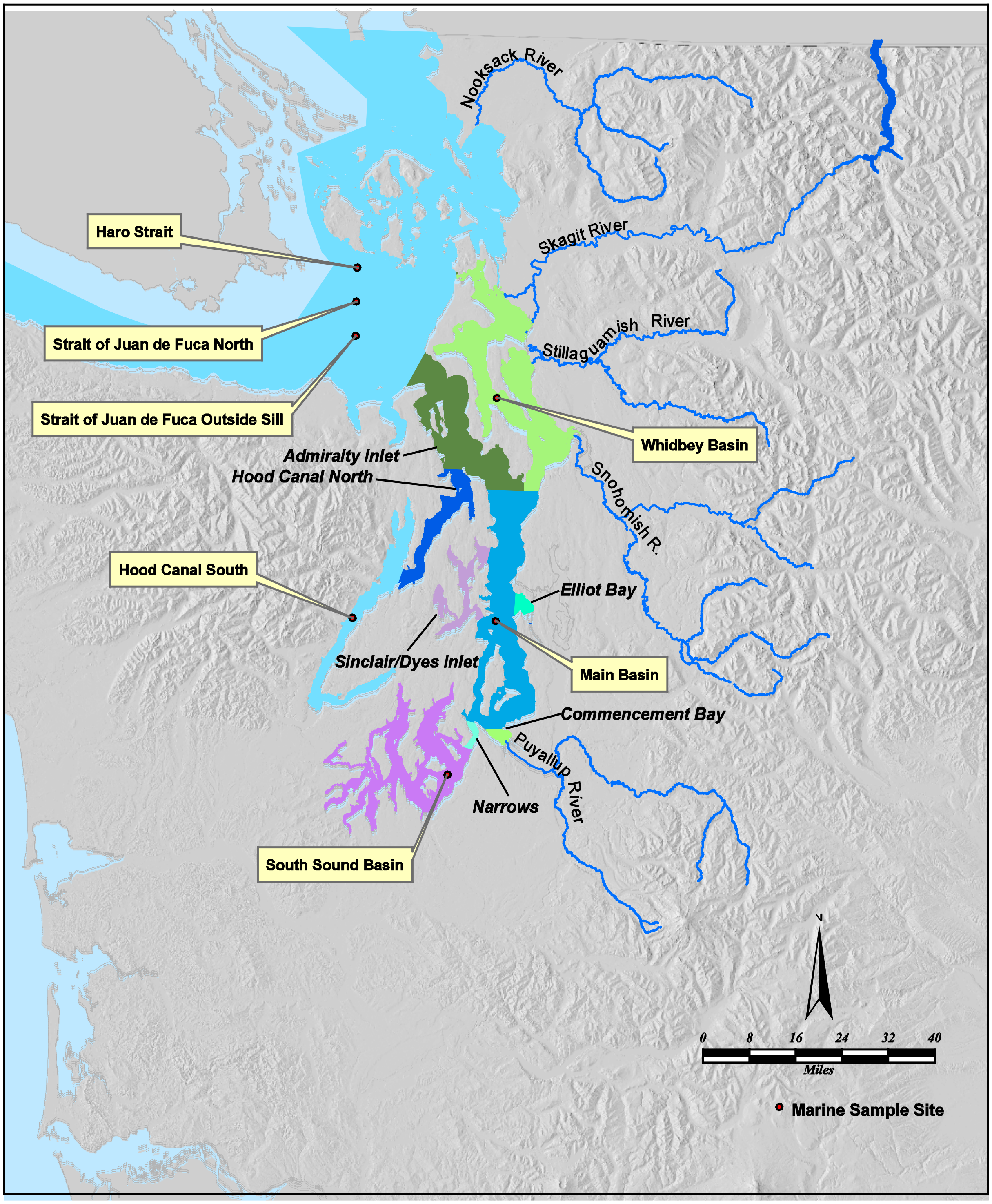

Figure 1. The Seven Marine Water Sampling Sites, Including the Four Puget Sound Toxics Box Model Basins.

Freshwater Sampling

Freshwater samples will be collected from the five largest freshwater discharges to Puget Sound (based on mean daily flow): the Nooksack, Skagit, Stillaguamish, Snohomish, and Puyallup Rivers. River sampling sites will be located at bridges over the lowest point in each drainage that allows sample collection above marine influence, co-located as close to permanent long-term flow stations as possible. River sampling sites, gaging stations, discharge, and drainage area information are described in Appendix A (Tables A2 and A3), and shown on Figure 2.

Freshwater samples will be depth-integrated composites collected at quarter points across the rivers. Individual grab samples will also be collected at quarter points along the river cross-section for HEM, TPH-gas, and TPH-diesel.

Discharge data for the time of sampling will be obtained from continuous long-term gaging stations operated by the USGS or Ecology. Loading rates will be calculated from instantaneous sample concentrations and flow. Annual loads will also be calculated using the mean sample concentrations and harmonic mean flows.

Collection of freshwater particulates will be from the same location as whole water samples. Representative samples of suspended particulates will be collected by pumping large volumes of water through continuous flow-through centrifuges. The time required to collect enough particulates to measure all target analytes will be based on TSS concentrations in the water column. Other toxic studies recently performed by Ecology have successfully used centrifuges to collect particulates (Serdar, 1997a, 1997b; Gries and Sloan, 2008).

Special Considerations for the Snohomish River

The Snohomish River begins at the confluence of the Skykomish and Snoqualmie Rivers. Most of the 20.5 river miles of the Snohomish River are tidally influenced. Water samples will be collected on the ebb tide from the Ecology long-term water quality monitoring station (Snohomish @ Airport Way) at river mile 12.7 in the city of Snohomish (Figure 2).

The only active gaging station on the Snohomish River is a USGS station located 0.1 miles downstream of the Skykomish-Snoqualmie confluence at river mile 20.4. Between the gaging station and the water sampling site, the Pilchuck River discharges to the Snohomish River at river mile 13.4, less than a mile upstream of the sampling location. The Pilchuck River has an active USGS gaging station. Therefore, flows for the Snohomish and Pilchuck Rivers will be combined for a total Snohomish River discharge at the sampling site.

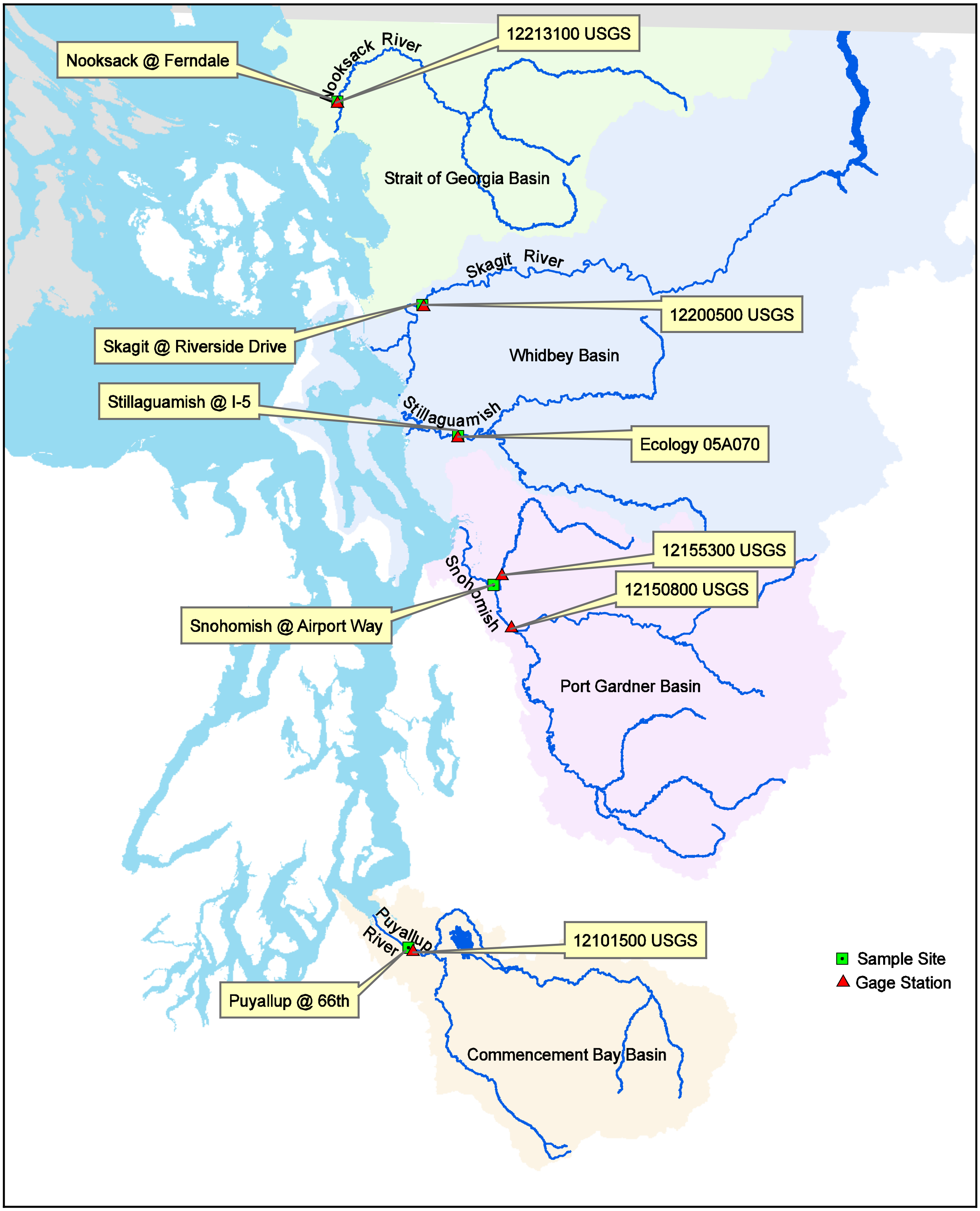

Figure 2. The Five Freshwater (River) Sampling Sites, Six Gage Locations, and Four Toxics Box Model Drainage Basins.

Sampling Schedule

Water samples will be collected at each of the seven marine and five freshwater sites on three occasions: once per month in June, September, and December of 2009. Sampling periods were selected to represent seasonal levels of contaminants over a wide range of discharge conditions. The timing of sample collection was chosen to represent contaminant concentrations following spring runoff (June), after the first flush event following the summer dry period (September), and during the wet weather of winter (December). Major river sampling will be conducted the week following the marine sampling events.

Sediment traps for collecting marine particulates will be moored in the four Puget Sound basin stations once, for a period of three months, beginning in October and ending in December 2009. Centrifugation for freshwater particulates in the major rivers will coincide with the deployment period for the sediment traps. Collection of river particulates will continue until particulate mass equals at least the minimum required for the targeted analyses. Therefore, the duration of collection will be determined by the TSS concentration in the rivers at the time of sampling.

Sampling Procedures

Marine Sampling

Water Column

The Ecology research vessel (R.V.) *Skookum* will be used as the sampling platform for the seven marine stations. The R.V. *Skookum* is a 26-foot aluminum hulled boat manufactured by Almar, equipped with hydraulic boom and winch. Boats can be a significant source of contamination when sampling for trace analytes. The hull of the R.V. *Skookum* has no antifouling coat, but has sacrificial zinc plates attached to the stern for prevention of electrolysis. Care will be taken to position the vessel down-current during sample collection. All sampling activities will be conducted on the windward side to minimize contamination from shipboard sources.

Sampling sites will be located by Global Positioning System (GPS) on board the R.V. *Skookum* and recorded in field logs. Water column samples will be collected from above and below the halocline. Historical salinity profiles will be reviewed from Ecology's Marine Ambient Monitoring Section database (www.ecy.wa.gov/apps/eap/marinewq/mwdataset.asp) at locations as close as possible to proposed sampling stations to estimate target depth requirements. A Conductivity/Temperature/Depth profiler (CTD; SBE25, Sea-Bird Electronics, Inc.) will be deployed on arrival to obtain a real-time salinity profile and confirm target depths. Collection of samples from below the halocline will precede above-halocline sampling at all locations. Sample collection depths will be recorded in field logs.

Water column samples will be collected with a pair of 10-liter, Teflon-coated GO-FLO discrete samplers (General Oceanics, Inc.). GO-FLO samplers have a *close-open-close* operation to avoid potential contamination from the microlayer at the water surface. Mounted back-to-back on a Kevlar or a like substitute rope, the samplers will be deployed in a closed position, open automatically by hydrostatic pressure release at a depth of ten meters, flush to sample depth, and close when triggered by Teflon-coated messenger. Detailed operating procedures for GO-FLO samplers are documented in Appendix D.

Immediately after retrieval of the GO-FLO samplers, they will be secured in a purpose-built storage cabinet for sample decanting. The salinity of the water in each sampler will be measured to evaluate the integrity of sampler closure. Unfiltered decanting will be conducted inside a portable glove box and will proceed in the following order: TSS, PCB and PBDE congeners, chlorinated pesticides, semivolatile organics, PAHs, and total recoverable metals. Filtration for dissolved metals will occur after all whole-water samples have been collected from the GO-FLO samplers. Filtration will employ a peristaltic pump and in-line filter following EPA Method 1669 (EPA, 1996). With the exception of a short length of MasterFlex-73 tubing in the pump head, all tubing will be Teflon. Filters will be Pall Corp., GWV high capacity capsules, 0.45-micron, or equivalent.

Table B1 in Appendix B lists the sample size, container, preservation, and holding times for each of the marine water column samples collected for the project. Approximately 16 liters of water is needed from each depth for marine samples, bottle rinses, and equipment flushes . The simultaneous deployment of two GO-FLO samplers will collect 20 liters of sample water, allowing a single cast for each sampling depth.

Following the collection of water samples from below and above the halocline, a CTD mounted on a compact rosette frame will be deployed at each station to obtain profiles of temperature, salinity, and dissolved oxygen. Field procedures for CTD operation are detailed in Appendix E. Data are recorded at eight measurements per second as the unit is lowered through the water column. The CTD and all auxiliary sensors will undergo an initial calibration prior to the first sampling event in June, and calibration samples will be collected periodically to verify continued accuracy throughout the year.

Four 1.5-liter Niskin bottles mounted on the rosette frame will collect additional water samples during the retrieval (upcast) of CTD deployments. The unit will be pre-programmed to trigger the closure of two Niskin bottles above and two Niskin bottles below the halocline corresponding to the depths of GO-FLO sampler collections. Salinity will be measured from each bottle to confirm collection depth and bottle closure. Water samples for TOC will be decanted, and samples for DOC will be filtered (following Stutes and Bos, 2007) from these Niskin bottle collections.

Particulates

Suspended marine particulates will be collected with the use of moored sediment traps. The traps consist of a straight-sided glass collection cylinder with an area of 78.5 cm^2 and a height-to-width ratio of 5. A schematic of the construction details of the traps and their moorings is presented in Figure 3. Further discussion can be found in Norton (2001 and 1996).

The four sediment trap sites in Puget Sound will be located by GPS on-board the R.V. *Skookum* and recorded in field logs. The traps will be positioned to collect particulates from above and below the halocline. Bottom traps will be moored at least 10 meters above the bottom to avoid collection of re-suspended materials. Near-surface sediment traps will use the same mooring as bottom traps, suspended by hard shell float and positioned roughly 10 meters below the surface. To meet minimum particulate mass requirements for the proposed analyses, at least two sediment traps will be deployed both above and below the halocline at each station.

Traps will be moored for a period of three months, with deployment in October and retrieval in December. If problems arise in deployment or retrieval of sediment traps, pumping and centrifugation may be conducted as an alternative collection method, generally following procedures detailed in Appendix F.

The R.V. *Skookum* will be used as the work platform for deployment and retrieval of sediment traps. At deployment, collection cylinders will be filled with two liters of high salinity water (4% NaCl) and sodium azide (2% Na_3N) as a preservative to reduce microbial degradation of the samples. Following retrieval of sediment traps, overlying water will be removed by peristaltic pump. The remaining sample will be placed in I-Chem sample jars supplied by MEL.

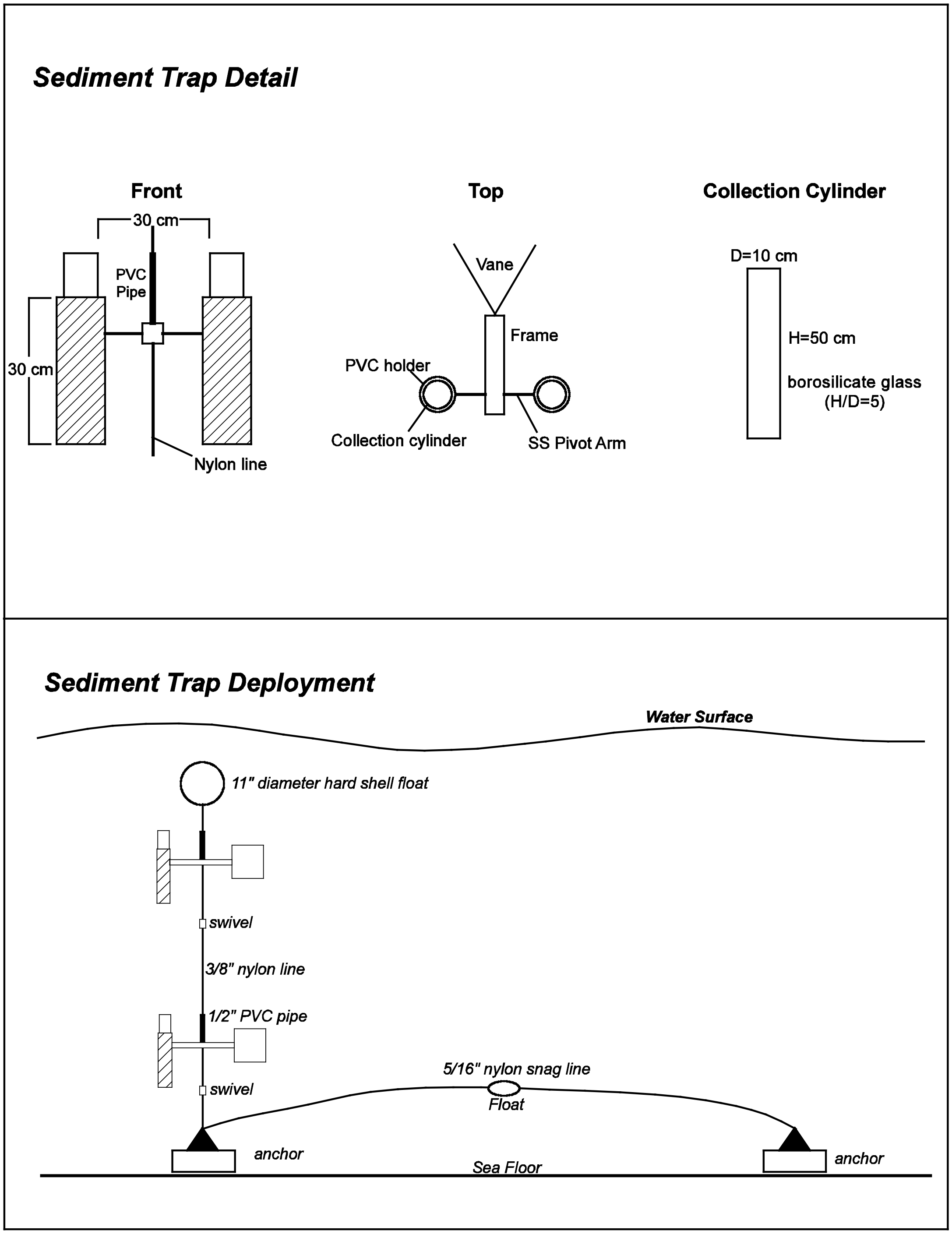

Figure 3. Schematic of Sediment Traps and Moorings.

Laboratories use dry weight sample minimums for solids to assure the lowest possible detection limits. Dry weights from wet samples are difficult to estimate, so sediment trap particulates will be centrifuged in the Ecology Headquarters laboratory before apportioning aliquots for individual analyses. If centrifuged samples are able to reach 90% solids, a minimum of 170 grams of sample from each site will be needed to complete required analyses. Following centrifugation of the sample, the particulates will be homogenized in a clean environment before aliquots are removed for TOC, metals, semivolatile organics, PAHs, chlorinated pesticides, and PCB and PBDE congener analyses. Table B2 in Appendix B lists the sample size, container, preservation, and holding times for each marine particulate sample collected during the project.

Freshwater Sampling

Water Column

Freshwater (river) sampling for most of the target parameters will be performed manually from bridges using a US DH-95 isokinetic, depth-integrating sampler (FISP, 2000). The DH-95 sampler consists of a plastic tail section and a plastic-coated bronze body into which a rigid 1-L Teflon bottle, cap, and nozzle are fitted. The nozzle points into the flow when submerged, minimizing the potential for contamination by avoiding contact of the sampled water with the sampler components. Water and suspended particulates flow through the nozzle into the collection bottle while air exhausts out a vent in the cap.

Sampling procedures for the DH-95 will be conducted according to USGS (2005) to the extent possible. A preliminary sounding will be made by lead weight to determine depth at each sampling point. During deployment, the DH-95 sampler will be lowered through the water column at a fixed rate until located within a meter above the streambed, where the sampler will then immediately reverse in direction and be raised at an equal rate. Each deployment (called a “vertical,” consisting of the complete downward and upward transit of the sampler) will be conducted at a rate that allows collection of 800 to 1000 mL of sample without overfilling the bottle. Transit rate will be dictated by the nozzle opening diameter, the river velocity, and river depth at each deployment following USGS (2005) and FISP (2000).

Verticals will be conducted at quarter points along the river cross-section. Finished samples will be manual composites of these quarter point collections (i.e., water from each quarter point will contribute one-third of the volume for analysis to the sample container). The total volume required for the target analyses is approximately 17 liters; therefore, a minimum of 6 liters will be collected at each quarter point. Table B3 in Appendix B lists the sample size, container, preservation, and holding times for each of the freshwater samples collected for the project.

Direct decanting from the sampler bottle into finished sample containers will be conducted on-site for TSS, TOC, hardness, and nutrients. Filtration of composite samples for DOC and orthophosphate will also be carried out in the field. Compositing and filtration activities for total and dissolved metals samples will be conducted within a portable glove box and will generally follow Ward (2007) and EPA (1996).

To minimize exposure to dust and particulates from the road and bridge, compositing for the most sensitive target analytes will not be conducted in the field. These analytes include semivolatile organics, PAHs, chlorinated pesticides, and PCB and PBDE congeners. Approximately 3.75 liters collected at a single quarter point will be combined in a one-gallon glass container and placed in a cooler on ice. Composite samples consisting of equal volume contributions from the quarter points for the above-mentioned analytes will then be decanted in a clean lab environment.

The only parameters that will not involve depth-integrated collection at quarter points will be TPH (both -gas and -diesel) and HEM. Sampling for these parameters will involve collection of grab samples at quarter points along the cross-section. Grabs will be collected from a depth of approximately 0.5 meters, and sampling will follow conventional practices except sample bottles will not be pre-rinsed.

Particulates

Suspended particulates will be collected by flow-through centrifuge at the river sampling sites. A detailed description of field operating procedures is documented in Appendix F. These procedures follow Gries and Sloan (2008) to the extent possible.

A pump (Model SP4, Gundfos Inc.) will be used to draw water from the location determined to be the average suspended sediment load at the site. The intake line for the pump will initially be positioned in the thalweg of the stream at 6/10 of depth. Positioning of the intake may be adjusted based on field observations and periodic measurements of water depth, velocity, and specific conductivity throughout the sampling event.

Two flow-through centrifuges (Alfa-Laval Corporate AB, MAB 103B) will receive the pumped water and remove the sediment. Removal efficiency of suspended particulates is expected to be >90%. The amount of collected sample will be monitored and removed as needed to maintain maximum retention efficiency.

River water will be centrifuged continually until the minimum amount of particulate is collected to allow analysis of all target parameters. Assuming a centrifuged sample is 90% solids, a minimum of at least 170 grams of sample from each site will be needed to complete the required analyses. The length of time centrifuges must run to collect this amount of particulate will depend on the concentration of TSS in the water column. During high or storm flows, TSS in rivers may be 50 mg/L or greater, while in low-flow periods TSS may be less than 3 mg/L. For a centrifuge operating at 360 liters/hour and 100% efficiency of particle retention, the range of time needed for collection of at least 170 grams of particulate sample at each site would be 9.4 to 157 hours for high (50 mg/L) and low (3 mg/L) TSS conditions, respectively.

When sample collection is concluded, particulates will be placed in the appropriate sample container and immediately placed in a cooler on ice. Once back from the field the particulate sample will be homogenized in a clean environment before aliquots are removed for TOC, metals, semivolatile organics, PAHs, chlorinated pesticides, and PCB and PBDE congener analyses. Table B4 lists the sample size, container, preservation, and holding times for each freshwater particulate sample collected for the project.

Measurement Procedures

The analytical parameters, sample numbers, methods, and reporting limits to be used for the study are presented in the Appendix C, Tables C1 through C3, for marine, river, and particulate samples. Method selection was based on the lowest detection limits available for the matrices. A complete analyte list for semivolatile organics, PAHs, and chlorinated pesticides can be found in Appendix C.

All sample containers will be obtained from MEL or the contract laboratories conducting the analysis and cleaned to analyte-specific standards. Chain-of-custody procedures will be followed throughout the sampling and analysis process.

All project samples will be analyzed at MEL or a laboratory contracted by MEL. Laboratories may use other appropriate methods as needed following consultation with the project manager.

Laboratories contracted by MEL must be on the Ecology list of accredited laboratories (www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html). Additionally, when available, laboratories conducting analysis for Ecology studies must be on the General Administration master contract.

Marine samples collected for metals analysis will be analyzed by Frontier GeoSciences, in Seattle, Washington. Marine and freshwater analyses of PBDE congeners will be contracted to the Pacific Rim Laboratory, in Surrey, British Columbia. Marine and freshwater analyses of PCB congeners will be contracted to Analytical Perspectives, in North Carolina.

The analytical cost for the project is estimated to be $294,208 (Table 6). The estimate includes a 50% cost discount for analysis conducted at MEL. Also included is a 25% surcharge for MEL's contracting services and data quality review for results from contract laboratories. The cost estimate assumes analysis of water samples collected on three occasions at seven marine sites (samples from two depths at each site) and at the five major rivers. Particulates will be collected once from the four Puget Sound stations (samples from two depths at each site) and from the five major rivers.

Table 6. Cost of Water and Particulate Sample Analyses (includes contract services).

Parameter	Number of Samples	Number of QA Samples	Sample Total Per Event	Cost Per Sample	Subtotal
Water					
TSS	19	3	22	11	242
TOC	19	4	23	33	759
DOC	19	4	23	35	805
Hardness	5	1	6	22	132
Nutrients (5)	5	1	6	78	468
Metals (Total and Dissolved) Marine Water:					
As, Cd, Cu, Pb, Zn	28	5	33	300	9900
Metals (Total and Dissolved) Freshwater:					
As, Cd, Cu, Pb, Zn	10	5	15	107	1605
TPH-diesel	15	1	16	104	1664
TPH-gas	15	1	16	75	1200
HEM (“oil and grease”)	15	2	17	55	935
Semivolatiles (BNA)	19	4	23	265	6095
PAHs	19	4	23	315	7245
Chlorinated Pesticides	19	4	23	250	5750
PCB Congeners	19	4	23	1250	28750
PBDE Congeners	19	4	23	750	17250
Cost per 1 event					$82,800
Cost per 3 events					$248,400
Particulates					
Percent Solids	13	2	15	11	165
TOC	13	2	15	42	630
Metals Total Recoverable:					
As, Cd, Cu, Pb, Zn	13	2	15	114	1710
Semivolatiles (BNA)	13	3	16	275	4400
PAHs	13	3	16	315	5040
Chlorinated Pesticides	13	3	16	250	4000
PCB Congeners	13	1	14	1250	17500
PBDE Congeners	13	1	14	750	10500
Cost per 1 event					$43,945

Other Materials	Number of Samples	Cost Per Sample	Subtotal Per Event	Number of Events	Subtotal
Metals Filters	8	27	216	3	648
Metals Bottles and Acid	15	27	405	3	1215
Subtotal Other Materials					$1,863
Subtotal Water Samples (3 Events)					$248,400
Subtotal Particulates (1 Event)					$43,945
Grand Total					$294,208

Quality Control Procedures

Field

Table 7 shows a list of the field quality control (QC) samples and types to be analyzed for the project. Field QC samples provide an estimate of the total variability of the results, field plus laboratory. Field QC will consist of collection and analysis of replicate samples and blanks. Replicate water samples will be two samples collected one after the other as close to the same time and location as possible. Equipment blanks will consist of reagent grade water prepared by MEL or their contractor passed through the sample equipment, placed in a sample container, and returned as other samples to the laboratory for analysis.

Table 7. Field Quality Control Samples for Water[1].

Analysis	Replicates[2]	Transfer Blanks	Filter Blanks
TSS	2/event[3]	--	--
TOC	1/event	--	--
DOC	1/event	--	--
Hardness	1/event	--	--
Nutrients	1/event	--	--
Marine Metals	1/event	1/event	1/event
Freshwater Metals	1/event	1/event	1/event
TPH-diesel	1/event	--	--
TPH-gas	1/event	--	--
HEM (“oil and grease”)	1/event	--	--
Semivolatiles (BNA)	1/event	1/event	--
PAHs	1/event	1/event	--
Chlorinated Pesticides	1/event	1/event	--
PCB Congeners	1/event	1/event	--
PBDE Congeners	1/event	1/event	--

[1] Includes marine and river samples.
[2] Independent sample collected at the same location.
[3] Sample collection events in June, September, and December.

All efforts will be made to avoid cross-contamination. Field staff will wear non-talc Nitrile gloves throughout the sample collection process. Immediately following collection, samples will be stored in iced coolers, until delivered to MEL.

To minimize field variability from sample collection, field samplers will be familiar with and follow methods for the collection and processing of water and particulate samples. Operating procedures are described in Appendix D for GO-FLO discrete water samplers, Appendix E for CTD deployment, and Appendix F for centrifuge operation for collection of particulates.

Additional guidance can be found in the Ecology SOPs *Manually Obtaining Surface Water Samples* (Joy, 2006) and *Collection and Field Processing of Metals Samples* (Ward, 2007), as well as PSEP (1997a and 1997b).

Any equipment used in collection or processing samples will be decontaminated prior to going to the field by washing thoroughly with hot tap water and Liquinox detergent, followed by sequential rinses of 10% nitric acid, de-ionized water, pesticide grade acetone, and finally, pesticide-grade hexane. After decontamination, sampling equipment will be air dried under a fume hood, covered with aluminum foil, and placed in a new plastic zip-lock bag until used.

Field QC for particulates will be split samples of remaining materials. Sediment trap particulates will require centrifugation back at the laboratory to concentrate solids. Until samples are processed, the total mass of particulates will be unknown. Target analytes for the study will be a higher priority for analysis than QC samples. If the particulate mass is not collected in sufficient quantity to submit QC samples for all parameters, a determination will be made at that time through consultation with the MEL as to prioritizing analyses for remaining particulates.

Laboratory

MEL routinely runs laboratory control samples for TSS, TOC, and DOC which will be satisfactory for the purposes of this project. MEL will follow standard operating procedures as described in the *Quality Assurance Manual for the Washington State Department of Ecology Manchester Environmental Laboratory* (MEL, 2006). Laboratory QC samples to be analyzed for this project are presented in Table 8.

Table 8. Laboratory Quality Control Samples for Water and Particulates.

Analysis	Method Blank	Check Standard	Duplicates	Surrogate Spikes	Labeled Compounds	MS/MSD[1]	OPR[3] Standards
Water							
TSS	1/batch	1/batch	1/batch	--	--	--	--
TOC	1/batch	1/batch	1/batch	--	--	1/batch	--
DOC	1/batch	1/batch	1/batch	--	--	1/batch	--
Hardness	1/batch	1/batch	--	--	--	--	--
Nutrients	1/batch	1/batch	--	--	--	--	--
Marine Metals	2/batch	1/batch	--	--	--	1/batch	--
Freshwater Metals	1/batch	1/batch	--	--	--	1/batch	--
TPH-diesel	1/batch	1/batch	--	--	--	--	--
TPH-gas	1/batch	1/batch	--	--	--	--	--
HEM (“oil and grease”)	1/batch	1/batch	--	--	--	--	--
Semivolatiles (BNA)	1/batch	1/batch	--	all samples	--	1/batch	--
PAHs	1/batch	1/batch	--	all samples	--	1/batch	--
Chlorinated Pesticides	2/batch	1/batch	--	all samples	--	1/batch	--
PCB Congeners	1/batch	1/batch	1/batch	--	all samples	--	each batch
PBDE Congeners	1/batch	1/batch	1/batch	--	all samples	--	each batch
Particulates							
Percent Solids	1/batch	1/batch	--	--	--	--	--
TOC	1/batch	1/batch	--	--	--	--	--
Metals[2]	1/batch	1/batch	--	--	--	1/batch	--
Semivolatiles (BNA)	1/batch	1/batch	--	all samples	--	1/batch	--
PAHs	1/batch	1/batch	--	all samples	--	1/batch	--
Chlorinated Pesticides	1/batch	1/batch	--	all samples	--	1/batch	--
PCB Congeners	1/batch	1/batch	--	--	all samples	--	each batch
PBDE Congeners	1/batch	1/batch	--	--	all samples	--	each batch

[1] = Matrix spike/matrix spike duplicate.
[2] = Total recoverable for particulate metals.
[3] = Ongoing precision and recovery.

Data Management Procedures

All field data and observations will be recorded in notebooks on waterproof paper. The information contained in field notebooks will be transferred to Excel spreadsheets after return from the field. Data entries will be independently verified for accuracy by another member of the project team.

Case narratives included in the data package from MEL will discuss any problems encountered with the analyses, corrective action taken, changes to the requested analytical method, and a glossary for data qualifiers. Laboratory QC results will also be included in the data package. This will include results for surrogate recoveries, laboratory duplicates, matrix spikes, and laboratory blanks. The information will be used to evaluate data quality, determine if the MQOs were met, and act as acceptance criteria for project data.

Field and laboratory data for the project will be entered into Ecology's EIM system. Laboratory data will be downloaded directly into EIM from MEL's data management system. Data from contract laboratories will be submitted in electronic format for inclusion into the EIM system.

Audits and Reports

MEL participates in performance and system audits of their routine procedures. Results of these audits are available upon request.

A draft report of the study findings will be completed by the principal investigator in June 2010 and a final report in September 2010. The report will include, at a minimum, the following:

- Map showing all sampling locations and any other pertinent features of the study area.
- Coordinates of each sampling site.
- Description of field and laboratory methods.
- Discussion of data quality and the significance of any problems encountered.
- Summary tables of the chemical and physical data.
- Results of the toxic contaminants related to available standards.
- Discussion of seasonal data on concentrations of toxic chemicals in marine waters and the freshwater inputs.
- Discussion of concentrations and fluxes of toxic chemicals associated with suspended particulate matter in both marine and freshwaters.
- Presentation of incoming (bottom layer) concentrations and estimated contaminant loads from ocean water to the Puget Sound, as well as outgoing (surface layer) concentrations and estimated loads for contaminant fluxes between Puget Sound and the ocean boundary.
- Discussion of toxic chemical loadings to Puget Sound from the major tributaries sampled.
- Comparison of Phase 2 loading estimates for PCBs from the Puget Sound Toxics Box Model with updated simulations generated using concentration data from the present study.
- Complete set of chemical and physical data and MEL quality assurance review in the Appendix.

Study data on contaminant concentrations and flow from the freshwater discharges will be provided electronically to Herrera Environmental Consultants for their use in development of an overall loading analysis for Puget Sound.

Upon study completion, all project data will be entered into Ecology's EIM system. Public access to electronic data and the final report for the study will be available through Ecology's Internet homepage (www.ecy.wa.gov).

Data Verification

Data verification is a process conducted by those producing data. Verification of laboratory data is normally performed by a MEL unit supervisor or an analyst experienced with the method. It involves a detailed examination of the data package using professional judgment to determine whether the measurement quality objectives (MQOs) have been met.

Final acceptance of the project data is the responsibility of the principal investigator. The complete data package, along with MEL's written report, will be assessed for completeness and reasonableness. Based on these assessments, the data will either be accepted, accepted with qualifications, or rejected and re-analysis considered.

Data verification involves examining the data for errors, omissions, and compliance with quality control (QC) acceptance criteria. MEL's SOPs for data reduction, review, and reporting will meet the needs of the project. Data packages, including QC results for analyses conducted by MEL, will be assessed by laboratory staff using the EPA Functional Guidelines for Organic Data Review.

MEL staff will provide a written report of their data review which will include a discussion of whether (1) MQOs were met, (2) proper analytical methods and protocols were followed, (3) calibrations and controls were within limits, and (4) data were consistent, correct, and complete, without errors or omissions.

Data Quality (Usability) Assessment

After the project data have been reviewed and verified, the principal investigator will determine if the data are of sufficient quality to serve as Puget Sound and major tributary baseline data for water column toxic contaminants. The data from the laboratory's QC procedures, as well as results from field replicates, laboratory duplicates, and surrogate recoveries, will provide information to determine if MQOs have been met. A review of sample results will be performed following each seasonal sampling event to assess the need for modifications to the sampling or analysis program. Laboratory and quality assurance staff familiar with assessment of data quality may be consulted. The project final report will discuss data quality and whether the project objectives were met. If limitations in the data are identified, they will be noted.

Some analytes will be reported near the detection capability of the selected methods. MQOs may be difficult to achieve for these results. MEL's SOP for data qualification and best professional judgment will be used in the final determination of whether to accept, reject, or accept the results with qualification. The assessment will be based on a review of field replicates, along with laboratory QC results. This will include assessment of laboratory precision, contamination (blanks), accuracy, matrix interferences, and the success of laboratory QC samples meeting control limits.

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Appendices

Appendix A. Station Location Information

Table A1. Sampling stations and coordinates for the marine water column.

Waterbody	Latitude	Longitude
Hood Canal South	47.55887	-123.00475
Puget Sound Main Basin	47.56157	-122.47593
Whidbey Basin	48.10833	-122.48999
South Sound Basin	47.18471	-122.63777
Haro Strait	48.41667	-123.02500
Strait of Juan de Fuca North	48.33333	-123.02500
Strait of Juan de Fuca at Sill	48.25000	-123.02500

Datum is NAD 83 HARN.

Table A2. Sampling stations and coordinates for the major rivers.

River	Latitude	Longitude
Nooksack	48.81898	-122.58010
Skagit	48.44500	-122.33510
Stillaguamish	48.19710	-122.21057
Snohomish	48.91074	-122.09852
Puyallup	48.20268	-122.29372

Datum is NAD 83 HARN.

Table A3. Flow station ID, river mile, discharge rate, drainage area, and latitude/longitude for the major rivers.

River	Gage ID	River Mile	Mean Daily Discharge[1]	Drainage Area (mi^2)	Latitude[2]	Longitude
Nooksack	12213100[3]	3.4	3,833	786	48.8190	-122.5800
Skagit	12200500[3]	15.9	16,580	3,093	48.4451	-122.3352
Stillaguamish	05A070[4]	11.1	4,696	557	48.1966	-122.2083
Snohomish	12150800[3]	20.4	9,514	1,714	47.8305	-122.0484
Pilchuck	12155300[3]	13.4	468	127	47.9349	-122.0737
Puyallup	12101500[3]	8.3	3,319	948	47.2026	-122.2937

[1] = Annual mean daily discharge in ft^3/second.
[2] = Datum is NAD83 HARN.
[3] = USGS gaging station.
[4] = Ecology flow and water quality site.

Appendix B. Sample Containers, Preservation, and Holding Times for Water and Particulate Samples

Table B1. Sample containers, requested volumes, preservation, and holding times for marine water column samples.

Parameter	Bottle Type and Volume	Sample Volume Requested	Preservative	Holding Time
TSS	1 L Poly	1 L	Cool to $\leq 6^o$ C	7 Days
TOC	60 mL Glass	60 mL	1:1 HCl to pH<2; Cool to $\leq 6^o$ C	28 Days
DOC	60 mL Glass	60 mL	Filter in field w/ 0.45 *u*m filter 1:1 HCl to pH<2; Cool to $\leq 6^o$ C	28 Days
Total Metals	500 mL HDPE	350 mL	HNO_3 to pH <2	6 Months
Dissolved Metals	500 mL HDPE	350 mL	Filter in field w/ 0.45 *u*m filter; add HNO_3 to pH ≤ 2; Cool to $\leq 6^o$ C	6 Months
Semivolatiles (BNA)	1 L Amber Glass	3 L	Cool to $\leq 6^o$ C	7 Days
PAHs	1 L Amber Glass	3 L	Cool to $\leq 6^o$ C	7 Days
Chlorinated Pesticides	1 Gallon Glass	3 L	Cool to $\leq 6^o$ C	7 Days
PCB Congeners	1 L Amber Glass	2 L	Cool to $\leq 6^o$ C	1 Year
PBDE Congeners	1 L Amber Glass	1 L	Cool to $\leq 6^o$ C	1 Year
Total 13.8 L				

Table B2. Sample containers, requested volumes, preservation, and holding times for marine particulate samples.

Parameter	Bottle Type and Volume	Sample Mass Requested (Wet Weight)	Preservative	Holding time
Percent Solids	2 oz Glass	50 Grams[1]	Cool to $\leq 6^{o}$ C	7 Days
TOC			Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	14 Days; 6 months frozen
Metals Total Recoverable			Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	6 months
Semivolatiles (BNA)	8 oz Glass	250 Grams[2]	Cool to $\leq 6^{o}$ C	14 Days; 1 year frozen
PAHs				
Chlorinated Pesticides		250 Grams	Cool to $\leq 6^{o}$ C	14 Days; 1 year frozen
PCB Congeners		50 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	1 year
PBDE Congeners		50 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	1 year
Total 650 Grams				

[1] = Percent solids, TOC, and metals will be collected into one sample container.
[2] = Semivolatile organics and PAHs will be collected into one sample container.

Table B3. Sample containers, requested volumes, preservation, and holding times for freshwater (river) samples.

Parameter	Bottle Type and Volume	Sample Volume Needed	Preservative	Holding time
TSS	1 L Poly	1 L	Cool to $\leq 6^{o}$ C	7 Days
TOC	60 mL Poly	50 mL	1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	28 Days
DOC	60 mL Poly	50 mL	Field Filter w/ 0.45 *u*m; 1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	28 Days
Hardness	125 mL Poly	100 mL	H_2SO_4 to pH<2; Cool to $\leq 6^{o}$ C	6 Months
Nutrients: PO_4^{-3}	125 mL Amber Poly	125 mL	Field Filter w/ 0.45 *u*m; Cool to $\leq 6^{o}$ C	48 Hours
Nutrients: TP, NO_2+NO_3, NH_3, TPN	125 mL Clear Poly	125 mL	Pre-acidify w/ H_2SO_4; Cool to <6^{o} C	28 Days
Total Metals	500 mL HDPE	350 mL	HNO_3 to pH <2; Cool to <6^{o} C	6 Months
Dissolved Metals	500 mL HDPE	350 mL	Field Filter w/ 0.45 *u*m; HNO_3 to pH ≤ 2; Cool to $\leq 6^{o}$ C	6 Months
TPH-diesel	1 L Amber Glass	3 L	Cool to $\leq 6^{o}$ C	14 Days
TPH-gas	40 mL VOAs	480 mL	1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	14 Days
HEM ("oil and grease")	1 L Glass	3 L	1:1 HCl, pH ≤ 2.0; Cool to < 6^{o} C	28 Days
Semivolatiles (BNA)	1 Gallon Glass	3 L	Cool to $\leq 6^{o}$ C	7 Days
PAHs	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	7 Days
Chlorinated Pesticides	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	7 Days
PCB Congeners	1 L Amber Glass	2 L	Cool to $\leq 6^{o}$ C	1 Year
PBDE Congeners	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	1 Year
Total 16.6 Liters				

PO_4^{-3} = orthophosphate phosphorus.
TP = total phosphorus.
$NO_{2\,+}\,NO_3$ = nitrite and nitrate nitrogen.
NH_3 = ammonia nitrogen.
TPN = total persulfate nitrogen.

Table B4. Sample containers, requested volumes, preservation, and holding times for freshwater (river) particulate samples.

Parameter	Bottle Type and Volume	Sample Mass Requested (Wet Weight)	Preservative	Holding time
Percent Solids	2 oz Glass	50 Grams[1]	Cool to ≤6° C	7 Days
TOC			Cool to ≤6° C; may freeze at -18°C	14 Days; 6 months frozen
Metals Total Recoverable			Cool to ≤6° C; may freeze at -18°C	6 months; 2 years frozen
Semivolatiles (BNA)	8 oz Glass	250 Grams[2]	Cool to ≤6° C; may freeze at -18°C	14 Days; 1 year frozen
PAHs				
Chlorinated Pesticides		250 Grams	Cool to ≤6° C; may freeze at -18°C	14 Days; 1 year frozen
PCB Congeners		50 Grams	Cool to ≤6° C; may freeze at -18°C	1 year
PBDE Congeners		50 Grams	Cool to ≤6° C; may freeze at -18°C	1 year
Total 450 Grams				

[1] = Percent solids, TOC, and metals will be collected into one sample container.

[2] = Semivolatile organics and PAHs will be collected into one sample container.

Appendix C. Laboratory Parameters, Number of Samples, and Analytical Methods for Water and Particulate Sample Analyses.

Table C1. Laboratory parameters, number of samples, and analytical methods for marine water analyses per sampling event.

Parameter	Sample Number + QA	Expected Range of Results	Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method
TSS (mg/L)	16	1.0 - 50	1.0	-	-	SM 2540 D
TOC (mg/L)	16	<1.0 - 10	1.0	-	-	SM 5310 C
DOC (mg/L)	16	<1.0 - 10	1.0	Filter 0.22 *u*m	-	SM 5310 C
Metals Total Recoverable (*u*g/L):						
Arsenic	25	0.5 - 2.0	0.05	Acid digest	-	FGS 054
Cadmium	25	0.02 - 0.20	0.01	Acid digest	-	FGS 054
Copper	25	0.1 - 1.0	0.05	Acid digest	-	FGS 054
Lead	25	0.005 - 0.20	0.05	Acid digest	-	FGS 054
Zinc	25	0.2 - 5.0	0.25	Acid digest	-	FGS 054
Metals Dissolved (*u*g/L):						
Arsenic	25	0.5 - 2.0	0.05	Filter 0.45 *u*m	-	FGS 054
Cadmium	25	0.02 - 0.20	0.01	Filter 0.45 *u*m	-	FGS 054
Copper	25	0.1 - 1.0	0.05	Filter 0.45 *u*m	-	FGS 054
Lead	25	0.005 - 0.10	0.05	Filter 0.45 *u*m	-	FGS 054
Zinc	25	0.2 - 5.0	0.25	Filter 0.45 *u*m	-	FGS 054
Semivolatiles (BNA) (*u*g/L)*	16	<1-100	0.25 - 1.0	Extraction	-	EPA 8270
PAHs (*u*g/L)*	16	<1 - 10	0.01	Solid Phase Extraction	-	EPA 8270 SIM
Chlorinated Pesticides (ng/L)*	16	0.10 - 3.0	0.10 - 3.0	EPA 3510	-	EPA 8081
PCB Congeners (pg/L)*	16	5 - 500	10	Dichloromethane Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (pg/L)*	16	5 - 500	10 - 250	Dichloromethane Extraction	Acid/base wash	EPA 1614 GC/HRMS

* Reporting limits and expected ranges of results will vary for different organic analytes.
SM = Standard Methods.
SIM = Selective Ion Monitoring.
FGS = Frontier GeoSciences.
GC/HRMS = Gas Chromatography / High Resolution Mass Spectrometry.

Table C2. Laboratory parameters, number of samples, and analytical methods for freshwater (river) analyses per sampling event.

Parameter	Sample Number + QA	Expected Range of Results	Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method
TSS (mg/L)	6	1.0 - 100	1.0	-	-	SM 2540 D
TOC (mg/L)	7	1.0 - 10	1.0	-	-	SM 5310 C
DOC (mg/L)	7	1.0 - 10	1.0	Filter 0.45 *u*m	-	SM 5310 C
Hardness (mg/L)	6	10 - 50	1.0	-	-	EPA 200.7 ICP
Nutrients 5 (mg/L)[1]	6	0.005 - 1.0	0.005 - 0.025	-	-	SM 4500
Metals Total Recoverable (*u*g/L):						
Arsenic	8	0.2 - 5.0	0.1	Acid digest	-	EPA 200.8 ICP/MS
Cadmium	8	0.05 - 1.0	0.1	Acid digest	-	EPA 200.8 ICP/MS
Copper	8	0.5 - 5.0	0.1	Acid digest	-	EPA 200.8 ICP/MS
Lead	8	0.04 - 0.5	0.1	Acid digest	-	EPA 200.8 ICP/MS
Zinc	8	5.0 - 10.0	5.0	Acid digest	-	EPA 200.8 ICP/MS
Metals Dissolved (*u*g/L):						
Arsenic	8	0.2 - 5.0	0.2	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
Cadmium	8	0.02 - 0.50	0.02	Filter 0.45 *u*m		EPA 200.8 ICP/MS
Copper	8	0.3 - 2.0	0.1	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
Lead	8	0.02 - 0.3	0.02	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
Zinc	8	0.4 - 5.0	1.0	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
TPH-diesel (mg/L)	16	0.1 - 50	0.05	Extraction	Acid/silica	ECY 97-602
TPH-gas (mg/L)	16	0.1 - 50	0.14	Extraction	Acid/silica	ECY 97-602
HEM (“oil and grease”) (mg/L)	16	2.0 - 150	1.7	-	-	EPA 1664A
Semivolatiles (BNA) (*u*g/L) *	7	<1 - 100	0.25 - 1.0	Extraction	-	EPA 8270
PAHs (*u*g/L) *	7	<1 - 10	0.01	Solid Phase Extraction	-	EPA 8270 SIM
Chlorinated Pesticides (ng/L) *	7	0.1 - 3.0	0.1 - 3.0	EPA 3510	-	EPA 8081 LVI
PCB Congeners (pg/L) *	7	5 - 500	10	Dichloromethane Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (pg/L) *	7	5 - 500	10 - 250	Dichloromethane Extraction	Acid/base wash	EPA 1614 GC/HRMS

*= Reporting limits and expected ranges of results will vary for different organic analytes.

SM = Standard Methods.
ICP = Inductively Coupled Plasma.
ECY = Ecology.
MS = Mass Spectrometry.
SIM = Selective Ion Monitoring.
LVI = Large Volume Injection.
GC/HRMS = Gas Chromatography / High Resolution Mass. Spectrometry.

Table C3. Laboratory parameters, number of samples, and analytical methods for marine water and freshwater (river) particulate analyses per sampling event.

Parameter	Sample Number + QA	Expected Range of Results	Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method
Marine	-	-	-	-	-	-
Percent Solids (%)	6	40-90%	1%	-	-	EPA 160.3
TOC (%)	8	< 1.0 - 5.0	0.1	PSEP, 1986/1996	-	PSEP, 1986/1997
Metals Total Recoverable (mg/Kg):						
Arsenic	8	1.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Cadmium	8	0.1 - 5.0	0.1	SW-846 3050B	-	EPA 200.8
Copper	8	2.0 - 50	0.1	SW-846 3050B	-	EPA 200.8
Lead	8	2.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Zinc	8	10 - 100	5	SW-846 3050B	-	EPA 200.8
Semivolatiles (BNA) (*u*g/Kg)*	9	<16 - 10,000	16 - 320	SW-846	-	EPA 8270
PAHs (*u*g/Kg)*	9	<1 - 10	0.01	Soxtherm Extraction	SilicaGel	EPA 8270
Chlorinated Pesticides (*u*g/Kg)*	9	<1 - 25	2 - 10	EPA 3541	-	EPA 8081
PCB Congeners (ng/Kg)*	8	5 - 500	3 -10	Soxhlet Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (ng/Kg)*	8	5 - 500	2 - 50	Soxhlet Extraction	Acid/base wash	EPA 1614 GC/HRMS
River						
Percent Solids (%)	6	40-90%	1%	-	-	EPA 160.3
TOC (%)	7	0.1 - 10	0.1	-	-	EPA 415.1
Metals Total Recoverable (mg/Kg):						
Arsenic	7	1.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Cadmium	7	0.1 - 5.0	0.1	SW-846 3050B	-	EPA 200.8
Copper	7	2.0 - 50	0.1	SW-846 3050B	-	EPA 200.8
Lead	7	2.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Zinc	7	10 - 100	5	SW-846 3050B	-	EPA 200.8
Semivolatiles (BNA) (*u*g/Kg)*	7	<16 - 10,000	16 - 320	SW-846	-	EPA 8270
PAHs (*u*g/Kg)*	7	<1 - 10	0.1	Soxhtherm Extraction	SilicaGel	EPA 8270
Chlorinated Pesticides (*u*g/Kg)*	7	<1 - 25	2 - 10	EPA 3541	-	EPA 8081
PCB Congeners (ng/Kg)*	6	5 - 2000	3 -10	Soxhlet Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (*u*g/Kg)*	6	5 - 2000	2 - 50	Soxhlet Extraction	Acid/base wash	EPA 1614 GC/HRMS

* = Reporting limits and expected ranges of results will vary for different organic analytes.
GC/HRMS = Gas Chromatography/High Resolution Mass Spectrometry.

List of analytes for semivolatile organics (BNA) analysis by EPA Method 8270.

Benzoic Acid[1]
Benzyl Alcohol
Bisphenol A
Butylbenzylphthalate
4-Bromophenyl-Phenylether
Di-N-Butylphthalate
Caffeine
Cholesterol[1]
4-Chloro-3-Methylphenol
4-Chloroaniline[1]
Bis(2-Chloroethoxy) Methane
Bis(2-Chloroethyl) Ether
Bis(2-Chloroisopropyl) Ether
2-Chloronaphthalene
2-Chlorophenol
4-Chlorophenyl-Phenylether
3B-Coprostanol[1]
3,3'-Dichlorobenzidine[1]
1,2-Dichlorobenzene[1]
1,3-Dichlorobenzene[1]
1,4-Dichlorobenzene[1]
2,4-Dichlorophenol
2,4-Dimethylphenol[1]
2,4-Dinitrophenol[1]
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
2-Fluorophenol
Hexachlorobenzene
Hexachlorobutadiene[1]
Hexachlorocyclopentadiene[1]
Hexachloroethane[1]
Isophorone
p-Isopropyltoluene[1]
4,6-Dinitro-2-Methylphenol[1]
2-Methylphenol[1]
4-Methylphenol[1]
2-Nitroaniline
3-Nitroaniline[1]
4-Nitroaniline[1]
Nitrobenzene
2-Nitrophenol
4-Nitrophenol[1]
N-Nitroso-Di-N-Propylamine
N-Nitrosodiphenylamine
N-Nitrosodimethylamine
4-Nonyl Phenol[1]
Pentachlorophenol[1]
Bis (2-Ethylhexyl) Phthalate
Diethylphthalate
Dimethylphthalate
Di-N-Octyl Phthalate
Phenol
Pyridine
Triclosan
1,2,4-Trichlorobenzene[1]
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

[1] These compounds have inconsistent and poor recoveries.

Surrogates
D4-2 Chlorophenol
1,2-Dichlorobenzene-D4
2-Fluorobiphenyl
D5-Nitrobenzene
D5-Phenol
D10-Pyrene
D14-Terpenyl

List of analytes for polynuclear aromatic hydrocarbons (PAHs) analysis by EPA Method 8270 SIM.

Naphthalene
2-Methylnaphthalene
1-Methylnaphthalene
2-Chloronaphthalene
Acenaphthylene
Acenaphthene
Dibenzofuran
Fluorene
Phenanthrene
Anthracene
Carbazole
Phenanthrene, 3,6-dimethyl-
Fluoranthene
Pyrene
Retene
Benzo(k)fluoranthene
Benzo(a)pyrene
Perylene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h,)anthracene
Benzo(ghi)perylene
Chrysene
Benzo(b)fluoranthene
Benzo(a)anthracene

Surrogates
Naphthalene-D8
Acenaphthene-D10
Fluorene-D10
Phenanthrene-D10
Anthracene-D10
Fluoranthene-D10
Pyrene-D10
Chrysene-D12
Perylene-D12

List of analytes for chlorinated pesticides analysis by EPA Method 8081.

Aldrin
alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Chlorpyriphos
cis-Chlordane (*alpha*-Chlordane)
trans-Chlordane (*gamma*)
Chlordane (Tech)
Dacthal (DCPA)[1]
2,4'-DDD
4,4'-DDD
2,4'-DDE
4,4'-DDE
4,4’-DDMU[1]
2,4'-DDT
4,4'-DDT
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan Sulfate
Endrin
Endrin Aldehyde
Endrin Ketone
Heptachlor
Heptachlor Epoxide
Hexachlorobenzene
Methoxychlor
Mirex
cis-Nonachlor
trans-Nonachlor
Oxychlordane
Pentachloroanisole[1]
Toxaphene

[1] These compounds have inconsistent and poor recoveries.

Surrogates
Decachlorobiphenyl (DCB)
Dibutylchlorendate (DBC)
Tetrachloro-m-xylene (TCMX)

Appendix D. Field Operation Procedures - GO-FLO Samplers

Effective control of contamination during the collection and handling of Puget Sound water column samples is of paramount importance. Many of the target analytes are ubiquitous on the sampling platform and equipment, often at several orders of magnitude higher than concentrations expected in ambient waters. Introduction of contamination at this stage will negate all care taken in subsequent analytical steps.

These field protocols are intended to provide a step-by-step procedure for the collection of contamination-free water samples from depth in marine waters. Guidance was taken from the trace constituent sampling literature, and to the extent possible EPA Method 1669 “clean hands/ dirty hands” techniques are employed. The resulting protocols are understood to be performance-based, and modifications to the sampling procedure will be enacted if alternate techniques can be demonstrated to improve effectiveness. Performance will be measured through the collection and analysis of blanks and replicates.

Overview

While there is no “standard” method for obtaining at-depth samples of marine waters for trace constituent analyses, a proven and widespread technique involves the deployment of one or more Teflon-coated GO-FLO samplers (General Oceanics, Inc.) on a non-metallic hydrowire (typically Kevlar). The procedures for Puget Sound sample water collection are based on this “standard” foundation as follows:

Two Teflon-coated GO-FLO samplers are mounted back-to-back on a non-metallic Vectran rope and lowered by hand to a predetermined, above-halocline sampling depth. The samplers are remotely triggered by Teflon-coated messengers. A non-metallic windlass drum and Acetal sheave facilitate recovery of the GO-FLO samplers and ensure that the rope does not contact potentially contaminating materials. Once on-board, the samplers are kept in polyethylene bags and secured in a purpose-built storage cabinet to minimize atmospheric exposure.

Subsampling activities are conducted within a simple portable glove box. Water samples are decanted from each GO-FLO sampler via Teflon tubing that connects to the sampler drain valve inside the storage cabinet and to a Teflon petcock inside the glove box. In this way, sample bottles for the various analytes are filled in an environment isolated from major air- and ship-borne contamination sources.

The GO-FLO samplers undergo a short cleaning procedure and are re-deployed to collect water from below the halocline. After retrieval and subsampling activities, a CTD rosette cast is conducted using a hydraulic winch and stainless steel cable. CTD sensors record on the downcast, and Niskin bottles collect additional water samples from above- and below-halocline depths on the upcast. Discrete salinity measurements from each GO-FLO sampler and Niskin collection are compared to evaluate the integrity of sampler closure. At the completion of a sampling cruise, the GO-FLO samplers undergo rigorous cleaning and storage procedures.

Principal Equipment

- 10-liter GO-FLO samplers (2) – Teflon-coated with Teflon drain valves and air vent screws; spare parts kit.
- Vectran 12-strand rope (600 ft) – marked at 1- and 5-meter increments.
- Teflon-coated messengers.
- Snatch block and non-metal sheave – Ronstan single snatch block with Trunnion head and Acetal sheave.
- Non-metallic line weight – lead “fish” encased in epoxy resin.
- Cabinet for clean storage and transportation of GO-FLO samplers – constructed of UHMW polyethylene and Teflon materials.
- Large polyethylene bags capable of completely enclosing a single 10-liter GO-FLO sampler.
- Elasticized polyethylene “shower caps” (Saranwrap Quick Covers).
- Talc-free Nitrile gloves.
- Clinometer or like instrument.
- Refractometer or YSI Conductivity Meter.
- Marine flight compact rosette:
  - CTD – Model SBE25 (Sea-Bird Electronics, Inc.).
  - 1.5-liter Niskin bottles (4) – silicon springs and O-rings; AFM model SBE32 (Sea-Bird).
- Hydraulic winch with ~1200 ft of stainless steel aircraft cable.

General Rules

- Personnel must wear clean Talc-free Nitrile gloves during all sampling and subsampling operations. If glove contamination is detected or suspected, work must be halted, the contaminated gloves removed, and a new pair of clean gloves put on. Wearing multiple layers of clean gloves will allow the old pair to be quickly stripped with minimal disruption to the work activity.
- The upper ball valve of each GO-FLO sampler must be covered with an elasticized polyethylene “shower cap” at all times except during active deployment. The drain valve of each GO-FLO sampler must be covered with a Nitrile glove at all times except during active deployment and sample decanting.
- Samplers are transported around the vessel within polyethylene bags and are handled only by gloved personnel. When transferring the GO-FLO samplers to or from the storage cabinet, work rapidly and minimize the time that the inside of the cabinet is exposed to outside air. The samplers should never be placed directly on deck or any hard surface where foreign particles might be lodged in the ball valves and cause contamination of subsequent samples. Improper use and handling of GO-FLO samplers can result in permanent contamination.
- Ensure at all times that the Vectran 12-strand rope does not make contact with any part of the vessel (other than the Acetal sheave and windlass drum). When not in use, remove the rope from the snatch block and coil it inside a clean polyethylene bag. Place the bagged rope within a sealed plastic container to minimize exposure to air- and ship-borne contaminants.
- Store the snatch block and the line weights in clean polyethylene bags when not in use.

- All polyethylene storage bags are considered “one-time use.” That is, once a piece of equipment is removed from its storage bag, a separate clean bag must be used for subsequent storage.

Preparation

- Upon arrival at the sampling location, turn the engine off and wait 10 minutes before placing any sampling equipment in the water. Allow the vessel to drift during all sampling operations and conduct all sampling on the windward side of the vessel to minimize contamination from shipboard sources.
- Remove the snatch block from its polyethylene storage bag and secure it to the A-frame.
- Tie off the bitter end of the Vectran rope to a plastic cleat to secure it in case of mishap. Feed the working end of the rope over the sheave, being careful not to touch any metal objects that could embed foreign particles in the braid. Keep as much standing rope inside the covered plastic container as possible.
- Remove the line weights from storage bags and attach the weights to the loop eye at the working end of the Vectran rope. Lift the weights overboard and lower them into the water so that approximately 10 meters of rope extend above the weights. Secure the rope to a plastic cleat to maintain this configuration, and replace any extra rope into the rope storage box.
- Arm the GO-FLO samplers and secure each to the Vectran rope – *This is a 2-person activity and personnel must wear clean gloves*. Layering of gloves is recommended to facilitate rapid discarding of dirty/contaminated gloves. Technicians should work carefully but quickly, striving to minimize the duration of atmospheric exposure for GO-FLO samplers secured to the Vectran rope. Follow the procedures listed below for the first GO-FLO sampler, and then repeat the procedure to arm and secure the second GO-FLO sampler.
  - Technician #1 (T1) opens the storage cabinet. Technician #2 (T2) quickly removes the sampler (keeping it inside the polyethylene bag in which it was stored). T1 closes and secures the cabinet.
  - T1 places a clean polyethylene bag flat on a stable surface away from contamination sources. T2 places the GO-FLO sampler (still inside its polyethylene storage bag) on the bag.
  - T1 puts on clean gloves and reaches inside the storage bag to arm the GO-FLO sampler; contact with the GO-FLO sampler is only made by T1. T2 assists by stabilizing the sampler and manipulating the storage bag for T1.
    - Reverse the spring over the pulley to release tension.
    - Pull the pressure release valve all the way out and position the lanyard poly-balls on either side between the valve and the stainless steel frame.
    - Attach the lanyard to the plunger mechanism by inserting the slack loop into the trip release.
    - Re-span the spring by rotating it over the pulley so that the spring and the lanyards are under tension.
    - *Optional:* Test the closing mechanism to verify that it functions properly.
      - Push the pressure release valve to cause the ball valves to move to the open position.

        - Press the plunger to release the lanyard, which results in bottle closure.
        - Re-arm the GO-FLO sampler after this check.
    - T2 carries the armed sampler (still inside the storage bag) to the Vectran rope. T1 reaches inside the storage bag and checks that the protective "shower cap" and Nitrile glove are securely covering the upper ball valve and drain valve, respectively. T1 then removes the GO-FLO sampler from the storage bag. T2 discards the storage bag and secures the GO-FLO sampler to the Vectran rope at the 10-meter marking above the line weights.
    - T2 puts on clean gloves, and the above procedure is repeated for the remaining GO-FLO sampler. Mount the second sampler just below the first, with the top of its plunger mechanism approximately one meter below the base of the upper sampler.
- To prepare the samplers for serial firing, attach a Teflon-coated messenger by its lanyard to the plunger mechanisms of the upper GO-FLO sampler, and then snap the messenger onto the Vectran rope between the two samplers.

Deployment

- GO-FLO samplers armed using the above procedures are set to be deployed in a *closed* position to avoid potential contamination from the surface microlayer. If the number of line weights needed to overcome the buoyancy of the air trapped in the GO-FLO samplers becomes prohibitive, consider deploying the samplers in the *open* position. The ball valves can be easily released to the *open* position by depressing the pressure release piston. Note that the poly-balls on the lanyards are under tension and will snap quite suddenly when the pressure release piston is pressed in. Keep hands well clear of the poly-balls, and use a pen wrapped in either a polyethylene bag or a clean glove to depress the pressure valve.
- By convention, at the water surface the GO-FLO samplers are at 0 meters depth. Record the depth marking at which the GO-FLO samplers are mounted on the Vectran rope. This length of rope between the samplers and the line weights is called the "Weight Segment". In calm conditions when the rope angle (deviation from vertical) is negligible, the length of rope from the depth of the GO-FLO samplers in the water column to the surface (called the Sampler Segment) is equal to the total length of rope payed out (Total Length) minus the Weight Segment.

  Sampler Segment = (Total Length) – (Weight Segment)

- Immediately before deployment, remove the protective "shower cap" from the upper ball valve and the Nitrile glove from the drain valve of each GO-FLO sampler. Wearing clean gloves, check that all drain valves and air vent screws are tightly closed.
- Slowly lower the GO-FLO samplers by hand to ~15-20 meters depth. The hydrostatic pressure release valve should cause the ball valves to open at approximately 10 meters.
- Verify that the ball valves have opened properly: the parcel of air trapped in each sampler will be visible as it bubbles to the surface. If bubbles are not seen and there is concern that a sampler did not open, raise the rope slowly until the status of the ball valves can be assessed visually. However, note that contamination risks increase as the samplers approach the surface and the vessel. If water conditions are turbid or rough, assume that the bottle is open and accept that redeployment may be necessary. The weight of a retrieved sampler will be indicative of it being empty or filled with water.

- Lower the GO-FLO samplers to the desired sampling depth.
- Pay out additional rope as needed to adjust for significant rope angles (e.g., caused by strong currents or wind).
    - Read the Total Length and subtract the Weight Segment to determine the Sampler Segment.
    - Measure the angle of the rope from vertical (called Rope Angle) using a clinometer.
    - Calculate the actual depth of the GO-FLO samplers, the "Sampler Depth":

      (Sampler Depth) = (Sampler Segment) x cosine (Rope Angle)

    - Use the vessel's depth sounder for general verification (GO-FLO samplers should be detected by the sounder).
- Remove a Teflon-coated messenger from its storage bag, attach it to the Vectran rope, and release. This messenger will trigger closure of the upper GO-FLO sampler, followed by release of the serial messenger and subsequent triggering of the lower GO-FLO sampler.
- Allow adequate time for the messenger to reach the GO-FLO samplers before retrieval.

Recovery

- Use the windlass to recover the GO-FLO samplers, and feed the rope into the storage container as it is collected to minimize the potential for contact with contamination sources. It may be necessary to have the vessel's engine running to avoid complete draw-down of the battery by the windlass. In that case, engine assistance may only be used to raise the samplers to a depth of 10 meters. Above (i.e., shallower than) 10 meters depth, the engine must be off to avoid introducing excess contamination to the water column through which the GO-FLO samplers will travel. After the engine is off, allow at least one minute for ship-influenced water to dissipate before resuming sampler recovery.
- Once the GO-FLO samplers are retrieved to deck level, quickly inspect for leakage. If leakage is detected or suspected, prepare all samplers for re-deployment as follows:
    - Empty each GO-FLO sampler.
    - Rinse the sample chamber, the drain valve, and the air vent screw with de-ionized (DI) water.
    - Wearing clean gloves, and with the GO-FLO samplers still mounted on the Vectran rope, re-arm the samplers.
    - Re-deploy the GO-FLO samplers.
- If no leakage is apparent, immediately place clean polyethylene "shower caps" on the GO-FLO samplers' top ball valves. Rinse the samplers' drain valves with DI water and cover each with a Nitrile glove.
- Disengage the GO-FLO samplers individually and transport each to the storage cabinet. *This is a 2-person activity and all personnel must wear clean gloves*. Follow the steps below for the first GO-FLO sampler, and then repeat for the second sampler.
    - T2 supports the GO-FLO sampler to be removed, and T1 releases the screws that secure the sampler to the line.
    - While T2 holds the GO-FLO sampler, T1 places a clean polyethylene bag over the unit. T2 adjusts so that the sampler is completely contained in the bag.

  - T2 carries the GO-FLO sampler to the storage cabinet; T1 acts as a spotter. The sampler should not make contact with any part of the vessel.
  - Working quickly but carefully, T1 opens the storage cabinet and T2 places the GO-FLO sampler inside in an upright position (it should remain in the polyethylene bag). T1 secures the GO-FLO sampler inside the cabinet using bungee cords.
  - T2 puts on clean gloves, opens the GO-FLO sampler's air vent screw, and removes the glove from the drain valve. T2 removes the Teflon stopper from the port at the bottom of cabinet.
  - Inside the glove box (situated under the cabinet), T1 removes a clean Teflon tubing/petcock assembly from its storage bag. The open end of the tubing remains covered in a small plastic sheath, and the petcock remains protected by a plastic glove until subsampling activities commence. T1 feeds the tubing from inside the glove box through the port on the underside of the cabinet, and checks that the petcock inside the glove box is closed.
  - T2 receives the Teflon tubing inside the cabinet, removes the plastic sheath, and connects the tubing to the drain valve. T2 opens the drain valve, and T1 makes sure that the petcock isn't leaking in the glove box. T2 closes the cabinet.
- Wearing clean gloves, remove the line weights and place them in polyethylene bags for storage. Release the Vectran rope from the snatch block. Coil the rope, place it in a polyethylene bag, and store it within the sealed container to protect against air- and ship-borne contaminants. Place the snatch block in a polyethylene bag for storage.

Subsampling

- Begin decanting samples from the GO-FLO samplers as soon as possible to prevent settling, biological activity, or adsorptive losses.
- Prior to the cruise, pre-labeled bottles for a specific sampling location and depth (henceforth called a "set") will have been assembled in two large, layered polyethylene bags. Wearing clean gloves, remove the outer polyethylene bag and transfer the set (still contained in the inner polyethylene bag) to the inside of the glove box.
- Place a wide-mouthed waste container inside the glove box.
- The flow of water from a GO-FLO sampler is controlled from inside the glove box using the Teflon petcock. Remove the protective Nitrile glove to access a petcock. Be extremely careful, and ensure that nothing in the glove box makes contact with the exposed petcock at any time.
- Drain the first 0.5 liters of water from each GO-FLO sampler into the waste container before decanting for analyte samples.
- Decant a small (<50 mL) sample from each GO-FLO sampler, and use a refractometer or YSI Conductivity Meter to determine the salinity of the water in each sampler. Compare the salinities of same-depth GO-FLO sampler collections to evaluate the integrity of sampler closure; salinities that do not agree indicate a problem with the deployment. If salinities do not match, the GO-FLO samplers should be emptied, rinsed, and re-deployed.
- Decant water whole-water samples.

  - Remove the analyte sample bottle(s) from the set bag as they are needed, and follow analyte-specific handling procedures (e.g. bottle rinses).
  - The recommended sequence for decanting analyte samples is as follows:
    - GO-FLO sampler #1:
      1. Total Suspended Solids – 1 L
      2. PCB Congeners – 2 L
      3. PBDE Congeners – 1 L
      4. Chlorinated Pesticides – 3 L
    - GO-FLO sampler #2:
      5. Semivolatile Organics – 3 L
      6. PAHs – 3 L
      7. Total Metals – 1 L
  - After each analyte sample bottle is filled, attach a sample tag with the required identification information (e.g., date/time, location, analyte, etc.). Seal the individual bottle inside a polyethylene bag and then inside another polyethylene bag. Place the double-bagged sample bottles in the set bag.
  - *Do not* allow the mouth of an analyte bottle to contact the petcock at any time.
  - *Do not* swirl or shake the GO-FLO samplers to re-suspend settled material, as this can alter partitioning between dissolved and particulate size fractions.
- Observing “clean hands/dirty hands” guidelines, set up the in-line filtration apparatus for collecting a dissolved metals sample from GO-FLO sampler #2. Flush the metals filter and tubing with 500 mL of sample water, and then rinse the dissolved metals bottle and cap with filtrate. Collect 1 liter of filtered sample for dissolved metals determination.
- When all analyte samples have been decanted, carefully remove the set bag (filled with all of the sample bottles) from the glove box and place it in a clean, large polyethylene bag. Place completed sample set in a cooler on ice.

Between Stations or Sampling Events

- To minimize the risk of contamination to the GO-FLO samplers during short-term storage, adhere to the following precautions:
  - Store the samplers in polyethylene bag(s) inside the storage cabinet, and only remove a sampler just prior to deployment.
  - All valves (i.e., ball valves, air vent screws, drain valves) should be stored in their final closed position.
  - Cover the upper ball valve with an elasticized “shower cap,” even when the sampler is inside a polyethylene storage bag.
  - Protect the drain valve by storing it covered by a Nitrile glove.
- If contamination of any GO-FLO sampler is suspected, stop using the sampler and return it to the lab for a thorough cleaning.

Extended Storage

- Prior to long-term storage, rinse the GO-FLO samplers with DI water.
- Ensure that all valves are in their final closed position.
- Cover the upper ball valve with a clean elasticized "shower cap," and place a clean Nitrile glove over the drain valve.
- Store the GO-FLO samplers in one or more clean polyethylene bag(s) within the storage cabinet, and pack the entire storage cabinet in another polyethylene bag if possible.
- If GO-FLO samplers are not to be used within 30-60 days, return the samplers to the lab and schedule a thorough cleaning and maintenance. Procedures will be guided by existing standard techniques for the cleaning of Teflon-coated sampling equipment for priority pollutant sampling.

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Appendix E. Field Operation Procedures - CTD Deployment

The Conductivity/Temperature/Depth profiler (CTD) mounted on a rosette unit is deployed as soon as possible after all subsamples have been drawn from GO-FLO samplers. Project-specific considerations for CTD deployment and Niskin bottle water collections are addressed below. Existing standard operating procedures for the compact marine flight rosette will be employed (Ecology's Marine Ambient Monitoring Section, pers. comm.), and as such are not comprehensively detailed here.

- Deployment of the CTD rosette will require use of the hydraulic winch with the vessel's engine running, creating a contamination-prone environment on-deck. Ensure that the GO-FLO samplers and all associated equipment are stored and secure prior to the CTD cast.
- Program the firing depth of the Niskin bottles to match the depth at which water samples were collected by GO-FLO samplers. Trigger two Niskin bottles at each sampling depth for redundancy.
- Secure the CTD rosette and weights (if necessary) to the stainless steel cable. Do not use the coated weights at this time, for there is a high risk of contamination from the equipment and steel cable.
- Lower the CTD rosette unit at a slow and constant rate, typically 0.5 m/s. Data recorded during the downcast will be used in later analyses; CTD and auxiliary sensor data from the upcast are discarded.
- Raise the CTD rosette unit at a velocity of approximately 0.5 m/s. Niskin bottles close at pre-programmed depths. The slow upward velocity ensures that water is obtained from a discrete depth, minimizing the vertical "smearing" of the collection through a depth interval.
- After the CTD rosette is recovered to deck level, immediately inspect the Niskin bottles for leakage. If leakage is detected or suspected, empty the Niskin bottles and prepare for re-deployment. Wait at least 5 minutes to allow quiescent conditions to re-establish before re-deploying.
- Turn off the engine off before commencing sample decanting and processing activities. Personnel must wear clean gloves during all subsampling procedures.
  - Measure sample water salinity from each Niskin bottle using a refractometer or YSI Conductivity Meter. Compare salinities of water samples collected at the same depth by Niskin bottles and GO-FLO samplers. Anomalous same-depth salinities may indicate incomplete bottle closure (and thus potential sample contamination by water from other depths), collection from the wrong sampling depth, or the influence of a dynamic water body. Discrete salinities should later be compared with the CTD salinity profile for further evaluation.
    - If Niskin sample salinities are comparable and agree with GO-FLO sampler salinities, then either Niskin bottle's contents can be used for TOC/DOC subsampling.
    - If Niskin sample salinities are comparable but disagree with GO-FLO sampler salinities:

                - ☐ The Niskin bottles or the GO-FLO samplers may have closed at the wrong depth. Consider re-deployment of the CTD rosette to evaluate further.
                - ☐ In areas affected by strong currents or wind-driven mixing, water at the sampling depth may have changed significantly between collection by the GO-FLO samplers and by the Niskin bottles. Make note of such physical factors and draw TOC/DOC subsamples from the Niskin collections, despite the discrepancy.
            - If Niskin sample salinities are *not* comparable but one agrees with GO-FLO sampler salinities, decant TOC/DOC subsamples from the Niskin bottle that has the same salinity as the GO-FLO sampler salinities.
            - If Niskin sample salinities are *not* comparable and both disagree with GO-FLO sampler salinities, new Niskin bottle samples must be collected before TOC/DOC subsamples can be drawn. The Niskin bottles may have closed at different depths, or sample integrity may have been compromised by incomplete bottle closure.
    - Acquire water for CTD and sensor calibration by decanting from one of the Niskin bottles.
    - Decant water from one of the Niskin bottles into TOC and DOC sample bottles. Conduct the necessary processing and filtration.
- Upload CTD data as needed (i.e., on-station, between stations, or post-cruise).
- Clear the CTD memory before the next cruise.

Appendix F. Field Operation Procedures - Collecting Suspended Sediment Using Flow-Through Centrifuges

(from Gries and Sloan, 2008)

Preparing for field work

- All equipment surfaces that will contact river water or centrifuged sediment will be cleaned appropriately (Ecology, 2006, 2008) to remove metals and organic residue:
    - Wash with phosphorus free soap (e.g., Luminox).
    - Rinse with a large volume of tap water.
    - Rinse with 10% nitric acid.
    - Rinse with deionized/distilled water and let dry.
    - Rinse with acetone and let air dry.
    - Rinse with hexane and let air dry.
    - Cover with foil.
- Replace consumables that have been used.
- Complete any maintenance or repairs.
- Assemble checklists and field logs.
- Label containers.
- Assemble field gear needed (from checklists).
- Complete field itinerary.

Set-up and pre-sampling

- Arrive at the sampling site and position centrifuge trailer so that:
    - It does not obstruct the road or bridge traffic.
    - Personnel have adequate access to the interior as well as exterior storage compartments.
    - It is easy to set up for pump sampling.
    - It is reasonably level.
- Set up centrifuge according to procedures described in operations manual (Seiders, 1990).
- Prepare tubing, attach pumps, prepare fish for deployment, and calibrate equipment.
- Start centrifuges and recycle approximately 10L of organic-free water through the entire system, including all sample tubing, for 30 minutes.
- Fill a 1L glass jar with water from the effluent (field blank).
- Profile the stream with the conductivity meter, especially near the streambed, to determine presence and extent of salt wedge.
- Profile the stream with the StreamPro according to the SOP to obtain flow and depth characteristics (minimum 4 passes).

- Use in-line sediment sensor (LISST-Streamside, Sequoia Scientific, Inc.) or turbidity meter (as surrogate) to map horizontal and vertical variability in profile of particle size distribution (PSD) in suspended sediments. Use the depth, flow, and particle size distribution/turbidity information to estimate most representative location(s) to place centrifuge intake tube. The default location will be center channel and 0.6 times the maximum depth of the freshwater layer.
- Set up tubing and pumps for sampling.
- Turn on pumps and recycle water back to the river for 10 minutes to flush the tubing, establish a constant flow, remove any bubbles in the tubing, and monitor for leaks.

Sampling

- After pumps are ready, attach tubing to the centrifuge apparatus and record in field logs: start time, tide phase (if tidal effects), stage height, centrifuge status, intake tube location, hertz, pump speed, and water flow.
- Start pumping to collect sandy suspended sediment on sieve by connecting the tubing and recording start time, tide phase, stage height, fish location, pump speed, and water flow.
- Monitor centrifuges for at least 20 minutes: influent, effluent, check for leaks, adjust flows, intake tube position, and overall operation.
- Collect samples of TSS in river water, centrifuge influent, and centrifuge effluent at designated times. Samples will be a combination of discrete and composite samples. Replicate and blank samples will also be taken.
    - Effluent water samples will be taken from a compositor located in the collection basin, while centrifuges are running.
    - Influent water samples will be taken by disconnecting the tubing just before the water enters each centrifuge. These 2 water samples will be combined into 1 influent sample.
    - Reconnect tubing to centrifuges.
- Measure flow and conductivity at designated time intervals.
- Record site conditions, weather, boat traffic, equipment performance, and any other important information in the log.
- Record changes in position of intake tube on centrifuge sample sheet including: tide phase, stage height, fish location, pump speed, water flow, and reason for relocation in the comments/notes column.
- Stop centrifuges and remove accumulation of suspended sediments using a Teflon spatula when substantial accumulation is predicted based on pumping rates and TSS. (Accumulated pellet will be removed to prevent it from contacting the discs in the bowl and decreasing retention efficiency). Place material in a pre-cleaned glass jar and seal. Put jar in cooler with ice. Record centrifuge data: stop time, elapsed time, tide phase, stage height, and total gallons pumped. Record sample data: collection time, MEL ID, sample ID, estimated amount of sample, and sample information.
- Restart centrifuges to continue collecting suspended sediment, recording the appropriate data.

- Remove sand-sized sediments from sieves when accumulation starts to restrict flow. Place sample in a pre-cleaned glass jar and put in cooler with ice. Record sieve data: stop time, elapsed time, tide phase, stage height, and estimated total gallons pumped. Record sample data: collection time, MEL ID, sample ID, estimated amount of sample, and sample information.
- Restart sieve apparatus to continue collecting sand-sized suspended sediments, recording the appropriate data.

Post-sampling

- When sampling is complete, stop centrifuges and pumps. Remove all accumulated sediments from the centrifuge and sieves, following the same procedures as removing accumulated sediments above.
- Take post-sampling flow measurements.
- Disassemble all equipment.
- Return to Ecology Operations Center and Headquarters in Lacey.

Sample processing

- Homogenize the centrifuge pellet using a stainless steel spatula.
- Split sample for analysis of study parameters.
- If needed, prioritize, with laboratory staff input, which contaminants to measure with sample mass.
- Send samples to appropriate laboratories, using chain-of-custody procedures.

Appendix G. Glossary, Acronyms, and Abbreviations

Ambient: Background (environmental).

Analyte: Water quality constituent being measured (parameter).

Bioaccumulate: Build up in the food chain.

Biota: Flora (plants) and fauna (animals).

Box model: A computer prediction tool to simulate the movement of water and pollutants within a waterbody.

Congener: In chemistry, congeners are related chemicals. For example, polychlorinated biphenyls (PCB) are a group of 209 related chemicals that are called congeners.

Flux: Amount that flows through a unit area per unit time.

Halocline: A strong vertical salinity gradient.

Loading: The input of pollutants into a waterbody.

Marine water: Salt water.

Parameter: Water quality constituent being measured (analyte).

Sediment: Solid fragmented material, that is transported and deposited by water, ice, or wind, that forms layers on the earth's surface.

Specific conductivity: A measure of water's ability to conduct an electrical current.

Thalweg: The deepest and fastest moving portion of a stream.

Acronyms and Abbreviations

BNA	Base/Neutral/Acids (semivolatile organics)
CTD	Conductivity/Temperature/Depth profiler
DOC	Dissolved organic carbon
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management system
EPA	U.S. Environmental Protection Agency
FISP	Federal Interagency Sedimentation Project
GPS	Global Positioning System
HEM	Hexane-extractable materials ("oil and grease")
JEMS	Joint Effort to Monitor the Strait of Juan de Fuca
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective

PAH	Polynuclear aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PSTLA	Puget Sound Toxics Loading Analysis
QAPP	Quality Assurance Project Plan
QC	Quality control
RPD	Relative percent difference
SOP	Standard Operating Procedure
SPM	Suspended particulate matter
TOC	Total organic carbon
TP	Total phosphorus
TPH	Total petroleum hydrocarbons (-gas and –diesel)
TPN	Total persulfate nitrogen
TSS	Total suspended solids
USGS	U.S. Geological Survey

NO_2 - NO_3	Nitrite and nitrate nitrogen
NH_3	Ammonia nitrogen
PO_4^{-3}	Orthophosphate phosphorus

As	Arsenic
Cd	Cadmium
Cu	Copper
Pb	Lead
Zn	Zinc

mg/L = milligram/liter (parts per million)
*u*g/L= microgram/liter (parts per billion)
ng/L = nanogram/liter (parts per trillion)
pg/L = picogram/liter (parts per quadrillion)

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Subject: RE: talk about human health criteria topics
Date: Thursday, September 06, 2012 1:16:50 PM
Attachments: image001.png
image002.png
image003.png
4-Stage process to new CWA HH criteria.docx

Cheryl,

Sorry for the delay. I was working on the attached and wanted to finish it so I could attach it to this reply. It just documents a process or way of organizing steps & questions that have been kicking around in my head. Getting it on paper relieves some head pressure, and allows me to share it with you and others, for refinement.

I am sure we'll all be talking a lot. It is probably better if we cross-pollinate as much as possible, share conundrums and possible solutions. So to that end, I definitely want to be part of a conversation with you Matt and Lisa. Not sure I understand all your 'things', and hope may attached will suggest other 'things' to add to your list.

Was skimming through EPA's HH Methodology again and came across this that relates to your first point:

"AWQC for the protection of human health are designed to minimize the risk of adverse effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish <u>obtained from surface waters</u>." [emphasis added]

Seems pretty clear to me AWQC are not intended to account for / regulate all sources of health risk, and it would be pretty intractable if they were.

Don't understand your second and third points, perhaps you can expound a bit.

Thanks for sharing your power point. Just started putting together one of my own, OK if I borrow from yours? Don't know who from DEQ was at the Spokane meeting, but had to be someone from our Coeur D'Alene regional office.

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From: Niemi, Cheryl (ECY) [mailto:cnie461@ECY.WA.GOV]
Sent: Thursday, September 06, 2012 12:44 PM
To: Don Essig
Subject: talk about human health criteria topics

Hi Don,

Hope all is well with you. Here are a couple of items:

1. I talked with Matt at EPA this morning. Asked him if he and Lisa would be interested in talking about some of the things that we have been mentioning and that we know will come up in the HHC rule-making process. These include things like:

- Role of CWA in public health protection
- Temporal and geographic scope of the CWA
- How explicitly do states spell out the different factors that drive their risk management decisions when it comes to HH criteria adoption
- If a chemical is both a carcinogen and a non-carcinogen do we use the most stringent criteria based on the RfD and the CSF? (Many states have 10^{-5} for PCBs – does that protect against non-cancer effects and if so have any states addressed this directly? Matt is looking into this.)

We will be talking about these and more at our rule-making policy forums, and I expect you will too.

Matt thought it would be good for the four of us to talk first and then bring in more people if we need to find out more info about or define these further prior to rule-making workshops.

What else should we add to the list? I am particularly interested in being very clear about where we have flexibility and where requirements are in law or regulation.

What do you think?

2. FYI - My power point presentation (on human health criteria) from last week's workshop is up at http://www.ecy.wa.gov/toxics/fish_publicinvolvement.html. I think someone from IDEQ was at the meeting in Spokane, but don't have a name. The workshop was videoed - is in progress of being set up - the whole thing will be on the web at some point.

Weather below!

Cheryl

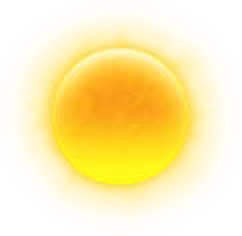
Beautiful Olympia Weather

PREVIOUS
Right Now
Right Now
NEXT
Hourly Forecast
Hourly Forecast

My Forecast for Today

Updated: Sep 6, 2012, 10:06am PDT

Day Sep 6



83°F High

Sunny

Chance of rain:
0%
Wind:
NE at 9 mph
Humidity:
45%
UV Index:
6 - High
Snowfall:
0 in

Sunny. Warm. High 83F. Winds NE at 5 to 10 mph.

Night

49° Low

Clear

Chance of rain:
0%
Wind:
NE at 7 mph
Humidity:
63%

Cheryl A. Niemi

Surface Water Quality Standards Specialist

Department of Ecology

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From: Don.Essig@deq.idaho.gov
Sent: Tuesday, June 24, 2014 9:38 AM
To: Niemi, Cheryl (ECY)
Subject: FW: EPA's Position on general population FC survey

FYI. May have forwarded this in the past, but this is the conversation between Barry and Christine is was referring to. Just inquired of Barry if he ever responded to Christine in writing, in a manner like Sen Ericksen's questions.

From: Barry Burnell
Sent: Friday, March 15, 2013 11:36 AM
To: Don Essig; Michael Mcintyre; Douglas Conde; Mary Anne Nelson; Miranda Adams; Jeffrey Fromm
Cc: Curt Fransen; Jess Byrne
Subject: RE: EPA's Position on general population FC survey

Christine just called and her message was two part. That EPA would not help fund the general population survey design. That EPA could help with a high fish consumer survey design. I got her to confirm that this included the resident angler survey design. I informed her that DEQ's position was that the core questions to get at a fish consumption rate should be compatible between all of the fish consumer surveys.

I also questioned how Region 10 could have a policy different than headquarters. She told me they region 10 was pursuing some rational about having region wide approach. I asked her if she realized that Idaho did not have ocean front property and that a region wide approach did not seem appropriate to Idaho. She understood the geography, but none the less EPA was still pursuing a regional approach.

The final discussion point that came out was basically EPA taking the position that the high fish consumption populations need to be protected at 10x-6. I again asked her how region 10 could be narrowing and restricting states from the national policy, and got the response that all states should follow what Oregon approach.

Seems like policy calls are being made by EPA without consulting DEQ and that Region 10 is trying to convince headquarters to go along with them.

From: Don Essig
Sent: Thursday, March 14, 2013 12:21 PM
To: Barry Burnell; Michael Mcintyre; Douglas Conde; Mary Anne Nelson; Miranda Adams; Jeffrey Fromm
Subject: EPA's Position on general population FC survey

Just got off a call with Lisa Macchio and Matt Szelag of EPA and Cheryl Niemi of WADOE on fish consumption rates and surveys. Cheryl had set up the call and invited me as her and I have been talking, collaboratively chewing if you will, on various questions, such as the need for data on fish consumption rates for the general population. Two very important things emerged from the call.

First, EPA has taken the position that there is no value in a general population fish consumption survey and Idaho (or WA) should not do such a survey and that EPA will not support our efforts to do a general population survey. Involved in the decision were both EPA region 10 and headquarters.

I asked what 'will not support' means. At the very least it means no financial support, no surprise there. However, when I pressed Lisa about whether it meant we could count on continued help from Lon, for example to follow through on orchestrating a conversations with Dr. Amy Subar at NCI to help us, Lisa said she could not answer, did not know. When I explained to Lisa that Idaho was not planning to do just a general population survey, but also a recreational angler survey and that we think the design should be a common design even if the target populations are different and asked whether that mattered - if EPA's would give us no support even for the recreational survey because we are set on doing a general population survey - she said she did not think EPA had yet thought this through that far.

This is disconcerting to me. Lack of financial support is one thing, turning a cold shoulder so to speak is another. I worry that EPA might even go so far as to speak badly of our efforts to others, such as tribes perhaps, saying they think we are wasting time and money, or even saying so publically. That would definitely be even worse.

So really want to know the extent of EPA's lack of support, hope it is only no funding. I understand Christine is planning to call you Barry, and would ask that you try to clarify with her and if need be argue to limit EPA's lack of support to only no funding.

Secondly, Lisa said that part of EPA region 10's rationale for the lack of value in a general population survey was that Idaho's water quality standards applied the 10-6 cancer risk factor to all Idahoans, even high risk subgroups. I had heard this through the grapevine earlier, so looked at what our WQS say.

Here are the pertinent sections of our rules:

Footnote l. EPA guidance allows states to choose a risk factor of 10^{-4} to 10^{-6}. Idaho has chosen to base this criterion on carcinogenicity of 10^{-6} risk.

210.05.b. Human Health Criteria.

i. When numeric criteria for the protection of human health are not identified in these rules for toxic substances, quantifiable criteria may be derived by the Department from the most recent recommended criteria defined in EPA's Integrated Risk Information System (IRIS). When using EPA recommended criteria to derive water quality criteria to protect human health, a fish consumption rate of seventeen point five (17.5) grams/day, a water ingestion rate of two (2) liters/day and a cancer risk level of 10^{-6} shall be utilized.

Granted our rule language does not explicitly state the 10-6 risk factor is for the general population, but neither does it state it is for high risk groups, or all people. I would say it is more reasonable in absence of specificity to say it applies to the general population rather than an unspecified high risk subgroup. This interpretation is supported by the fact that these criteria are rooted in the NTR, and so I believe this the only fair interpretation. So EPA has interpreted our WQS contrary to how I think we would. If this is indeed the basis, or even a basis, for their disapproval and stance against a general population survey, it is something that needs to get straightened out.

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From: Niemi, Cheryl (ECY)
To: Susewind, Kelly (ECY); Gildersleeve, Melissa (ECY)
Subject: Just FYI - Suppression info from EPA
Date: Wednesday, October 01, 2014 12:46:19 PM

Just FYI - info from EPA below.

Cheryl A. Niemi
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From: Don.Essig@deq.idaho.gov [mailto:Don.Essig@deq.idaho.gov]
Sent: Tuesday, September 30, 2014 1:24 PM
To: Niemi, Cheryl (ECY)
Subject: FW: Call from Lisa and Lon on suppression

FYI.

From: Don Essig
Sent: Tuesday, September 30, 2014 2:00 PM
To: Barry Burnell; Michael Mcintyre; Douglas Conde (Douglas.Conde@deq.idaho.gov); Jeffrey Fromm; Miranda Adams; Josh Schultz
Subject: Call from Lisa and Lon on suppression

Lisa and Lon called me just now to say they had talked a bit after our call yesterday and talked with headquarters and are prepared to make these three points about suppression of fish consumption in our meeting on Thursday:

1) Suppression is multi-faceted, has several causes (various forms of reduction in quality and quantity basically)
2) EPA is not sure how suppression should be factored into criteria but stand by the statement in their Human Health FAQs, *"It is also important to avoid any suppression effect that may occur when a fish consumption rate for a given subpopulation reflects an artificially diminished level of consumption from an appropriate baseline level of consumption for that subpopulation because of a perception that fish are contaminated with pollutants"*
3) Jeff Bigler of EPA-HQ is working on a revision to EPA's 1998 guidance on conducting fish contaminant surveys, to address suppression and how to estimate it.

Don A. Essig
WQS / Idaho DEQ
208-373-0119

Keep in mind that all of the water we have today is all of the water that ever was and all of the water there will ever be.

From: Braley, Susan (ECY)
Sent: Thursday, January 09, 2014 3:07 PM
To: Melissa McCoy; Niemi, Cheryl (ECY); Don.Essig@deq.idaho.gov
Subject: RE: EPA's FAQs on Fish Consumption Rates
Attachments: RE: Draft - Comments to ACWA on EPA HHC FAQ+dae.docx

Hi Melissa—Speaking for Ecology, we never got answers from EPA on these FAQs that showed up without advance notice and with no state involvement, nor EPA follow-up that was promised in the ACWA meeting discussions (I think there were two...April 17 and then an ACWA webinar on September 18). In fact we've heard nothing as far as I know (Cheryl or Don may have had more dialogue then me so I will let them speak for themselves).

I am attaching an email string following the April 17 ACWA discussion. As Martha notes it was a somewhat disappointing dialogue. I believe at that time (April 17) we were told that EPA would take down the January 2013 FAQ and make "corrections" based on WA and ID comments, and others that came out of the AWCA discussion (well, I should say we requested that EPA take the FAQ off line until they had made corrections). At the September 18 meeting we asked again why EPA hadn't followed through with their earlier commitment to make corrections to the January 2-013 FAQs and repost. We were told that EPA would look into it. Obviously, nothing happened because the January 2013 FAQs are still on line and unchanged.

What REAQLLY needs to happen is that EPA needs to pull the 2013 FAQs and have greater dialogue with states on these very important risk-based issues, and then come out with guidance that the states can work with. They do this with other guidance documents they have developed, so this one was a mystery, why it showed up without warning or any state input at all. What we heard at the September 18 ACWA meeting from EPA was that there was some urgency because of the work Florida was doing, and thus EPA felt the need to rush out with these FAQs. We all know that with water quality standards, anything that's rushed and not vetted is likely to be in error, especially when the state agencies who implement the standards don't have an opportunity to provide input.

It has been very frustrating, especially as we get closer to developing new human health criteria and are being told that these FAQs must be followed or we risk not getting approval.

Anything you can do to facilitate further discussion would be appreciated!

Susan

From: Melissa McCoy [mailto:mmccoy@acwa-us.org]
Sent: Thursday, January 09, 2014 1:51 PM
To: Niemi, Cheryl (ECY); Don.Essig@deq.idaho.gov; Braley, Susan (ECY)
Subject: EPA's FAQs on Fish Consumption Rates

Hi Susan, Don, and Cheryl,

I got some background on EPA's FAQs on FCRs from Susan here at ACWA, and noticed that the version on EPA's website is still dated January 2013. So I wanted to check in and see if discussing these FAQs with EPA resolved your concerns, or if there is still unfinished business on this topic.

Melissa

Melissa W. McCoy, Ph.D.
Environmental Program Manager

rom: Braley, Susan (ECY)
Sent: Monday, July 28, 2014 3:53 PM
To: 'Don.Essig@deq.idaho.gov'
Subject: RE: Question on June 30th call with EPA on HHC

Yes, Melissa might be able to recall...I just remember Cheryl and I being a little stunned at the news. Why they would go to so much trouble with the 94 chems if they plan to update the methodology to boot. Sure hope we can get that on a slow track....

From: Don.Essig@deq.idaho.gov [mailto:Don.Essig@deq.idaho.gov]
Sent: Monday, July 28, 2014 3:10 PM
To: Braley, Susan (ECY)
Subject: RE: Question on June 30th call with EPA on HHC

Thanks. Good to know that it was an ACWA arranged call, a call I could have been on if not home sick. I'll inquire with Melissa McCoy, maybe she took some notes.

From: Braley, Susan (ECY) [mailto:SUBR461@ECY.WA.GOV]
Sent: Monday, July 28, 2014 4:04 PM
To: Don Essig; Niemi, Cheryl (ECY)
Subject: RE: Question on June 30th call with EPA on HHC

on—I am PRETTY sure it was the call that Melissa McCoy set up on Monday, June 30th at 10:30am PST. Jim Keating from EPA (manager, I think?) was sort of apologetic about not taking action on the FAQs sooner after we pointed out that over a year had gone by that EPA had indicated they would at least update the FAQs with a disclaimer and make a few other clarifications (none of which happened). At some point I believe Elizabeth indicated that in fact they were planning in about a year to open up the methodology. So, I think it's okay to even state something to the effect that "At a meeting with ACWA and several states regarding discussion of the HHC FAQs, EPA indicated...."

Better have Cheryl ground truth my recollection, but I'm pretty sure it was at that meeting because we were all a little shocked—esp given the recent release of the 94 chems!

Susan

From: Don.Essig@deq.idaho.gov [mailto:Don.Essig@deq.idaho.gov]
Sent: Monday, July 28, 2014 2:17 PM
To: Niemi, Cheryl (ECY)
Cc: Braley, Susan (ECY)
Subject: Question on June 30th call with EPA on HHC

Cheryl,

I know you are on vacation, but I'll queue this up for your return, or maybe Susan can answer. Was the June 30th call with EPA HQ you mentioned, in which EPA said they were considering announcing revision of their 2000 HH methodology within 8 months, a call between DOE and EPA, or was it an ACWA call?

Want to make the comment I shared with you last Friday, that EPA should hold off on its current HH criteria updates if it intends to soon update its methodology, but not sure how to state my knowledge of their plans. This is what I have now:

PCBs in Municipal Products

REVISED

Pg. 12 Revised
July 21, 2015

Ecology Municipal Stormwater Grants of Regional or Statewide Significance
Grant No. G1400545

Prepared by:

City of Spokane
Wastewater Management Department

Contents

PCBs in Municipal Products

INTRODUCTION

Polychlorinated biphenyls (PCBs) are a toxic manmade chemical found ubiquitously in the environment. Historically, PCBs were primarily used in coolants and lubricants in electrical equipment, such as transformers and capacitors. In the United States, PCBs were largely sold under the trade name Aroclor. Direct production of PCBs was halted in the US in the 1970's due to evidence of human toxicity and persistence in the environment. Since that time, however, PCBs have been incidentally produced in a multitude of manufacturing processes as an unintended byproduct of processes that use heat, chlorine, and carbon.

The Washington State 2008 303(d) list holds 113 Category 5 listings for PCBs, covering 59 waterbodies. Several segments of the Spokane River are included in this list. The City of Spokane has performed stormwater sampling in several of its outfalls that drain to the Spokane River. PCBs were detected in each sample, with a typical sample in the range of 7,000 picograms per liter (pg/L), or parts per quadrillion (ppq).

Once thought to be only a legacy contaminant, PCBs have been found in numerous commercially available products. These PCBs are not intentionally produced, but are rather unintended byproducts of the manufacturing process. Materials containing less than 50 parts per million (ppm) are not considered "PCB-contaminated" under the Toxics Substances Control Act (TSCA) (40 CFR 761.3). For comparison to water quality considerations, 50 ppm is equivalent to 50,000,000,000 ppq. The current Washington State human health surface water quality standard for PCBs is 170 ppq (derived from the National Toxics Rule, 40 CFR 131.36). The Spokane Tribe adopted a water quality standard of 1.3 ppq due to higher fish consumption rates used to derive the standard.

Many products can easily come into contact with rain water and contribute to PCB concentrations in stormwater runoff. Municipalities are concerned about the presence of PCBs in commonly used products such as road paint, asphalt sealers, pesticides, and de-icer, to name a few. However, limited data is available as to the concentration of PCBs in products used for road and facility maintenance.

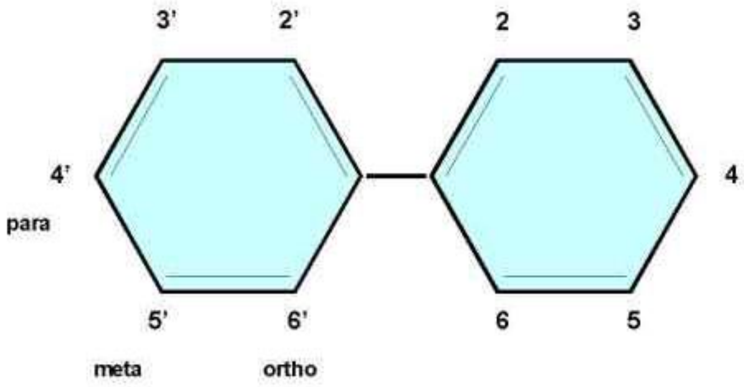
Nearly 50 product samples were collected and analyzed for PCBs using EPA Method 1668C. This method is capable of detecting low concentrations of PCBs for all 209 congeners. The majority of samples were composed of roadway, pipe, and vehicle maintenance products. Because PCBs are also ubiquitously detected in sanitary wastewater samples, five personal care products were sampled as well.

PCB 101

Chemical Structure

PCB molecules are composed of two joined benzene rings with varying degrees of chlorination, as depicted in Figure 1. PCBs can have between one and ten chlorine atoms. There are 209 different arrangements of this molecule, each known as a congener. Congeners are named PCB-1 through PCB-209, with greater numbers corresponding to greater degrees of chlorination. Homologues are the group of PCB molecules having the same degree of chlorination. For example, monochlorobiphenyls (monoCB) is the group of PCBs having one chlorine, dichlorobiphenyls (diCB) are the group of PCBs having two chlorines, etc.

MonoCBs = 1 chlorine
DiCB = 2 chlorines
TriCB = 3 chlorines
TetraCB = 4 chlorines
PentaCB = 5 chlorines
HexaCB = 6 chlorines
HeptaCB = 7 chlorines
OctaCB = 8 chlorines
NonaCB = 9 chlorines
DecaCB = 10 chlorines (PCB-209)



Structure of Polychlorinated Biphenyl (PCB) Molecule

Figure 1. (EPA, 2010b)

During the laboratory analytical process, some congeners cannot be distinguished from one another and are quantified as a complex of more than one congener. These are known as coeluting congeners, and are denoted with a slash in the figures in this report (e.g. 5/8).

Aroclors

Monsanto was the major US manufacturer of PCBs, and sold them under the trade name Aroclor until 1977 (Erickson, 1986). Aroclors were made of standard PCB mixtures to achieve the desired chemical properties. Each type of Aroclor was given a 4-digit identification number, with the second two digits indicating percentage of chlorine by weight (ASTDR, 2000). For example, Aroclor 1254 contains about 54% chlorine by weight. Homologue patterns for standard Aroclor mixes are shown in Appendix A. Homologue patterns for environmental and product samples can be compared to homologue patterns for Aroclors to give clues as to whether the PCB content may be a legacy Aroclor or not.

METHODOLOGY

Product Selection

Municipalities use numerous products in the roadway environment for construction, traffic safety, and maintenance purposes. Little is known about the PCB content in these products. To help guide product sampling, a literature search was performed to determine the potential for products to contain PCBs. In general, processes that involve chlorine, carbon, and high temperatures have the potential to inadvertently produce PCBs (Munoz, 2007).

Numerous studies have associated pigments with inadvertent PCB production (Christie, 2014; Ecology, 2014; Hu and Hornbuckle, 2010; Rodenburg, 2012). In particular, yellow pigments and white pigments (titanium dioxide) are associated with PCB-11, 206, 208, and 209. Yellow, orange, and red products that are derived from azo pigments (monoazo (Hansa Yellows and azonaphthols) and diarylide yellows) are associated with inadvertent PCB production, as are phthalocyanine blues and greens. Therefore, many items sampled for this study contained colored items. Various yellow and white road paints were sampled as well as hydrant paint and utility locate paint. Personal care products were selected that contain pigments.

Inadvertent PCB production is also associated with the manufacture of a multitude of various other chlorinated chemicals. Table 1 shows chemicals associated with various products that can be exposed to stormwater or enter the wastewater system:

Table 1. Example of Chemicals Associated with Inadvertent PCB Production

Chemical	Associated Products
Ethylenediamine	Surfactants, fungicides, fuel additives, EDTA, hair care products, soaps
Ethylene dichloride	Polyvinyl chloride (PVC), solvents
Phenylchlorosilanes	Silicones: lubricants, adhesives, coatings, hoses
Chlorinated benzidines	Pigments
Chlorinated paraffins	Flame retardants in plastics, paints, adhesives, sealants, and caulks
Glycerol/Glycerin (synthesized by epichlorohydrine)	Toothpaste, numerous personal care products, antifreeze, resins

(Information in this table adapted from Munoz, 2007)

One of the most consistent illicit discharge complaints received by the City of Spokane is vehicles dripping fluids onto the roadway. In 2011, the City sampled various off-the-shelf motor oils and transmission fluid to assess the potential for PCBs to enter stormwater through this pathway. PCBs were detected in appreciable concentrations in each of the samples, as shown in Table 2. Because PCBs are known to be present in these materials, additional motor oils and other petroleum products were sampled for this product sampling study.

Table 2. Oil and Transmission Fluid Sample PCB Concentrations (City of Spokane, 2011)

Sample	Total PCB, micrograms per kilogram (ppb) (EPA Method 1668)
Pennzoil SAE5W-30	37.8
Quaker State SAE5W-30	14
Valvoline Mercon V	49.5
Red Line D4 Automatic Transmission Fluid	8.8
Valvoline Full Synthetic 5W-30	116

One of the objectives of this project is to inform municipalities across the state. To gain a better understanding of which products and brands are most widely used, a survey was distributed across the state to willing participants. Ten jurisdictions responded, 6 from eastern Washington and 4 from western Washington. Results of the survey showed that one traffic paint brand is commonly used on both sides of the state under a state contract with WSDOT. Other product brands varied widely across the region, and the brand names used by the City of Spokane were not uncommon, so the products available at the City of Spokane were sampled.

Quality Assurance Project Plan (QAPP)

A QAPP was prepared for this project and approved by Ecology prior to the collection of samples (LimnoTech, 2014). A copy of the QAPP is available upon request.

Experimental Design

Ultra clean sampling techniques were followed to reduce the chance of sample contamination from ambient sources. Samples were collected August to October, 2014. Products were placed directly into laboratory-prepared sample jars whenever possible. Where equipment was necessary to remove the sample from its container and place it into the sample jar, clean decontaminated equipment was used.

Each product was assigned a three-digit Product ID number. Liquid and gel samples were placed in 40-milliliter glass vials. Solid samples were placed in 4-ounce glass jars. Pipe samples were wrapped in aluminum foil. Spray paint samples were sent to the laboratory in the original spray cans. All readily available product information was recorded at the time of sampling, including product type, brand name, lot number, manufacture date and country of origin in addition to standard sampling information such as time and date, sampler, and sample location.

Four field replicate samples were collected for field sampling quality control purposes. Replicate samples were collected for product ID 001, 003, 008, and 018.

A chain of custody form was filled out for each sample batch. Samples were packed into coolers, chilled to a maximum of four degrees Celsius, and shipped to Pacific Rim Laboratories for analysis. Samples were analyzed using EPA Method 1668C for all 209 PCB congeners.

Laboratory Quality Control

The laboratory maintains internal quality control procedures, including method blanks, laboratory control samples, laboratory duplicates, and labeled compound, cleanup, internal, and injection standards. In addition, data verification was performed by the City's project quality assurance (QA) officer. Data was validated by both the laboratory and the QA officer and was found to be acceptable.

EPA Method 1668 detects PCBs at very low concentrations. PCBs are truly ubiquitous and can be detected in even the most pristine laboratory environment. Therefore, PCBs are frequently detected in blank samples. To account for this, any congener that was detected in a product sample that was within three times the concentration detected in the associated blank sample were removed from the total PCB value. These congeners are also not included in the graphs in this report.

RESULTS AND DISCUSSION

The results of PCB product sampling are summarized in Table B-1 of Appendix B and in more detail in the following sections. PCBs were detected in all but two of the products that were sampled in the parts per trillion to parts per million range. The units reported by the laboratory are in micrograms per kilogram (ug/kg), or parts per billion. Note that Spokane water quality standards are 1.3 picograms per liter, or parts per quadrillion. One part per billion is 1,000,000 times greater than one part per quadrillion. Therefore, products detected at these concentrations are of concern to water quality practitioners.

Traffic Marking Samples

Several traffic paint samples were collected due to the association between yellow and white pigments and PCBs. One brand of traffic paint is predominantly used by municipalities and agencies throughout the state, sold by Ennis-Flint. Various types of this paint brand are available. Product numbers 983711 and 983712, low VOC, 100% acrylic waterborne traffic line paint, were sampled from the end of a spray nozzle in a City of Spokane shop. A liquid sample, replicate liquid sample, and a dried sample were analyzed (each for white and yellow). The paint was collected in a clean glass beaker and then immediately distributed to each of the sample vials. Dried paint samples were created by City of Spokane staff by pouring a small amount of paint onto a clean Teflon liner and allowing it to dry before sending it to the laboratory for analysis. The purpose of analyzing the dried sample was to determine if some PCB congeners are volatilized after paint application. Ennis-Flint PreMark thermoplastic road striping was also sampled, both in yellow and white.

For comparison, a lesser-used brand of road paint was sampled. Sherwin-Williams Promar solvent based acrylic traffic marking paint is used by some municipalities in southeast Washington. Samples were collected for both yellow and white paint. Replicates of all of the traffic marking samples (except the dried paint) were shipped to Ecology for their own product sampling study. Results of Ecology's analysis will be reported by Ecology. Total PCBs are shown in Tables 3 and 4 along with the percentage of the three most prevalent congeners, PCB-11, 77, and 209.

Table 3. Yellow Traffic Marking

Type	Total PCB (ug/kg)	PCB-11	PCB-77	PCB-209
Ennis	0.73	7%	35%	36%
Ennis (replicate)	2.69	17%	58%	8%
Ennis (dried)	0.565	9%	39%	35%
Promar	64.88	98%	1%	0%
Thermoplastic	10.78	79%	1%	0%

Table 4. White Traffic Marking

Type	Total PCB (ug/kg)	PCB-11	PCB-77	PCB-209
Ennis	0.41	18%	0%	61%
Ennis (replicate)	0.4	23%	0%	57%
Ennis (dried)	0.38	17%	0%	69%
Promar	0.28	41%	1%	0%
Thermoplastic	3.33	22%	0%	0%

Figure 2 shows the congener patterns for both the wet and dried Ennis yellow traffic marking paint samples. Generally the same congeners were detected in each of the samples, with slightly lower concentration in the dried sample than the liquid paint sample. This suggests that some congeners may be volatilizing into the air. However, as the difference in the liquid and duplicate liquid sample show, further study would be warranted to better determine volatilization rates. The Material Safety Data Sheet (MSDS) indicates that the paint composition contains methyl alcohol, titanium dioxide, propylene glycol, 2-butyoxyethanol, and quartz. Pigment content is not listed.

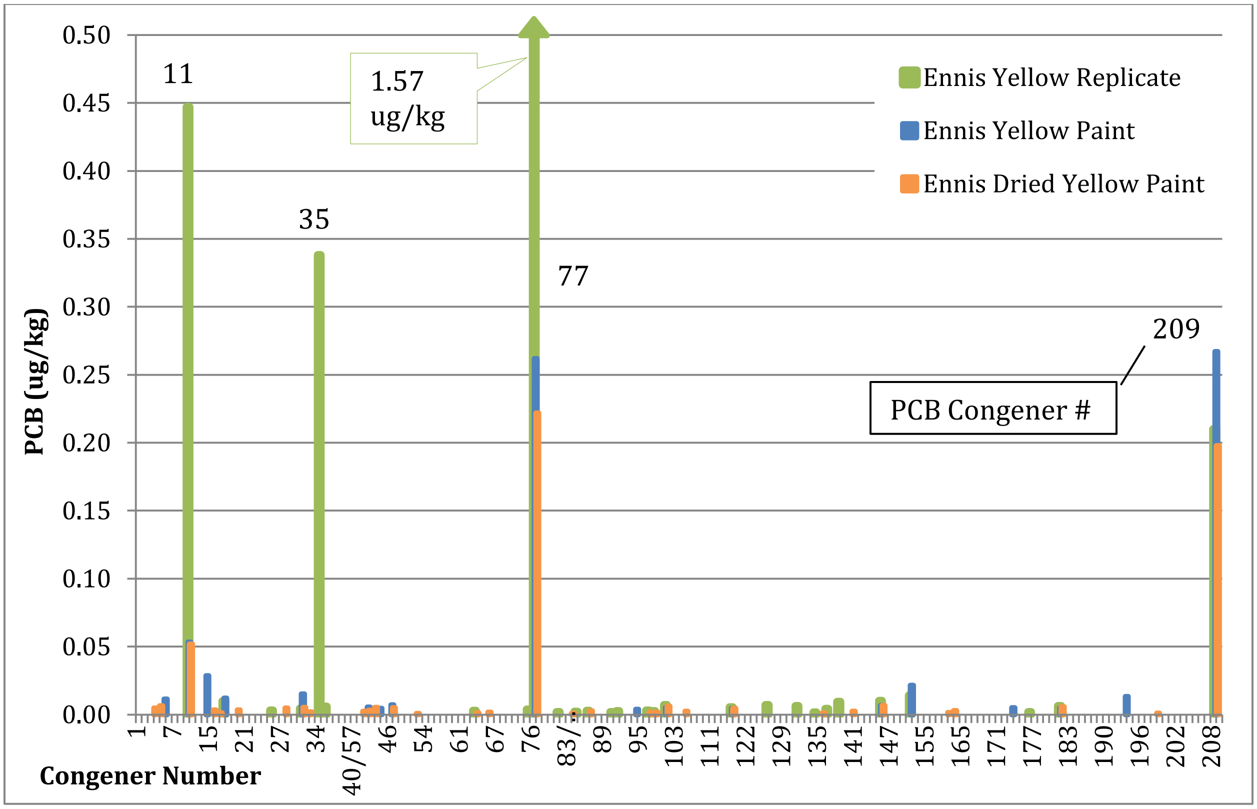


Figure 2. Ennis Wet and Dried Yellow Paint PCB Congeners

Figure 3 shows the congener patterns for the wet and dried Ennis white paint samples. The congener patterns are similar between the three samples. There is no discernible difference between the liquid and dried samples. Interestingly, PCB-11 was detected in the white paint samples in greater concentration than two of the yellow paint samples, although PCB-11 is usually associated with yellow pigment. The concentration of PCB-209 is similar between the yellow and white samples. The MSDS sheets for these products indicate that the yellow paint contains 3-7% titanium dioxide and the white paint contains 7-13% titanium dioxide.

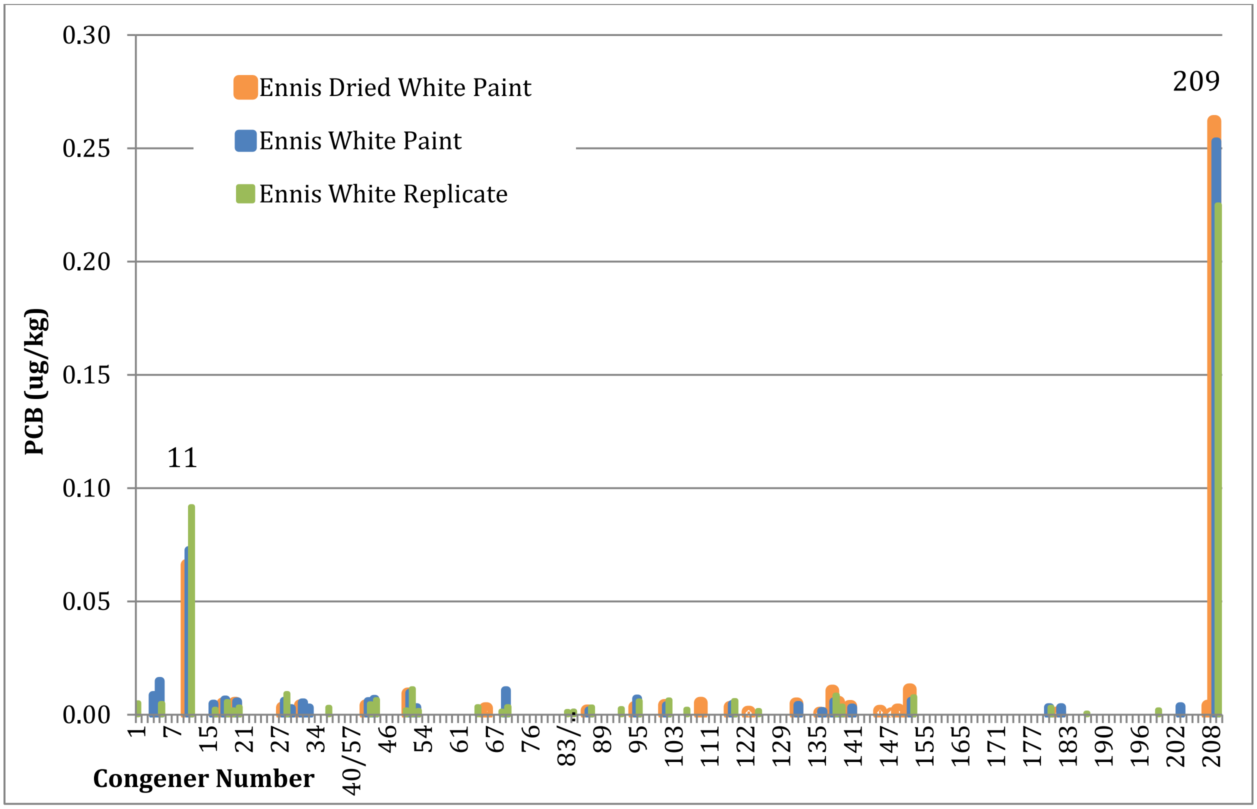


Figure 3. Ennis Wet and Dried W Paint PCB Congeners

Sherwin-Williams Promar yellow and white paint samples are shown in Figure 4. PCB-11 was detected in the yellow paint sample at a significant concentration of 63.8 ug/kg. PCB-35 and 77 were detected similar to the Ennis paint, but PCB-209 was not detected. The MSDS indicates that both white and yellow paints contain ethylbenzene, xylene, acetone, quarts, and titanium dioxide (2% titanium dioxide by weight for yellow and 4% for white). Both yellow and white paints contain approximately 55% pigment by weight.

Figure 5 shows congener patterns for the yellow and white Ennis-Flint PreMark thermoplastic tape samples. Total PCBs are greater than the paint samples (see Table 4 and 5), and there are more congeners detected. Most of the congeners are in the mono-CB through tetra-CB range (having one through four chlorine atoms). The MSDS for this product indicates that it contains the following components in increasing order of concentration: pigments, alkyd resins, polymers, fillers, and glass beads.

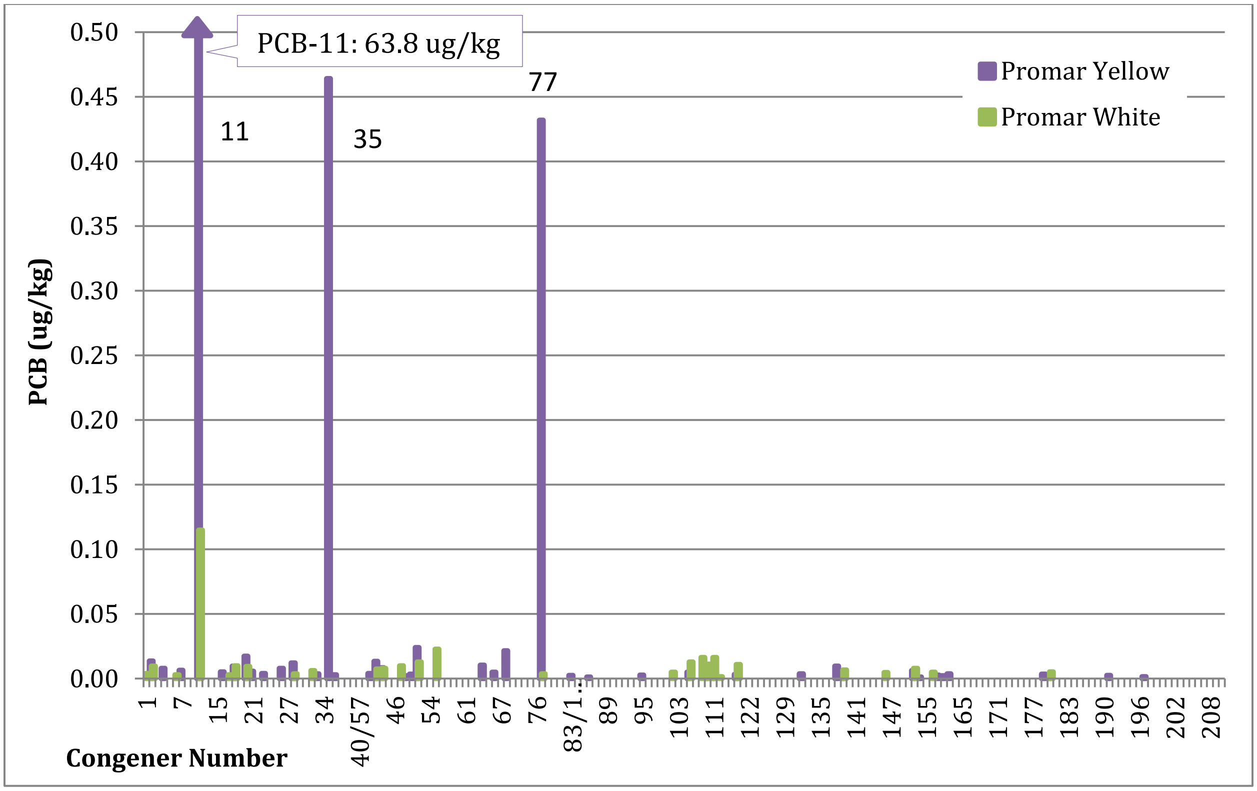


Figure 4. Sherwin-Williams Promar Yellow and White Paint Congeners

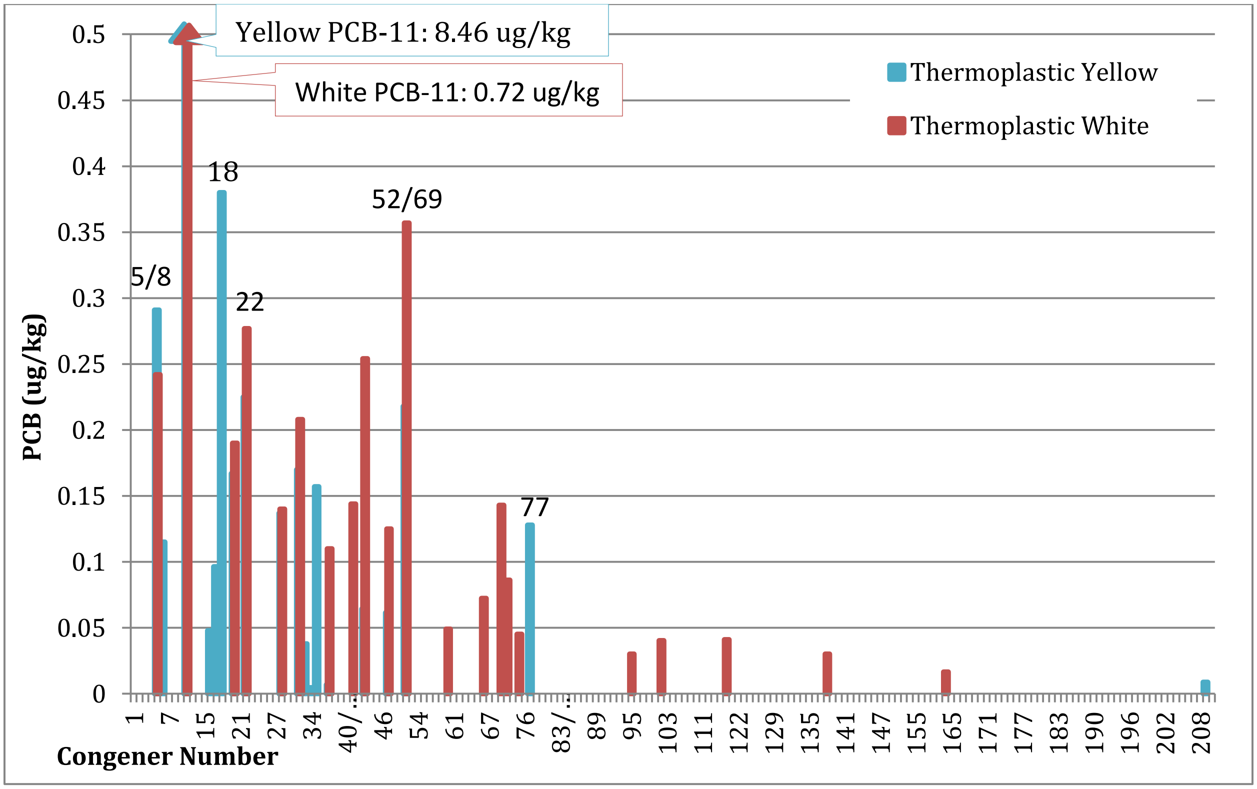


Figure 5. Ennis PreMark Thermoplastic Tape Congners

For samples that have a wide array of PCB congeners, such as the white thermoplastic tape sample, a homologue pattern graph can be a useful tool. These graphs depict the percentage of various homologues that make up the total PCB sample. Figure 6 shows the homologue patterns for both the yellow and white thermoplastic tape samples. The white thermoplastic tape, in particular, has a similar homologue and congener pattern to Aroclor 1016 (Appendix A). Yellow thermoplastic tape also has a similar pattern, but is dominated by PCB-11, a diCB. Aroclor 1016 was one of the lesser used Aroclor mixtures and was used in capacitors.

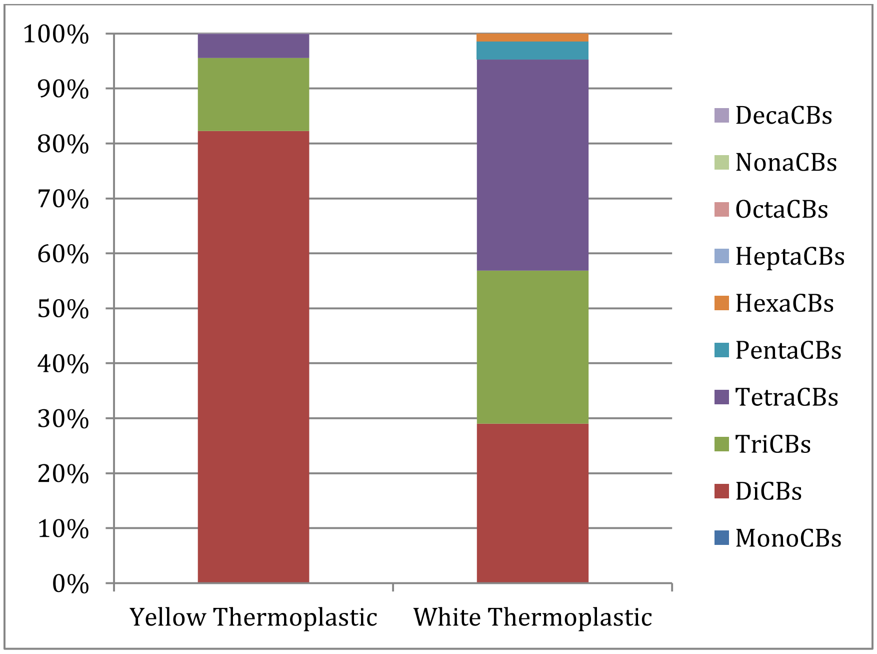


Figure 6. Thermoplastic Tape Homologue Patterns

Hydrant and Utility Locate Paints

Two additional types of paint commonly used on or near roadways were sampled. Fire hydrants are re-painted periodically using spray cans, typically in an aluminum color on the barrel and red on the nozzles. Rustoleum Professional High Performance Enamel Fast-Dry spray paint in Silver Aluminum was sampled. The product contains acetone, liquefied petroleum gas, toluene, xylene, aluminum flake, and ethylbenzene. Total PCBs detected in the sample were **0.0032 ug/kg**, consisting of only the congener PCB-19.

Utility locate paint is sprayed on or near the roadway frequently to mark underground utilities in a variety of colors, including pink, white, green, blue, purple, yellow, orange, and red. The green color denoting sewer utilities was sampled. The product sampled was Rustoleum Industrial Choice Solvent-Based Precision Line inverted marking paint in safety green. The total PCBs detected were **21.527 ug/kg**.

Ingredients listed on the green utility locate paint MSDS include acetone, liquefied petroleum gas, aliphatic hydrocarbon, limestone, xylene, modified alkyd, barium sulfate, talc, naptha (petroleum, hydrotreated light), titanium dioxide, ethylbenzene, and toluene. Most of the ingredients listed on the MSDS (with the exception of titanium dioxide) are not specifically listed as having the potential to inadvertently produce PCBs in the Munoz (2007) paper, although there may be unlisted intermediate compounds that may produce PCBs. The most likely source of PCB is the pigment, and is most likely a phthalocyanine green based on the presence of PCB-11, 206, 207, 208, and 209. Titanium dioxide may also be contributing to the PCB-206, 208, and 209. On the Rustoleum product website, “phthalo green” is a common pigment used in various paint products, although not specifically listed for this product. The pigments used are proprietary information and would not be shared by the company.

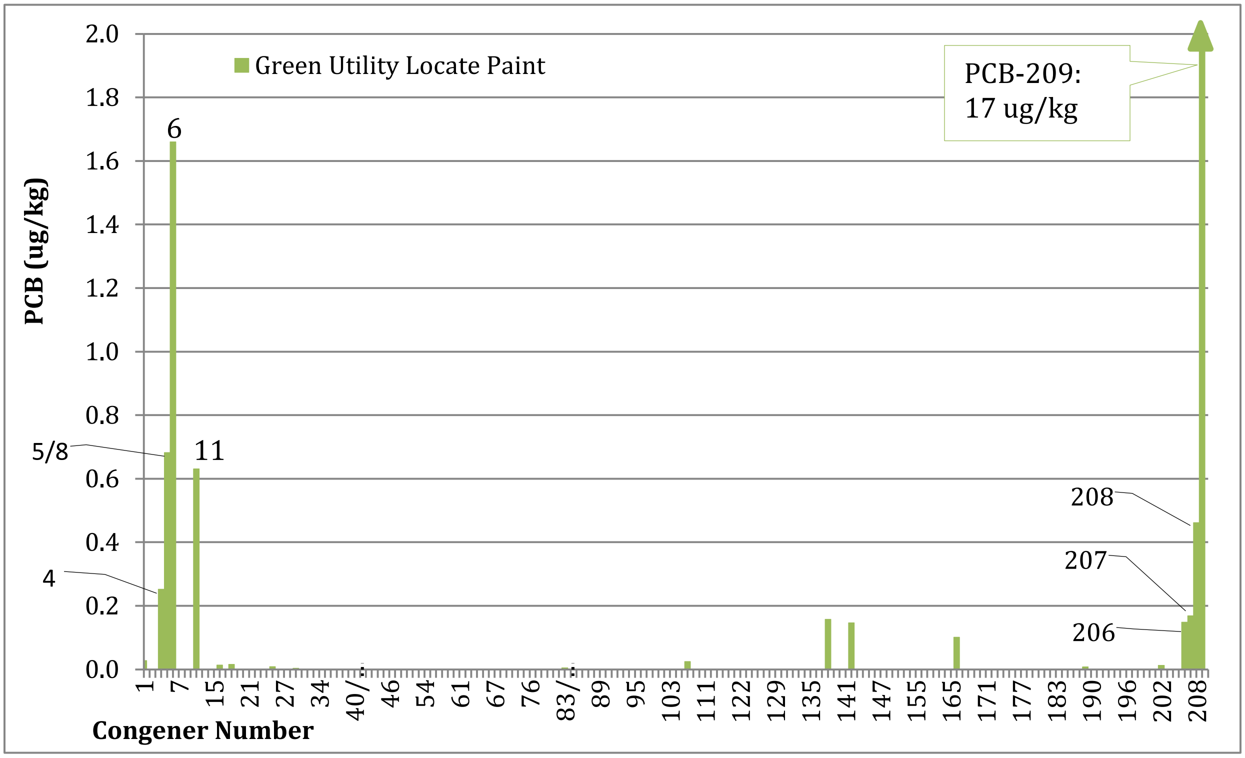


Figure 7. Green Utility Locate Paint Congeners

Deicer

The City of Spokane uses FreezeGard magnesium chloride for roadway deicing. Of the municipalities surveyed, most in eastern Washington use magnesium chloride while most in western Washington use calcium chloride. The Washington State Department of Transportation (WSDOT) Eastern Region uses an enhanced salt brine with sugar beet boost. Both the City of Spokane and WSDOT deicers were sampled. Total PCBs are shown in Table 5.

Table 5. Deicer Total PCB

Sample	Total PCB (ug/kg)
Magnesium Chloride	1.332
Magnesium Chloride Replicate	1.952
SB Boost	0.038

The magnesium chloride is sourced from naturally occurring minerals in the Great Salt Lake.

The magnesium chloride samples were dominated by tetraCBs, while the SB Boost sample congeners were distributed between the triCB to heptaCB range. Homologue patterns are shown in Figure 8 and congener patterns are shown in Figure 9.

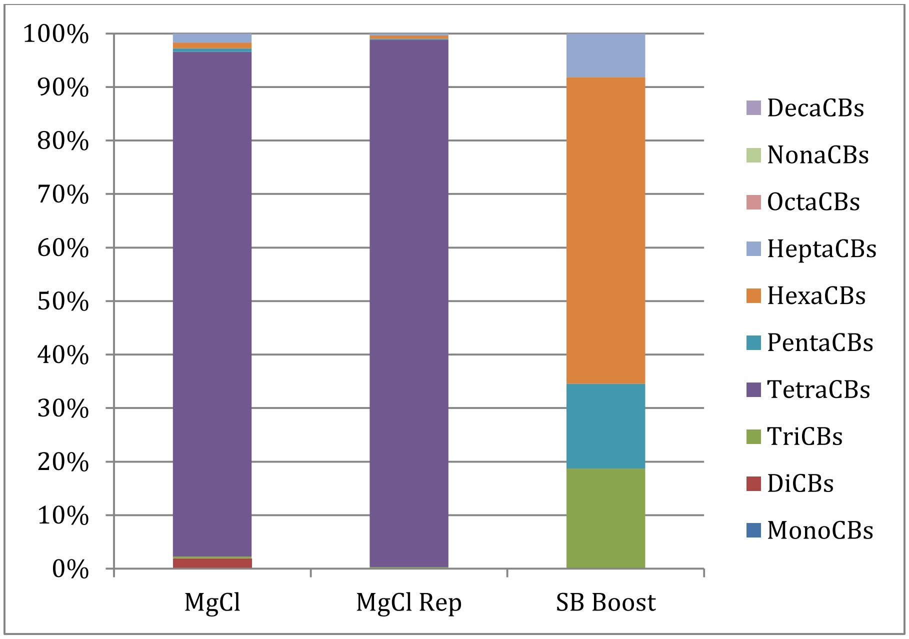


Figure 8. Deicer Homologue Patterns

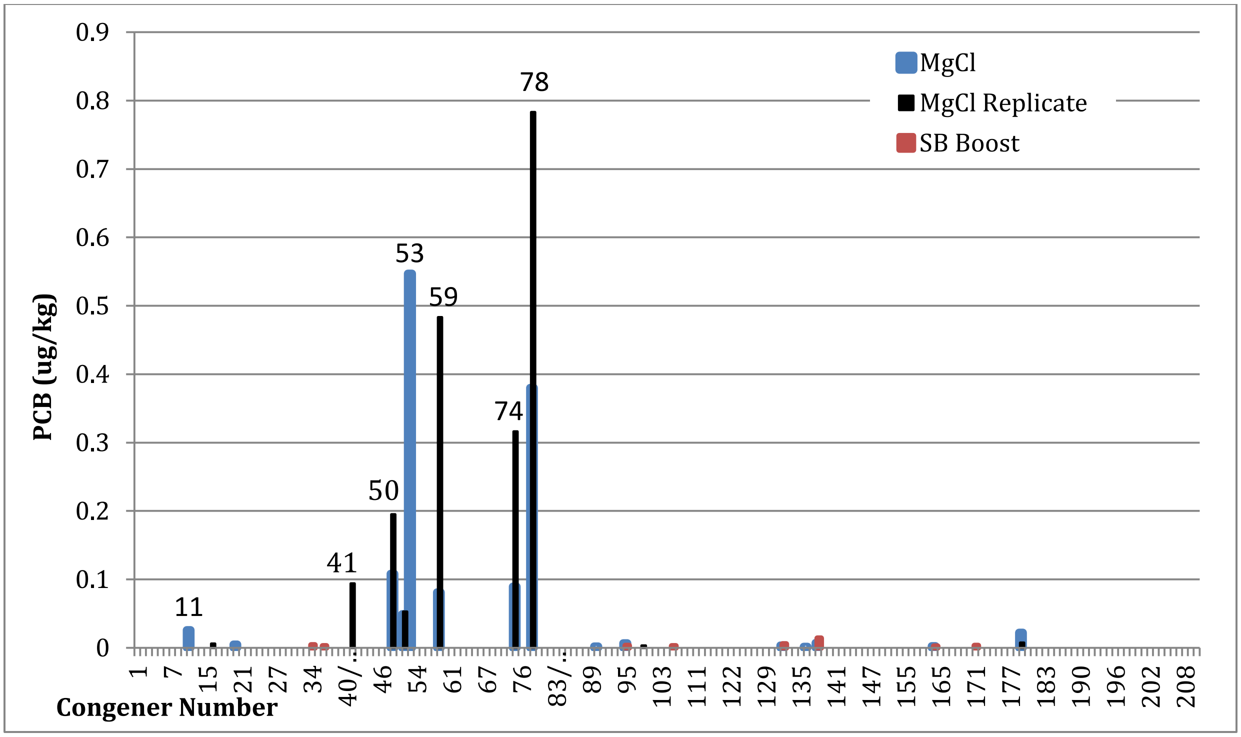


Figure 9. Deicer PCB Congeners

Antifreeze

Antifreeze mixtures may contain inadvertently generated PCBs, particularly those made with glycerol (also known as glycerin) synthesized from epichlorohydrine (Munoz, 2007). Kool Green Extended Life antifreeze was sampled, which contains a yellow color. The MSDS indicates that it contains ethylene glycol, diethylene glycol, and proprietary additives, inhibitors, and dye. The ethylene and diethylene glycols and glycerol have a similar chemical structure, but are not the same compound. Total PCB detected in the sample was **0.018 ug/kg**. Despite its yellow color, PCB-11 was not detected in the sample.

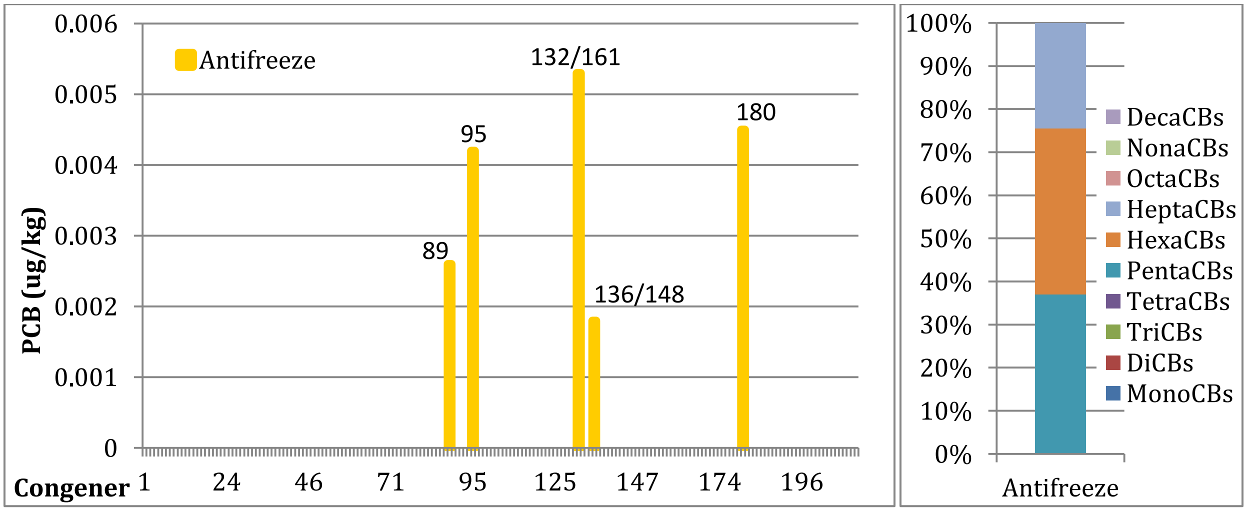


Figure 10. Antifreeze PCB Congeners and Homologue Patterns

Pesticides

Three types of pesticide and one adjuvant were sampled, including Weedar 64 (2,4-D formula), Portfolio 4F, Roundup Pro Max, and the adjuvant Crosshair. The chemical processes that make up chlorinated pesticides have been broadly determined by EPA to have a high potential for inadvertent PCB generation (Munoz, 2007).

PCBs were **non-detect** in the Weedar 64 sample and laboratory duplicate. None of the congeners were flagged for blank contamination. The main ingredients listed on the MSDS are 2,4-dichlorophenoxy acetic acid (2,4-D), dimethylamine salt, and trade secret inert ingredients. Interestingly, chemicals with similar structures to 2,4-D, including trichlorophenoxy acetic acid and dichlorophenyl acetic acid are listed as having the potential for inadvertent PCB generation, but 2,4-D is not (Munoz, 2007).

The total PCBs detected in the Portfolio 4F sample were **6.89 ug/kg**. The majority of this sample was composed of the coeluting congeners PCB-64 and 72. Sulfentrazone is the active ingredient in Portfolio 4F, making up about 40% of the product. Its chemical name is N-[2,4-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]phenyl]methanesulfonamide. Other ingredients include toluene and propylene glycol.

Total PCBs detected in the Roundup Pro Max sample were **0.012 ug/kg**. The active ingredient, making up about 49% of the product, is potassium salt of N-(phosphonomethyl) glycine (potassium salt of glyphosate). Glycine is listed as a chemical product having the potential to contain inadvertently generated PCBs (Munoz, 2007).

The sample of the adjuvant Crosshair contained **0.316 ug/kg** total PCBs. It is composed of methyl ester, modified soybean oil. Soybean oil can be modified through a number of different processes. One option is to synthesize it from epoxidised soybean oil using methylene chloride (Xu et al., 2011). If this process was used, it could possibly be the pathway for inadvertent PCB generation because chlorine is introduced in the process. Glycerine is also a byproduct of this process, which is also listed as a potential inadvertent PCB generating substance when a chlorinated compound is used (Munoz, 2007). Figure 11 shows the congeners detected in the pesticide and adjuvant samples.

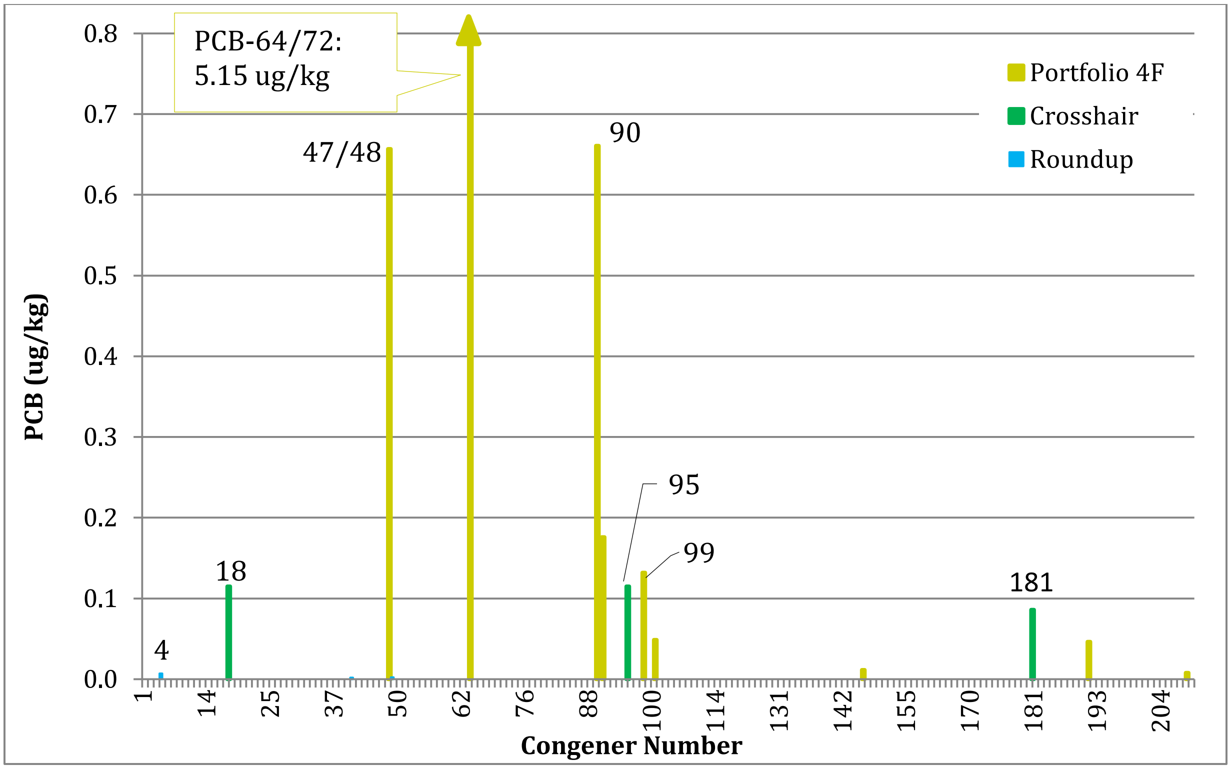


Figure 11. Pesticide and Adjuvant Congeners

Motor Oil and Lubricant

The Fleet Maintenance department primarily uses ConocoPhillips Firebird SAE 15W-40 Heavy Duty EC oil to maintain the City's vehicle fleets. This oil is made from greater than 50% re-refined base stocks. Because this same oil is used in many vehicles and serviced at the same shop, there was an opportunity to sample the same type of oil both before use and after an oil change for comparison. Additionally, Valvoline Full Synthetic SAE 5W-30 was sampled off-the-shelf from a local automotive store. This oil was sampled by the City in 2011 and contained the greatest concentration of PCBs of the oils sampled (see Table 2). A lubricant, MP Gear Lube SAE 85W-140 by Phillips 66 was also sampled. Total motor oil and lubricant PCB concentrations sampled in 2014 are shown in Table 6.

Table 6. Motor Oil and Lubricant Total PCBs

Sample	Total PCB (ug/kg)
Firebird 15-40 Bulk	0.856
Used Firebird 15-40 Bulk	0.502
Used Firebird 15-40 Bulk Replicate	2.375
Valvoline Full Synthetic 5-30	0.969
Gear Lube	0.623

There was a wide range of PCB congener distribution for the various oil and lubricant samples. Most of the congeners were in the low to mid chlorinated range. The used Firebird motor oil sample and its duplicate were not similar to each other in total PCB concentration or congener distribution as a result of its heterogeneity.

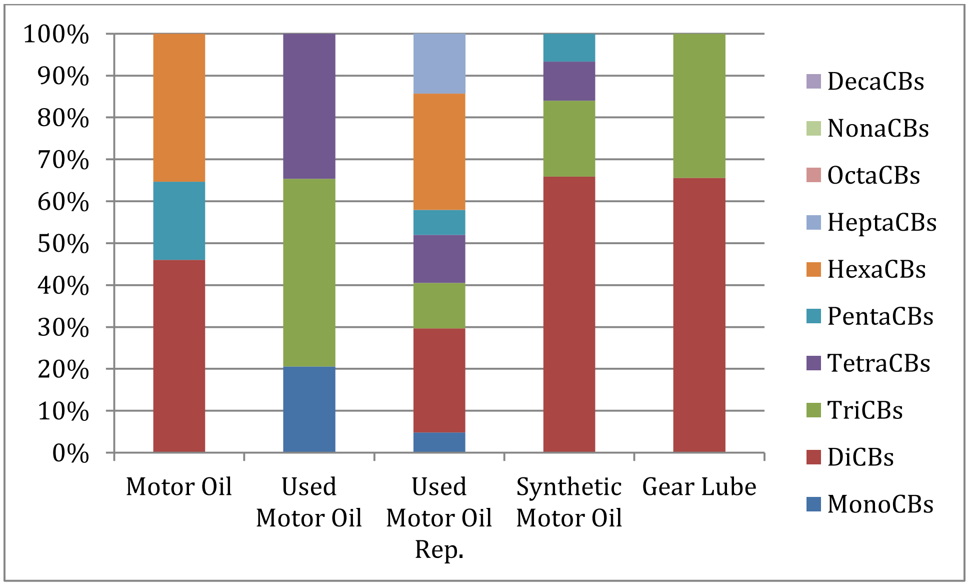


Figure 12. Motor Oil and Lubricant PCB Homologue Patterns

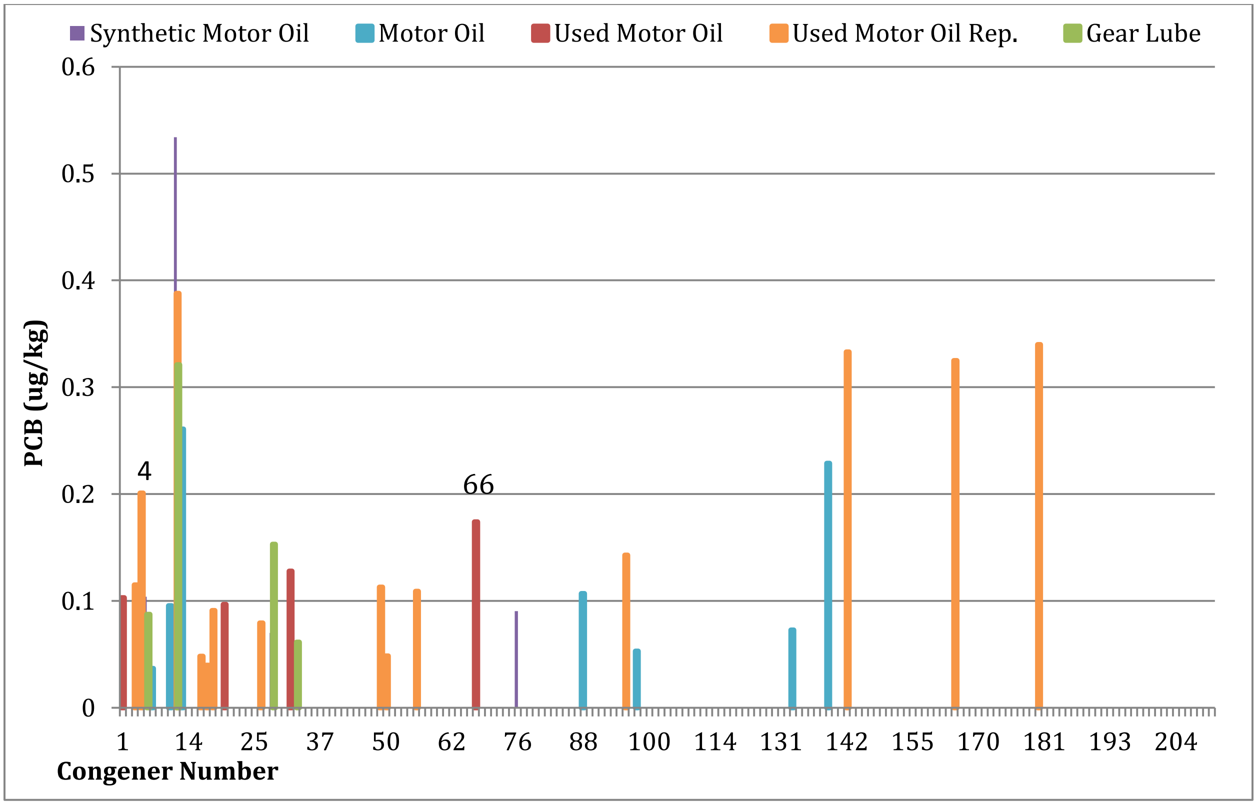


Figure 13. Motor Oil and Lubricant PCB Congeners

Gasoline and Diesel

Regular unleaded gasoline and #2 dyed diesel were sampled from the fuel tanks at the City's Riverside Park Water Reclamation Facility. The diesel sample was non-detect. During laboratory analysis, coextracting interferences resulted in the detection limits being raised to 2 ug/kg for each of the monoCB, diCB, and triCB congeners. Therefore, PCBs may still be present in diesel at less than 2 ug/kg per congener, but were unable to be detected due to interferences.

The total PCBs for the gasoline sample was **0.935 ug/kg**. Nearly all of the sample was composed of PCB-2 (0.93 ug/kg). The remainder was the coeluting congeners PCB-138 and 160.

Dust Suppressant

The City of Spokane has some unimproved roads that have not been paved and require dust control. Three forms of dust control approved for use in the City are magnesium chloride (at a different concentration than the deicer), emulsified asphalt dust abatement (EADA), and lignosulfonate. Samples were collected from each of these three dust suppressants.

The magnesium chloride dust suppressant brand is DustGard, made from naturally occurring minerals from the Great Salt Lake. EADA is a petroleum-based product, containing primarily petroleum asphalt and petroleum bitumen with water and a proprietary mix of petroleum distillates, polymer modifier, surfactants, emulsifier, and other additives. Ligno Road Binder lignosulfonate is derived from natural polymers in wood, and contains sucrose, plant fiber, and an aquatic solution according to its MSDS.

Table 7. Dust Suppressant Total PCBs

Sample	Total PCB (ug/kg)
EADA	0.091
Lignosulfonate	0.086
Magnesium Chloride	3.574

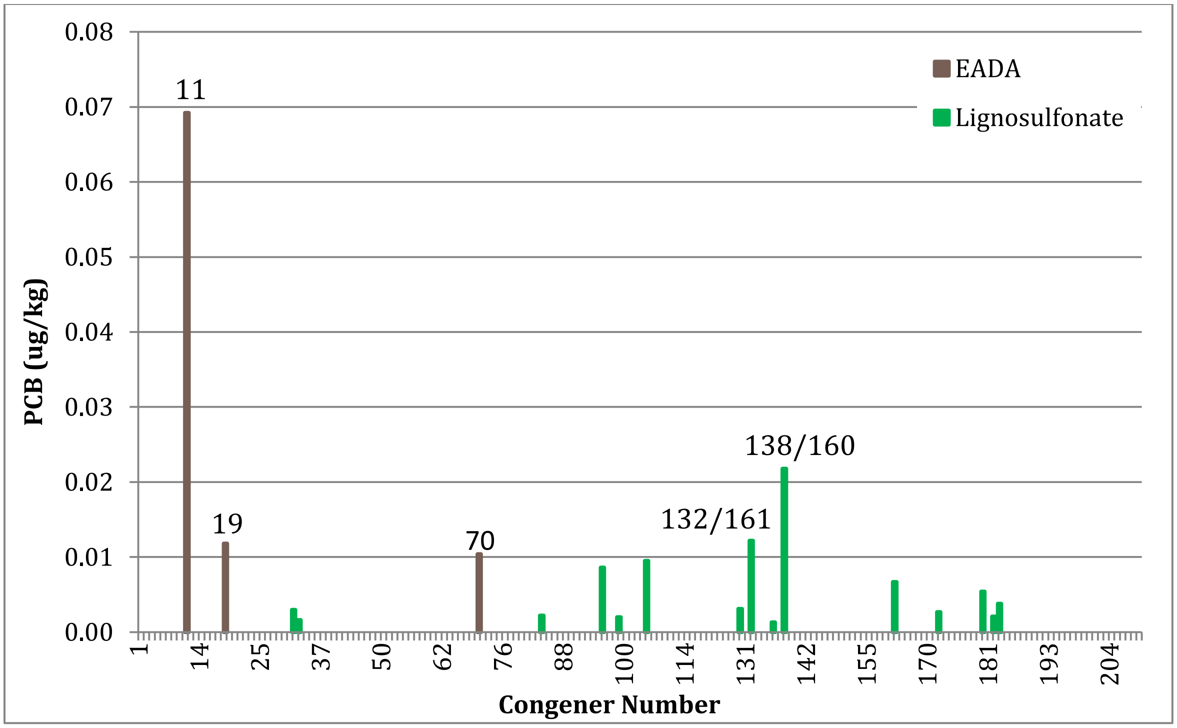


Figure 14. EADA and Lignosulfonate Congeners

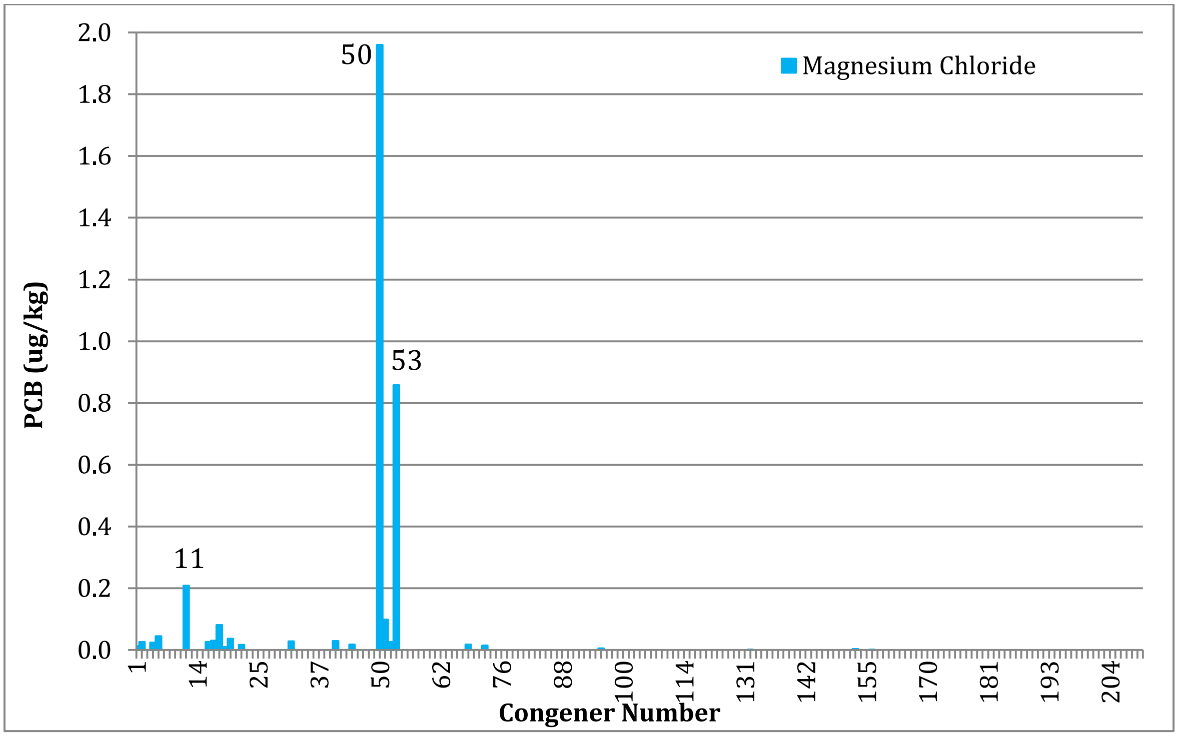


Figure 15. DustGard Magnesium Chloride Congeners

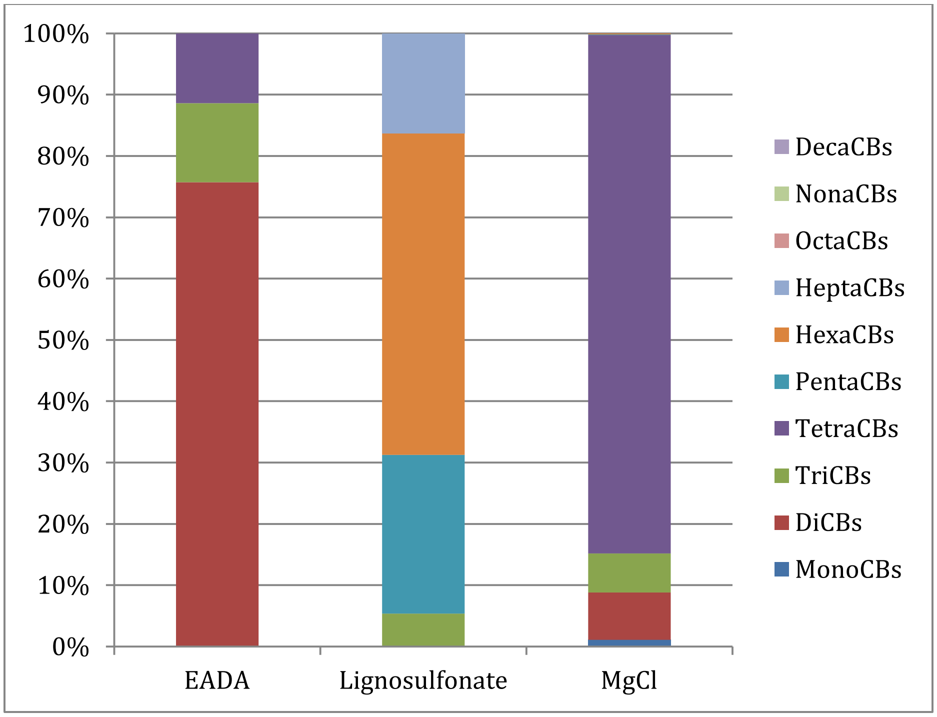


Figure 16. Dust Suppressant Homologue Patterns

The homololgue pattern for EADA is similar to synthetic oil (Figure 12), dominated by diCBs with lesser percentages of triCBs and tetraCBs. Lignosulfonate has a somewhat similar homologue pattern to Aroclor 1260, but the individual congener patterns don't match up well (see Appendix A).

Asphalt Related Products

The asphalt products that were sampled include asphalt tack, crack sealer, and an asphalt release agent. Asphalt tack is made of an asphalt emulsion, and is placed between old and new asphalt layers to adhere them to one another. The crack sealer, SA Premier, is made of asphalt, vacuum distillate, petroleum distillate, styrene-butadiene block copolymer, vulcanized rubber compound, mineral filler, methyl methacrylate, and linear low density polyethylene. The asphalt release agent brand is Soy What by TechniChem, and is "crafted from a by-product that is extracted from soybeans," according to the technichemcorp.com website. Total PCBs and congener and homologue patterns are shown in the following table and figures.

Table 8. Asphalt Related Product Total PCBs

Sample	Total PCB (ug/kg)
Asphalt Tack	0.085
Crack Sealer	7.975
Asphalt Release Agent	0.558

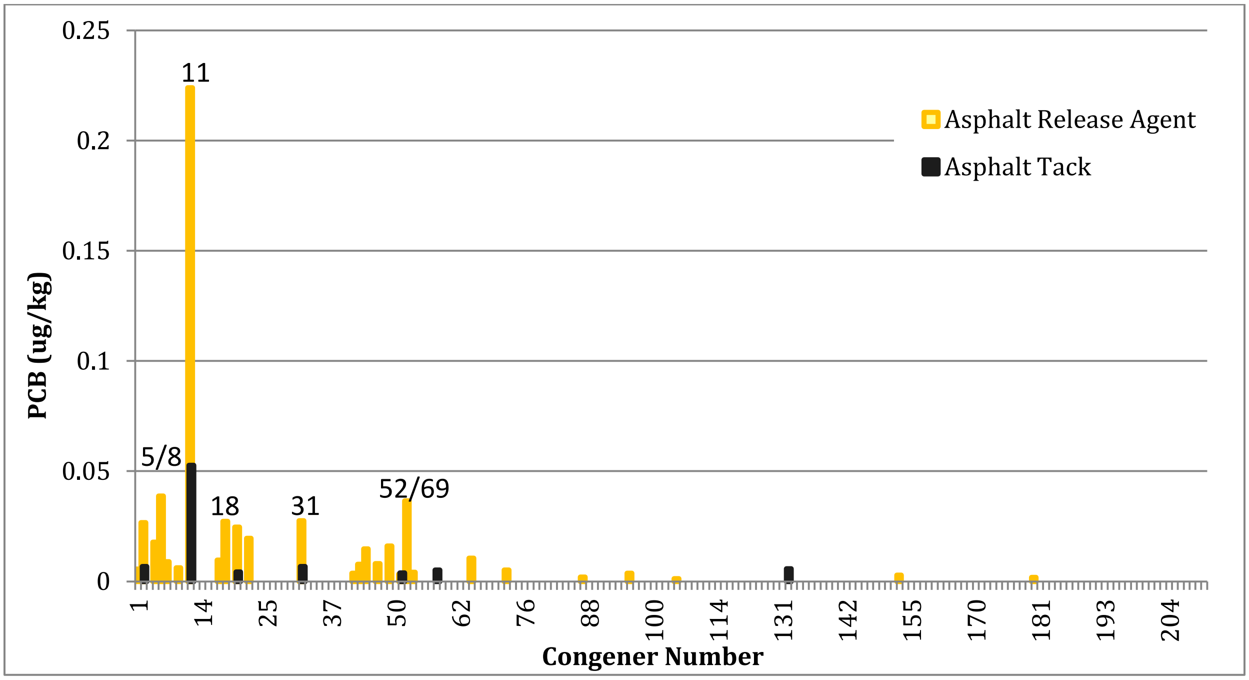


Figure 17. Asphalt Release Agent and Tack Congener Patterns

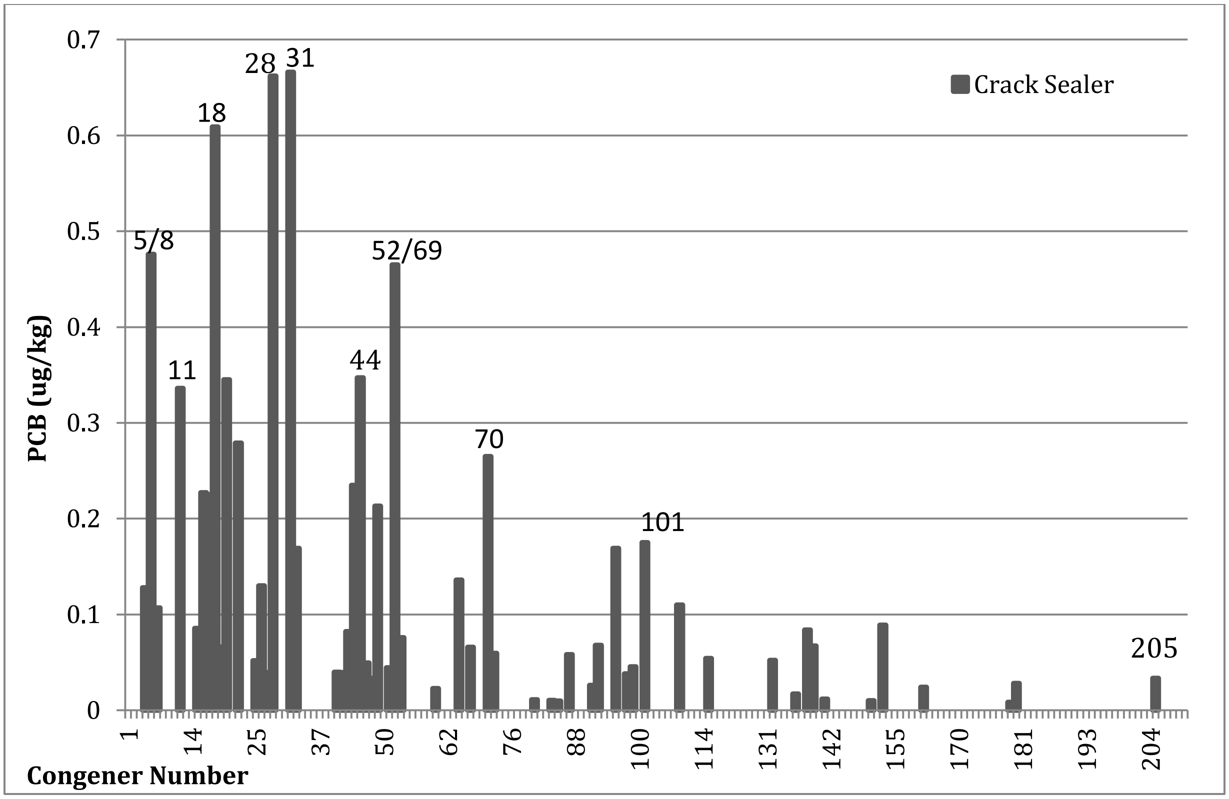


Figure 18. Crack Sealer Congener Pattern

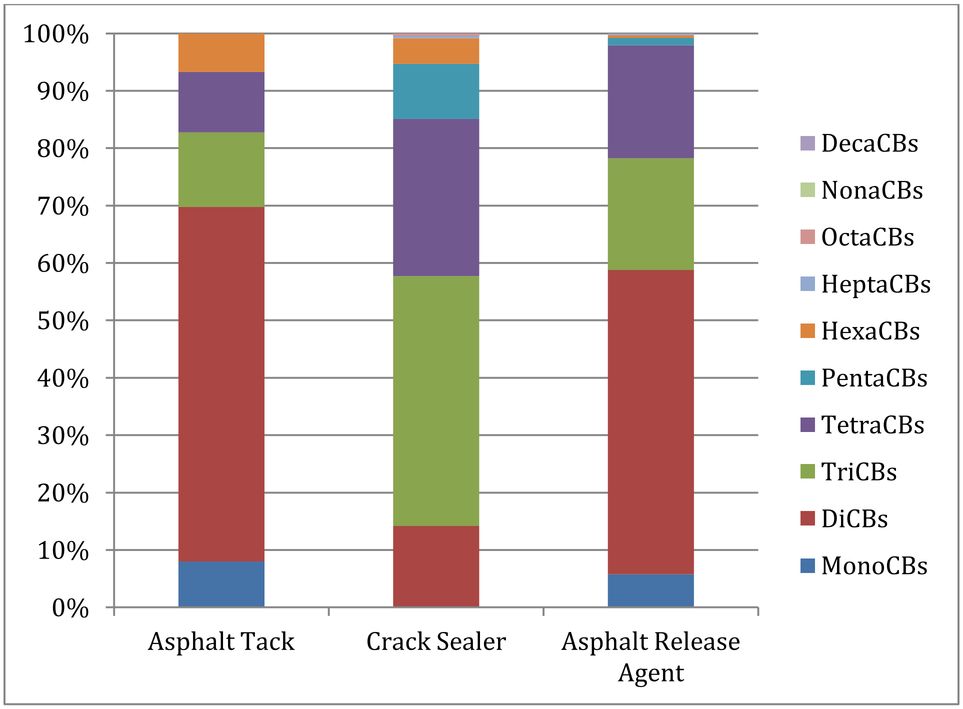


Figure 19. Asphalt Product Homologue Patterns

The crack sealer has a similar congener and homologue pattern to Aroclor 1242. The congeners from the crack sealer sample were converted to percent of total PCB by weight and are plotted against Aroclor 1242 in the same units in Figure 20. Aroclor 1242 had a wide variety of end uses, one of them being in rubbers. One of the ingredients in the crack sealer is vulcanized rubber compound. PCB-11 was detected at over 4% of the crack sealer PCB composition, but is not present in most Aroclor mixes.

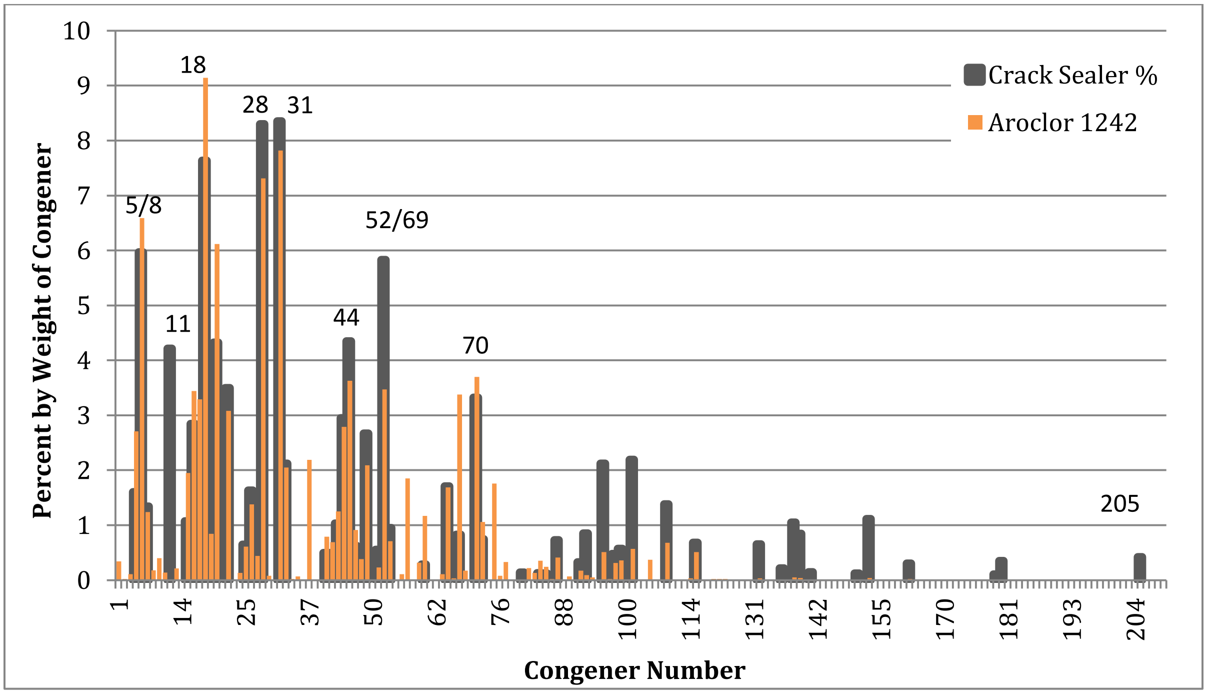


Figure 20. Crack Sealer and Aroclor 1242 Congener Distributions

Hydroseed

A hydroseed mix was sampled due to the prevalent use of hydroseed in roadside projects and its typical green coloring. The sample was collected from a new 50 pound bag of Nature's Own Hydromulch, which was not yet mixed with seed, fertilizer, or other additive. The Nature's Own Hydromulch MSDS indicates that it is composed of primarily wood fiber material with green liquid and a surfactant. The sample contained shredded colored newspaper cellulose. Total PCBs detected in the sample was **2,509 ug/kg**. The following figures show the congeners detected and homologue patterns for the sample.

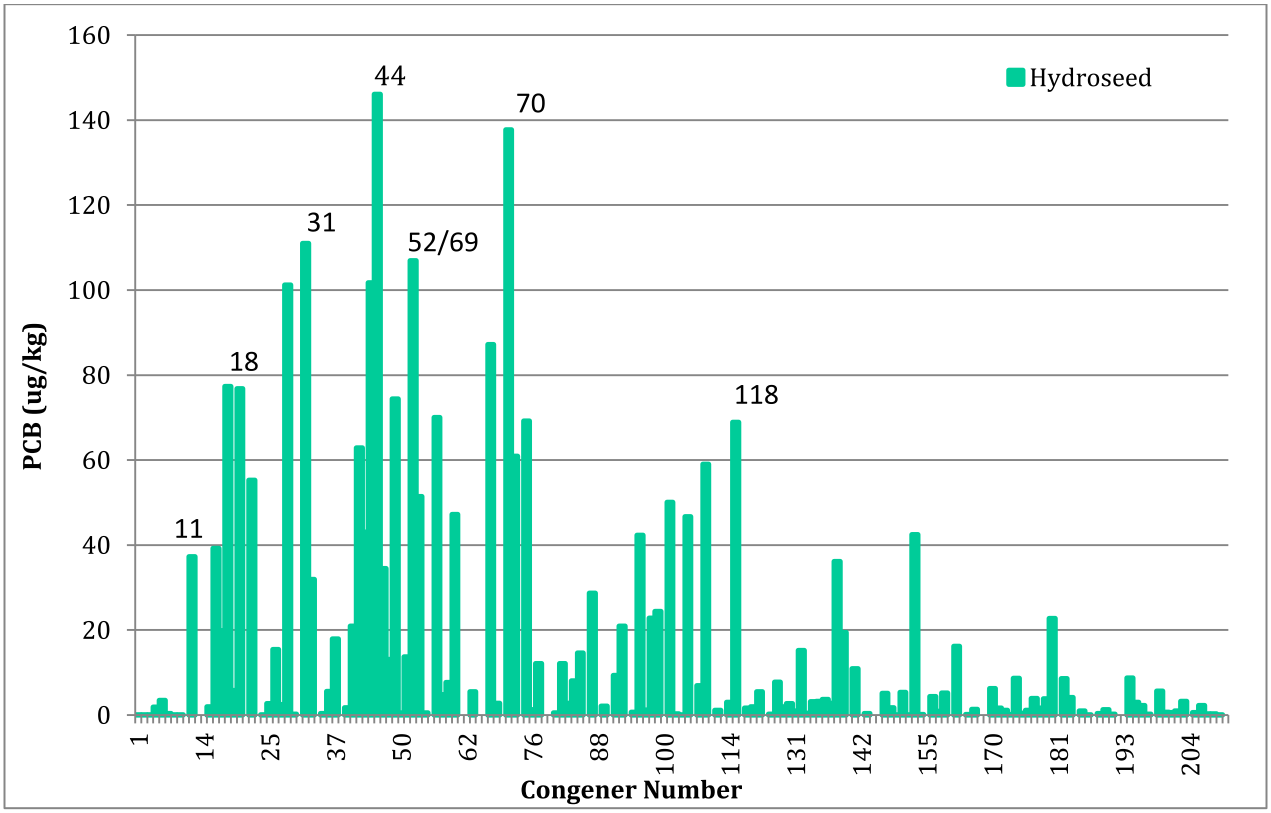


Figure 21. Hydroseed Congeners

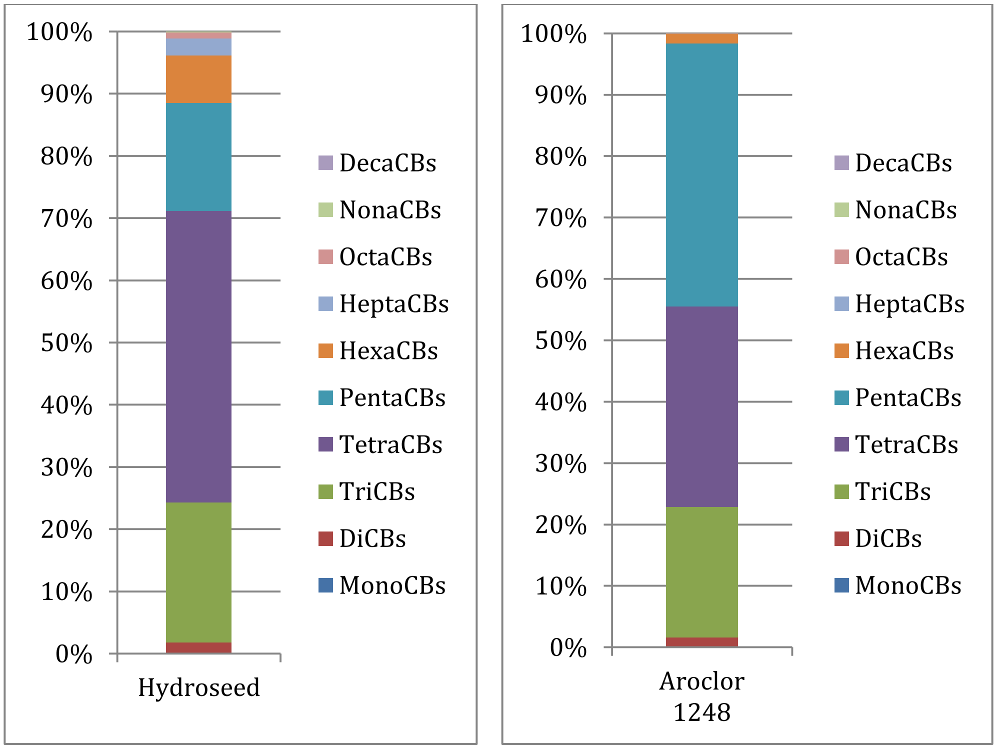


Figure 22. Hydroseed and Aroclor 1248 Homologue Patterns

In an unrelated incident, a landscape contractor received a penalty from the State of Iowa for illegally discharging a hydroseed mixture on the bank of a creek (Scriven-Young, 2010). The hydroseed contained 320 parts per billion of Aroclor 1248 as well as the pesticides DDT and DDE. Interestingly, the sample collected by the City of Spokane has a homologue pattern very similar to that of Aroclor 1248.

The hydroseed congeners from the City's sample were converted to percent of total PCB by weight and are plotted against Aroclor 1248 in the same units in Figure 23 below. The two congener patterns are quite similar. Note that PCB-11 is present in the hydroseed, but not the Aroclor. This indicates a secondary source of PCBs from pigment that is relatively minor compared to the Aroclor.

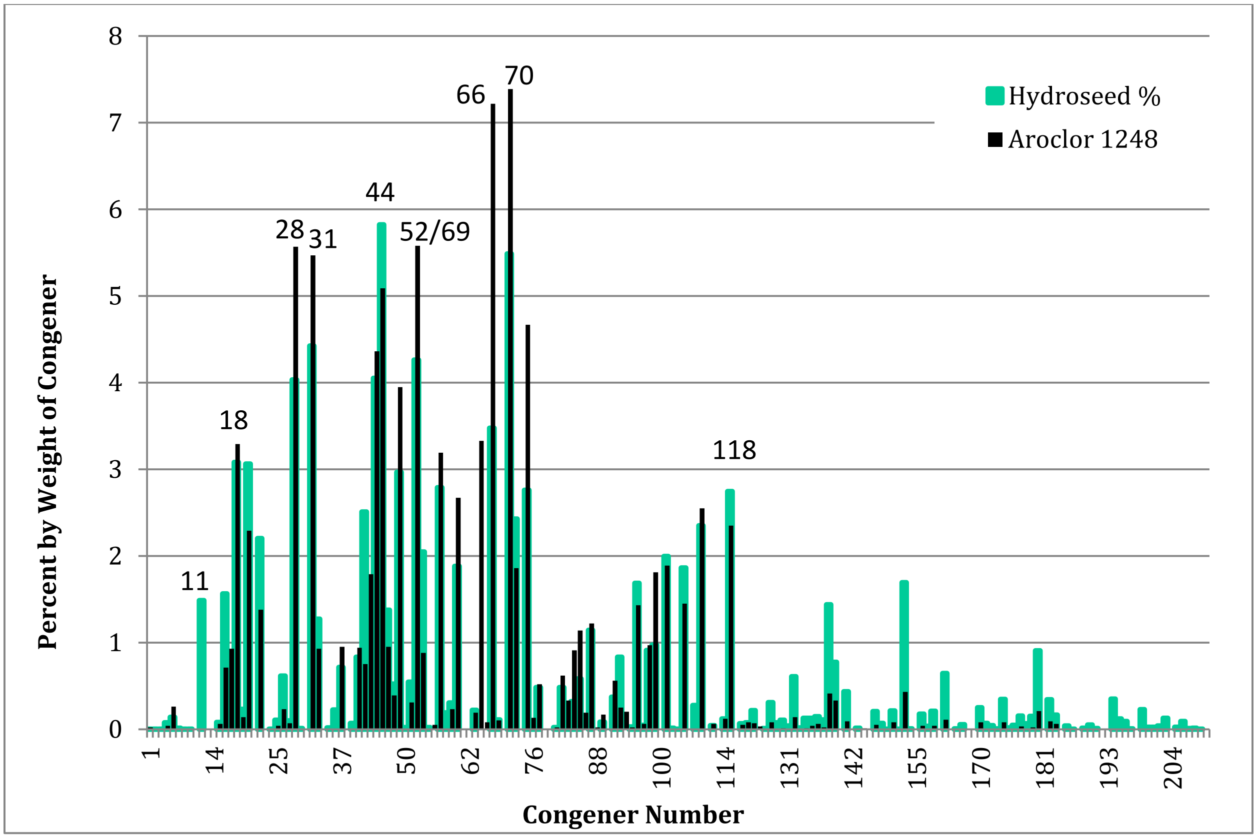


Figure 23. Hydroseed and Aroclor 1248 Congener Distributions

Pipe Material

There are hundreds of miles of PVC pipe used in the City's sanitary and storm sewer systems. Dischargers in the Spokane region have been collecting sanitary and stormwater samples for ultra low-detection PCB analysis, and many of these samples have traveled through miles of PVC pipe prior to collection. In an effort to screen the potential for PCB contribution from pipe material, PVC pipe, cast in place pipe (CIPP) liner and shortliner pipe repair materials were sampled.

The type of PVC sampled was ASTM 3034 collected from a new, unused eight-inch diameter pipe. CIPP is constructed from a felt tube saturated with resin and coated with polyurethane, and is cured inside an existing pipe. The section of CIPP liner sent in for analysis was originally collected from a construction project in northeast Spokane in April, 2013. It was kept in an office environment and not exposed to the elements after that time. Shortliner pipe repair is constructed in the same way, and made of a polyester-fiberglass liner impregnated with thermosetting epoxy resin. A test section of shortliner was cured in a new pipe on the ground surface at the City's Sewer Maintenance Department in October, 2014 for use in this sampling study.

Pieces of pipe were sent to the laboratory for analysis to help determine the PCB content in the material itself. The potential for PCBs to leach from the pipe material to stormwater and sanitary sewage is outside the scope of this project, but future analysis is warranted based on the results shown in Table 9.

Table 9. Pipe and Pipe Repair Material Total PCBs

Material	Total PCB (ug/kg)
PVC (ASTM 3034) Pipe	1.999
CIPP Liner	1.110
Shortliner	17.780

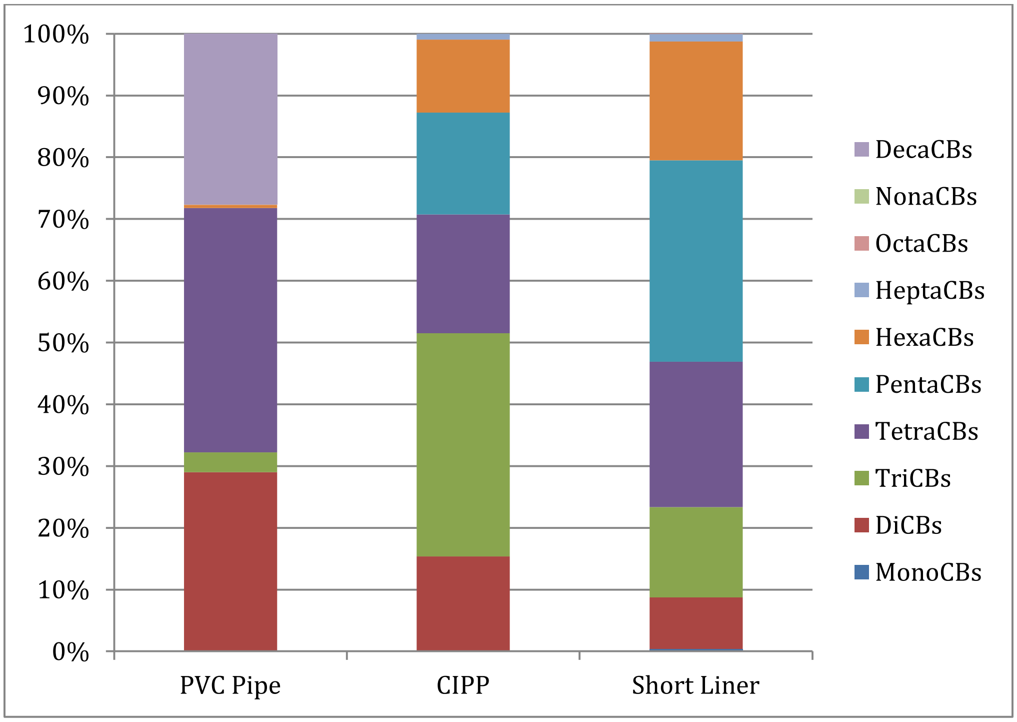


Figure 24. Pipe Material Homologue Patterns

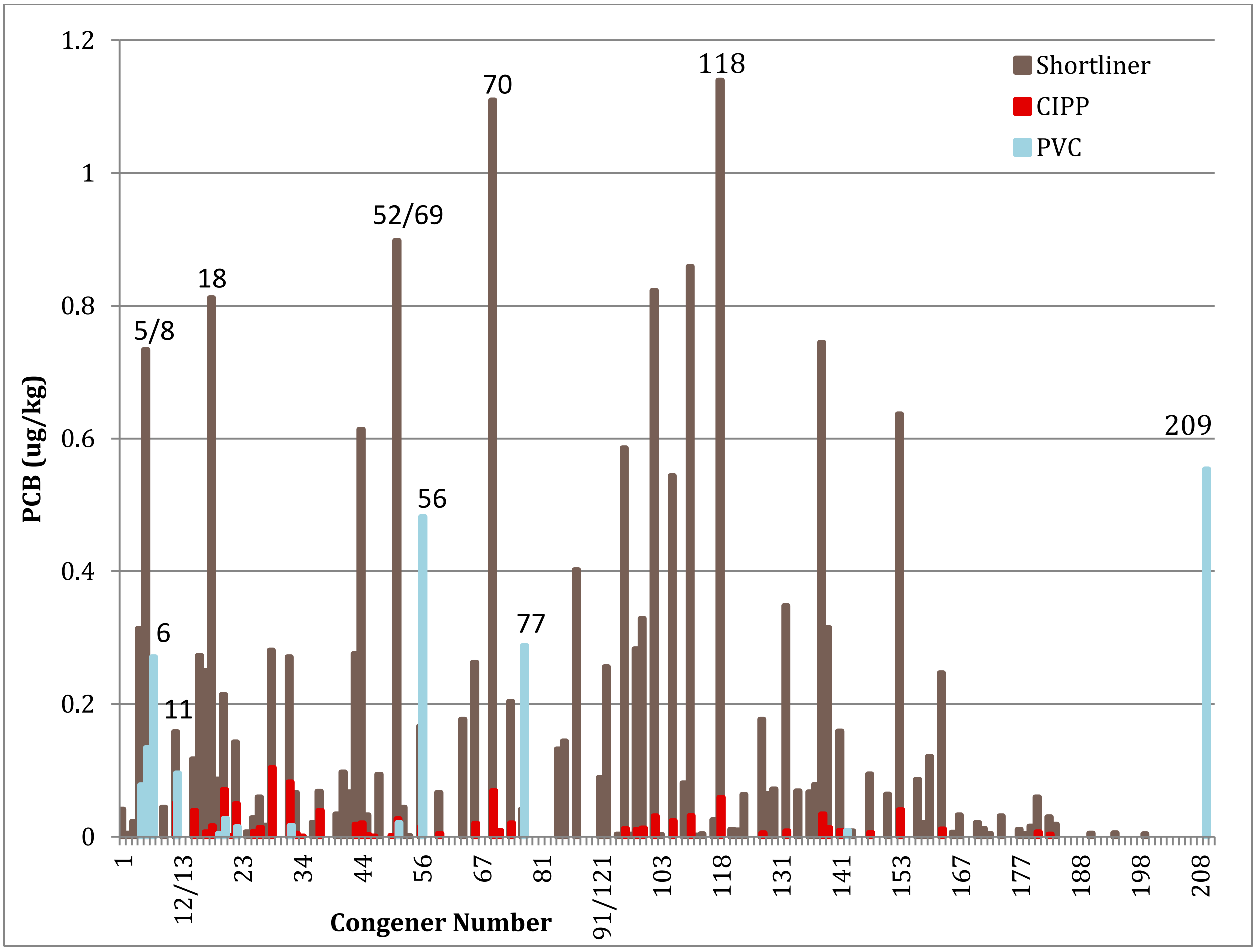


Figure 25. Pipe Material PCB Congeners

Figure 25 shows congener patterns for the sampled pipe materials. Congener distributions (percent of total PCB) for the pipe materials were then compared to congener patterns for Aroclors. The PVC and CIPP samples did not appear to correlate with Aroclor patterns. The Shortliner sample appears to correlate somewhat with a combination of two or more Aroclors. Specifically, a combination of both Aroclors 1242 and 1248 matches the shortliner sample the most closely (Figure 26).

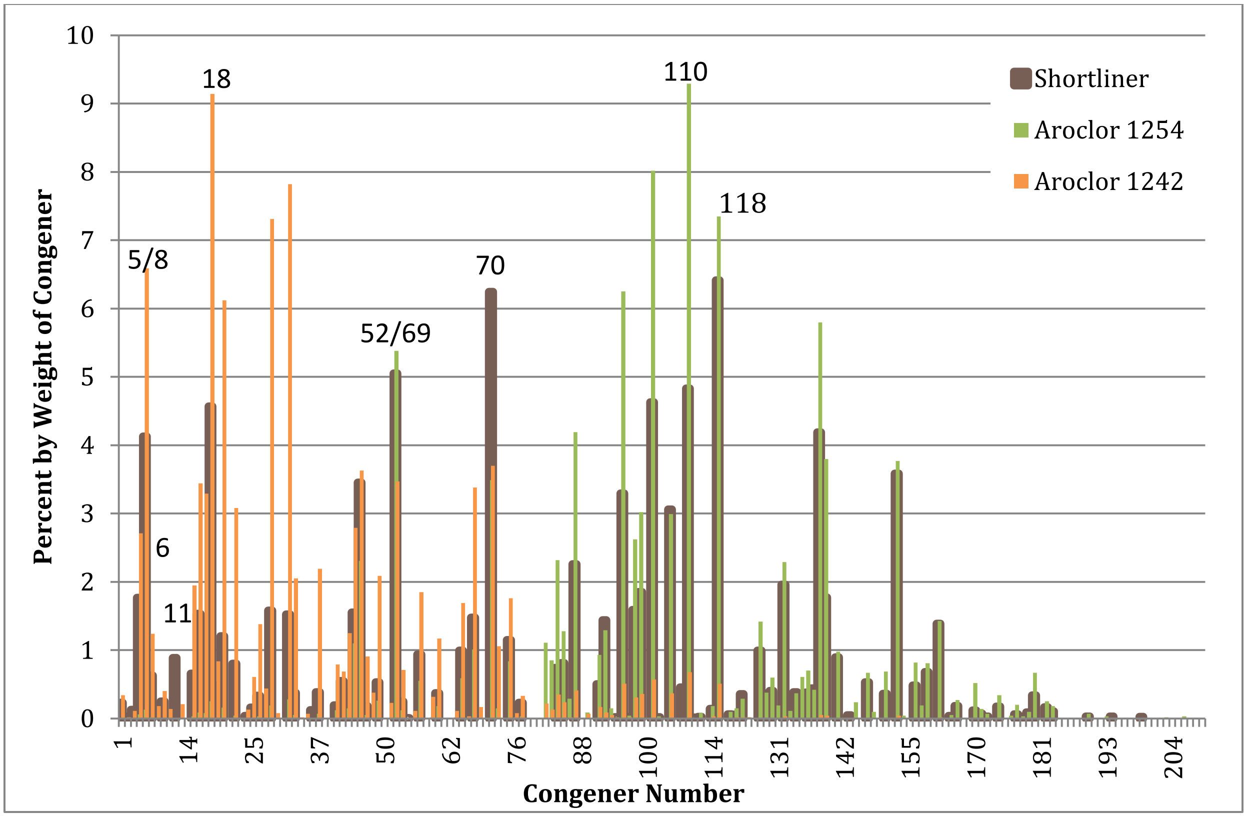


Figure 26. Shortliner Congener Distribution Compared to Aroclors 1242 and 1254

Firefighting Foam

Discharges from emergency firefighting activities are an exempt activity under the Phase II Eastern Washington Municipal Stormwater Permit. However, these discharges can easily enter a storm sewer system without proper containment and contribute contaminants to the environment. Alcoseal 3-3 Class B firefighting foam was sampled. Ingredients listed on the MSDS sheet include hydrolyzed protein, fluorosurfactants, 1,2 benzoisothiazelin, and hexylene glycol. The total PCB concentration was **0.029 ug/kg**. The associated congener and homologue patterns are shown in Figure 27.

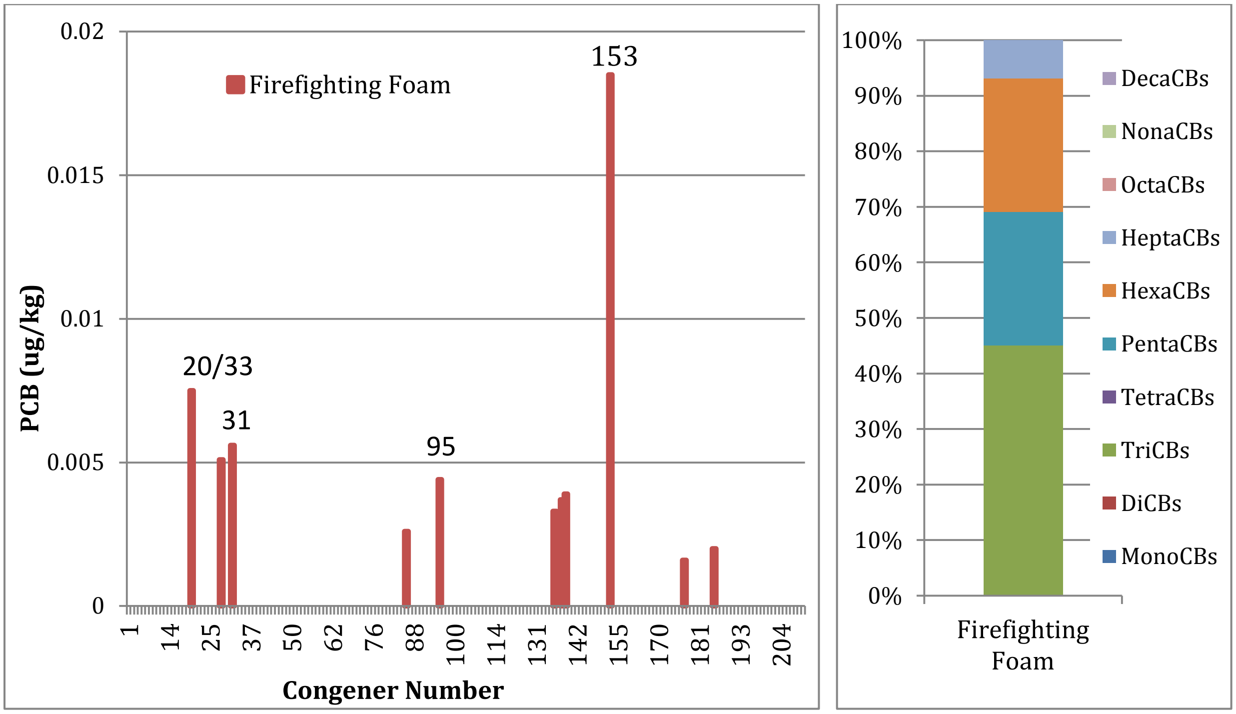


Figure 27. Firefighting Foam PCB Congeners and Homologue Pattern

Cleaners and Degreasers

Inadvertent PCB generation is possible with the manufacture of soaps, detergents, surfactants, and degreasers (Munoz, 2007). A detergent made by Hotsy was sampled as well as Simple Green degreaser.

The Hotsy Super XL detergent contained **0.003 ug/kg** total PCBs. A laboratory duplicate was analyzed, containing 0.068 ug/kg total PCBs. This product contains trisodium phosphates, alkaline builders, and surfactants. Congener distributions from the primary sample are shown in the figure below, containing only PCB-36.

The Simple Green degreaser contained **0.068 ug/kg** total PCBs, with nearly half of this total from PCB-11. The ingredients consist of primarily water with 2-butoxyethanol, ethoxylated alcohol, tetrapotassium pyrophosphate, sodium citrate, and a proprietary mix of fragrance and polymeric colorant.

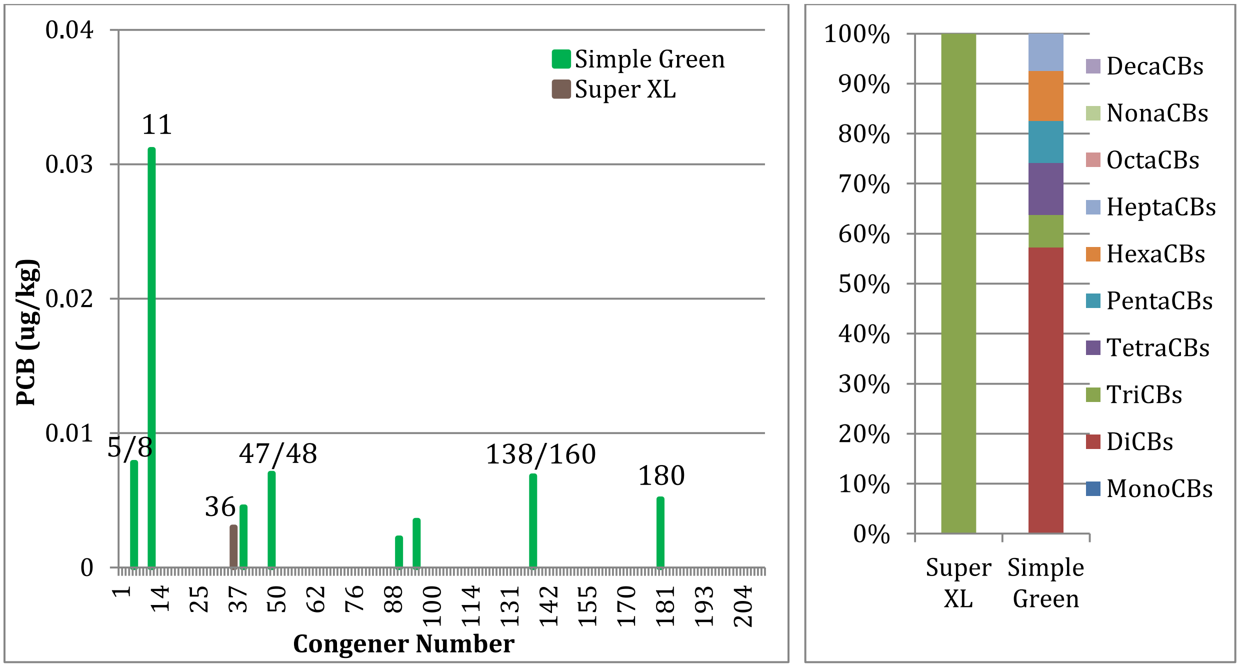


Figure 28. Simple Green and Super XL PCB Congeners and Homologue Pattern

Personal Care Products

Sampling in the storm and sanitary sewer systems over the past several years has indicated that total PCB concentrations in the sanitary sewer collection system are slightly greater than average concentrations in stormwater. So, in addition to products that can contribute PCBs to stormwater, five personal care products that may contribute PCBs to the sanitary sewer collection system were sampled. The products sampled were liquid and contained pigments. Table 10 shows the product brands sampled, total PCBs, pigments listed in the ingredients, and the so-noted ‘ingredients of interest.’ Many of these products have a long list of ingredients. Those ingredients that are chlorinated, contain benzene rings, or are suspected to be associated with inadvertent PCB production based on the literature search are included in Table 10 as ingredients of interest.

Table 10. Personal Care Products

Brand	Total PCB (ug/kg)	Ingredients of Interest	Pigments
Dial Antibacterial hand soap (pomegranate and tangerine)	0.037	Triclosan, tetrasodium EDTA, sodium chloride, polyquaternium-7	Yellow 6, Red 33, Red 40

Brand	Total PCB (ug/kg)	Ingredients of Interest	Pigments
Tide Original laundry detergent	0.174	Ethanolamine, Benzene sulfonic acid (sodium salt and monoethanolamine salt), disodium diaminostilbene disulfonate, dimethicone (type of silicone)	Liquitint® Blue HP (Polymeric colorant)
Dawn Ultra antibacterial dish soap	0.083	Chloroxylenol, sodium chloride	Yellow 5, Blue 1
Suave Naturals shampoo	0.058	Tetrasodium EDTA, ammonium chloride, methylchloroisothiazolinone	Blue 1, Red 33
Aquafresh Extreme Clean Whitening toothpaste	0.032	Glycerin, titanium dioxide, sodium saccharin	Red 30

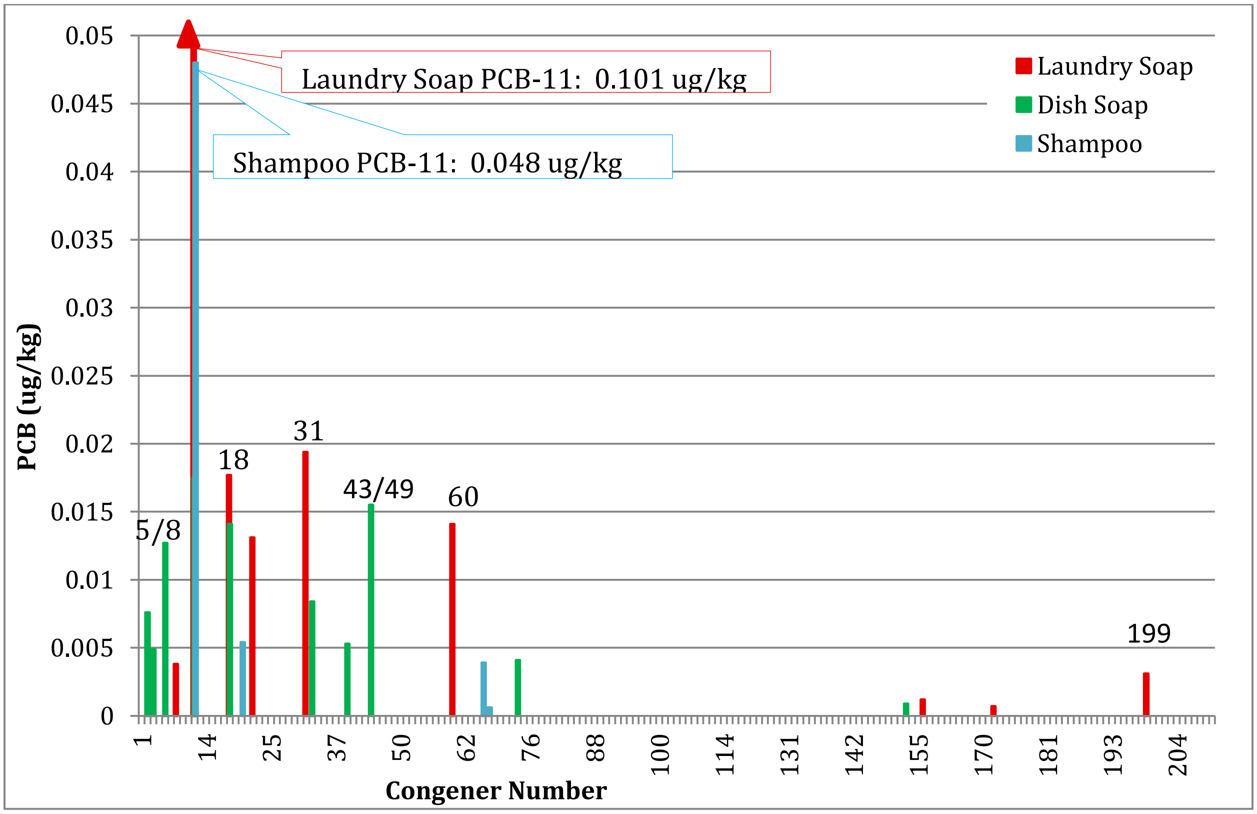


Figure 29. Laundry Soap, Dish Soap, and Shampoo Congeners

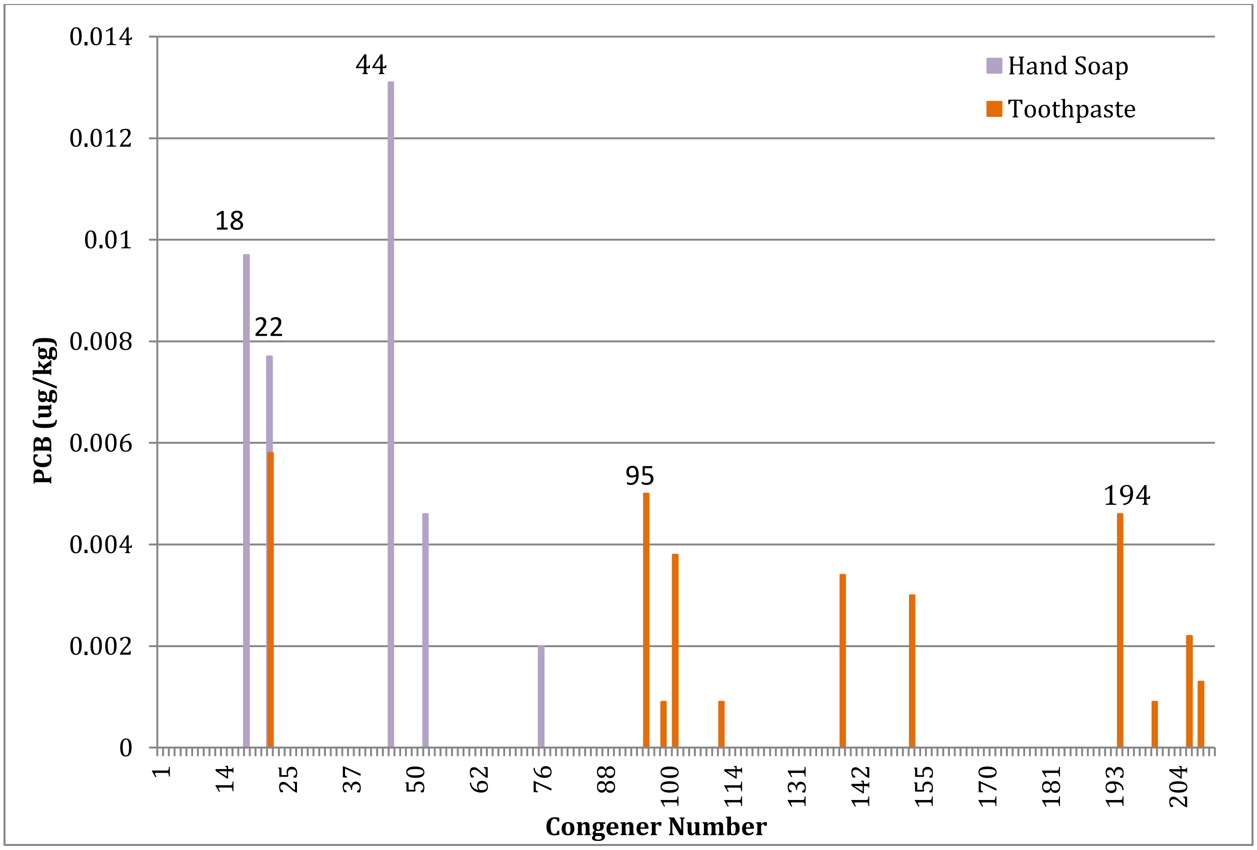


Figure 30. Hand Soap and Toothpaste Congeners

Figure 31. Personal Care Product Homologue Patterns

CONCLUSIONS

PCBs were detected in 39 of the 41 product samples, with a wide range of congener patterns. Figure 32 shows the frequency of detection of each congener in this study. The congeners most frequently detected are the coeluting congeners PCB-52/69 (detected in 30 of the samples) followed by PCB-11 and PCB-28 (detected in 25 of the samples). PCB-52 is one of the most abundant congeners found in the environment, and is found in Aroclor mixtures from 0.1% to 5.6% of the mixture by weight (Frame et. al, 1996). PCB-28 is also commonly found in Aroclor mixtures at up to 8.5% of the total mixture by weight (Frame et. al, 1996). Because PCB-11 was one of the most frequently detected congeners, and it is generally not found in Aroclor mixes, pigments are likely a common source of inadvertently produced PCBs in the products sampled.

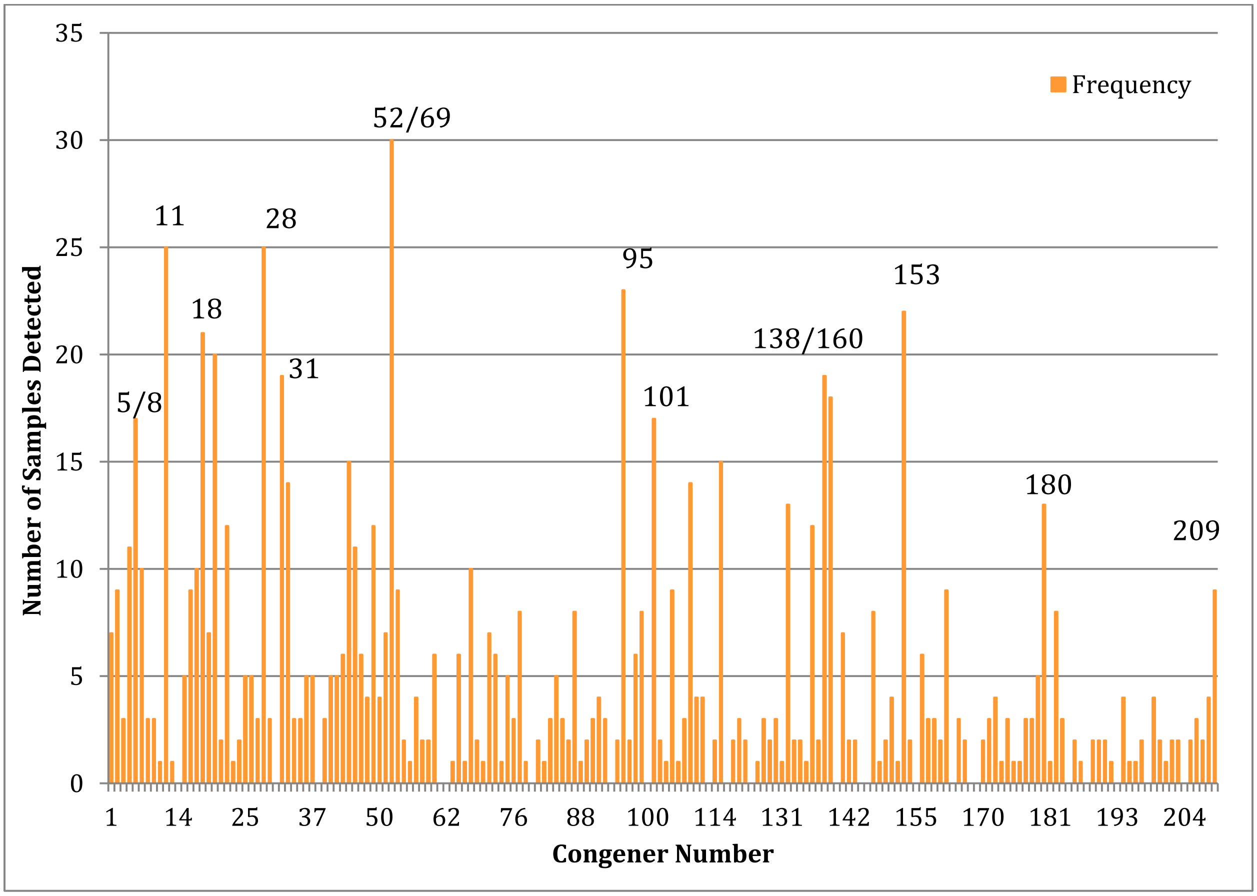


Figure 32. Frequency of Detections per Congener

The results from this report may be used for a number of PCB tracking and reduction activities. Additional research may be needed to determine potential pathways between some of the sampled products and stormwater. For PCB reduction activities, total PCB loading (volume of product used) should be assessed to aid in prioritization. Manufacturers may also be interested in exploring PCB-free alternatives where feasible.

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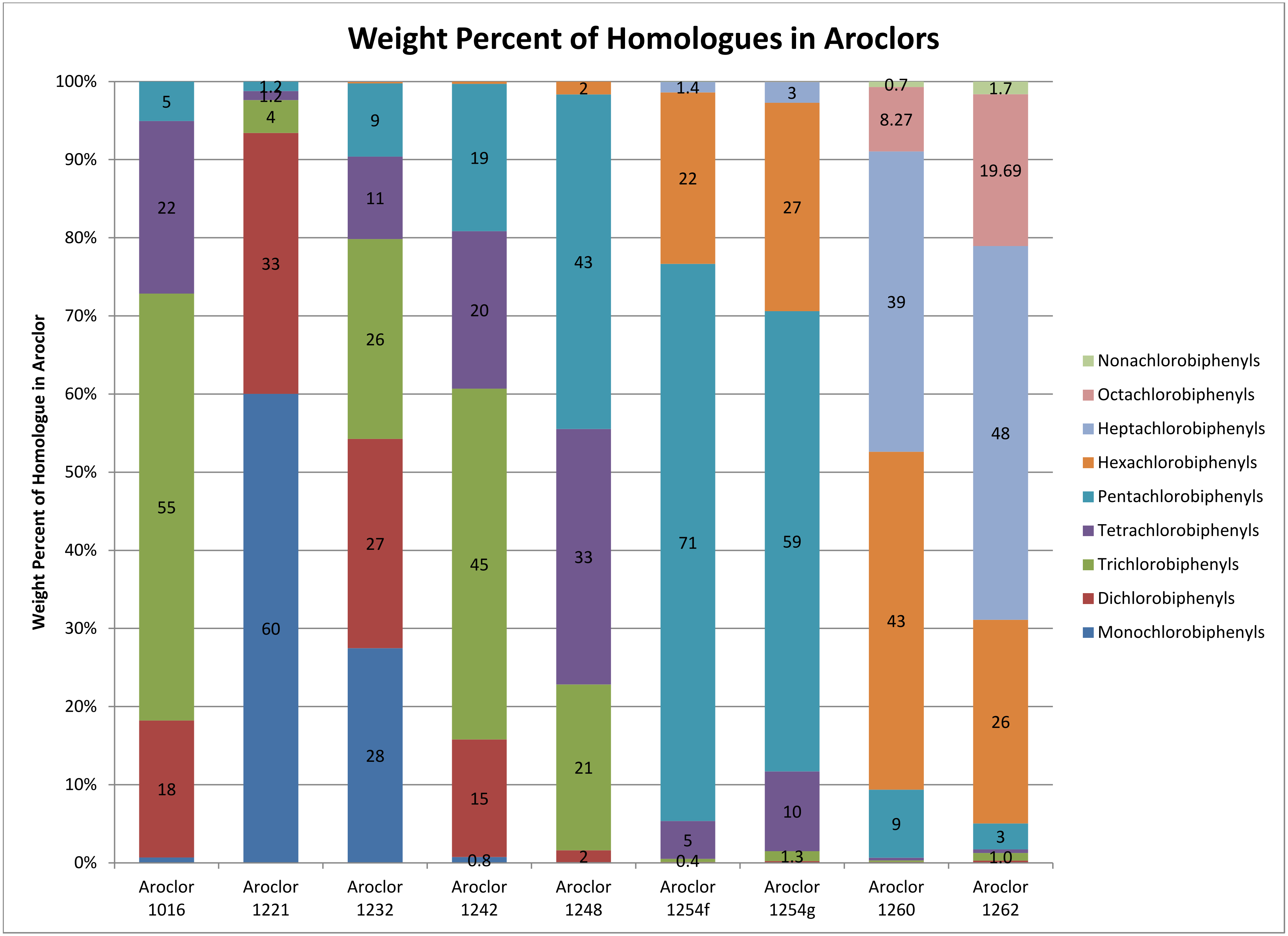
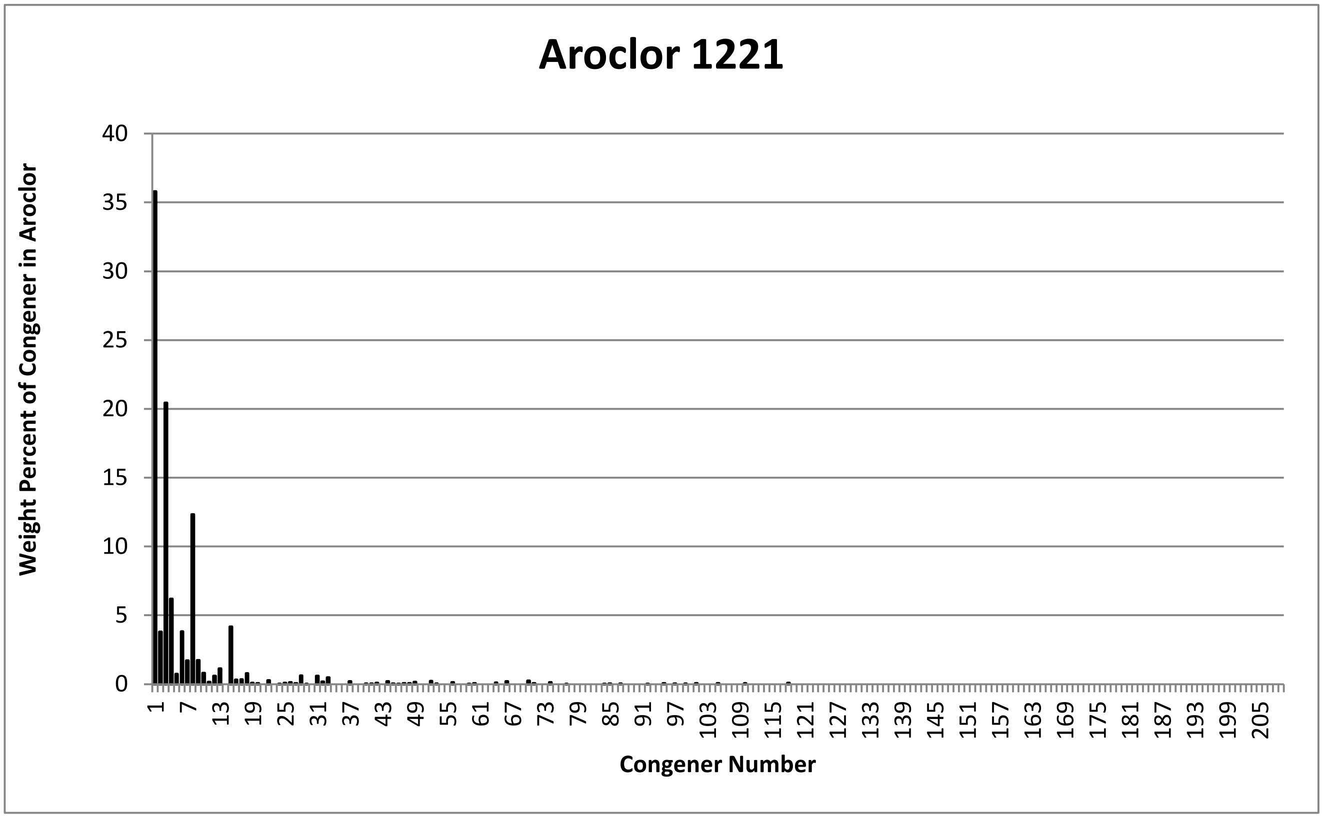
Appendix A

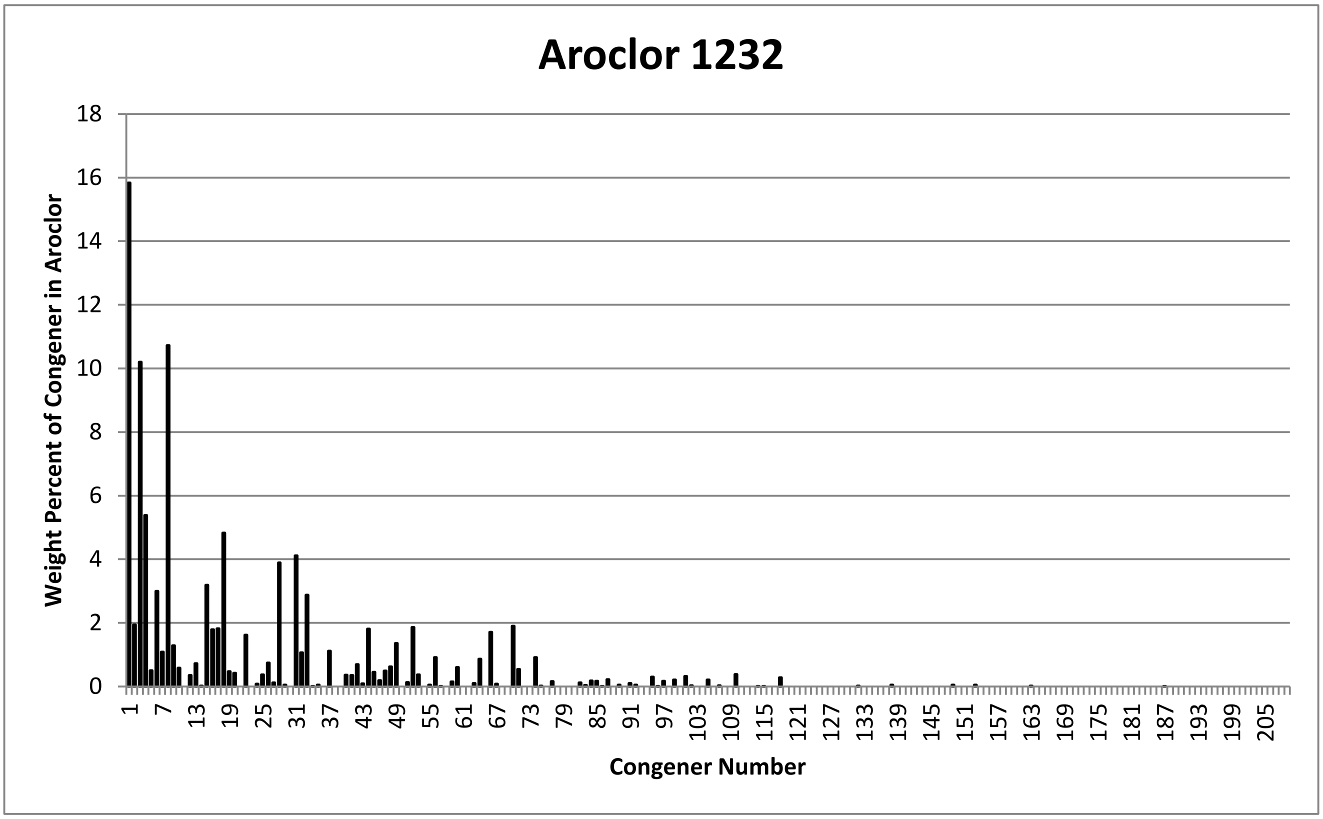
AROCLOR HOMOLOGUES AND CONGENERS



Adapted from ASTDR, 2000.

Weight Percent of Congeners in Aroclors





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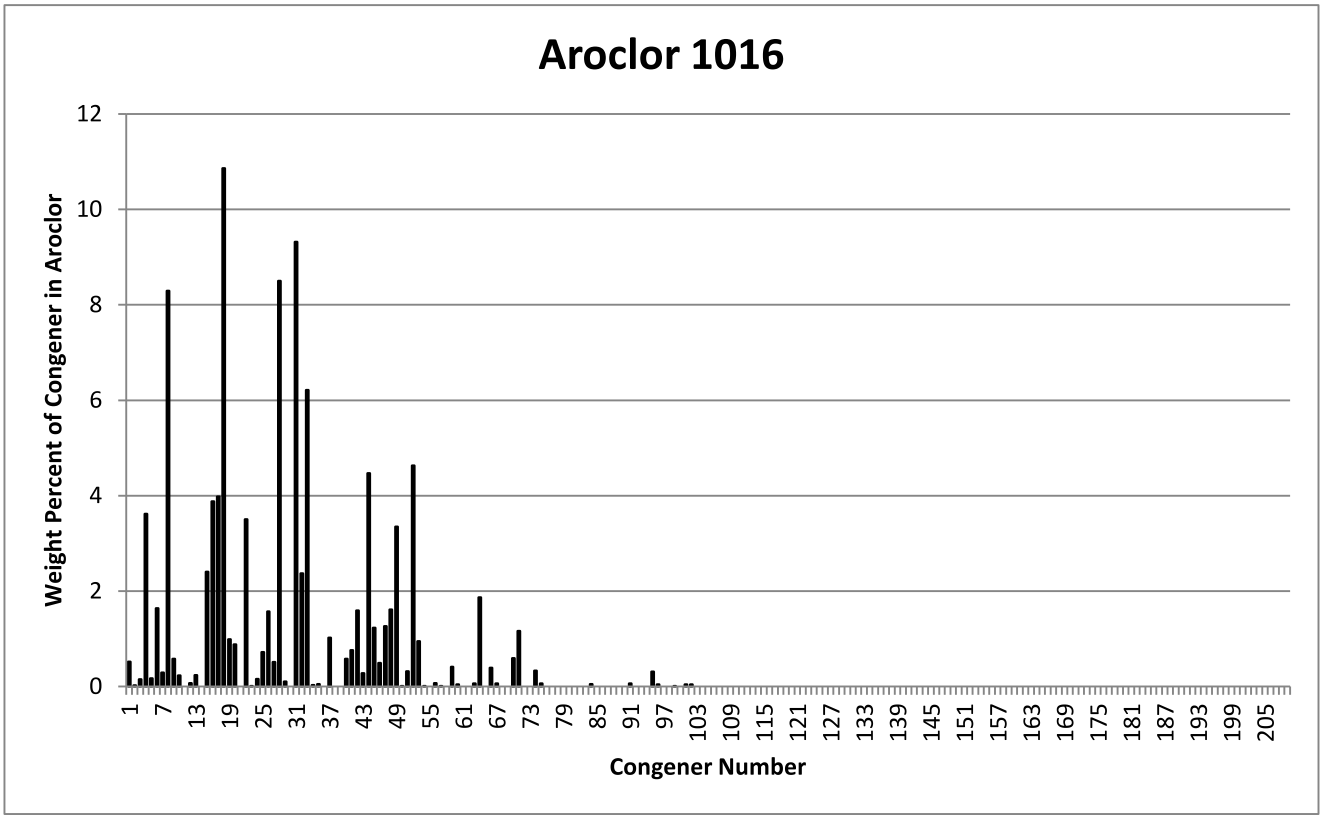

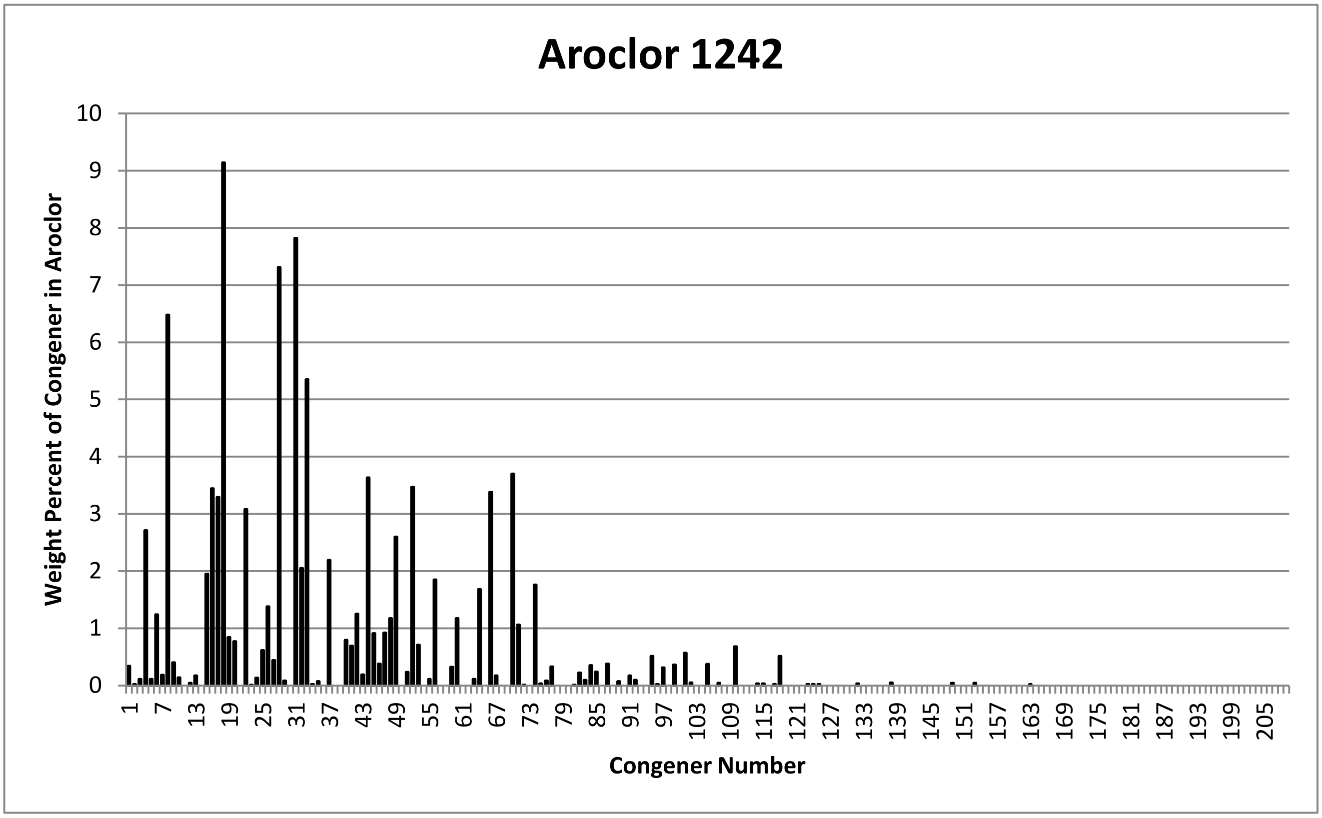

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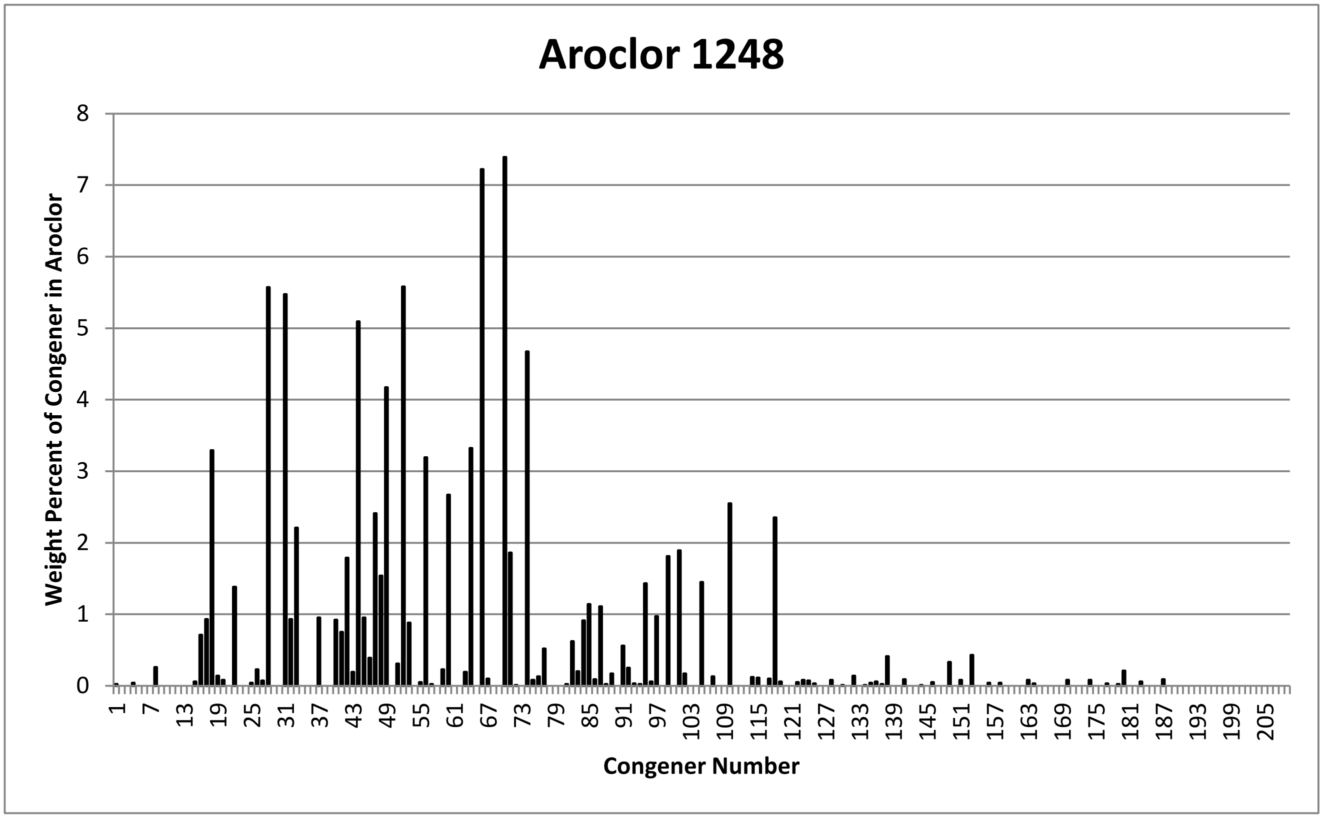

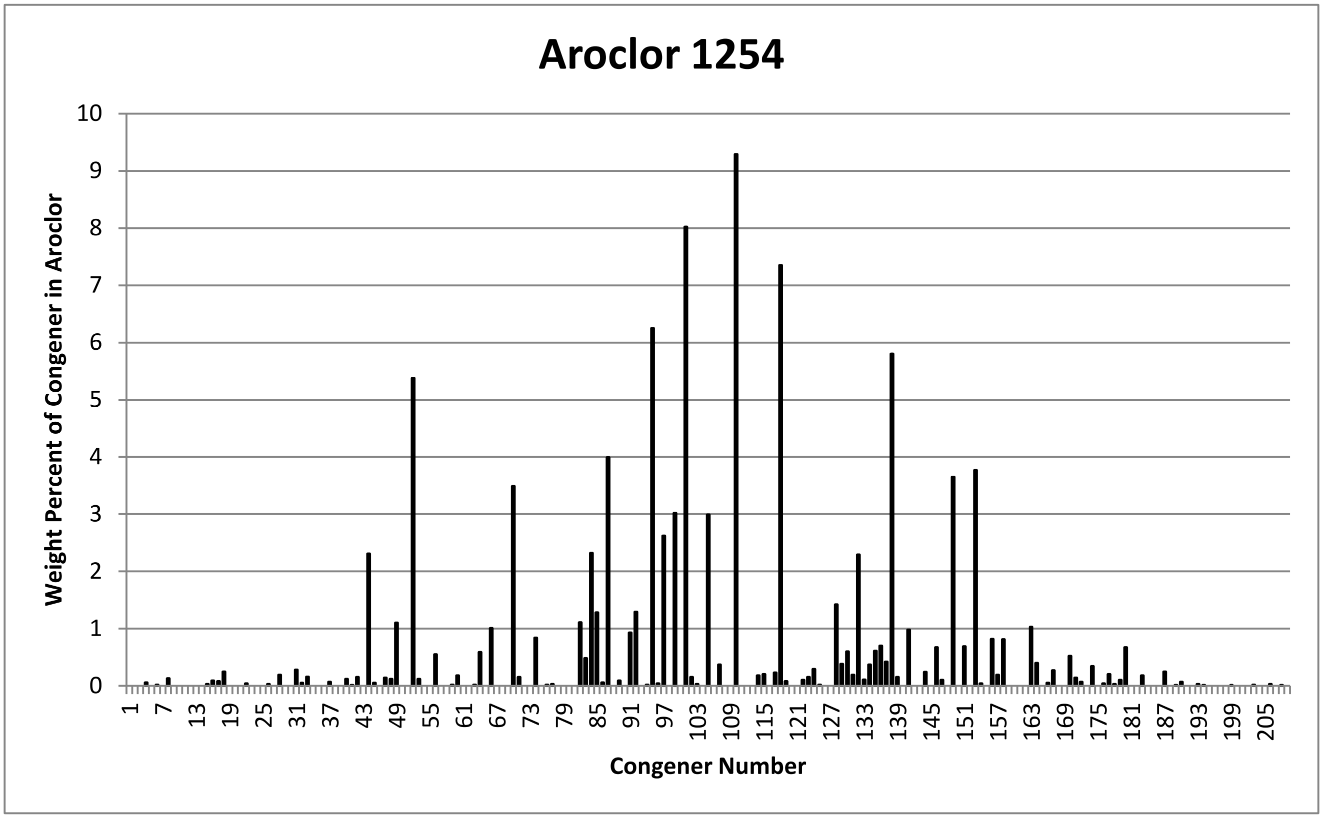

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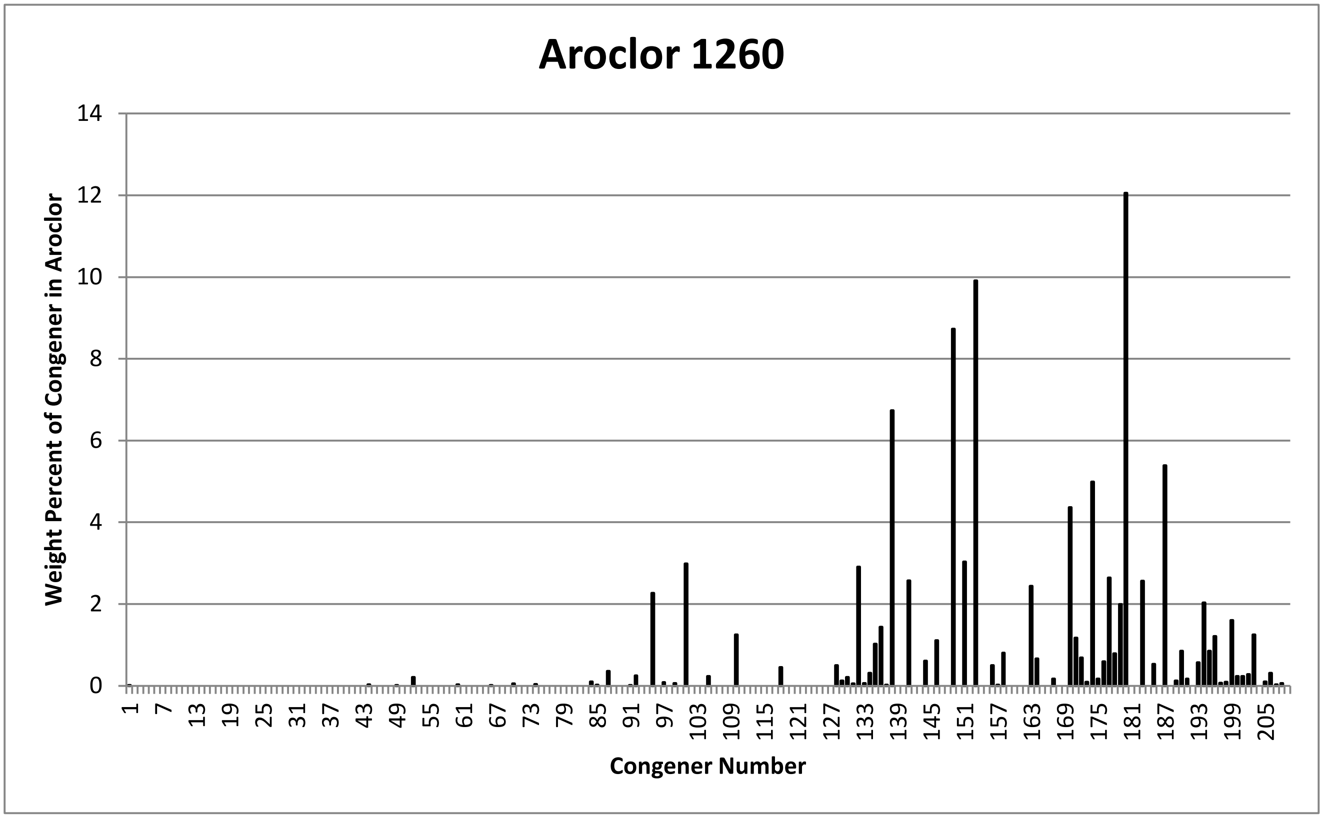
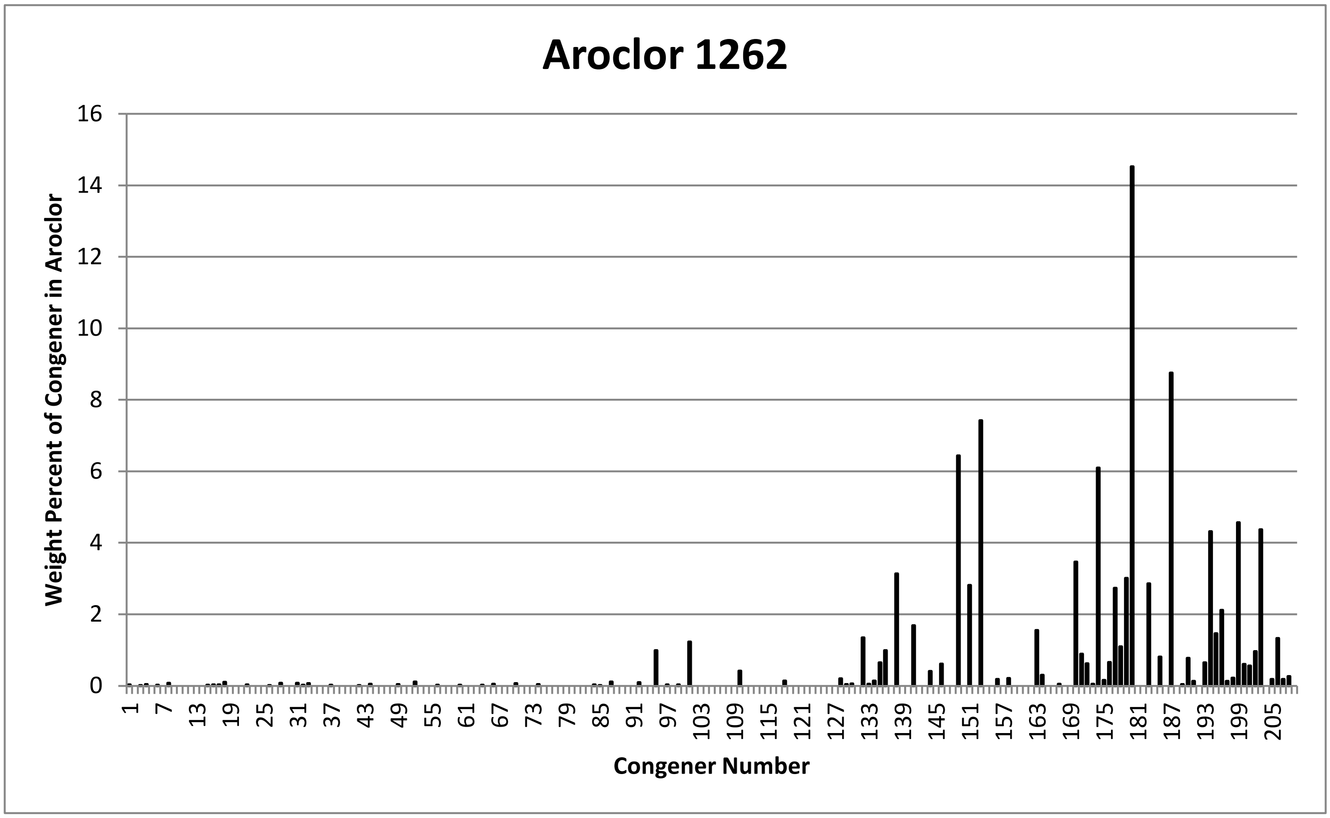


Aroclor 1260



Aroclor 1262

(Adapted from Frame et. al, 1996)

Appendix B

SUMMARY OF RESULTS

Table B-1

Summary of PCB Product Sampling Results

Product Type	Media	Product ID	Total PCB (ug/kg or ppb)	Field Replicate (ppb)	Lab Duplicate (ppb)	Brand
Yellow road paint	Liquid	001	0.732	2.686		Ennis standard #2 - Product # 983712
Yellow road paint	Liquid	002	64.880			Sherwin Williams Promar TM 5713
White road paint	Liquid	003	0.414	0.396		Ennis standard #2 - Product # 983711
White road paint	Liquid	004	0.281		0.220	Sherwin Williams Promar TM 5712
Hydrant Paint	Liquid/Spray	005	0.003		0.010	Rustoleum Pro HP Enamel - Aluminum
Utility Locate Paint	Liquid/Spray	006	21.527			Rustoleum Industrial Choice, Solvent-based - green
Class B Firefighting Foam	Liquid	007	0.029			Alcoseal 3-3 (AR-FFFP)
Deicer	Liquid	008	1.332	1.952		MgCl Freezegard
Deicer	Liquid	009	0.038			Enhanced salt brine with SB Boost
Vehicle wash soap	Liquid	010	0.003		0.068	SuperXL, Hotsy
Vehicle wash soap	Liquid	011	0.068			Simple Green
Pesticide/Herbicide	Liquid	012	<0.0001		<0.0001	2-4D: Nufarm Weedar 64
Pesticide/Herbicide	Liquid	013	6.890			Portfolio 4F, Wilbur-Ellis
Pesticide/Herbicide	Liquid	014	0.012			Roundup Pro Max, Monsanto
Pesticide/Herbicide	Liquid	015	0.316			Crosshair, Wilbur-Ellis
Motor oil	Liquid	016	0.856		0.826	SAE 15W-40 Firebird Heavy Duty EC (bulk), Connell Oil
Motor oil	Liquid	017	0.969			Valvoline Full Synthetic 5W-30
Used motor oil	Liquid	018	0.502	2.375		SAE 15W-40 Firebird Heavy Duty EC, Connell Oil
Diesel	Liquid	019	<0.019			#2 Diesel, dyed
Gasoline	Liquid	020	0.935		0.811	Regular unleaded
Dirt road dust suppressant	Liquid	021	0.091			Asphalt emulsions- EADA
Dirt road dust suppressant	Liquid	022	0.086			Lignosulfonate- Ligno Road Binder (natural polymer in wood)
Dirt road dust suppressant	Liquid	023	3.574			Dustguard Liquid MgCl (different concentration than deicer)
Lubricant	Liquid	024	0.623			MP Gear Lube SAE 85W-140, Phillips 66 Company
Asphalt tack	Liquid	025	0.085			SSR1 asphalt tack
Crack sealer	Solid	026	7.975			Special Asphalt SA Premier (3405- midrange crack sealer)
Asphalt release agent	Liquid	027	0.558		0.443	Soy What, TechniChem Corp.
Hydroseed	Solid	028	2,509.088			Natures Own Hydroseeding Mulch, Hamilton Mfg Inc
PVC pipe	Solid	029	1.999			ASTM 3034 8", Diamond PVC
CIPP liner	Solid	030	1.110			Cast in place pipe liner, installed by SAK
Shortliner	Solid	031	17.780			Infrastructure Repair Systems Inc
Yellow road paint, dried	Solid	032	0.565			Ennis standard #2 - Product # 983712
White road paint, dried	Solid	033	0.379		0.335	Ennis standard #2 - Product # 983711

Product Type	Media	Product ID	Total PCB (ug/kg or ppb)	Field Replicate (ppb)	Lab Duplicate (ppb)	Brand
Thermoplastic tape road striping	Solid	034	10.776			Ennis-Flint Pre-Mark
Antifreeze	Liquid	035	0.018			Kool Green Extended Life (recycled)
Thermoplastic tape road striping	Solid	036	3.325			Ennis-Flint Pre-Mark

Personal Care Products

Product Type	Media	Product ID	Total PCB (ug/kg or ppb)	Field Replicate (ppb)	Lab Duplicate (ppb)	Brand
Hand soap	Liquid	101	0.037			Dial Antibacterial, pomegranate and tangerine
Laundry soap	Liquid	102	0.174			Tide original liquid
Dish soap	Liquid	103	0.083			Dawn Ultra antibacterial
Shampoo	Liquid	104	0.058			Suave naturals
Toothpaste	Liquid	105	0.032			Aquafresh Extreme Clean Whitening

Notes:

Total PCB values have been blank corrected: congeners < 3 times the associated blank value not included in total.

ug/kg = micrograms per kilogram

ppb = parts per billion

The Role of Hatcheries in North American Wild Salmon Production

Key Points

- ✔ A significant share of the salmon caught by North American commercial fishermen are released from hatcheries. In recent years, hatchery fish have accounted for about 38 percent of total Alaska “wild” salmon catches, including about 40 percent of Alaska pink salmon catches and 69 percent of Alaska chum salmon catches. Most Alaska hatchery production is concentrated in Southeast Alaska and Prince William Sound. The importance is highlighted by ADF&G: “The ocean ranching program provides hundreds of Alaskans with seasonal jobs. It is now considered the largest agricultural industry in Alaska” (Farrington 2004 p. 2).
- ✔ The Alaska hatchery program faces significant economic and political challenges, including:
  - Lower economic net return due to lower prices
  - Declining state financial support for hatcheries
  - Declining direct benefits to fishermen from hatcheries as the share of catches needed to cover costs of hatchery operations increases
  - Opposition from fishermen dependent on natural wild salmon catches who argue that large-scale hatchery catches has depressed ex-vessel prices they receive
  - Lack of markets for “dark” hatchery fish (fish that have physiologically changed as they move back to fresh water) in some years, leading to discarding of fish carcasses after extraction of salmon roe
  - Concerns about potential adverse effects of hatchery releases on Alaska natural wild salmon runs.
- ✔ There are also significant hatchery programs in British Columbia, the U.S. Pacific Northwest and California, which account for significant shares of the commercial and recreational fisheries.
- ✔ Hatcheries add another dimension of complexity and ambiguity to the discussion over environmental, economic and social issues related to wild and farmed salmon. Some of the environmental and economic issues associated with salmon farming are also associated with commercial hatchery production.

Introduction[1]

It is common to think of salmon as either “wild” or “farmed.” However, not all “wild” salmon are equally wild. A large share of the salmon returning to North American streams, and a large share of the salmon caught by North American commercial fishermen, are released from hatcheries and are considered ‘ranched’ salmon. However, most discussion is framed in a ‘wild’ salmon context which includes both ‘natural wild’ and ‘ranched.’

In some ways, hatchery salmon are more like farmed salmon than natural wild salmon.[2]

- Like farmed salmon, hatchery salmon spend the first part of their lives in hatchery incubation systems and/or rearing containers, eating similar kinds of feeds.
- Like those farmed salmon which escape into the natural environment, hatchery salmon may potentially affect the genetic diversity of natural wild salmon stocks. This is particularly a concern in Washington, Oregon and California.
- Like farmed salmon, hatchery salmon compete in world markets with natural wild salmon.
- Like farmed salmon, there are significant costs in producing hatchery salmon, and the extent to which hatcheries are economically viable depends upon market conditions.

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[1] A good deal of the discussion of this chapter, in particular the portion on Alaska’s hatchery programs, is drawn from Knapp (1999).

[2] See footnote 2 in Chapter II.

Unlike farmed salmon, hatchery fish compete with natural wild fish for food. For these reasons, hatcheries add another dimension of complexity and ambiguity to the discussion over environmental, economic and social issues related to wild and farmed salmon.

Once thought of as a way to restore and enhance natural wild salmon runs, hatchery salmon are now recognized as potentially harmful to natural wild salmon runs because of genetic interactions and competition for food and habitat in freshwater and marine environments. There is an active debate among scientists, commercial fishermen and the public as to the appropriate role and scale of salmon hatcheries. This is particularly true in the U.S. Pacific Northwest.

In this chapter we review the role of hatchery salmon in North American commercial wild salmon fisheries, and the economic issues associated with hatchery salmon.

Overview of North American Hatchery Programs

Salmon hatcheries have been established in North America for many purposes including:

- Introducing salmon fisheries where none previously existed.
- Replacing or enhancing natural salmon runs which were extinct or diminished.
- Increasing abundance of salmon for sports fisheries
- Increasing abundance of salmon for commercial fisheries.

Hatcheries were first established in North America in the second half of the nineteenth century, motivated by the recognition that natural stocks of salmonids were in decline and the desire to introduce salmon and trout outside their native ranges (Thorpe 1980). The first hatchery propagation of Pacific salmon (*Oncorhynchus* spp.) took place in Canada in 1857 (Bardach et al. 1972). Soon after, salmon hatchery techniques were adopted in the United States. The first U.S. hatchery was opened in 1864 in New York State to raise brook trout (Calabi 1990). However, hatchery-based enhancement programs were introduced at a significant scale only after the 1950s. Hatcheries were introduced to Japan in 1877.

More than two billion Pacific salmon were released in 2000 by North American salmon hatcheries (Table IV-1). Alaska accounted for 69 percent of total releases, while Canada and the U.S. Pacific Northwest each accounted for about 16 percent (Table IV-2).

Alaska releases were mostly pink and chum salmon, western Canadian releases (mostly British Columbia) were mostly sockeye, chum and chinook salmon and U.S. Pacific Northwest releases were mostly chinook and coho salmon. Alaska accounted for the largest share of pink and chum salmon releases; Canada accounted for the largest share of sockeye releases, and the U.S. Pacific Northwest accounted for the largest share of chinook and coho releases (Table IV-2).

Table IV-1 **Salmon Fry Releases by Species, Region, and Area, 2000 (millions of fish)**

		Chinook	Sockeye	Coho	Pink	Chum	Total
Alaska		9.2	59.8	19.3	879.7	507.7	1479.7
Canada	Yukon	0.2	0.0	0.0	0.0	0.0	0.2
	Queen Charlotte	0.2	0.0	1.3	0.0	22.2	23.7
	North Coast	4.3	90.5	1.6	0.2	12.7	109.3
	West Coast Vancouver Island	17.5	0.0	2.7	0.0	31.8	51.9
	South Coast	29.2	39.3	14.8	16.9	30.6	130.7
	Interior B.C.	2.2	19.2	0.7	0.0	0.0	22.1
	Canada Total	53.5	148.9	21.1	17.0	97.3	337.9
Pacific Northwest	Washington	117.4	16.9	43.9	1.6	38.8	229.5
	Oregon	32.3	0.0	8.7	0.0	0.0	46.8
	California	43.8	0.0	0.6	0.0	0.0	46.8
	Idaho	6.8	0.1	0.5	0.0	0.0	15.3
	Pacific Northwest Total	200.3	17.0	53.7	1.6	38.8	338.4
TOTAL		**263.0**	**225.7**	**94.2**	**898.4**	**643.8**	**2156.0**

Source: North Pacific Anadromous Fish Commission, NPAFC Hatchery Release Data.

Note: Includes all juvenile salmon releases.

Table IV-2 **Share of Salmon Fry Releases, by Region and Species, 2000**

	Chinook	Sockeye	Coho	Pink	Chum	Total
Alaska	3%	26%	21%	98%	79%	69%
Canada	20%	66%	22%	2%	15%	16%
Pacific Northwest	76%	8%	57%	0%	6%	16%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: NPAFC Hatchery Release Data

Table IV-3 **Number of Fry Released per Kilogram of Commercial Catches, 1997-2001**

	Chinook	Sockeye	Coho	Pink	Chum	Total
Alaska	2.3	0.7	1.5	5.5	6.3	4.3
Canada	53.4	18.3	115.6	2.3	15.3	14.2
Pacific Northwest	52.1	15.8	42.1	1.8	16.2	34.9

Note: Calculated by dividing average fry releases for the period 1997-2001 (thousands of fish) by average commercial catches for the period 1997-2001 (thousands of kilograms). For the Pacific Northwest, average fry releases for the period 1997-2000 were used becauses 2001 data were not available.

Table IV-3 provides a general indicator of the relative scale of hatchery releases in comparison to commercial harvests. For chinook, sockeye and coho salmon, hatchery releases per kilogram of commercial catches were much higher in Canada and the U.S. Pacific Northwest than in Alaska—suggesting that commercial fisheries for these species are relatively more dependent on hatcheries in Canada and the U.S. Pacific Northwest than Alaska. For pink and chum salmon, hatchery releases per kilogram of commercial catches were much more comparable among the three regions.

The Hatchery Process

The production of salmon in hatcheries recreates the early portion of the life cycle of the species in a protected environment (Willoughby 1999). Salmon hatcheries consist of both a freshwater and a marine phase. The freshwater phase encompasses the spawning cycle, egg production, hatching and first-feeding stages. As the fry develop, they turn into fingerlings (or parr as the Europeans tend to call them), and finally grow to become smolts. At this point the fish have become physiologically adapted to seawater conditions.

- Broodstock management: Broodstock are the fish from which the eggs and milt (sperm) are taken. Selection of the broodstock from adults returning to the hatchery has changed significantly over time. Until recently, little concern was given to such things as managing to maintain the genetic integrity of a river's native salmon. In recent years, scientists have determined that these needs must be addressed and have prescribed methods to choose broodstock in a more careful manner (National Research Council 1996).
- The hatchery: The hatchery phase is probably the most technically demanding, requiring a high degree of organization and planning. The objective of this portion of the cycle is to fertilize and hatch the eggs then raise the fry until release to open water. After hatching, the young fish feed on the contents of their yolk sac for several weeks and are called yolk-sac fry or alevins. A short time after hatching the yolk sac has been almost totally consumed and the alevins are generally developed enough to start feeding. Starter diets formulated with feed ingredients, such as fishmeals and fish oils, give rapid growth.
- Fry and fingerling development: When the alevins begin to feed they are known as fry. During this phase, growth is rapid. As they develop, fry become more accustomed to solid feed and increase their activity. When the fry are sufficiently developed, they are transferred into larger tanks. Once the fry reach an average weight of about 5 g, they are known as *fingerlings*.
- Smolt production: Once the larger fingerlings are sufficiently developed, they will undergo major physical and physiological changes to become smolts. These changes mark the transformation from a freshwater fingerling to a seawater fish (Fitzgerald et al. 2002). The smoltification process involves changes in most organ systems, morphological (silvery color), physiological (ATPase activity) and behavioral (swimming with the current), which will allow the fish to survive, grow and develop normally in the marine environment.

Hatcheries managed for stock enhancement of the commercial and sport fisheries, generally release fish to the open water at either the fry, fingerling or smolt stage depending on species and management objectives. Pink and chum salmon are generally released at the fry stage with a large number of fry released. In British Columbia, the U.S. Pacific Northwest, where the purpose of the hatcheries are generally to ensure the survival of the stock, species such as chinook, coho and sockeye are released as smolts to increase the probability of survival in the wild.

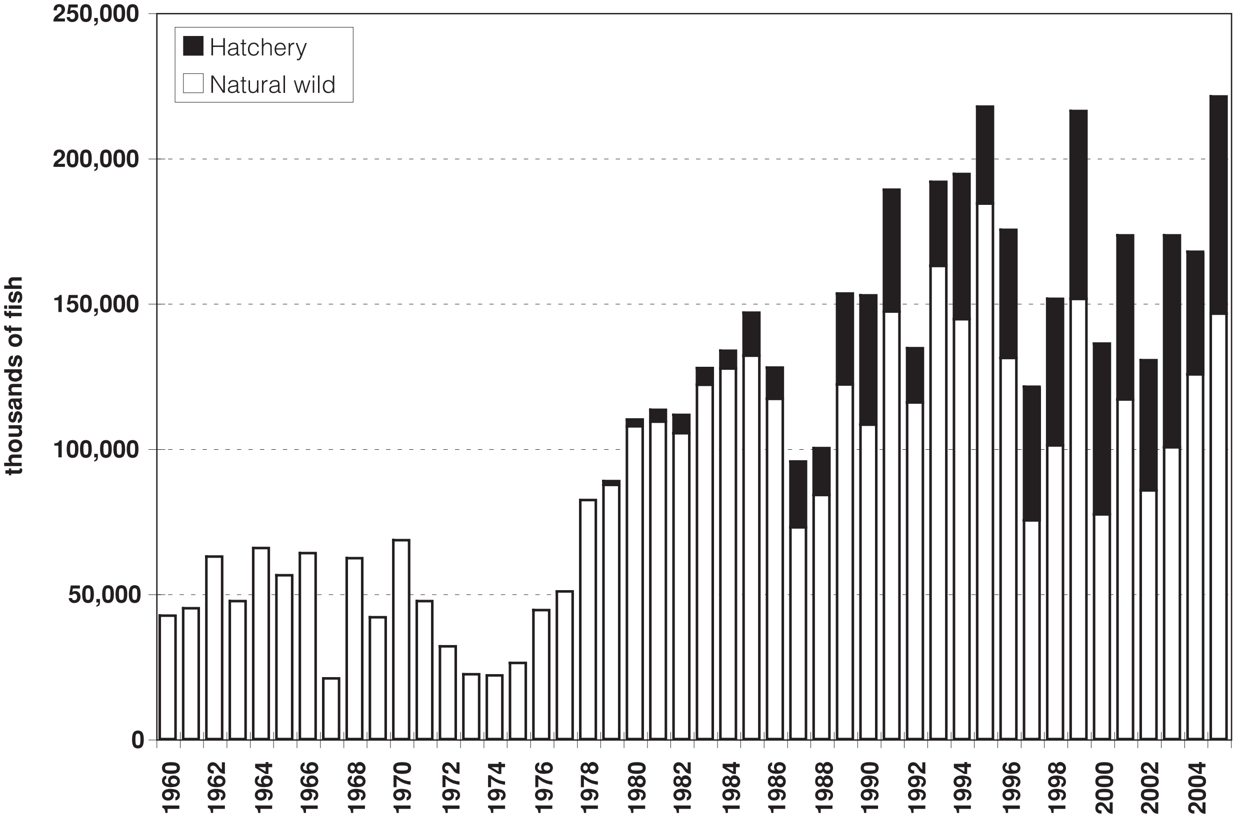
The Alaska Salmon Enhancement Program

Beginning in the 1970s, the State of Alaska supported the development of numerous salmon hatcheries, with the goal of increasing and stabilizing Alaska salmon returns.[3] State support of the Alaska salmon enhancement program was linked to the rapid rise in Alaska oil revenues following the discovery and development of oil on Alaska's North Slope. The State supported hatchery development by loaning money to private non-profit organizations for hatchery construction and operation, as well as by building and operating State-owned hatcheries which were later transferred to private non-profit regional aquaculture associations.

Beginning in the 1980s catches of both hatchery salmon and natural wild salmon increased rapidly. In 2002, the total catch of hatchery fish was 45 million salmon, about one-third of the total Alaska salmon catch (Figure IV-1).[4]

The relative importance of hatcheries varies between different Alaska salmon species. During the period 2000-2002, hatchery fish accounted for 69 percent of Alaska chum salmon catches, 40 percent of pink salmon catches and 12 percent of catches of other species (Table IV-2). Hatchery fish accounted for about

Figure IV-1 **Alaska Commercial Salmon Catches Since 1960: Natural Wild Salmon and Hatchery Salmon**



Source: Data for 1960-1978: ADFG Catch Data 1878-1981; Data for 1979-2005: ADFG Hatchery Data

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[3] The Alaska Department of Fish and Game's annual reports on the Alaska Salmon Enhancement Program, available at www.cf.adfg.state.ak.us/geninfo/enhance/enhance.php, provide detailed information about the program.

[4] Hatchery fish are identified in several ways, including coded wire tags, fin clips and otolith marking (a process by which an identifiable microscopic colored ring sequence in fish ear bones is created by exposing fish to a series of planned temperature changes).

28 percent of the total ex-vessel value of Alaska catches. The importance is highlighted by ADF&G: "The ocean ranching program provides hundreds of Alaskans with seasonal jobs. It is now considered the largest agricultural industry in Alaska" (Farrington, C., ADF&G,. 2004 p. 2).

The relative importance of hatcheries also varies between different areas of Alaska. In 2002, Southeast Alaska and Prince William Sound accounted for about 80 percent of hatchery catches (Table IV-4).

Certain Alaska fisheries are overwhelmingly dependent on hatchery salmon, including the Southeast Alaska chum salmon fishery, the Prince William Sound chum salmon fishery and the Prince William Sound pink salmon fishery. In other major fisheries, such as western Alaska sockeye salmon fisheries and the southeast Alaska pink salmon fishery, hatchery fish account for only a small share of total catches. Note that the two highest value species, chinook and sockeye, are less dependent on hatcheries. Part of the explanation is the health of the natural sockeye stocks in Alaska, and the relatively high cost and time it takes to raise chinook smolts.

Although hatcheries have clearly increased Alaska salmon catches, they have not stabilized catches. Salmon catches by region and in the state as a whole still vary greatly from year to year, even with hatchery programs, because hatchery fish are subject to the same ocean conditions as wild salmon. This is illustrated in Figure IV-2. During the period 1990-2005, Alaska hatchery releases of pink salmon were relatively stable, ranging between 800 million and 1 billion fish. During the same period, returns of Alaska hatchery pink salmon ranged from 15 million to 69 million fish. The percentage of fish returning varied from 1.7 percent to 7.2 percent.

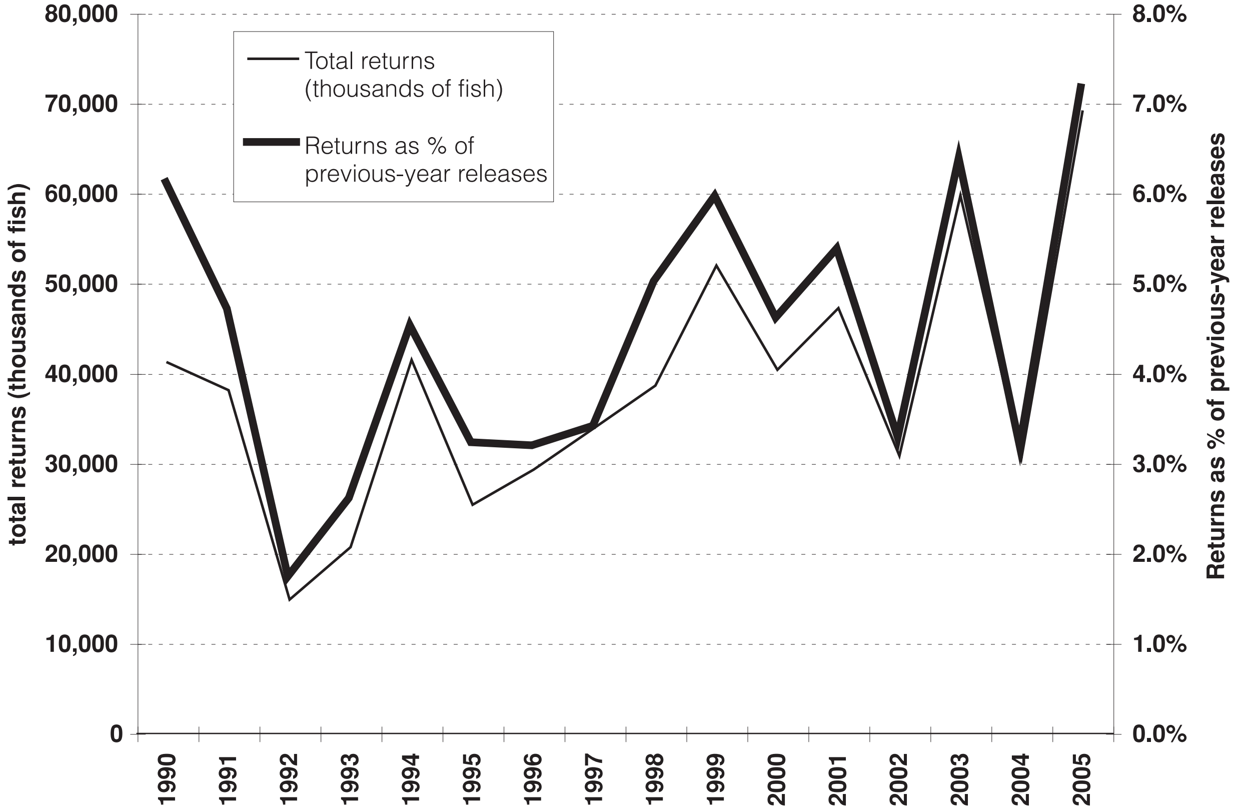
Large numbers of hatchery fish are caught by commercial fishermen prior to their return to the hatcheries. Near hatchery sites, boats hired by the hatchery catch additional large numbers of fish in the so-called 'cost recovery' fishery. All the proceeds from this fishery go to the hatchery. Any remaining hatchery fish are left to mill around the hatchery and die. They are not 'programmed' with a stream in mind to return to. Although some may stray may find a stream and spawn in it, this is neither intended nor desired.

Table IV-4 **Alaska Salmon Catches by Species and Region, Hatchery & Total, 2002**

	Area	Chinook	Sockeye	Coho	Pink	Chum	Total
Commercial catches of hatchery fish (000 fish)	Southeast	87	120	1,425	1,924	5,617	9,173
	Prince William Sound	0	1,164	36	18,772	6,112	26,084
	All other areas	1	1,466	217	7,747	88	9,519
	Alaska total	**88**	**2,750**	**1,678**	**28,443**	**11,817**	**44,776**
Share of total hatchery catches, by species	Southeast	1%	1%	16%	21%	61%	100%
	Prince William Sound	0%	4%	0%	72%	23%	100%
	All other areas	0%	15%	2%	81%	1%	100%
	Alaska total	**0%**	**6%**	**4%**	**64%**	**26%**	**100%**
Share of total hatchery catches, by area	Southeast	99%	4%	85%	7%	48%	20%
	Prince William Sound	0%	42%	2%	66%	52%	58%
	All other areas	1%	53%	13%	27%	1%	21%
	Alaska total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Total commercial catches (000 fish)	Southeast	372	787	2,986	45,612	6,294	56,051
	Prince William Sound	40	2,262	650	18,950	6,373	28,275
	All other areas	128	19,438	1,135	23,000	2,357	46,058
	Alaska total	**540**	**22,487**	**4,771**	**87,562**	**15,024**	**130,384**
Hatchery share of commercial catches	Southeast	23%	15%	48%	4%	89%	16%
	Prince William Sound	0%	51%	6%	99%	96%	92%
	All other areas	1%	8%	19%	34%	4%	21%
	Alaska total	**16%**	**12%**	**35%**	**32%**	**79%**	**34%**

Source: ADFG Hatchery Data.

Figure IV-2 **Estimated Returns of Alaska Hatchery Pink Salmon, 1990-2005**



Source: ADFG Hatchery Data.

Challenges for the Alaska Salmon Enhancement Program

The Alaska Salmon Enhancement Program consists of a variety of public and private sector salmon rehabilitation and enhancement projects. In 2002, these included 29 non-profit corporation hatcheries (by far the most significant component of the program), two state-operated hatcheries, two Federal or Bureau of Indian Affairs hatcheries and several streamside incubation and restoration projects (Farrington 2003).

The Alaska Salmon Enhancement Program has clearly succeeded in increasing total salmon catches, particularly in Southeast Alaska and Prince William Sound. However, the program faces a number of challenges which could affect the future scale of hatchery releases and thus total Alaska salmon catches, particularly of pink and chum salmon. Below, we briefly review these challenges.

Lower Prices

A fundamental problem for the Alaska Salmon Enhancement Program is that real (inflation-adjusted) prices have declined significantly since the start of the program, in particular for chum and pink salmon (Figure IV-3). As a result, investing in raising and releasing young salmon results in less of an increase in future catch value, for any given rate of ocean survival.

In theory, we might expect that as prices decline the net economic benefits of hatcheries would decline, and at some point total hatchery releases would begin to decline. However, this has not yet happened to any significant extent. Hatchery releases of pink and chum salmon stopped growing in the mid-1990s, but have not shown any significant decline (Figure IV-4).

In order to understand the relationship between salmon prices and hatchery releases, we must review the structure of hatchery operations and how they are financed. Most salmon hatcheries in Alaska are now operated by private non-profit (PNP) organizations, most of which received initial funding from state grants and capital and operating loans, to be repaid from hatchery revenues. There are two categories of PNP organizations: independent PNPs and regional aquaculture associations.

Hatcheries may earn revenues to cover operating expenses and repay state loans in two ways. First, hatcheries are authorized to catch a percentage of the adult salmon returning to terminal “special harvest areas" for sale. These are referred to as "cost-recovery" catches." Typically cost-recovery fish are caught by just a few boats, catching very large volumes, working under contract to the hatcheries in the special harvest areas. All other returning hatchery salmon are caught in "common-property fisheries" by commercial, sport and subsistence fishermen.

Second, in management areas with regional aquaculture associations, fishermen may vote to assess an "enhancement tax" on the ex-vessel value of their salmon landings. These enhancement tax funds also support hatchery operations. Enhancement tax rates are presently 3 percent in southeast Alaska and 2 percent in Prince William Sound, Cook Inlet and Kodiak. No enhancement taxes are assessed in other areas.

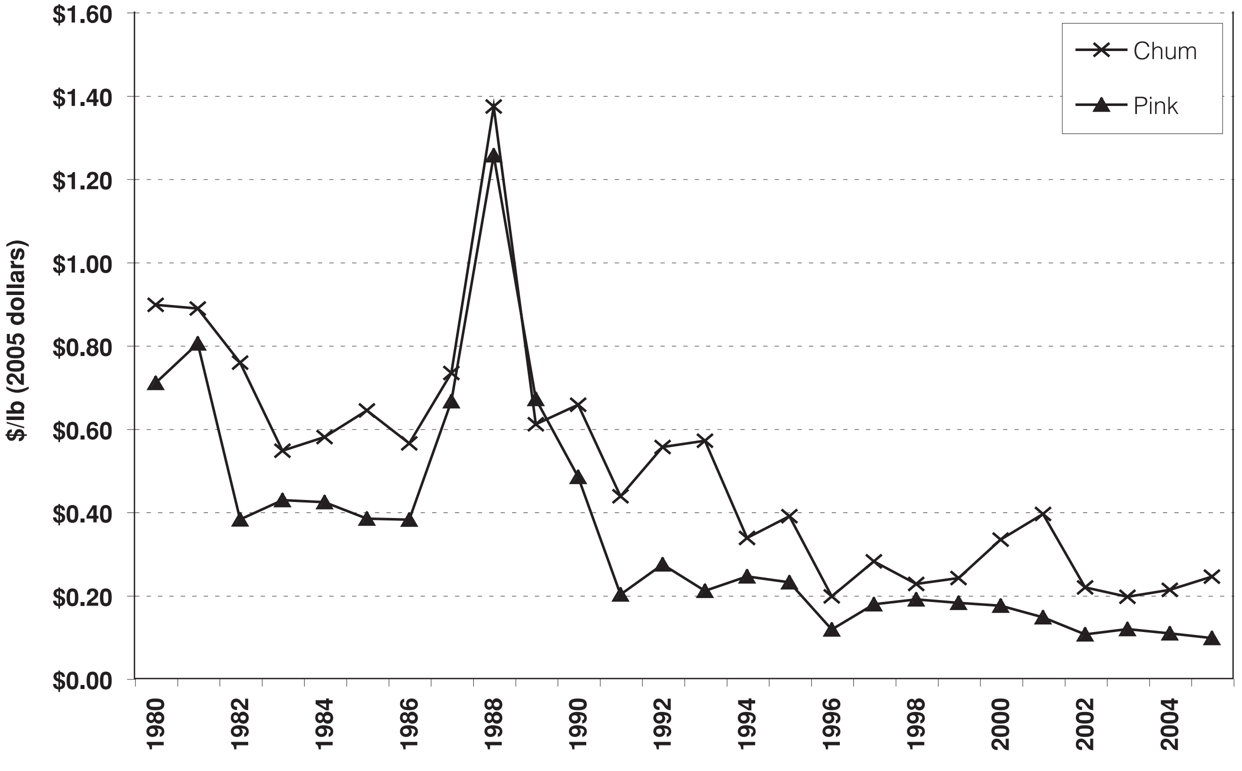
As ex-vessel prices have declined, enhancement tax collections have declined, so that the hatcheries have had to rely on cost-recovery catches for a greater share of their revenues. In addition, because prices are lower, hatcheries need to catch more fish in the cost-recovery fisheries to meet any given revenue target. As a result, as prices decline an increasing share of the hatchery returns have been caught in cost-recovery fisheries rather than by commercial fishermen in the common property fisheries. This trend is particularly evident for chum salmon, for which the cost-recovery share of catches increased from less than 30 percent in the early 1990s to more than 51 percent in 2003 (Figure IV-5).

As the cost-recovery share of hatchery catches increases, the share of the benefits captured by commercial fishermen (other than those few who participate in the cost-recovery fishing) declines. Put differently, an increasing share of the fish goes to support the hatcheries, rather than the original concept of increasing the total volume of fish available to all fishermen.

Increasing the share of hatchery fish going to cost-recovery harvests has allowed the hatcheries to continue to operate despite lower salmon prices. However, over time, this may create a political problem for the hatcheries, which depend upon enhancement taxes paid by fishermen on all catches—not just catches of hatchery fish—and which also depend upon the political support of commercial fishermen to address other issues which they face (discussed below).

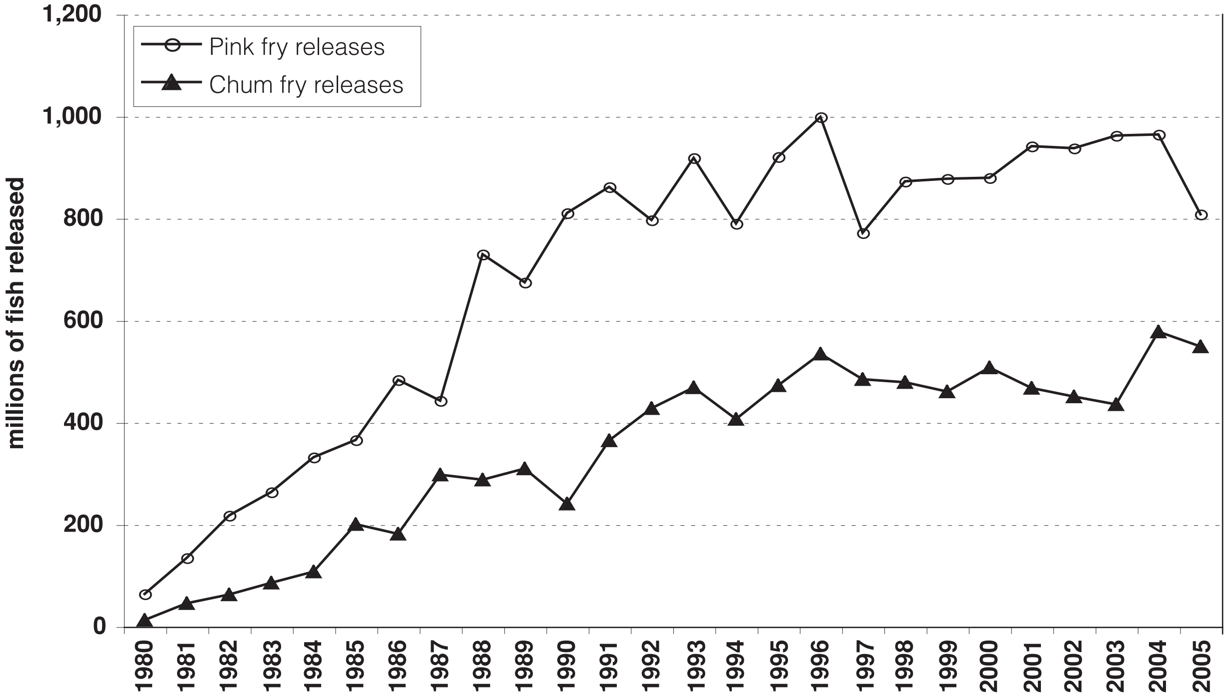
In addition to covering their operating costs, hatcheries also need to make payments on the loans they have received from the State of Alaska's Fisheries Enhancement Revolving Loan Fund. During the early 1990s, as ex-vessel prices declined, many hatcheries requested and received permission to reschedule loan repayments. As Alaska's oil revenues have declined, the State is less likely to extend this kind of assistance should hatcheries face financial difficulties in the future.

Figure IV-3 **Average Real Ex-Vessel Prices for Alaska Chum and Pink Salmon, 1980-2005**



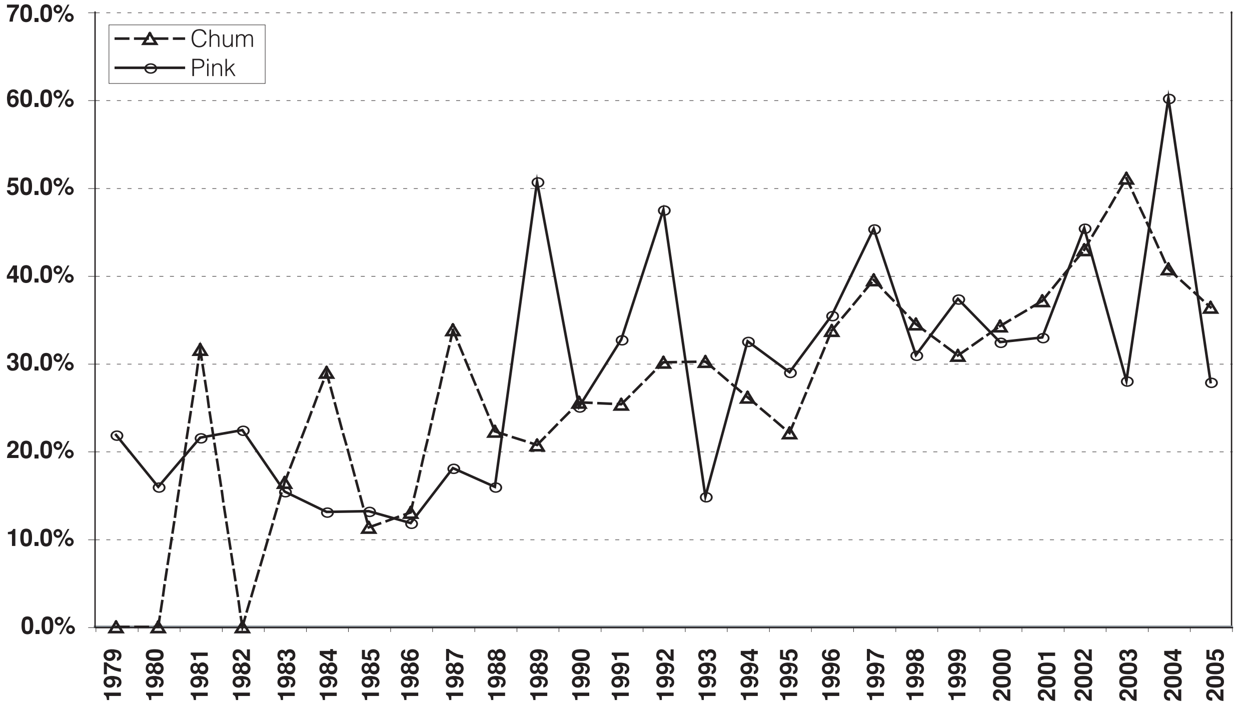
Source: ADFG Catch data.   Adjusted for inflation based on Anchorage CPI.

Figure IV-4 **Alaska Hatchery Releases of Pink and Chum Salmon Fry, 1980-2005**



Source: ADFG Hatchery Data.

Figure IV-5 **Hatchery Cost-Recovery Share of Alaska Hatchery Salmon Catches**



Source: ADFG Hatchery Data.

Market Effects of Hatchery Production

As we discuss in future chapters, salmon prices are sensitive to total salmon supply.

During the 1990s, fishermen in regions of Alaska without hatchery production—in particular areas of interior and western Alaska dependent on chum salmon—argued that increased hatchery catches were responsible for the disastrous decline in prices which they had experienced. More generally, the question began to be raised whether Alaska salmon hatcheries were actually increasing the total value of Alaska salmon catches, or whether the value of the increased harvests was being offset by corresponding negative effects on prices.

How much Alaska hatchery catches may have depressed Alaska salmon prices, or whether or not hatcheries have actually increased the total ex-vessel value of Alaska salmon catches (not to mention net economic value after subtracting costs of hatchery operations) is not an easy question to answer. As we discuss in subsequent chapters, salmon markets are complex and are affected by many factors. In addition, they are subject to structural change, so that the effects of a given volume of hatchery catches on prices may have changed over time.[5]

In the short-term, higher catches in a given region in any given year tend to lower ex-vessel prices in that year. Over the longer term, prices are driven by world supply and demand rather than supply and demand from any particular region. If, as with hatchery production, other regions have the ability to respond to higher prices by increasing production, then higher or lower production by a particular region will not necessarily affect long-term world prices.

In general, it seems likely that Alaska hatchery production has had some negative effects on ex-vessel prices of chum and pink salmon, but that hatcheries are not the only factor contributing to lower prices. Clearly, hatcheries have benefited fishermen and processors in some areas (primarily Prince William Sound and Southeast Alaska) by greatly increasing catches. At the same time, hatcheries have not benefited, and may well have harmed, fishermen and processors in other areas without hatchery production. Thus, the Alaska salmon hatchery program has at times been an issue between different regions of Alaska.[6]

Roe "Stripping" or "Salvaging"

A particularly contentious issue associated with the Alaska salmon hatchery program has arisen as a result of declining prices for fresh, frozen and canned salmon while prices for salmon roe have remained strong. In some years the value of fresh, frozen and canned products have fallen below the costs of processing, particularly for lower-quality "dark" salmon caught in hatchery terminal areas after they have begun to undergo physiological changes associated with return to fresh water, and when unexpectedly large returns exceed local processing capacity. For these fish, the most economically profitable utilization is to extract the salmon roe but to dispose of the salmon carcass.

Normally, it is illegal to dispose of salmon harvested in Alaska without utilizing the fish, under a State law which bans the "waste" of commercially harvested fish. However, in some years hatcheries and processors have applied for exemptions from this law and have received permission to grind up and dispose of salmon carcasses at sea, after first removing valuable salmon roe. This practice is commonly referred to as "roe-stripping" or "roe-salvaging" depending on one's perspective on it.

This "dumping" of salmon has been strongly criticized by some segments of the Alaska salmon industry and the public who have argued that it is immoral to waste fish and that the "stripped" or "salvaged" roe competes unfairly with other roe production. Others have responded that utilizing the valuable salmon roe is better than the alternative of not harvesting the fish at all, in particular since returning hatchery fish provide no ecological benefit and large volumes of dead fish in hatchery terminal areas would pollute these areas.

One example of this issue occurred during the 2003 pink salmon season in Prince William Sound, when 49 million pink salmon were caught after a preseason harvest projection of 27 million fish. More than 4 million pink salmon (about 8 percent of the Prince William Sound pink salmon catch and about 3 percent of the total Alaska pink salmon catch) were ground and "recycled" after the eggs were removed (Tkacz 2003).

When low prices or lack of processing capacity lead to the disposal of hatchery fish after roe extraction, it usually contributes to adverse publicity for the salmon hatchery program and questioning whether the hatchery production is needed—adding to the other political issues faced by hatcheries.[7]

Effects of Hatcheries on Alaska Natural Wild Salmon

To minimize potential adverse effects of hatchery releases on natural wild runs, the State has established an extensive regional planning process for salmon enhancement and set strict conditions for egg collection, fish transport and release and management

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[5] Market effects of the Alaska hatchery program were addressed by Boyce et al. (1993) and Herrmann (1993). These analyses were critiqued by Wilen (1993).

[6] A different market-related issue is whether hatchery sales of cost-recovery catches may depress prices paid to local fishermen for both hatchery and natural wild fish caught in common-property fisheries.

[7] In an *Anchorage Daily News* article, a Prince William Sound fisherman who is a former chairman of the Alaska Seafood Marketing Institute was quoted as commenting: "It's just disappointing. . . We've got the mother of all runs, and we can't sell all of the fish. I'm worried. I'm worried that some fishermen and legislators in other areas might think it's a mistake to be generating these pink salmon, but we're pretty grateful for them around here for all the opportunity they create. Nobody anticipated this kind of return. We should not do anything knee-jerk about occasionally having overproduction." (Loy 2003).

of enhanced stocks. Hatcheries may only use eggs collected originally from local wild salmon stocks.[8]

However, as in other areas, some critics still question whether the Alaska salmon hatchery program may adversely affect Alaska's natural wild salmon runs. One concern relates to the potential for competition for food between hatchery salmon and natural wild salmon, both for juvenile fish in near-shore waters as well as in the open ocean.

Another set of issues relate to the management of commercial fisheries in which fishermen are catching mixed stocks of hatchery and natural wild salmon. If large returns of hatchery fish are mixed with depleted runs of natural wild fish, there is the potential for over-harvests of natural wild fish runs.

Another concern relates to the "straying" of returning hatchery fish into streams with natural runs of wild salmon, with the potential for genetic change in the natural wild salmon populations. For all of these concerns, the scientific complexity of the issues, together with lack of data and research, makes it difficult to determine how serious the potential problems associated with the hatchery program may or may not be.[9]

"Wild" Image of Alaska Salmon

An issue which may grow in importance over time is the effect of Alaska's salmon hatchery program on the "wild" image of Alaska salmon fisheries. The salmon farming industry has been subject to growing criticism over alleged adverse environmental effects as well as market effects on wild salmon fisheries. As we discuss in later chapters, the argument has been made that because of these alleged adverse effects of farmed salmon, consumers should favor wild salmon over farmed salmon. Over time, some salmon farmers may respond to these criticisms by pointing out problems associated with wild salmon. One response is likely to be that not all Alaska salmon are fully "wild," and that there are environmental and market issues associated with hatchery salmon as well as farmed salmon.[10] If this caused Alaska's hatchery program to become a concern for some consumers in the future, it could possibly reduce political support within Alaska for the hatchery program.

It should be noted that Alaska chum salmon, which account for by far the largest share of United States consumption of fresh and frozen Alaska wild salmon, is also the species most dependent on the Alaska hatchery program.

The Future of the Alaska Salmon Enhancement Program

The issues discussed above are the subject of an intense and long-running political debate about the Alaska salmon hatchery program, between supporters of the program and those who argue for substantially scaling back hatchery releases. The debate is not widely understood outside of Alaska or the salmon industry.

A series of special studies and task forces and special studies have examined the issues related to hatcheries, and at various times proposals to limit hatchery production have been debated before the Board of Fisheries. In 1991, a committee of the Alaska Senate undertook a special review of fisheries enhancement in Alaska, in order to "assemble and analyze information about the program and the global context in which it operates," and to "serve as the first step in ensuring that current and future enhancement efforts will be economically and biologically sound, while fulfilling the goals for which the program was established" (Alaska State Senate 1992). In 1996, a "Hatchery Policy Group" was appointed to review and make recommendations on state-wide hatchery production policy and hatchery loan policy (Gardiner 1996). In 2002, the Alaska legislature established a Joint Legislative Salmon Industry Task Force to review issues facing the salmon industry and make recommendations to the legislature. The Task Force formed a number of subcommittees, including a 'Hatchery Subcommittee' which was charged with examining Alaska hatchery policy issues.[11]

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[8] See McGee (1995) for a useful review of the planning process and state policies related to the hatchery program and protection of wild salmon.

[9] These concerns were summarized in Environment and Natural Resources Institute (2001): "Alaska's ocean-ranching salmon hatcheries operate amidst considerable uncertainty. Perhaps the most striking feature uncovered by this review was the many gaps in the scientific data from which one could fairly draw conclusions of the effects hatcheries may or may not have on wild salmon. Alaska has been successful in augmenting salmon harvest with hatchery-produced fish, but whether or not salmon biodiversity has been adequately protected in the process is unanswered. . . . With respect to fish-culture practices, Alaska's hatcheries are among the best in North America. . . . Given the late date at which Alaska's ocean-ranching program was established, the state was able to benefit from mistakes made elsewhere. The program started on better footing by having genetic oversight of operations through fish transport permits, hatchery siting, egg takes, broodstock development, etc." Nevertheless, the report concluded that, as a result of mixed-stock management issues, competition for resources between hatchery and wild salmon stocks, and potential effects on genetic diversity of wild salmon populations, "industrial-scale hatchery salmon production . . . could be jeopardizing Alaska's wild salmon."

[10] Dodd (2003) suggested that "the fish which the hatcheries produce for commercial fishermen undoubtedly eat sizeable quantities of prey species as they move up the feed chain towards harvest time, prey that would otherwise be available to truly 'wild' fish." Another example is provided by an article posted on the website of the Washington Fish Growers Association (www.wfga.net): "Salmon farming vs. salmon ranching is another interesting issue that likely doesn't make its way into the 'wild is good, farmed is bad' marketing campaign. In order to help maintain its commercial fishery, and enhance wild fish stocks, Alaska decided to forego the salmon farming route and do salmon ranching instead. Salmon ranching is a lot like salmon farming. Fish are raised in ocean-based pens, fed a steady diet of processed food (purchased in British Columbia, interestingly enough, and consumed at nearly six times the rate used in British Columbia fish-farm operations), fed some dyes important to their health and colour, also antibiotics. When they're big enough, they let them go. Alaska releases more than 1.5 billion "ranched" fish into the waters every year, and they happily swim away, competing for food with their natural-born cousins, and eventually get caught (along with the wild fish) in the commercial fishery. . ."

[11] Information about the activities of the Task Force, including proposed legislation developed by the task force, was posted on the website of the United Fishermen of Alaska, at www.ufa-fish.org/taskforce/.

Earlier task forces and studies have not resulted in major changes to the Alaska's hatchery program policies or the scale of hatchery releases. However, the underlying political issues remain and the debate over the program continues, even expanding into new fora. With the Marine Stewardship Council's (MSC) certification of the Alaska salmon fishery as a sustainable fishery (see Chapter XVI for a more thorough discussion), one of the concerns brought up in the certification process in 2000-2001 was the hatchery program. In particular, the assessment team was concerned about the lack of research on the potential effects of salmon hatcheries on the wild stock gene pool and reproductive fitness (Scientific Certification Systems 2000). This concern remained in 2005 as the Alaska salmon fishery entered its new five-year assessment for re-certification under the MSC program.

It is possible that Alaska hatchery salmon releases and catches could decline significantly in the future due to lower economic return of hatcheries and/or changing political circumstances. It is difficult to predict whether such a decline will in fact occur or when it might occur. It could be that hatchery salmon—as opposed to natural wild salmon—would be most affected by changing economic circumstances in wild fisheries.

The British Columbia Salmonid Enhancement Program

In 1977, in response to declining British Columbia salmon runs, the Canadian federal Department of Fisheries and Oceans (DFO) launched a Salmonid Enhancement Program (SEP). The program included both the construction of hatchery facilities as well as a variety of other habitat enhancement projects such as spawning channels, incubation boxes and lake enrichment.

DFO estimates that about 10-20 percent of the British Columbia sport and commercial salmon catch originates from SEP projects, and about a dozen terminal fisheries are dependent on enhanced stocks (DFO 2000a). A terminal fishery is one that occurs at the place where the hatchery salmon were released into fresh water.

In a 2000 review of the Salmonid Enhancement Program, the Pacific Fisheries Resource Conservation Council (PFRCC 2000; DFO 2000b) concluded that:

> *In hindsight, it is difficult to say whether the Salmonid Enhancement Program and its predecessors, which have accounted for close to a half-billion dollars in public investments over the years, have produced any net return on investment, if measured by a net gain of salmon. There is evidence to suggest a net loss of wild salmon abundance, directly and indirectly because of enhancement initiatives. . .*
>
> *The Council's review of the Salmonid Enhancement Program leads inevitably to the conclusion that some facilities created by it have resulted in the displacement of wild salmon by hatchery-produced fish. This has occurred when hatchery salmon have attracted fishing effort that unavoidably produced unsustainably high rates of harvest on co-migrating wild salmon. It has also occurred because juvenile fish from wild populations have been subjected to competition from hatchery fish in rearing areas, and in the ocean phase of the salmon life cycle.*
>
> *Declines in numerous wild-salmon populations, concurrent with increases in production from a few large hatcheries, tend to create a situation in which salmon abundance is attributable to ever-fewer stocks. This places the salmon resource at an increasingly greater risk of random, catastrophic disruption.*

History of Salmon Hatcheries in the U.S. Pacific Northwest

Hatchery techniques for the artificial propagation of Pacific salmon were developed for the first time in Canada around 1857 and soon spread to the United States (Bardach et al. 1972).

The construction and operation of the first hatcheries for Pacific salmon in the United States began on the McCloud River in northern California in 1872 and in 1877 and 1878 on the Clackamas and Rogue Rivers in Oregon (Atkinson 1988). In 1883, the first Canadian hatchery for Pacific salmon was built at Bon Accord (near New Westminster, British Columbia) on the Fraser River (PCSF 2004). The first hatchery in Washington State was built on the Kalama River in 1895 (WDFW 2004). Four years later, the Washington Department of Fish and Wildlife began the construction of salmon hatcheries in the mid-Columbia River region, on the Wenatchee and Methow Rivers (Wahle and Pearson 1984).

Hatcheries were originally built to reverse the trend of declining populations of wild salmon and to compensate for land use decisions that permanently altered large areas of fish habitat (WDFG 2004). Emphasis was initially placed on chinook and coho salmon despite an incomplete understanding of the complex life history of these species. Hatcheries propagated and stocked salmon for many years without concrete evidence of the success and long-term implications of their efforts.

Large-scale construction of salmon hatcheries began in 1938, when Congress passed the Mitchell Act to provide federal money for construction of hatcheries as a way of replacing the thousands of acres of salmon spawning grounds that were blocked or flooded behind dams. Subsequently, more than 80 hatcheries were built in the Columbia River basin (Novak 1998).

Currently, the State of Washington has one of the largest artificial propagation systems in the world, with a hatchery program that operates 24 complexes with 91 rearing facilities. Together they raise and release more than 201 million Pacific salmon, 8.5 million steelhead (salmon) trout and 22.6 million trout and warm-water fish (Maynard and Flagg 2001). Hatchery-bred fish help support the State's $850 million per year sportfishing industry (*The Wave News Network* 2004).

A group called the Hatchery Review Group unveiled a new blueprint for the State of Washington's hatchery programs on April 23, 2004 (*The Wave News Network* 2004). The blueprint cost $28 million to write and has more than 1,000 recommendations for improving the large salmon hatchery system. Examples include closing some hatcheries that are especially detrimental to wild stocks, and limiting the number of hatchery fish released so that they do not overrun wild stocks protected under the Endangered Species Act.

In addition, the state has 12 federal hatcheries and 35 tribal rearing facilities which produce another 50 million salmonids for release. In Oregon, the Department of Fish and Wildlife operates 34 hatcheries and 15 other rearing facilities, which release about 43 million Pacific salmon, 5.7 million steelhead (salmon) trout and 8.3 million trout. California has eight salmon and steelhead (salmon trout) hatcheries.

Depending on species and area, the salmon enhancement programs in the U.S. Pacific Northwest produce as much as 70 to 90% of salmon harvested in the commercial and recreational fisheries.

The potential for hatchery salmon to affect wild stocks went unrecognized for many years. Between the mid-1950s and early 1970s, scientists found increasing evidence that hatchery salmon was harming the remaining wild salmon runs. It seems clear now that hatcheries have had demographic, ecological and genetic impacts on wild salmon populations.

These effects include the reduction of genetic diversity within and between salmon populations, creation of mixed-population fisheries, altered behavior of fish, ecological imbalances due to the elimination of the nutritive contribution of carcasses of spawning salmon from streams, and the displacement of the remnants of wild runs (NRC 1996). As Hilborn (1992) notes:

> *Large-scale hatchery programs for salmonids in the Pacific Northwest have largely failed to provide the anticipated benefits; rather than benefiting the salmon populations, these programs may pose the greatest single threat to the long-term maintenance of salmonids… I argue that hatchery programs that attempt to add additional fish to existing healthy wild stocks are ill advised and highly dangerous.*

As a result, academic, environmental and salmon advocate groups have proposed a redesign of the traditional objectives of hatchery management, which needs to shift away from producing more fish for harvest towards providing a means for the recovery and conservation of wild salmon populations (LLTK 2004; NRC 1996).

It is worth noting that there have been a few attempts at private salmon ranching, such as Ore Aqua Foods, a subsidiary of Weyerhaeuser and Anadromous Inc., a subsidiary of British Petroleum, both operating in Oregon during the late 1970s and 1980s. Private salmon ranching is based on the premise that smolts released from the private hatchery will return and will be captured by the "owner" of the fish. These have been unsuccessful primarily because ocean mortality is high and uncertain, and property rights related to salmon released to the ocean are poorly defined. In addition to these problems, salmon enhancement (public or private) may undermine the management of wild stocks through direct and indirect competition.

The 2005 *Atlas of Pacific Salmon* summarized the breadth and complexity of the issues related to salmon hatcheries in the U.S. Pacific Northwest and elsewhere.

> *The benefits of hatcheries are compelling: they may offset losses in abundance in naturally spawning stocks and reduce harvest pressure on wild populations; they help stabilize commercial harvest; and they serve as laboratories for the study and preservation of biodiversity. Hatcheries also provide a solid economic base for salmon-dependent communities, including native peoples.*
>
> *Yet these benefits are counterbalanced with significant scientific uncertainty regarding freshwater and ocean carrying capacity, particularly within a trans-Pacific context . . . Interbreeding and brood stock transfer among rivers can challenge wild population viability and genetic integrity. Hatchery production can mask ecological problems at the heart of declines in wild populations. Artificial propagation can deprive rivers of marine-derived nutrients . . . essential to functioning freshwater ecosystems. Unfortunately, isolating impacts of hatchery fish on wild populations is extremely difficult, and so efforts to determine hatchery success or failure remain inconclusive.*
>
> *Two legislative debates—whether to count hatchery fish under endangered species legislation . . . and whether to allow surplus hatchery fish to spawn in the wild—have fulminated in recent years, underscoring the fact that hatchery management is among the most controversial issues in fisheries today.*

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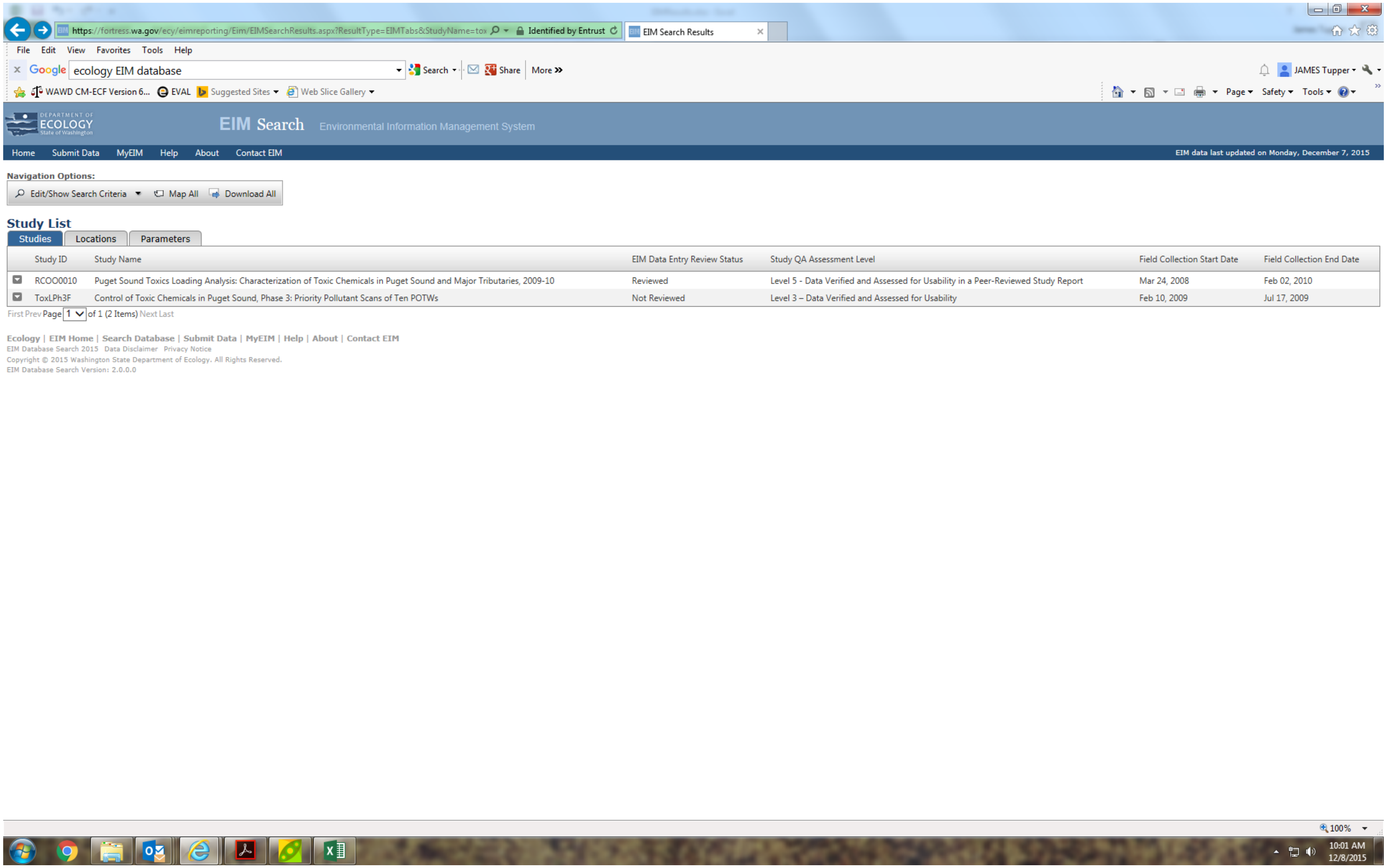

EIM Search Environmental Information Management System

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
WATER

JUN 25 2004

Ms. Maxine I. Lipeles, J.D.
Director, Interdisciplinary Environmental Clinic
Washington University in St. Louis
1 Brookings Drive #1120
St. Louis, MO 63130

Dear Ms. Lipeles:

Thank you for your letter of February 25, 2003, to Administrator Whitman transmitting a petition on behalf of the Ozark Chapter of the Sierra Club requesting that the U.S. Environmental Protection Agency (EPA) set consistent and adequate water quality standards for defined portions of the Mississippi and Missouri rivers. EPA has carefully considered your petition and our formal response is enclosed.

In summary, EPA agrees with the Sierra Club that the Mississippi and Missouri Rivers are valuable resources that must be protected. After evaluating the currently approved water quality standards applicable to the petition area waters, the existing scientific knowledge for each pollutant at issue, and whether the affected states are working to establish or revise water quality standards in a manner that would address potential concerns, EPA is denying the Sierra Club's specific request but committing to further action.

In our discussions with you and the Sierra Club, you specified that two of your highest priority issues are numeric criteria for nutrients and bacteria. You also indicated that if federal promulgation of numeric nutrient criteria was not an option, you would like to see more federal leadership on nutrient issues in the petition area. In response to the petitioners' request to promulgate numeric nutrient criteria, we do not believe it is appropriate to promulgate numeric criteria for these specific waters until the science and the development of numeric nutrient criteria in the big rivers are better understood. However, in response to your request for more federal leadership, in addition to the ongoing work to address hypoxia in the Gulf of Mexico, EPA is committing to convene a multi-day national workshop to bring together states and others to discuss the development and adoption of appropriate ambient water quality criteria for nutrients for the Mississippi and Missouri Rivers to protect the rivers as well as the Gulf of Mexico. Following the workshop, EPA will publish a report that will summarize the results of the workshop, identify next steps, and establish a roadmap for how EPA would work with its partners to address nutrients in the Mississippi and Missouri Rivers. EPA has identified the necessary funds and will begin planning the workshop immediately with the intent to hold the workshop in 2005. EPA hopes that the Sierra Club and other stakeholders will actively participate in this effort to help ensure success. In the interim, EPA will continue to assist the states and invest additional resources in the development and adoption of nutrient criteria for the rivers' tributaries, with the expectation that state adoption and implementation of nutrient criteria for tributaries of the Mississippi and Missouri Rivers will lead to an overall reduction of nutrient loadings entering the petition area and thus flowing to the Gulf of Mexico.

With regard to the petitioners' request to promulgate bacteria criteria in the petition area, we are pleased to inform you that both Illinois and Missouri have sent EPA formal letters committing to adopt *E. coli* criteria for the petition area (among other waters) within their states. Missouri has committed to adopt *E.coli* criteria (as well as appropriate recreation uses) by July of 2005. Illinois has committed to initiate its rulemaking process to adopt *E. coli* criteria by September 30, 2004. The remaining six states have either adopted *E. coli* criteria or have proposed *E. coli* criteria in their state rulemaking process and are moving forward to adopt it into state regulation. If any state does not follow through on its commitment, EPA will, if necessary, promulgate water quality standards for the petition area within these states.

The Agency expects states to protect their waters consistent with the requirements of the Clean Water Act and the federal regulations. While EPA is not promulgating water quality standards for the petition area in response to the petition at this time, EPA is committed to continue to work with states and others to ensure these valuable waters are adequately protected.

We understand the Sierra Club's concern regarding the consistency, adequacy, and effective monitoring of water quality standards for the Mississippi and Missouri Rivers. I want to assure you EPA carefully considered the petition and the additional information you provided in our decision making process. If you would like to discuss your concerns further, please feel free to contact me at (202) 564-5700 or Geoffrey Grubbs, Director of the Office of Science and Technology at (202) 566-0430.

Sincerely,

[Signed by Ben Grumbles, June 25, 2004]

Benjamin H. Grumbles
Acting Assistant Administrator

Enclosure

cc. J. I. Palmer, Jr, Regional Administrator, Region 4
Bharat Mathur, Acting Regional Administrator, Region 5
Richard Greene, Regional Administrator, Region 6
James B. Gulliford, Regional Administrator, Region 7

DECISION ON PETITION FOR RULEMAKING TO PUBLISH WATER QUALITY STANDARDS FOR THE MISSISSIPPI AND MISSOURI RIVERS WITHIN ARKANSAS, ILLINOIS, IOWA, KANSAS, KENTUCKY, MISSOURI, NEBRASKA AND TENNESSEE

On February 26, 2003, the Ozark Chapter of the Sierra Club (hereafter Sierra Club or petitioner) submitted a petition to the United States Environmental Protection Agency (hereafter "EPA" or Agency) requesting that EPA publish water quality standards for the Mississippi and Missouri Rivers within the petition area. As described below, EPA has given careful consideration to the issues raised in the petition and its request but is HEREBY DENYING the petition for the reasons set forth below.

Petition for Rulemaking

On February 26, 2003, the Ozark Chapter of the Sierra Club submitted a petition requesting that EPA set consistent and adequate water quality standards for defined portions of the Mississippi and Missouri Rivers ("petition area"). The petition area includes portions of the Mississippi and Missouri Rivers in Arkansas, Illinois, Iowa, Kansas, Kentucky, Missouri, Nebraska, and Tennessee ("the petition states"). The Sierra Club submitted this petition pursuant to Paragraph 9 in the Settlement Agreement in American Canoe Ass'n v. Browner, 98-1195-CV-W and 98-482-CV-W (W.D. Mo.) (Effective date 2-27-01).

The petitioner summarizes its request as follows:

> Pursuant to the Settlement Agreement[1], the Ozark Chapter requests that, within one year of receipt of this petition, the EPA publish water quality standards for the Mississippi and Missouri Rivers within the petition area states. Such standards should be:
>
> 1) Consistent among the states on each river, such that no state impairs the ability of any other affected state (whether across-stream or downstream) to achieve its water quality standards; and
> 2) Adequate:
>   a) Including numeric criteria for chlordane, atrazine, polychlorinated biphenyls, *E. coli*, enterococci, conventionals (including dissolved oxygen and ammonia), nutrients, sediments, and an index of biological integrity for the aquatic community ("the petition pollutants"), among other criteria; and
>   b) Reflecting criteria sufficient to achieve and maintain fishable/swimmable water quality criteria.
> *3)* In addition, such standards should include monitoring requirements sufficient to support a uniform, statistically based method for determining whether the rivers are meeting their water quality standards. Petition at 2 – 3.

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[1] Settlement Agreement. American Canoe Ass'n v. Browner, 98-1195-CV-W and 98-482-CV-W (W.D.M.o). Effective date 2-27-01. The Settlement Agreement provides that EPA will "grant or deny" the petition within a year of its receipt. On February 26, 2004, the parties to the settlement agreed to extend the date by which EPA would respond to the petition to June 25, 2004.

Statutory and Regulatory Background

The Clean Water Act (CWA) establishes a comprehensive program "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." CWA section 101(a). The interim goal of the CWA is to attain water quality that provides for the protection and propagation of fish, shellfish, and wildlife. CWA section 101(a)(2).

The CWA section 303 requires states to adopt (subject to federal approval) water quality standards. The principle components of states' water quality standards are: (a) designated uses for waters, such as water supply, recreation, fish propagation, agriculture, and navigation; (b) water quality criteria, which define the amounts of pollutants the waters may contain without impairing their designated uses; and (c) antidegradation requirements, which protect existing uses and otherwise limit degradation of waters. CWA section 303(c)(2)(A) and 303(c)(2)(B), and 40 C.F.R. §§131.3(b), 131.3(f), 131.3(i), 131.6, 131.10-.11 (uses and criteria); and 40 C.F.R. §131.12 (antidegradation).

Designated Uses

Pursuant to CWA section 303(c)(2)(A) and 40 C.F.R. §131.10(a), states must designate appropriate water uses to be achieved and protected taking into consideration the use and value of water for public water supplies, protection and propagation of fish, shellfish, and wildlife, recreation in and on the water, agricultural, industrial, and other purposes including navigation. Where existing water quality standards specify designated uses less than those that are presently being attained, the state shall revise its standards to reflect the uses actually being attained. 40 C.F.R. §131.10(i). A state must conduct a use attainability analysis (UAA) where a state designates or has designated uses that do not include uses specified in section 101(a)(2) (sometimes referred to as "fishable/swimmable"), or where the state wishes to remove designated uses specified in section 101(a)(2), or to adopt subcategories of uses specified in section 101(a)(2) which require less stringent criteria. 40 C.F.R. §131.10(j).

Water Quality Criteria

The CWA section 304(a)(1) provides that EPA shall develop (and from time to time thereafter, revise) recommended water quality criteria based on current data and scientific judgment regarding the relationship between pollutant concentrations and environmental and human health effects. EPA's recommended section 304(a) criteria serve as guidance for states to use in deriving criteria to protect states' adopted designated uses.

EPA currently derives its section 304(a) water quality criteria for the protection of aquatic life using EPA's *Guidelines for the Derivation of Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* ("Guidelines") (Stephan et al. 1986. NTIS: PB85-227049). The Guidelines provide that each criterion is derived from the evaluation of toxicological data from a representative universe of species, allows for the inclusion of site-specific considerations, and results in a chemical concentration expected to be protective of aquatic life and their uses.

EPA currently derives its section 304(a) water quality criteria for the protection of human health using the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)* ("Methodology") (EPA-822-B-00-004, www.epa.gov/waterscience/humanhealth/method). The Methodology details the necessary components of the risk assessment: hazard (cancer and non-cancer effects), exposure (from drinking water and fish consumption rates), and bioaccumulation (from measured or calculated bioaccumulation factors). The exposure component of criteria is based on consumption of contaminated aquatic organisms and drinking water. Many of the hazard identification and dose response assessments can be found in EPA's Integrated Risk Information System (IRIS)[2], a database that summarizes available toxicity data and contains EPA's assessment of the data. EPA establishes criteria at a recommended risk level for carcinogens; however, selection of a specific risk level is a risk management decision and EPA believes adoption of either a 10^{-6} or a 10^{-5} risk level represents an acceptable range of discretion for states and tribes[3].

The scientific efforts that lead to the publication of a final ambient water quality criterion for protection of either aquatic life or human health typically need 18 months or more to complete. EPA follows the procedures described in EPA's *Guidelines for the Derivation of Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* and the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)*, as well as Agency policy and procedures governing the development of scientific data and documents. This process includes an extensive search of peer reviewed literature, data quality evaluation, criterion and supporting documentation derivation, public scientific input, and peer review. Both the derivation process and the public and peer participation are critical to ensuring that the final section 304(a) criteria meet the clarity, transparency, and scientific rigor standards of the Agency. These steps ensure that the final criteria are scientifically defensible and that risk management decisions based on the criteria are legally defensible.

Ultimately, water quality criteria provide a basis for controlling discharges or releases of pollutants into surface waters. In establishing criteria, EPA's regulations require states to adopt water quality criteria to protect designated uses by adopting EPA's section 304(a) criteria recommendations, modifying EPA's section 304(a) criteria recommendation to reflect site-specific conditions, or deriving and adopting criteria based on other scientifically defensible methods. 40 C.F.R.§131.11. In addition, states may establish narrative criteria where numeric criteria cannot be established or to supplement numeric criteria.

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[2] U.S. Environmental Protection Agency. Integrated Risk Information System. < http://www.epa.gov/iriswebp/iris/index.html>

[3] U.S. Environmental Protection Agency. *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000).* Office of Water, Washington D.C., EPA-822-B-00-004. October 2000.

Under the regulations[4], narrative criteria have the same force and effect as numeric criteria. The National Pollutant Discharge Elimination System (NPDES) regulations require that the permitting authority establish water quality-based effluent limits for any parameters in the discharge of a point source that the permitting authority determines are or may be discharged at a level which will cause, have reasonable potential to cause, or contribute to an excursion above any applicable state water quality standards, including narrative criteria. 40 C.F.R. §122.44(d)(1)(i). EPA regulations specify three options for deriving a numeric effluent limitation for a particular parameter designed to implement a narrative criterion: (1) use a calculated numeric water quality criterion; (2) use EPA's section 304(a) water quality criteria on a case-by-case basis, supplemented by other relevant information; or (3) use an indicator parameter (see 40 C.F.R. §122.44(d)(1)(vi)). CWA section 303(d) requires states to identify water quality limited segments (i.e. impaired waters) that do not meet applicable water quality standards. For those water quality limited segments identified under 40 C.F.R. § 130.7, the CWA and EPA's regulations require states to develop Total Maximum Daily Loads (TMDLs) which specify the maximum pollution loads the water body can assimilate and still meet water quality standards. TMDLs also allocate these loads among the various pollution sources. For the purposes of CWA section 303(d), "applicable water quality standards refers to water quality standards established under CWA section 303 "…including numeric criteria, narrative criteria, [and] water body uses…" 40 C.F.R. §130.7(b)(3).

Protection of Downstream Uses

The federal regulations state, "In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters." 40 C.F.R. §131.10(b). The regulations do not compel states to adopt the same criteria and uses, nor do they suggest that this is the only way a state can meet these requirements. The water quality program is structured to provide states with flexibility to determine the best way to meet their obligations under § 131.10(b).

Under the NPDES permitting regulations, no permit may be issued "when the imposition of conditions cannot ensure compliance with applicable water quality requirements of all affected States[.]" 40 C.F.R. §122.4(d). To obtain approval of a state NPDES program, the CWA requires the state to have the authority to notify other affected states of applications for permits and provide an opportunity for a hearing. CWA section 402(b)(3). Further, the state must allow any state whose waters may be affected by the discharge to submit recommendations. If the permitting state rejects the recommendations, it must notify the affected state and EPA Administrator. CWA section 402(b)(5). Where EPA determines the permitting state rejected the recommendations for inadequate reasons, EPA may exercise its discretionary authority to object to the permit. If the objection is not resolved, EPA may issue a federal permit. 40 C.F.R. §123.44 (c)(2).

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[4] 40 C.F.R. §122 and 40 C.F.R. §130

EPA's Authority and Role

Whenever a state adopts new or revised water quality standards, the state is required under the CWA section 303(c) to submit such standards to EPA for review and approval or disapproval. EPA reviews and approves or disapproves the water quality standards based on whether the standards meet the requirements of the CWA and federal regulations as discussed above.

If EPA determines that a new or revised water quality standard submitted for its review is consistent with the CWA's requirements, the standards "shall thereafter be the water quality standard for the applicable waters" of the state. If EPA determines that a new or revised water quality standard is inconsistent with the CWA's requirements, EPA is to notify the state of the relevant shortcomings (i.e. EPA will "disapprove" the state's water quality standards) and specify the changes needed to meet the CWA's requirements. The state then has ninety days to adopt the changes specified. CWA Section 303(c)(3). If such changes are not adopted, EPA is then required to promulgate a federal standard. In doing so, EPA shall "promptly prepare and publish proposed regulations setting forth a revised or new water quality standard for the navigable waters involved" and promulgate ninety days thereafter if the state still has not adopted water quality standards in accordance with the CWA. CWA Section 303(c)(4).

In addition to EPA's authority to review and approve new and revised water quality standards, EPA also has a separate, discretionary authority to promulgate federal water quality standards for a state if the Administrator determines that new or revised water quality standards are necessary to meet the requirements of the CWA. CWA Section 303(c)(4)(B), 40 C.F.R. §§131.5(b), 131.22(b). In its petition to EPA, the Sierra Club asks that the EPA Administrator exercise his discretionary authority under the Clean Water Act to correct the perceived deficiencies identified by the Sierra Club in its petition. Therefore, in deciding if promulgation of water quality standards is "necessary to meet the requirements of the CWA," EPA has evaluated whether the minimum requirements of the Act and the federal regulations (i.e., designated uses consistent with sections 101(a)(2) and 303(c)(2)(A) and criteria protective of those uses), are satisfied by the existing state water quality standards. Below, each of the specific issues raised by the Sierra Club are reviewed against this standard.

The structure of the Water Quality Standards program, as described, reflects Congress' intent to "recognize, preserve, and protect the primary responsibilities and rights of states to prevent, reduce, and eliminate pollution [and] to plan the development and use (including restoration, preservation and enhancement) of … water resources[.]" CWA Section 101(b). Accordingly, the CWA confers to the states primary authority for setting water quality standards. EPA's role is largely one of oversight, in which it reviews a state's new or revised water quality standards as they are adopted by the states and submitted to EPA. CWA Section 303(c). EPA exercises its discretionary authority under CWA section 303(c)(4)(B) only when the Administrator has determined that the existing state water quality standards are insufficient to meet the requirements of the CWA.

EPA's approach to evaluating the petition, state standards, and the need for Federally promulgated water quality standards

In determining how to respond to the petition, EPA considered the following:

(1) What are the currently approved water quality standards that apply to the petition area and what are the apparent differences in state water quality standards that the petitioner identifies?

EPA reviewed the petition and the addenda in the petition, which contain multiple tables comparing uses and criteria within the petition area. After reviewing this information, EPA conducted its own independent analysis of the currently approved state water quality standards.[5, 6]

(2) Are the water quality standards of the petition states inconsistent with the CWA? Do any differences in water quality standards among the petition states indicate the standards are inconsistent with the CWA?

As discussed earlier, the federal regulations do not compel states to adopt the same criteria and uses to meet the requirements of the Act. Therefore, differing water quality standards do not necessarily indicate that the water quality standards are inconsistent with the CWA. Where differences in water quality standards were confirmed in EPA's analysis, EPA examined whether the various state water quality standards nonetheless provided protection for the petition area waters. Such protection could be afforded in a number of ways. EPA looked to see if a state applies ambient water quality criteria, either as part of general standards that apply to all waters or criteria to protect another designated use that would protect the designated uses applicable to the petition area. EPA looked to see if a state might have implementation procedures outside of EPA approved water quality standards (e.g., procedures to derive numeric criteria) that would further describe how the state implements its water quality standards and whether this information would resolve any apparent inconsistencies/inadequacies. EPA also reexamined the state water quality standards to determine why the differences might exist. To do so, EPA compared state water quality criteria to EPA's previous section 304(a) criteria recommendations and looked at the assumptions/policy decisions that states used to determine if the criteria were derived using scientifically defensible methods.

(3) Are the differences in water quality standards a basis for environmental concern?

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[5] See Attachment A

[6] See Attachment B

Where EPA confirmed states have different designated uses and/or criteria for the petition area, EPA evaluated the degree of environmental concern linked to those specific differences. EPA evaluated the petition data to determine whether the petitioner identified any specific information to indicate where the differences were causing an environmental problem of concern. EPA then reviewed states' section 303(d) impaired waters lists for 2002 to see whether the states themselves identified segments within the petition area to be impaired by the petition pollutants. If a state identified the pollutant on the section 303(d) list, EPA then investigated whether any documented evidence exists to show that water from an upstream state or across stream state was the leading cause of the impairment even if that water body was meeting the upstream or across stream states' water quality standards.

(4) Is the current level of scientific knowledge sufficient to determine the criteria appropriate to adequately protect designated uses?

EPA investigated the current status of scientific knowledge for each pollutant identified by the petitioner. EPA first identified its most current section 304(a) criteria recommendation. EPA then considered where it is in the process to either revise its section 304(a) criteria recommendations or to derive a section 304(a) criteria recommendation for pollutants where one does not exist. EPA also evaluated the scientific understanding of these pollutants to determine whether the science is sufficient at this time to support federal or state development of numeric ambient water quality criteria for the petition area.

(5) Are the states working to revise their water quality standards in a way that would address the concerns of this petition?

Development and implementation of water quality standards to protect state waters are primarily the state's responsibilities. CWA section 101(b). EPA identified the instances where adjacent states adopted different ambient water quality criteria for pollutants that EPA has provided section 304(a) criteria recommendations and determined if these differences have the potential to cause adverse effects. In these cases, EPA evaluated whether the states are making a good faith effort to revise their water quality standards to address these concerns and incorporate the latest scientific knowledge.

Issues Identified by Petitioner and EPA's Response

1) Designated Uses

Petitioner's Position - The Sierra Club claims that while variations in designated uses are acceptable in some circumstances, states have designated uses throughout the petition area that vary inappropriately. The petitioner maintains that as a result of these inconsistencies, "when downstream states designate these interstate rivers for uses such as drinking water, fishing, and contact recreation, but upstream states do not protect for those uses, downstream states may be unable to achieve their water quality standards." Petition at 12. In the petition, the Sierra Club specifically identifies that, unlike their surrounding states, Kentucky does not designate the Mississippi River for drinking water, Iowa does not designate the Mississippi or Missouri Rivers for a fishing use, and Missouri does not designate the Mississippi or Missouri Rivers for primary contact recreation. The Sierra Club also claims that Iowa designates one portion of the Missouri River for non-contact recreation whereas stretches above and below that portion of the river are classified for primary contact recreation. Petition at 10 – 11. The petitioner requests that EPA use its authority under the CWA section 303(c)(4) to promulgate water quality standards applicable to the Mississippi and Missouri Rivers in the eight state region around the rivers' confluence. Such standards should be consistent among the states on each river, such that no state impairs the ability of any other affected state (whether across-stream or downstream) to achieve its water quality standards. Petition at 1 and 3.

EPA Response – For the reasons provided below, EPA concludes that it is unnecessary to federally promulgate, at this time, any designated uses for the petition area to meet the requirements of the CWA section 303(c) or the federal water quality standards regulations at 40 C.F.R. Part 131.

a) Aquatic life Use

In the petition, the Sierra Club did not discuss any specific concerns regarding the designated aquatic life uses within the petition area. However, tables contained in the petition's addenda (see addenda 6 and 7), showed that some petition states designate aquatic life uses for the petition area differently from their neighboring states.

The Sierra Club's addenda show that all states within the petition area designate an aquatic life use to these waters but label the uses differently. To understand the significance of these differences, EPA evaluated the currently approved state water quality standards to determine whether the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of aquatic life uses is necessary.   EPA found that while the specific terms used by each state may differ (e.g., Significant Resource Warm Water (IA), Warm Water Aquatic Habitat (KY), Perennial Delta Fishery (AR))[7], each state designates uses to protect aquatic life consistent with the CWA and federal regulations. Based on this information, EPA determined that each state designates a use to provide for the protection and propagation of fish, shellfish, and wildlife. Therefore, EPA does not believe it is necessary to federally promulgate, at this time, aquatic life uses for the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B).

b) Drinking water supply

The Sierra Club points out in the designated use section of the petition that Kentucky does not designate the Mississippi River for drinking water uses whereas surrounding states have

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[7] See Attachment B

made such a designation. Petition at 10. Addendum 6 of the petition also indicates that Tennessee does not designate a drinking water use for the segment of Mississippi River from the upstream end of the Loosahatchie Bar to the Mississippi/Tennessee state line. The petitioner did not provide any specific evidence of adverse impacts on drinking water uses resulting from these differences. EPA evaluated the information contained in the petition and the currently approved state water quality standards to determine if the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of drinking water uses is necessary. To assess the potential for human health impacts, EPA also identified the drinking water intake locations and assessed whether there is any evidence that the drinking water use at these intakes is impaired as a result of different water quality standards within the petition area.

EPA found that where segments of the Mississippi and Missouri Rivers in the petition area are used for drinking water (i.e., drinking water intakes exist) states have designated those segments for a drinking water use. Kentucky does not designate its portion of the Mississippi River for drinking water supply because the state does not use the Mississippi River as a source of drinking water. Tennessee does not designate the segment of the Mississippi River from the upstream end of Loosahatchie Bar to the Mississippi/Tennessee state line as drinking water because they do not use this segment for drinking water. This Tennessee segment, however, while identified in addendum 6, is not within this petition area as defined in the petition. Therefore, EPA will not address this segment further in its response.

Since Kentucky does not designate the Mississippi River for a drinking water source, EPA evaluated whether an across stream or downstream state's drinking water uses are impaired by Kentucky's lack of designated drinking water use. While it is true that Missouri and Tennessee designate the Mississippi River located within the petition area for a drinking water use, EPA confirmed that Missouri does not have any drinking water intakes along the Mississippi River located across from Kentucky (Cape Girardeau south to Kentucky/Tennessee border) and Tennessee (which is downstream of Kentucky) does not have any drinking water intakes at all along the Mississippi River. In addition, neither Missouri nor Tennessee lists the drinking water uses on the Mississippi River within their jurisdiction as impaired. Therefore, EPA concludes that Kentucky's lack of a drinking water use is not preventing a downstream or across stream state from attaining and maintaining a drinking water use since there are no drinking water intakes or drinking water use impairments downstream or across stream from Kentucky. Therefore, Kentucky's lack of a public water supply designated use is consistent with the CWA and federal regulations at 40 C.F.R. §131.10(b). EPA concludes it is unnecessary to federally promulgate, at this time, drinking water uses for Kentucky within the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B).

c) Fish Consumption

The Sierra Club asserts that Iowa does not designate the Mississippi and Missouri Rivers for fish consumption although its waters are adjacent to Illinois, which the Sierra Club indicates has designated a fish consumption use. Petition at 10 – 11. Addenda 6 and 7, however, show that Illinois does not designate the Mississippi River for fishing. EPA evaluated this information and the currently approved state water quality standards to determine if the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of fish consumption uses is necessary.[8] EPA first looked to see which states explicitly designate fish consumption as a use applicable to the petition area. For those states that do not, EPA evaluated the states' water quality standards to determine whether the criteria applicable to the petition area protect fish consumption uses in the petition area.

Missouri's aquatic life use is labeled Warm Water and Human Health Fish Consumption. Kansas designates the Missouri River for Food Procurement which is defined as "the use of surface waters other than stream segments for obtaining edible forms of aquatic or semiaquatic life for human consumption"[9], thus protecting human health for fish consumption. The remaining six states (Kentucky, Tennessee, Iowa, Nebraska, Illinois and Arkansas) do not explicitly designate fish consumption as a use within the petition area; however, all six of these states apply ambient water quality criteria to the petition area applicable to all surface waters or to protect another designated use that were derived to protect humans from possible risks posed by fish consumption. For example, Kentucky's minimum criteria applicable to all surface waters includes water quality criteria for the protection of human health from the consumption of fish tissue (See 401 KAR 5:031 Surface Water Standards, Section 2 Minimum Criteria Applicable to Surface Waters, Table 1 Water Quality Criteria for the Protection of Human Health from the Consumption of Fish Tissue).[10]

With regard to the Sierra Club's specific concern that Iowa lacks a fish consumption use, Iowa's Class B (WW) or Warm Water Aquatic Life use, which applies to both the Mississippi and Missouri Rivers within the petition area, includes a narrative provision (see Iowa State Standards at 567 IAC 61.3(1)(b)(4)) to prohibit the contamination of fish tissue which would present a hazard to human health as well as numeric water quality criteria for specific pollutants intended to protect human health from possible risks posed by fish consumption (See Iowa State Standards, 567 IAC 61.3(3) Table 1).

EPA concludes that while all the petition states do not specifically designate the petition area for fish consumption, all petition states apply human health criteria to protect humans from possible risks posed by fish consumption and therefore effectively protect fish consumption uses consistent with the CWA and federal regulations at 40 C.F.R. Part 131. Therefore, it is unnecessary for EPA to federally promulgate, at this time, a fish consumption use for any state within the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B).

d) Recreation

The Sierra Club points out that Missouri designates the Mississippi and Missouri Rivers for secondary contact recreation use while surrounding states designate the waters for primary contact recreation use. The petition further states that one portion of the Missouri River in Iowa's jurisdiction is designated for non-contact recreation instead of primary contact recreation

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[8] See Attachment B
[9] See Attachment A
[10] See Attachment A

uses. Petition at 10 – 11. Addenda 6 and 7 reiterate this information. EPA evaluated this information and the currently approved state water quality standards to determine if the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of recreation uses is necessary.[11] EPA first reviewed each state's water quality standards to determine what recreation uses and associated criteria apply to protect these uses. Where EPA found a primary contact recreation use and/or the associated ambient water quality criteria absent, EPA discussed its findings with the state to determine whether the state intended to revise its water quality standards in the near future, and if that revision would resolve the issue identified in this petition.

EPA's analysis shows that Illinois, Kentucky, Tennessee, Arkansas, Nebraska, Kansas, and Iowa have all adopted primary contact recreation uses and the water quality criteria to protect a primary contact recreation use for all segments of the Mississippi and/or Missouri Rivers within the petition area. While the petitioner identifies Iowa as not applying a primary contact use to one segment along the Missouri River, EPA's analysis showed that Iowa has designated all portions of the Missouri River within the petition area for primary contact recreation. The stretch of the Missouri River within Iowa's jurisdiction flows from the confluence with the Big Sioux River to the Iowa/Missouri state line. Iowa's water quality standards specifically state that the Missouri River from the Iowa/Missouri state line to the confluence with the Big Sioux River is designated for Class A (waters "to be protected for primary contact recreation"), among other uses (See Iowa State Standards, 567 IAC 61.3(5)(e)).

On October 14, 2003, the Missouri Coalition for the Environment filed a lawsuit against EPA alleging that EPA has a duty to promulgate water quality standards for Missouri. One of the issues raised in the lawsuit is Missouri's lack of primary contact recreation uses. The state of Missouri has provided EPA a letter committing to adopt a primary contact use (labeled "whole body contact" by the state of Missouri) for the waters within the petition area (among others in the state). Missouri has committed to completing its rulemaking process to adopt such uses by July of 2005.

To summarize, seven of the eight petition states have adopted primary contact recreation uses for the petition area consistent with the CWA and federal regulations at 40 C.F.R. Part 131 and Missouri has initiated a rulemaking process to adopt primary contact uses for the petition area by January 2005, for the petition area. For this reason, EPA concludes that it is unnecessary for EPA to federally promulgate, at this time, a primary contact use for Missouri or Iowa within the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B) in response to this petition.

e) *Agriculture, Aesthetics, Irrigation, Livestock & Wildlife watering, Navigation, Industrial uses*

In the petition, the Sierra Club did not identify any specific instances where states designated agriculture, aesthetic, irrigation, livestock and watering, navigation or industrial uses to the petition area differently. However, tables contained in the petition's

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[11] See Attachment B

addenda (see addenda 6 and 7), showed some differences in how petition states designate these uses for the petition area.

The addenda show differences among the states' designations for agriculture, aesthetics, irrigation, livestock and wildlife watering, navigation, and industrial uses. For example, while Iowa, Illinois, Arkansas and Tennessee designate the Mississippi River within the petition area for agricultural uses, Missouri does not. To understand the significance of these differences, EPA evaluated the currently approved state water quality standards to determine whether the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of any of these uses is necessary. Based on a review of the petition states' approved water quality standards[12], the criteria adopted to protect aquatic life uses are more stringent than the criteria that are or would be applied to protect agriculture, aesthetics, irrigation, livestock and wildlife watering, navigation, or industrial uses within the petition area. Therefore, EPA concludes that the most stringent criteria that the states apply to the petition area to protect aquatic life will also protect agriculture, aesthetics, irrigation, livestock and wildlife watering, navigation and industrial uses wherever they have been designated in the petition area. Accordingly, it is not necessary for EPA to promulgate, at this time, any of these uses for the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B).

2) Water Quality Criteria

Petitioner's Position – In addition to the concerns regarding designated uses, the Sierra Club asserts that the problems in the petition area are compounded by states applying different criteria or no criteria to protect designated uses even in the situations where the underlying designated uses are equivalent. The Sierra Club specifically identifies the following pollutants at issue: chlordane, atrazine, polychlorinated biphenyls, *E. coli*, enterococci, dissolved oxygen, ammonia, nutrients, and sediments. They also identify the need for an index of biological integrity for the aquatic community. Petition at 3. The petitioner requests that EPA exercise its authority under section 303(c)(4) of the CWA to promulgate water quality standards applicable to the Mississippi and Missouri Rivers in an eight state region around the rivers' confluence. EPA should set standards that are adequate to achieve the CWA's fishable/swimmable requirements.

EPA's Response – EPA evaluated the currently approved water quality criteria within the petition area for chlordane, atrazine, polychlorinated biphenyls, *E. coli*, enterococci, dissolved oxygen, ammonia, nutrients, sediments, and an index of biological integrity for the aquatic community to determine if the criteria are consistent with the requirements of the CWA section 303(c) and the federal water quality standards regulations at 40 C.F.R. Part 131. These criteria were identified in Paragraph 9 of the Settlement Agreement in American Canoe Ass'n v. Browner, 98-1195-CV-W (W.D. Mo.) (effective date 2-27-01), as well as in the Sierra Club's petition. EPA finds that the petitioner has not demonstrated that a federal promulgation of new or revised water quality criteria for the

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[12] See Attachment A

petition area is needed to meet the requirements of the CWA and the federal regulations. Therefore, EPA denies the petitioner's request to promulgate any numeric water quality criteria, at this time, for the pollutants specifically identified by the petitioner, to apply to the petition area. EPA's detailed rationale for its conclusions regarding each of the pollutants is discussed in greater detail in the following paragraphs.

a) Atrazine

Aquatic Life Protection. The petition does not identify any specific concerns with the petition states' atrazine criteria for the protection of aquatic life. Addendum 8 of the petition describes the atrazine criteria that the states have adopted for the Mississippi River. It shows that none of the states along the Mississippi River have adopted numeric atrazine criteria to protect aquatic life uses (or any other use, except drinking water, as discussed below). Neither the petition nor the addenda contain any information or discussion of atrazine criteria to protect aquatic life uses on the Missouri River.

EPA evaluated this information as well as the currently approved state water quality standards to determine if the state water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric atrazine criteria for the protection of aquatic life is necessary for the petition area. EPA first reviewed the states' currently adopted and approved water quality standards to validate the petitioner's findings. Specifically, EPA looked to see whether any states have adopted numeric or narrative atrazine criteria to protect aquatic life. EPA also reviewed the petition states' 2002 section 303(d) lists[13] to determine if any state identified atrazine as a pollutant responsible for impairing an aquatic life use. Finally, EPA evaluated the scientific understanding of atrazine to determine if the science is sufficient at this time to support EPA or state development of numeric ambient water quality criteria for the protection of aquatic life.

According to EPA's evaluation of the states' water quality standards, all eight of the petition states currently have narrative criteria related to toxic pollutants that may be used for establishing NPDES permits, listing waters as impaired by atrazine on section 303(d) lists and developing TMDLs, if necessary. As discussed earlier in the "Statutory and Regulatory Background" section, narrative criteria may form the regulatory basis for these purposes. While the petition's addendum 8 indicates that no state has adopted numeric atrazine criteria, EPA found that three states, Illinois, Nebraska and Kansas, have numeric aquatic life criteria for atrazine.[14] Illinois has an EPA approved procedure for implementing their narrative criteria at Title 35, Subtitle C, Chapter 1, Section 302.210 in Illinois' water quality standards. This procedure derives numeric values to be used as ambient water quality criteria for toxic pollutants, including atrazine.[15] Nebraska

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[13] See Attachment G

[14] See Attachment B

[15] Derived Water Quality Criteria, Illinois Environmental Protection Agency <http://www.epa.state.il.us/water/water-quality-standards/water-quality-criteria.html>

and Kansas have explicitly adopted ambient water quality criteria for atrazine.[16] However, these states adopted criteria at the state's own initiative without the benefit of a final EPA CWA section 304(a) criteria recommendation. These states exercised their discretion to adopt a numeric criterion for atrazine based on other scientifically defensible methods. None of the petition states identified (nor has EPA proposed to identify) atrazine as an impairing pollutant within the petition area on their 2002 section 303(d) impaired waters list.[17]

On November 7, 2003, EPA released and requested scientific views on a revised draft ambient water quality criteria document for atrazine to protect aquatic life. This document provides EPA's draft acute and chronic criteria recommendations for atrazine designed to protect aquatic life in both freshwater and saltwater. The revised draft criteria incorporate toxicity information for atrazine that had not been available at the time EPA published its 2001 draft recommendations (see EPA's website at http://www.epa.gov/waterscience/criteria/atrazine/). In addition to revising the 2001 draft criteria recommendations to reflect scientific views EPA received from the public during the comment period, the Office of Water has been closely coordinating with the Office of Pesticide Programs (OPP) to ensure that the draft ambient water quality criteria recommendation is consistent with OPP's ecological risk assessment. OPP used its ecological risk assessment for atrazine to ensure that its decision to reregister atrazine did not result in unreasonable adverse effects.

Since EPA is currently in the process of developing a final numeric atrazine water quality criterion to protect aquatic life and atrazine may be controlled, if necessary, in all petition states based on narrative criteria where numeric atrazine criteria to protect aquatic life uses do not exist, EPA concludes that it is not necessary for EPA to promulgate numeric atrazine criteria to protect aquatic life for the petition area, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B). Once EPA's recommendations are finalized, it is EPA's policy to allow states an appropriate amount of time to incorporate EPA's newest recommendations into their water quality standards. When EPA's section 304(a) atrazine criterion to protect aquatic life is final and states have had appropriate time to incorporate the updated science into their water quality standards, EPA will evaluate the need for a federal promulgation where it is determined that atrazine criteria are necessary to protect designated uses in the petition area.

Human Health Protection. The Sierra Club's addendum 8 shows that Iowa, Missouri and Tennessee have adopted an ambient water quality criterion for atrazine of 3 µg/L to protect drinking water supplies along the Mississippi River while Arkansas, Illinois and Kentucky have not adopted numeric criteria for atrazine. In the petition's water quality criteria section, the Sierra Club specifically expresses a concern that Kentucky, the only state that does not designate the Mississippi River for a drinking water use, does not have a numeric criterion for atrazine to protect public health. The petition does not discuss atrazine criteria to protect human health on the Missouri River.

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[16] See Attachment B

[17] See Attachment G

EPA evaluated this information as well as the currently approved state water quality standards to determine if the state water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric atrazine criteria for the protection of human health is necessary for the petition area. EPA first reviewed the states' currently adopted and approved water quality standards to validate the petitioner's findings. Specifically, EPA looked to see if any states have adopted numeric atrazine criteria to protect human health. EPA also reviewed the 2002 section 303(d) lists[18] to determine if any state identified atrazine as a pollutant responsible for impairing human health uses. Finally, EPA evaluated the scientific understanding of atrazine to determine if the science is sufficient at this time to support EPA or state development of numeric ambient water quality criteria to protect human health.

According to EPA's evaluation of the states' water quality standards, all of the petition area states along the Missouri River (Iowa, Nebraska, Missouri, and Kansas) apply 3 μg/l to protect public water supplies. Iowa, Missouri, and Tennessee have adopted 3 μg/l into their water quality standards to protect public water supplies on the Mississippi River. Kentucky, Illinois, and Arkansas have not adopted numeric water quality criteria for atrazine to protect human health. All eight of the petition states currently have narrative criteria related to toxic pollutants that may be used for establishing NPDES permits and TMDLs, if necessary. As discussed earlier in the "Statutory and Regulatory Background" section, narrative criteria can form the regulatory basis for these purposes. No state within the petition area has included atrazine as a pollutant on their section 303(d) impaired waters list nor did the petitioner raise any specific instances of concern in the petition.

The ambient water quality criterion of 3 μg/l that five of the eight petition area states have adopted to protect public water supplies is based on EPA's maximum contaminant level (MCL) published under § 1412(b)(4) of the Safe Drinking Water Act that applies to treated drinking water, not to ambient surface waters. EPA has not yet developed ambient water quality criteria recommendations for atrazine to protect human health under section 304(a) of the CWA because the science necessary to develop appropriate criteria for surface waters is not yet complete. Currently, the Agency is reassessing the available toxicity information on atrazine (OPP recently conducted a human health risk assessment for atrazine and concluded that there was a reasonable certainty of no harm from the reregistration of atrazine). Once this scientific evaluation is completed, EPA will consider developing ambient water quality criteria for atrazine. In the interim, states continue to have the discretion to adopt a numeric criterion for surface waters to protect human health based on other information, such as MCLs.[19]

In response to the petitioner's specific concern with respect to Kentucky, EPA concludes that since Kentucky does not use the Mississippi River as a drinking water

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[18] See Attachment G

[19] U.S. Environmental Protection Agency. 1994. *Water Quality Standards Handbook: Second Edition.* Office of Water, Washington, D.C. EPA-823-B-94-005a.

source, there are no drinking water intakes across or immediately downstream from Kentucky, and Kentucky could use narrative criteria to control atrazine if necessary, Kentucky's water quality standards are consistent with the CWA and federal regulations. Therefore, it is unnecessary for EPA to federally promulgate numeric atrazine criteria for Kentucky to protect human health uses, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B).

With regard to Illinois and Arkansas, EPA concludes that a federal promulgation is unnecessary, at this time, to meet the requirements of the CWA CWA section 303(c)(4)(B). This conclusion is based on the following facts: The science is currently under review in preparation for criteria development; the states have not specifically identified atrazine as a pollutant impairing human health uses on their impaired waters list; the petitioner has not identified any specific concerns; and the petition states' current narrative criteria provide a basis for pollutant control in the absence of numeric criteria to protect local and downstream water quality standards (40 C.F.R. §131.10(b)), if necessary. However, once EPA issues section 304(a) criteria recommendations for atrazine for the protection of human health and EPA has provided states appropriate time to incorporate the latest science into water quality standards, EPA will reevaluate the need for a federal promulgation where it is determined that atrazine criteria are necessary to protect designated uses in the petition area.

b) PCBs

The Sierra Club identifies a specific concern regarding PCB criteria for two states, Iowa and Nebraska, both of which are upstream of Missouri on the Mississippi River and the Missouri River, respectively. The Sierra Club points out that Iowa's and Nebraska's PCB criteria are nearly ten times less stringent than Missouri's PCB criteria. Petition at 13 - 14. Addenda 10 and 11 of the petition provide tables describing the PCB criterion that each petition state applies to the petition area, as evaluated by the Sierra Club, and shows that the petition states have adopted varying criteria to protect their designated uses.

EPA evaluated the information provided by the petitioner as well as the currently approved state water quality standards for all petition states to determine if the PCB criteria in the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric PCB criteria is necessary. EPA first reviewed the states' currently adopted and approved water quality standards to validate the petitioner's findings. Specifically, EPA identified exactly what numeric and/or narrative PCB criteria states have currently adopted to apply to the petition area.[20] EPA then investigated the basis for these criteria to determine if the states had adopted criteria based on EPA's recommendations or on other scientifically defensible methods. Finally, EPA looked for any documented evidence that may suggest the differences in criteria are preventing a downstream or across stream state from attaining and maintaining its water quality standards.

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[20] See Attachment B

Adverse human health effects are expected at much lower concentrations of PCBs than in aquatic life. As a result, EPA's CWA section 304(a) criteria recommendations for PCB to protect human health have generally been more stringent than those to protect aquatic life. In the case where states have adopted PCB criteria to protect both human health and aquatic life, the criteria to protect human health are more likely to drive regulatory decisions. Therefore, in its evaluation of currently approved PCB criteria, EPA focused on whether the states have adopted numeric criteria for PCBs to protect human health-related designated uses. EPA acknowledges there are variations in the numeric PCB criteria adopted by the petition states. There are four legitimate reasons why the numeric PCB criteria vary within the petition area:

(1) EPA published section 304(a) criteria recommendations several times over the past 20 years. EPA's revised section 304(a) criteria recommendations reflect the most current scientific knowledge but do not always result in more stringent criteria recommendations (e.g., EPA's 1999 section 304(a) recommendations for PCB were less stringent than its 1986 section 304(a) recommendations.)[21,22] States have adopted and revised PCB criteria at different points in time. The criteria the petition states adopted depended on the recommendations and information available at that time. For example, Kentucky and Kansas adopted human health criteria based on EPA's 1986 section 304(a) criteria recommendation while Nebraska (which evaluates the aquatic life and human health criteria and adopts whichever one is most stringent) adopted human health criteria based on EPA's 1992 National Toxics Rule (See 40 C.F.R. §131.36). These values were also published as section 304(a) criteria in 1999. On the Missouri River, even though Kansas' human health criterion for PCB is more stringent than Nebraska's (the upstream state), Nebraska's criterion is in fact based on more recent science. Therefore, comparing stringency of criteria is not an adequate method of determining whether states have appropriate criteria to protect the designated uses or whether they are providing for the attainment and maintenance of downstream water quality standards as required under 40 C.F.R. §131.10(b).

(2) While EPA did not publish revised section 304(a) criteria for PCBs between 1986 and 1999, EPA updated toxicity information for PCBs in EPA's IRIS[23] database in 1989. As a result, Iowa, Missouri, Arkansas, and Tennessee took EPA's 1986 section 304(a) criteria recommendations and incorporated the new toxicity information from IRIS to derive a revised ambient water quality criterion for PCBs. States have the discretion to derive criteria based on other scientifically defensible

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[21] U.S. Environmental Protection Agency. *Quality Criteria for Water*. Office of Water, Washington, D.C. < http://www.epa.gov/waterscience/criteria/goldbook.pdf > EPA 440/5-86-001. May 1986

[22] U.S. Environmental Protection Agency. *National Recommended Water Quality Criteria – Correction*. Office of Water, Washington, D.C. < http://www.epa.gov/waterscience/pc/1999table.pdf> EPA 822-Z-99-001. April 1999

[23] 23 U.S. Environmental Protection Agency . Integrated Risk Information System. < http://www.epa.gov/iriswebp/iris/index.html>

methods (40 C.F.R. §131.11). These states used EPA's method to derive criteria but used more recent toxicity information to ensure their criteria incorporated the latest scientific information at the time of adoption.

(3) As discussed in the "Statutory and Regulatory Background" section, EPA publishes section 304(a) criteria based on a 10^{-6} risk level for carcinogens; states may select a specific risk level based on their own risk management decisions. EPA believes that adoption of criteria within a risk level of 10^{-6} (one in a million incremental risk for cancer) or 10^{-5} (one in one hundred thousand incremental risk for cancer) represents an acceptable range of risk management discretion for states and tribes.[24] Within the petition states, each state adopts criteria to protect human health based on risk management decisions. Iowa, Arkansas, Tennessee, and Nebraska have adopted PCB criteria based on a 10^{-5} risk level; Illinois, Kentucky and Missouri have adopted PCB criteria based on a 10^{-6} risk level; and Kansas chose to adopt a PCB criterion to protect human health at a 10^{-7} risk level.

(4) EPA's regulations provide that states may adopt EPA's section 304(a) criteria recommendations, modify EPA's section 304(a) criteria to reflect site-specific conditions, or derive and adopt criteria based on other scientifically defensible methods. (40 C.F.R. §131.11 (b)). Illinois developed a procedure to translate its narrative criteria and derive numeric values for certain pollutants. EPA determined that this procedure is scientifically defensible and considers the numeric values derived using this procedure to be within the acceptable range to protect designated uses. Illinois uses this procedure to derive numeric values for PCBs that may be used to issue NPDES permits, to determine if a waterbody is impaired for PCBs and thus listed under CWA section 303(d) listings, and/or to develop a TMDL.

As discussed above, Iowa and Missouri adopted a numeric PCB criterion to protect human health based on the toxicity information available in IRIS that was updated in 1989. With regard to the Sierra Club's specific concern about Iowa's PCB criterion as compared to Missouri's criterion, EPA found that Iowa's criterion is an order of magnitude greater than Missouri's because Iowa has chosen to protect human health at a 10^{-5} risk level while Missouri protects human health at a 10^{-6} risk level. With regard to the Sierra Club's specific concern about Nebraska's PCB criterion as compared to Missouri, EPA found that Nebraska adopted a numeric PCB criterion to protect human health based on EPA's section 304(a) criteria recommendations published in 1999 (Missouri used the updated 1999 IRIS data), but chose a 10^{-5} risk level. As a result, Nebraska's PCB criterion is greater than Missouri's criterion.

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[24] U.S. Environmental Protection Agency. *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000).* Office of Water. Washington, D.C. EPA-822-B-00-004. <http://www.epa.gov/waterscience/humanhealth/method > October 2000.

As described in the “Statutory and Regulatory Background” section, the regulations do not compel states to adopt the same criteria and uses in order to provide for attainment and maintenance of downstream water quality standards (40 C.F.R. §131.10(b)), nor do the regulations suggest that this is the only way a state can meet the requirements under § 131.10(b). The water quality program is structured to provide states with flexibility to determine the best way to protect their designated uses and meet their obligations under § 131.10(b). The petitioner has not provided any specific instances where the differences in PCB criteria are preventing a downstream or across stream state from attaining its designated uses as required by 40 C.F.R. §131.10(b).

The PCB criteria adopted by the petition states vary due to any one or a combination of the above reasons. EPA found that the petition states adopted criteria based on an EPA section 304(a) criteria recommendation or another scientifically defensible method and these criteria are within the scientifically acceptable range to protect designated uses consistent with 40 C.F.R. §131.11. In addition, since the production of PCBs have been banned in the United States, EPA believes it is unlikely that any differences in criteria will lead to future increases in the discharge of PCBs. While the petition states do apply different numeric PCB criteria to the petition area and some states have listed certain segments of the petition area waters as impaired for PCBs, EPA is unaware of any evidence that indicates the impairments are a result of anything but local water quality or sediment quality issues. Therefore, EPA has no reason to believe that an upstream or across stream state is causing the impairments. For example, on the Missouri River, while Missouri lists the Missouri River as impaired at the Iowa/Missouri state line due to PCBs, Iowa does not. EPA has no reason to believe that the mere listing of the Missouri River for PCBs is due to the different PCB criterion in Iowa instead of water quality issues wholly within the state of Missouri. Since the petition states have adopted PCB criteria based on EPA recommendations or other scientifically defensible methods, states have mechanisms available to them to ensure downstream water quality standards are attained and maintained, if necessary, and because the petitioner has not provided any specific instances (nor has EPA identified) where the differences in PCB criteria are preventing a downstream or across stream state from attaining its designated uses (40 C.F.R. §131.10(b)), EPA concludes that it is unnecessary for EPA to federally promulgate numeric PCB criteria for the petition states at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B).

c) Chlordane

The Sierra Club identifies a specific concern regarding chlordane criteria for two states, Iowa and Nebraska. The Sierra Club specifically points out that Iowa’s and Nebraska’s chlordane criteria are nearly ten times less stringent than Missouri’s chlordane criteria. Petition at 13 – 14. Addenda 12 and 13 of the petition provide tables describing the chlordane criteria that each petition state applies to the petition area, as evaluated by the Sierra Club, and shows that the petition states have adopted varying criteria to protect their designated uses.

EPA evaluated the information provided by the petitioner as well as the currently approved state water quality standards for all petition states to determine if any of the chlordane criteria in the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric chlordane criteria is necessary. EPA first reviewed the states' currently adopted and approved water quality standards to validate the petitioner's findings. Specifically, EPA identified exactly what numeric and/or narrative chlordane criteria states have adopted to apply to the petition area.[25] Then EPA investigated the basis for these criteria to determine if states had adopted criteria based on EPA's recommendations or on other scientifically defensible methods. Finally, EPA looked for any documented evidence that may suggest the differences in criteria are preventing a downstream or across stream state from attaining and maintaining its water quality standards.

Adverse human health effects are expected at much lower concentrations of chlordane than in aquatic life. As a result, EPA's criteria recommendation for chlordane to protect human health is generally more stringent than those to protect aquatic life. In the case where states have adopted chlordane criteria to protect both human health and aquatic life, the criteria to protect human health are more likely to drive regulatory decisions. Therefore, in its evaluation of currently approved chlordane criteria, EPA focused on whether states have adopted numeric criteria for chlordane to protect human health-related designated uses. EPA acknowledges that there are variations in the numeric chlordane criteria adopted by the petition states. There are three legitimate reasons why the numeric chlordane criteria vary within the petition area:

(1) EPA published section 304(a) criteria recommendations several times over the past 20 years. EPA's revised section 304(a) criteria reflects the current scientific knowledge but does not always result in more stringent criteria recommendations (e.g., EPA's 1999 section 304(a) recommendations for chlordane were less stringent than its 1986 section 304(a) recommendations.)[26,27] States have adopted and revised chlordane criteria into their water quality standards at different points in time. The criteria the petition states adopted depended on the recommendations and information available at that time. For example, Missouri, Kansas, and Nebraska (Nebraska evaluates the aquatic life and human health criteria and adopt whichever one is most stringent) adopted human health criteria based on EPA's 1986 section 304(a) criteria recommendation while Iowa and Kentucky adopted human health criteria consistent with EPA's 1992 National Toxics Rule (see 40 C.F.R. §131.36). On the Mississippi River, even though Missouri's human health criterion for chlordane is more stringent than Kentucky's (the across stream state), Kentucky's criterion is, in fact, based on more recent science. Therefore, comparing stringency

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[25] See Attachment B

[26] U.S. Environmental Protection Agency. *Quality Criteria for Water*. Office of Water, Washington, D.C. < http://www.epa.gov/waterscience/criteria/goldbook.pdf > EPA 440/5-86-001. May 1986

[27] U.S. Environmental Protection Agency. *National Recommended Water Quality Criteria – Correction*. Office of Water, Washington, D.C. < http://www.epa.gov/waterscience/pc/1999table.pdf> EPA 822-Z-99-001. April 1999.

of criteria is not always an adequate method of determining whether states have appropriate criteria to protect the designated uses or whether they are providing for the attainment and maintenance of downstream water quality standards as required under 40 C.F.R. §131.10(b).

(2) As discussed in the "Statutory and Regulatory Background" section, EPA publishes section 304(a) criteria based on a 10^{-6} risk level for carcinogens; states may select a specific risk level based on their own risk management decisions. EPA believes that adoption of criteria within the risk level of 10^{-6} (one in a million incremental risk for cancer) or 10^{-5} (one in one hundred thousand incremental risk for cancer) represents an acceptable range of discretion for states and tribes.[28] Within the petition states, each state adopts criteria to protect human health based on different risk management decisions. Iowa, Arkansas, Tennessee, and Nebraska have adopted chlordane criteria based on a 10^{-5} risk level while Illinois, Kentucky, Kansas and Missouri have adopted chlordane criteria based on a 10^{-6} risk level.

(3) EPA's regulations provide that states may adopt EPA's section 304(a) criteria recommendations, modify EPA's section 304(a) criteria to reflect site-specific conditions, or derive and adopt criteria based on other scientifically defensible methods. (40 C.F.R. §131.11 (b)). Illinois developed a procedure to translate its narrative criteria and derive numeric values for certain pollutants. EPA determined that this procedure is scientifically defensible and considers the numeric values derived using this procedure to be within the acceptable range to protect designated uses. Illinois uses this procedure to derive numeric values for chlordane that may be used to issue NPDES permits, to determine if a waterbody is impaired for chlordane and thus listed under CWA section 303(d) listings, and/or to develop a TMDL.

With regard to the Sierra Club's specific concern about Iowa's chlordane criterion as compared to Missouri's criterion, EPA found that Missouri adopted a numeric chlordane criterion to protect human health based on EPA's 1986 section 304(a) criteria recommendation, while Iowa adopted human health criterion consistent with EPA's National Toxics Rule. Iowa's chlordane criterion is an order of magnitude greater than Missouri's because Iowa has chosen to protect human health at a 10^{-5} risk level while Missouri protects human health at a 10^{-6} risk level. With regard to the Sierra Club's specific concern about Nebraska's chlordane criterion as compared to Missouri's criterion, EPA found that both Missouri and Nebraska adopted chlordane criteria based on EPA's 1986 section 304(a) criteria, however, Nebraska's policy is to evaluate the aquatic life and human health criteria and to adopt whichever is most stringent to protect both aquatic life and human health. In 1986, EPA's section 304(a) criteria

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[28] U.S. Environmental Protection Agency. *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000).* Office of Water, Washington, D.C. EPA-822-B-00-004. <http://www.epa.gov/waterscience/humanhealth/method > October 2000.

recommendation to protect aquatic life was slightly more stringent than the 10^{-5} human health recommendations. Nebraska adopted one criterion to protect for both aquatic life and human health by adjusting EPA's recommended human health criterion for chlordane to protect human health at a 10^{-5} risk level. Therefore, the magnitude of Nebraska's chlordane criteria is close to an order of magnitude greater than Missouri's criterion because while Nebraska has chosen to protect human health at a 10^{-5} level, Missouri protects human health at a 10^{-6} risk level.

As discussed earlier, **t**he regulations do not compel states to adopt the same criteria and uses in order to provide for attainment and maintenance of downstream water quality standards (40 C.F.R. §131.10(b)), nor do the regulations suggest that this is the only way a state can meet the requirements under § 131.10(b). The water quality program is structured to provide states with flexibility to determine the best way to protect their designated uses and meet their obligations under § 131.10(b). The petitioner has not provided any specific instances where the differences in chlordane criteria are preventing a downstream or across stream state from attaining its designated uses (40 C.F.R. §131.10(b)).

The chlordane criteria adopted by the petition states vary due to any one or a combination of the above reasons. EPA found that the petition states adopted criteria based on an EPA section 304(a) criteria recommendation or another scientifically defensible method and these criteria are within the scientifically acceptable range to protect designated uses consistent with 40 C.F.R. §131.11. In addition, since the use of chlordane has been banned in the United States, EPA believes it is unlikely that any differences in states' criteria will lead to a future increase in discharge of the pollutants. While the petition states do apply different numeric chlordane criteria to the petition area and some states have listed certain segments of the petition area waters as impaired for chlordane, EPA is unaware of any evidence that indicates the impairments are a result of anything but local water quality or sediment quality issues. Therefore, EPA has no reason to believe that an upstream or across stream state is causing the impairments. For example, on the Missouri River, while Missouri lists the Missouri River as impaired at the Iowa/Missouri state line due to chlordane, Iowa does not. EPA has no reason to believe that the mere listing of the Missouri River for chlordane is due to the different chlordane criterion in Iowa instead of water quality issues wholly within the state of Missouri. Since the petition states have adopted chlordane criteria based on EPA recommendations or other scientifically defensible methods, states have mechanisms available to them ensure downstream water quality standards are attained and maintained, if necessary, and because the petitioner has not provided any specific instances (nor has EPA identified) where the differences in chlordane criteria are preventing a downstream or across stream state from attaining its designated uses (40 C.F.R. §131.10(b))**,** EPA concludes that it is unnecessary for EPA to federally promulgate numeric chlordane criteria for the petition states, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B).

d) *E. coli*/enterococci

The Sierra Club requests that EPA ensure water quality standards are adequate in the petition area by publishing water quality standards that include numeric criteria for *E. coli* and enterococci. Further, the Sierra Club illustrates its assertion that states protect their designated uses inconsistently by pointing out that Missouri's narrative criteria (i.e. lack of numeric criteria) for fecal coliform may be less protective than the numeric fecal coliform criteria that Nebraska and Kansas apply to the Missouri River. (See also discussion in "Recreation" section.) The Sierra Club concludes that this apparent inconsistency causes Nebraska and Kansas to violate water quality standards where they share a border with Missouri. Petition at 14. Addendum 14 of the petition describes which states have adopted fecal coliform criteria for the Missouri River and shows that Missouri is the only state along the Missouri River within the petition area that has not adopted a fecal coliform criterion of 200 organisms per 100 milliliters. The petition's addendum also shows that no state along the Missouri River in the petition area has adopted *E. coli* or enterococci criteria. Neither the petition nor its addenda include any information regarding the applicability of fecal coliform, *E. coli*, or enterococci criteria for the Mississippi River.

EPA evaluated the information submitted by the petitioner as well as the currently approved state water quality standards to determine if the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric bacteria criteria is necessary. EPA first reviewed the states' currently adopted and approved water quality standards to validate the petitioner's findings. Specifically, EPA evaluated state adopted numeric bacteria criteria to protect recreational uses and whether these are consistent with EPA's latest scientific recommendation.[29] EPA then sought to understand where various states were in their water quality standards review process to determine if any state is in the process of revising its bacteria criteria or is planning to in the near future.

EPA published its latest recommendation for bacteria criteria in 1986.[30] This 1986 criterion recommended that states adopt *E. coli* or enterococci as indicators for gastrointestinal illness in fresh recreation waters instead of fecal coliform, as previously recommended. Of the eight states in the petition area, Kansas, Nebraska, Iowa and Tennessee have adopted and EPA has approved *E. coli* criteria to protect a primary contact recreation use in the Mississippi and/or Missouri Rivers. Arkansas has adopted *E. coli* criteria and EPA expects Arkansas to submit revised water quality standards to EPA in June 2004. Kentucky has proposed adopting *E. coli* in its state rulemaking process and EPA expects Kentucky to submit revised water quality standards to EPA in the fall of 2004. On November 7, 2003, Missouri sent EPA a formal letter committing to adopt *E. coli* criteria for the petition area by July 2005. On March 23, 2004, Illinois sent EPA a formal letter committing to initiate adoption of *E. coli* criteria into water quality standards by September 30, 2004.

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[29] See Attachment B

[30] U.S. Environmental Protection Agency. *Ambient Water Quality Criteria for Bacteria – 1986*. Office of Water, Washington, D.C. EPA 440/5-84-002. < http://www.epa.gov/waterscience/beaches/1986crit.pdf> January 1986.

In its 1986 guidance, EPA recommended that states adopt *E. coli* or enterococci criteria in order to protect contact recreation uses in freshwaters, including those within the petition area, and enterococci in marine waters. Congress endorsed EPA's recommendation in 2000 with respect to coastal waters when it amended the CWA by enacting the Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act). The newly added CWA section 303(i) requires, by April 2004, that states "…adopt and submit to the Administrator water quality criteria and standards for the coastal recreation waters of the state for those pathogens and pathogen indicators for which the Administrator has published criteria under section 304(a)." (Coastal waters are defined in section 502(21) to include waters of the Great Lakes and marine coastal waters designated for use for swimming, boating, surfing, and similar water contact activities.) Further, section 303(i) directs EPA to propose and promulgate standards as protective as the 1986 criteria recommendations for states that fail to comply with section 303(i).

Based on the current scientific knowledge, EPA continues to recommend that states adopt *E. coli* or enterococci criteria to protect recreation waters. As described earlier, the CWA provides EPA the discretionary authority to set a new or revised standard for a state if the Administrator determines that new or revised water quality standards are necessary to meet the requirements of the CWA. However, with regard to the petition area, EPA concludes that it is unnecessary to initiate a rulemaking to promulgate federal *E. coli* or enterococci criteria for the petition area at this time to meet the requirements of the CWA under CWA section 303(c)(4)(B) since all eight states have either adopted *E. coli* or enterococci criteria, proposed adoption, or have committed to adopting such criteria to protect recreation uses in the petition area within a reasonable timeframe. EPA's decision is consistent with Congress' intent to "recognize, preserve, and protect the primary responsibilities and rights of states to prevent, reduce, and eliminate pollution…of … water resources." CWA Section 101(b).

Further, EPA believes the BEACH Act expresses Congress's intent for EPA to address the nation's coastal recreation waters as a first priority to ensure appropriate bacteria criteria are in place to protect beachgoers. As a result, EPA is focusing its efforts to assist states in adopting bacteria criteria consistent with the requirements under CWA section 303(i) and intends to promulgate bacteria criteria for coastal recreation waters, where necessary. If, however, Kentucky, Arkansas, Missouri or Illinois fail to follow through on their commitment to adopt appropriate bacteria criteria for the petition area, EPA will, if necessary, initiate a federal rulemaking to establish *E. coli* or enterococci criteria for the petition area within these states.

e) Dissolved Oxygen

While listed as one of the pollutants at issue, neither the petition nor the addenda to the petition discuss any specific issues/concerns related to numeric dissolved oxygen criteria in the petition area. Nonetheless, in the absence of any information from the petitioner, EPA analyzed currently approved state water quality standards, in conjunction with implementation procedures that further describe how the state implements its water quality standards, and found that all of the petition states apply a dissolved oxygen criterion of 5 mg/l to protect aquatic life consistent with the CWA.[31] Therefore, it is unnecessary for EPA to federally promulgate numeric dissolved oxygen criteria for the petition area, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B

f) Ammonia

While listed as one of the pollutants at issue, neither the petition nor the addenda to the petition discuss any specific issues/concerns related to numeric ammonia criteria in the petition area. Nonetheless, in the absence of any information from the petitioner, EPA evaluated the petition states' currently approved water quality standards to determine if the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric ammonia criteria is necessary. EPA first reviewed the states' currently adopted and approved water quality standards to validate the petitioner's findings. Specifically, EPA looked to see whether any states have adopted numeric and/or narrative ammonia criteria to protect aquatic life consistent with EPA's recommendations.[32] If the criteria varied state to state, EPA looked to see why the criteria varied and whether the variation was within the states' scientific discretion and whether the resulting criteria were protective of the designated use. Finally, EPA looked at the petition states' 2002 section 303(d) impaired waters lists[33] to determine if any petition state identified ammonia as an impairing pollutant responsible for impairing aquatic life uses.

All eight of the petition states have adopted numeric ammonia criteria applicable to the portions of the Mississippi and Missouri Rivers within their jurisdiction. Kansas, Iowa, Nebraska and Tennessee adopted numeric ammonia criteria identical to EPA's most recent section 304(a) criteria recommendation published in 1999. Missouri, Illinois, and Kentucky have adopted criteria based on EPA's section 304(a) recommendations published before 1999. Arkansas adopted numeric ammonia criteria on April 23, 2004 and is expected to submit their revised water quality standards for EPA review and approval in June 2004. In the interim, Arkansas's narrative criterion may be used to control ammonia levels, if necessary, through water quality-based NPDES limits or TMDLs.[34] In EPA's review of the petition states' section 303(d) lists[35], no state within the petition area included (nor did EPA propose to include) ammonia as a pollutant impairing designated uses.

In developing its 304(a) criteria recommendations, EPA took into account the fact that ammonia is a complex pollutant with its effect on aquatic life dependent on several

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[31] See Attachment B
[32] See Attachment B
[33] See Attachment G
[34] See Attachment A
[35] See Attachment G

factors, including temperature and pH. EPA's most recent recommended criteria reflect these complexities by providing numeric calculation approaches that consider these two variables. Further, states may modify EPA's section 304(a) criteria recommendations based on their own analysis of the available toxicity data taking into account local characteristics. In addition, EPA has not recommended a specific method to determine the appropriate temperature and pH to use when deriving numeric ammonia criteria. As a result, states may use temperature and pH differently leading to variations in the derived state numeric ammonia criteria. EPA evaluated these states' currently adopted and approved numeric ammonia criteria taking into account these variations and determined that all of the numeric ammonia criteria values applied by the petition states to the petition area are within the scientifically reasonable range and are expected to protect the designated uses consistent with the federal regulations at 40 C.F.R. §131.11. EPA continues to work with all states to ensure the latest scientific knowledge regarding ammonia is incorporated into state water quality standards.

Since ammonia criteria will generally vary with pH and temperature, any comparison of stringency among the state criteria depends on the pH and temperature used for the comparison. Scientifically, it is unclear what the most relevant pH and temperature conditions would be for making such comparisons. Therefore, it is not possible to rank, with confidence, state ammonia criteria by stringency. As mentioned earlier, the petition did not identify any specific instances of concern related to numeric ammonia criteria in the petition states nor do any of the petition states identify ammonia as an impairing pollutant on their section 303(d) list. Taking this into consideration as well as the fact that seven of the eight states' currently approved ammonia criteria are within the scientifically reasonable range and are expected to protect the designated uses consistent with the federal regulations at 40 C.F.R. §131.11 and the remaining state (Arkansas) has adopted a numeric ammonia criterion, EPA concludes it is unnecessary to federally promulgate numeric ammonia criteria for the petition area, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B).

g) Nutrients

The Sierra Club raises several concerns regarding nutrients in the petition. They assert that states inconsistently apply numeric criteria for nitrogen and phosphorus to the Mississippi and Missouri and that inadequate nutrient criteria in the petition area contributes to the hypoxic zone in the Gulf of Mexico. Petition at 17. Regarding the petitioner's concern of inconsistent nutrient criteria, the Sierra Club specifically indicates that Kentucky has a narrative criterion while neighboring Missouri has a numeric nitrogen criterion and that Arkansas is the only state in the petition area to apply a numeric phosphorus criterion to the Mississippi River. Petition at 13 – 14. Addenda 9 and 15 appear to support these examples of inconsistent criterion on the Mississippi River and offer additional information, but only describe the criteria applicable to the Mississippi River and not the Missouri River within the petition area.

To support their request that EPA publish numeric criteria for nutrients in the petition area, the Sierra Club referred to a recent General Accounting Office (GAO) report that stated "sediments, nutrients and pathogens (including *E. coli* and enterococci) - account for fifty percent [sic] of the impaired waters nationwide." The petitioner goes on to state that despite this statistic, EPA has not developed recommendations for numeric water quality criteria for nutrients. Petition at 15 – 16. The GAO report indicates that EPA is in the process of developing numeric criteria for nutrients.[36]

EPA evaluated the petition information as well as the currently approved state water quality standards to determine if the petition states' water quality standards are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric nutrient criteria is necessary. EPA first looked to see which states have adopted numeric nitrogen or phosphorus criteria to protect designated uses. Second, EPA looked to see if the petition states have adopted narrative criteria for nutrients and whether there are accompanying procedures to derive numeric criteria. Third, EPA identified the current state efforts and where the petition states are in their process to adopt numeric criteria based on the latest scientific information. Finally, EPA collected information regarding the scientific understanding of nutrients and designated uses (in local waters and the effect on the Gulf of Mexico) to determine if the science is sufficient, at this time, to support EPA or state development of numeric ambient water quality criteria for the Mississippi and Missouri Rivers.

Based on its evaluation, EPA found that Tennessee recently adopted, and EPA approved, narrative criteria for nutrients along with a procedure to derive numeric nutrient criteria applicable to free flowing streams to protect designated uses from the effects of excessive algal growth. Kansas applies numeric criterion for elemental phosphorus for the petition area. Iowa, Illinois, Missouri, Nebraska, and Kansas apply a numeric criterion for nitrates and/or nitrites to the petition area to protect human health. Arkansas has recently adopted narrative criteria for nutrients in place of previous numeric phosphorus guidelines (which is not considered to be a criterion). However, through its implementation procedures approved by EPA, Arkansas does establish point source discharge limits for nitrate-nitrogen to protect drinking water uses in surface waters.[37] EPA is currently working with these states to determine if additional criteria or procedures are necessary for nitrogen and phosphorus to protect surface waters from adverse effects due to nutrient overenrichment. All eight petition states have narrative criteria applicable to nutrients that may be used for establishing NPDES permits, listing waters as impaired by nutrients on section 303(d) lists and developing TMDLs, if necessary.

As indicated earlier, the petitioner further expresses its concern regarding nutrients in the Mississippi and Missouri Rivers by referencing the hypoxic zone in the

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[36] General Accounting Office. *Water Quality: Improved EPA Guidance and Support Can Help States Develop Standards that Better Target Cleanup Efforts*. GAO-03-308 < http://www.gao.gov/new.items/d03308.pdf> (January 2003). p 37.

[37] Arkansas Department of Environmental Quality. *Arkansas Water Quality Planning and Management: State Continuing Planning Process*. Little Rock, Arkansas. 1999.

northern Gulf of Mexico as "a graphic demonstration of the inadequacy of current water quality standards in the vicinity of the petition area." Petition at 16. While the Sierra Club specifically quotes the discussion contained in The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force's *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico* regarding the significant impact of nutrients carried to the Gulf (from the Mississippi River basin) on the Hypoxic zone, the *Action Plan* also states that "There are no simple solutions that will reduce hypoxia in the Gulf. An optimal approach would take advantage of the full range of possible actions to reduce nutrient loads and increase nitrogen retention and denitrification."[38]

According to the *Action Plan*, 56% of the nitrate load enters the Mississippi River above the Ohio River and the Ohio River basin itself adds 34% of the nitrate load. About 90% of the total nitrate load to the Gulf comes from nonpoint sources. Modeling by Alexander et al (2000)[39] indicates that more than 90% of the nitrate reaching the Mississippi River will be transported downstream to the Gulf of Mexico. This implies that the Mississippi River primarily transports nutrients downstream with little or no processing or removal of nitrogen occurring.[40,41] Battaglin et al (2001) believe that the ability of the Mississippi River to process nitrate normally is being overwhelmed by the nitrate loads from upstream sources. As a result, the Mississippi River is unable to achieve the net decrease in nitrate amounts that normally would occur. USGS studies show that denitrification could be optimized in the Upper Mississippi River (source of Mississippi River to confluence with Illinois River) by diverting water from the river to off-channel "backwater" areas that have conditions to promote nitrogen removal during non-flooding periods. However, even optimal denitrification in the Upper Mississippi River would only result in 5-10% reduction in load to the Gulf of Mexico.[42] The ability to use this method to achieve optimal denitrification in the middle and lower Mississippi Rivers is very small since the River is essentially disconnected from the carbon-rich floodplain ecosystem that could help process nitrogen, by flood control levees.[43] In other words, even if the Mississippi River could optimally process nitrogen like many other waters, the amount of nitrogen being loaded into the river prevents the river from reducing total nitrogen loadings into the Gulf more than 10%. These studies emphasize how complex the nutrients problem is in the Mississippi River basin and the need for states to control nutrients at the source.

In 2001, EPA began providing states with waterbody specific technical guidance manuals and numeric nutrient criteria recommendations for states to use as starting points

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[38] Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico.* http://www.epa.gov/msbasin/actionplan.htm. January 2001.

[39] Alexander, R.B., Smith, R.A., and Schwarz, G.E. 2000. *Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico*. Nature 403: 758-761.

[40] Richardson, W.B., Strauss, E.A., Bartsch, L.A., Monroe, E.M., Cavanaugh, J.C., Vingum, L., and Soballe, D.M. *Denitrification in the Upper Mississippi River: rates, controls, and contribution to the nitrate flux.* (in press).

[41] Battaglin, W.A., Kendall, C., Chang, C.C.Y., Silva, S.R., and Campbell, D.H. 2001. Chemical and isotopic evidence of nitrogen transformation in the Mississippi River, 1997-1998. Hydrol. Process. 15: 1285-1300.

[42] Richardson, W.B., Strauss, E.A., Bartsch, L.A., Monroe, E.M., Cavanaugh, J.C., Vingum, L., and Soballe, D.M. *Denitrification in the Upper Mississippi River: rates, controls, and contribution to the nitrate flux.* (in press).

[43] U.S. Geological Survey. *Nutrients in the Upper Mississippi River: Scientific Information to Support Management Decision, The Upper Mississippi River – Values and Vulnerability*. USGS Fact Sheet 105-03. July 2003.

to protect aquatic life from eutrophication resulting from excessive nutrients, not just toxic effects. EPA has provided nutrient criteria recommendations for most of the freshwater in the nation, excluding wetlands (see http://www.epa.gov/ost/standards/nutrient.html).

States throughout the United States have been working with EPA to develop appropriate nutrient criteria plans to quantitatively address nutrients in their waters. EPA expects these plans to be developed collaboratively with EPA and to include descriptions of the approach the state will use to develop criteria, the relative priorities of waterbodies or waterbody type, data collection plans, and a schedule describing the major milestones for developing and adopting nutrient criteria. EPA's policy was described to the states in a November 14, 2001, memo available at http://www.epa.gov/waterscience/criteria/nutrientswqsmemo.pdf. Since data are more readily available and the science is better understood for lakes, reservoirs and tributaries to the Mississippi and Missouri Rivers, states have generally indicated in their plans that they are focusing on developing nutrient criteria for these waters prior to adopting quantitative nutrient criteria specifically for the Mississippi and Missouri Rivers.

EPA believes that it is important that states establish quantitative nutrient criteria, where necessary to protect designated uses, for all waters where criteria can be developed based on sound science. The studies discussed above support EPA's position that state adoption and implementation of nutrient criteria for tributaries of the Mississippi and Missouri Rivers will lead to an overall reduction of nutrient loadings in the Mississippi and Missouri River basin. These reductions will improve water quality and help protect the designated uses of these rivers as well as the Gulf of Mexico, in the near term. Therefore, while states are not currently focused on adopting quantitative nutrient criteria specifically for the Mississippi and Missouri Rivers, EPA believes that the states in the petition area are appropriately focusing attention and resources on the smaller waterbodies that flow into these rivers before addressing these two large rivers themselves. EPA intends to work with the states to establish quantitative nutrient criteria for these waters. As a result, EPA also expects, as the *Action Plan* states, that "…. actions taken to address local water quality problems in the basin will frequently also contribute to reductions in nitrogen loadings to the Gulf."[44]

EPA will work closely in the petition area with the five states that have not yet provided EPA with draft nutrient criteria plans to ensure that an appropriate approach and timeframe to develop nutrient criteria is established consistent with its November 2001 policy memo. EPA will work with the other states in the petition area that have developed nutrient criteria plans to ensure successful implementation. Whether a state has developed a nutrient criteria plan or not, EPA expects states to adopt nutrient criteria for the tributaries to the petition area in a timeframe consistent with EPA's guidance in the November 2001 policy memo and will evaluate the need to promulgate federal nutrient criteria, as necessary, if a state fails to do so. In the interim, petition states'

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[44] Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico.* http://www.epa.gov/msbasin/actionplan.htm. January 2001.

narrative criteria may serve as the basis for NPDES permits, section 303(d) listings and TMDLs, if necessary.

Although EPA has provided nutrient criteria recommendations for the ecoregions that encompass the Mississippi and Missouri Rivers, EPA's water quality criteria recommendations for nutrients are based on a reference condition approach (a reference condition reflects minimally impacted water quality conditions). In deriving the criteria recommendations, EPA incorporated data from the Mississippi and Missouri Rivers, however, since EPA's recommendations are based on reference conditions and are statistically derived to generally protect the designated uses of specific waterbody types in a specific ecoregion, it is not likely that EPA's approach which takes the 25th percentile of data from all flowing waterbodies in the ecoregions containing the Mississippi and Missouri Rivers will generate a reference condition value appropriate to base development of a nutrient criterion for these rivers. The Mississippi and Missouri Rivers have unique qualities (i.e., flow, depth, temperature and nutrient-algal response relationships) in their respective ecoregions, and EPA believes further consideration of historical data and water quality conditions are necessary before establishing nutrient criteria specifically for these rivers. Until more monitoring and research have been conducted to better understand how these large and complex rivers respond to nutrient enrichment, establishing numeric nutrient criteria for the petition area, today, would be less meaningful and effective than ensuring that quantitative nutrient criteria are adopted for waters where the linkage between nutrient concentrations and biological response are better understood and where the sources of nutrient loadings can be adequately controlled.

The *Action Plan* acknowledges the complex nature of nutrient cycling in the Mississippi and Atchafalya River basins as well as the Gulf of Mexico. As a result, it is "…difficult to predict specific improvements in water quality that will occur both in the Gulf as well as the entire Mississippi River basin for a given course of action….Further, …while the current understanding of the causes and consequences of Gulf of Mexico hypoxia is drawn from a massive amount of direct and indirect evidence collected and reported over many years of scientific inquiry, significant uncertainties remain. Further monitoring, modeling, and research are needed to reduce those uncertainties in future assessments and to aid decision making in an adaptive management framework." The Mississippi River/Gulf of Mexico Watershed Nutrient Federal, State, and Tribal Task Force (Nutrient Task Force) was chartered in 1998 to understand the causes and effects of eutrophication in the Gulf of Mexico and to coordinate activities to reduce the size, severity and duration of the Hypoxic zone and its effects. To combat the issues identified in the *Action Plan*, the Nutrient Task Force is developing the document *A Strategy for Monitoring, Modeling, and Research in Support of Managing Excess Nutrients in the Mississippi River Basin and Hypoxia in the Northern Gulf of Mexico*, that is intended to describe a framework for implementing monitoring, modeling, and research activities. This framework will provide a sound basis of scientific information to support implementation of a management plan to address nutrient over-enrichment in the Mississippi River basin and Hypoxia in the northern Gulf of Mexico. Scientific information will be provided in an adaptive-management framework through monitoring and periodic interpretation, model analysis, and continual improvement in knowledge and methods by supporting research. The Task Force is also investigating ways to track how existing federal, state, and local efforts are likely to decrease the size of the hypoxic zone.

Once the complex effects of nutrients unique to the Mississippi River basin and their affect on the hypoxic zone in the Gulf of Mexico are better understood, EPA will be able to confidently evaluate whether states have adopted nutrient criteria into water quality standards that adequately protect designated uses in the Mississippi and Missouri Rivers and the Gulf of Mexico, and ascertain whether federally promulgated nutrient criteria are needed. EPA has taken a strong leadership role in the Nutrient Task Force's efforts to establish a strategy to reduce the size of the hypoxic zone and is working with federal and state partners to investigate remaining scientific uncertainties. EPA agrees with the petitioner that it is important that states establish quantitative nutrient criteria for the Mississippi and Missouri Rivers to protect designated uses and serve as appropriate benchmarks for nutrient controls. Yet, EPA also believes that nutrient criteria must be based on sound science. Therefore, EPA intends to continue its leadership role on nutrients and facilitate federal and state collaborative efforts that will support the development and adoption of quantitative nutrient criteria into water quality standards that will not only protect against local effects of nutrients within the Mississippi River basin, but also help to reduce the size of the hypoxic zone in the Gulf of Mexico. EPA will work with key partners to determine the appropriate ambient water quality criteria for nutrients necessary to protect the unique ecosystems of the Mississippi and Missouri Rivers based on a sound scientific understanding of the relationship between nutrient concentrations and the biological response in these rivers.

EPA believes the most effective way to begin to address ambient water quality criteria for nutrients in the Mississippi and Missouri Rivers is to reach a consensus with the affected entities on a coordinated approach on addressing nutrients in the basin. Therefore, EPA will convene key partners at a multi-day national workshop to discuss the development and adoption of appropriate ambient water quality criteria for nutrients into water quality standards for the Mississippi and Missouri Rivers that will protect the rivers and the Gulf of Mexico. The workshop will include invitees from various federal agencies (e.g., U.S. EPA's Office of Water and Office of Research and Development, U.S. Geological Survey, and U.S. Department of Agriculture), states and other stakeholders with the objective of identifying the existing federal and state nutrients efforts along the Mississippi River, the Missouri River and the Gulf of Mexico; understanding the current state of the science and the barriers states are facing; determining additional research needs and priorities; and how federal and state agencies and stakeholders can work together to develop quantitative nutrient criteria for the Mississippi and Missouri Rivers. Following the workshop, EPA will publish a report to summarize the results of the workshop and identify next steps. This report will establish a roadmap for how EPA intends to work with its partners to address nutrients in the Mississippi and Missouri Rivers. This effort will also be closely linked with the Task Force to ensure that all related nutrient work is effectively coordinated. EPA has identified the needed funds and will begin planning the workshop immediately with the intent to hold the workshop in 2005. EPA agrees with the petitioner that the Mississippi and Missouri Rivers and the Gulf of Mexico are valuable resources and hopes that the Sierra Club and other stakeholders will actively participate in this effort to help ensure success.

Since EPA's current criteria recommendations may not be appropriate to promulgate for the Mississippi and Missouri Rivers, EPA intends to convene a national workshop that will initiate discussions on a collaborative approach to determining the appropriate ambient water quality nutrient criteria for the Mississippi and Missouri Rivers (taking into account the effects on the Gulf of Mexico). In order for EPA to promulgate nutrient criteria for the petition area based on sound science, EPA must first address the scientific uncertainties that remain regarding ambient water quality criteria for nutrients for the Mississippi and Missouri Rivers. In the interim, however, the states are actively working with EPA to develop and adopt quantitative nutrient criteria for tributaries to these rivers that will lead to an overall reduction of nutrients within the basin. Therefore, in the absence of scientifically sound criteria appropriate for these rivers, EPA concludes that it is unnecessary for EPA to federally promulgate numeric nutrient criteria for the petition area, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B).

h) Sediments

In section IV of the petition titled "Existing water quality standards for the Mississippi and Missouri Rivers in the Petition area are inadequate", the Sierra Club discusses the January 2003 GAO report stating that EPA has not yet developed national numeric criteria for sedimentation despite the fact that "sediments, nutrients and pathogens (including *E. coli* and enterococci) - account for fifty percent [sic] of the impaired waters nationwide,". Neither the petition nor the addenda to the petition discuss any specific issues of concern related to numeric sedimentation criteria in the petition area. In the absence of any information from the petitioner, EPA evaluated the petition states' currently approved water quality standards to determine if they are inconsistent with the CWA and federal regulations at 40 C.F.R. Part 131 such that a federal promulgation of numeric sedimentation criteria is necessary. EPA first looked to see whether any states have adopted numeric and/or narrative criteria related to sedimentation to protect designated uses. Then EPA evaluated the scientific understanding about sedimentation and designated uses to determine if the science is sufficient at this time to support EPA or state development of ambient water quality criteria.

All eight of the petition states currently have narrative criteria related to sedimentation that may be used for establishing NPDES permit limits, listing waters as impaired by sediments on section 303(d) impaired waters lists, and developing TMDLs, if necessary. Arkansas applies a numeric criterion for turbidity to the petition area.

EPA has not yet published numeric criteria recommendations under section 304(a) of the CWA for sediments (suspended and bedded sediments (i.e. sediments accumulated on the bottom of a stream bed)) because the science is not yet fully understood regarding how to appropriately establish criteria for sedimentation in surface waters. As part of the Water Quality Standards and Criteria Strategy, finalized in August 2003 (see EPA's website at http://www.epa.gov/waterscience/standards/strategy/), EPA committed to developing a Suspended and Bedded Sediment Criteria Strategy after consulting with EPA's Science Advisory Board. This strategy will inform EPA's development of guidance on controlling excess sediments. The suspended and bedded sediment strategy is expected to identify methods for developing numeric suspended and bedded sediment criteria and lead to recommendations that states can use to adopt their own numeric criteria for suspended and bedded sediments. These recommendations will also provide a benchmark for EPA to evaluate the effectiveness of state water quality standards programs. Since the Agency is currently developing a Suspended and Bedded Sediment Criteria Strategy to inform EPA's criteria recommendations for suspended and bedded sediment criteria and all the petition states have narrative criteria to provide a basis for controlling suspended and bedded sediments in the interim, if necessary, EPA concludes that it is unnecessary for the Administrator to federally promulgate numeric sedimentation criteria for the petition states, at this time, to meet the requirements of the CWA under CWA section 303(c)(4)(B), at this time. However, once EPA has published section 304(a) criteria recommendations for suspended and bedded sediments and has provided states appropriate time to incorporate the latest science into water quality standards, EPA will reevaluate the need for the Administrator to determine that a federal promulgation of numeric suspended and bedded sediment criteria is necessary to meet the requirements of the CWA.

i) IBI

Neither the petition nor the addenda to the petition discuss any specific concerns related to an index of biological integrity (IBI) in the petition area beyond their request that EPA publish numeric criteria. An index of biological integrity adopted as a water quality criterion in water quality standards is known as "biocriteria". EPA does not require that states adopt biocriteria into water quality standards to protect designated uses, however EPA believes that biocriteria and bioassessments are desired elements of a robust water quality program, which help to achieve the objectives of the CWA under section 101(a).

The CWA section 304(a)(8) provides that EPA shall publish "…methods for establishing and measuring water quality criteria for toxic pollutants on other bases than pollutant-by-pollutant criteria, including biological monitoring and assessment methods." Since numeric biocriteria (response criteria based on water body condition) must be developed on a regional or water body-specific basis using bioassessment monitoring data gathered from those water bodies, EPA does not publish national recommended biocriteria. Instead, states use EPA's recommended methods to develop and adopt biocriteria to protect their designated uses, as needed.

EPA has published biocriteria methods for streams, small rivers, lakes, reservoirs, wetlands, and estuaries and continues to develop methods for all other water body types. (see http://www.epa.gov/waterscience/biocriteria/). EPA's 10 Regional Offices have developed biocriteria implementation strategies for their individual states and the Agency provides technical support through grants, contracts and training. As of 2001, all states and some Tribes and territories had bioassessment programs for streams and small rivers and most are in the process of developing quantitative biocriteria. In the petition area, Nebraska and Missouri have adopted narrative biocriteria into water quality standards. Arkansas, Kentucky, and Tennessee have adopted narrative biocriteria into water quality standards and have also developed a quantitative implementation procedure or translator to interpret this narrative for wadeable streams. Missouri is currently working to develop a procedure for wadeable streams to interpret their narrative, while Iowa is actively working to develop narrative and numeric biocriteria for wadeable streams.[45] Since EPA has not yet provided biocriteria methods for large rivers, it is unlikely that the procedures adopted by the petition states are applicable to the Mississippi and Missouri Rivers. However, it is clear the states are making substantial progress toward developing and adopting biocriteria for other water bodies, statewide. Further, CWA section 106(e)(1) includes biological monitoring in the description of a monitoring program necessary to receive a grant from the Administrator. Since 40 C.F.R. §130.7(b)(5) requires states to "assemble and evaluate all existing and readily available water quality-related data and information," any available biological information will continue to be a part of the state assessment process.

While EPA has not yet developed biocriteria methods for large rivers, EPA is developing large river indicators of biological and physical habitat condition to help states and tribes assess the water quality conditions and identify impairments in large rivers. Two guidance manuals have been produced to date. One of these manuals details the differences between the methods used by various agencies to assess small and large rivers in the U.S. (see http://www.epa.gov/nerleerd/MCD_nocover.pdf); the second manual is a logistical guide for conducting ecological assessments in large rivers (http://www.epa.gov/nerleerd/logistics_nocover.pdf). New methods specifically designed to adequately sample large rivers are being tested currently. The results from this research will provide additional information to enable states and tribes to make informed decisions about the selection of scientifically robust and efficient methods to assess the biological conditions of large rivers using various relevant endpoints.

EPA is promoting state collection of biological data in large rivers in several other ways. For example, two classes addressing large river bioassessment and monitoring were taught at the first National Biocriteria Workshop at Coeur d'Alene, Idaho in 2003. The workshop was very well attended by states, including those along the Mississippi and Missouri Rivers. In addition, EPA scientists are working with the Kentucky Department of Natural Resources (DNR) in their implementation of the large river monitoring component of a Conservation Reserve Enhancement Program (CREP). This work is serving as the first step in Kentucky DNR's effort to initiate a state-wide large river bioassessment and monitoring program, and it may serve as an

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[45] U.S. Environmental Protection Agency. *States and Tribes Embrace Bioassessment and Biocriteria for Protecting Streams and Small Rivers*. EPA - 822-F-03-005. June 2003.

example for other states to follow. Also, a team of scientists composed of national and regional large river experts is using the findings of completed research to develop a scientifically sound and logistically feasible large river bioassessment program for the Mississippi DNR.

For the reasons discussed above, EPA concludes that it is unnecessary for EPA to federally promulgate water quality standards that include an index of biological integrity for the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B). However, EPA believes that biocriteria and biomonitoring are important tools to support the state water quality programs and will continue to work with and encourage states to incorporate biological conditions/criteria into state water quality programs.

3) Monitoring

Petitioner's Position – The Sierra Club believes that limited and inconsistent water quality monitoring by states in the petition area is "a weak link in this system." Petition at 17. They assert that most of the states in the petition area do not routinely monitor water quality and that very little funding is devoted to ambient water quality monitoring. The Sierra Club also asserts that state monitoring approaches and methodologies lack consistency across the area leading to inconsistent and unreliable conclusions about waters meeting the applicable water quality standards, waters being listed as impaired under CWA section 303(d), and in identifying causes of impairment. The petitioner requests that EPA promulgate water quality standards that include monitoring provisions to support uniform, statistically based method for determining whether the rivers are actually meeting applicable water quality standards.

EPA's Response – EPA denies the petitioner's request that EPA promulgate monitoring requirements as part of state water quality standards for the petition area. The "Statutory and Regulatory Background" section of this response describes the requirements for state water quality standards programs. Neither the CWA nor the implementing regulations require that water quality standards include monitoring provisions. EPA agrees with the petitioner that addressing shortcomings in state monitoring programs is a priority but believes that EPA's non-regulatory approaches planned and underway will achieve the outcome of strengthened and more consistent monitoring and assessment activity in the petition states.

Background

CWA section 305(b) requires a comprehensive biennial report on water quality and CWA section 303(d) requires states to assess waters and develop lists of impaired waters that do not meet water quality standards, even after point sources of pollution have installed the required levels of pollution control technology. States have flexibility to devise various approaches to assess waters and determine which waters are impaired and should be listed under section 303(d). EPA does not approve or disapprove a state's assessment and listing methodology but does approve or disapprove a state's section 303(d) list and may raise any issues about the state assessment methodology during this process. When developing the list of impaired waters, the CWA and EPA's implementing regulations require that states "…assemble and evaluate all existing and readily available water quality-related data and information." 40 C.F.R. §130.7(b)(5).

The CWA and implementing regulations confer broad latitude on states and provide for state flexibility in assigning priorities and employing different assessment and water quality management methods. Assessment and listing of interstate waters can pose challenges because of differences among methodologies and priorities in state water quality management programs. As the petition demonstrates, different state approaches on shared waterbodies can also create public concern and confusion. Major contributors to uncertainty about the water quality status of many waters, including shared waters, are gaps in monitoring and assessment.

EPA Efforts to Improve State Monitoring and Assessment Overall

Improving the rigor and consistency of state monitoring and assessment programs is a top priority for EPA because the Agency recognizes these programs are an essential foundation for effective water quality management. EPA is devoting substantial resources and attention to this issue. In fiscal year (FY) 2004, EPA received $4 million to improve our ability to answer questions about water quality on a national basis. The President's FY 2005 Budget Request seeks $20 million to help states and tribes develop and implement statistically representative water quality monitoring programs. A key objective of this effort is greater consistency in monitoring across state programs.

In addition, EPA issued *The Consolidated Assessment and Listing Methodology (CALM) (July 2002)*[46]. CALM provides a framework for states to document how they collect and use water quality data and information for environmental decision-making, in particular for determining whether waters are attaining water quality standards, identifying waters that are impaired and need to be included in the section 303(d) lists, and identifying waters that are meeting standards so that they can be removed from the list.

In March 2003, EPA provided guidance to states on the elements needed to strengthen state monitoring and assessment programs, *Elements of a State Water Monitoring and Assessment Program.*[47] The guidance calls for states to develop or commit to develop a Comprehensive State Monitoring Strategy in FY04. This strategy should be a long-term implementation plan for improving monitoring and assessment and emphasize a comprehensive approach to assessing all waterbody types over time through the use of multiple tools.

In a related effort, EPA is encouraging states to adopt a consistent format for categorizing and reporting the status of waters according to whether they have met water quality standards, require more data, or require a Total Maximum Daily Load (TMDL). This "integrated reporting" guidance emphasizes the importance for states to clearly articulate their methodology

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[46] U.S. Environmental Protection Agency. Consolidated and Assessment Listing Methodology.: Toward a Compendium of Best Practices. 2002. <http://www.epa.gov/owow/monitoring/calm.html>

[47] U.S. Environmental Protection Agency. Elements of a State Water Monitoring and Assessment Program. 2003. < http://www.epa.gov/owow/monitoring/elements/elements03_14_03.pdf> EPA 841-B-03-003.

for assessing waters and provide the public an opportunity to comment on both the methodology and proposed list of impaired waters. See *EPA's Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d) and 305(b) of the Clean Water Act, July 2003* (www.epa.gov/owow/tmdl/tmdl0103/index.html). The guidance also emphasizes that, where waters are shared among states, states should work together to collect, assemble, solicit, and assess all readily available data and information relevant to shared waters so that assessments are as consistent as possible. This coordination on shared waters is especially important for waters that are to be listed as impaired under CWA section 303(d) which then requires developing a TMDL.[48]

EPA expects that, through targeted funding and greater implementation of recent agency guidance, the quality and consistency of state monitoring and assessment programs will improve.

EPA and State Efforts to Improve Monitoring and Assessment in the Mississippi and Missouri Rivers

The challenge of improving water quality monitoring programs is even more daunting for large rivers such as the Mississippi and Missouri Rivers. The size and complexity of these rivers make representative data collection more difficult. Due to dilution in rivers of this size, localized water quality impairments may go undetected without intensive monitoring. Further, variability in river conditions means there is limited ability to extrapolate site-specific data where it does exist. To address the assessment challenges specific to large rivers, EPA's Office of Research and Development is preparing The Great Waters Initiative, a framework for state-based monitoring programs to assess the ecological condition of the Mississippi, Missouri and Ohio Rivers (see http://www.epa.gov/emap/greatriver/FactSheet.pdf). The framework is expected to include a probability-based design and indicators that could be used to assess the ecological condition of the three great rivers.

In the Upper Mississippi River basin, EPA Regions 5 and 7 are working directly with states to improve coordination on water quality management issues. The Upper Mississippi River Basin Association (UMRBA) is a regional interstate organization formed by the governors of Illinois, Iowa, Minnesota, Missouri, and Wisconsin to help coordinate the states' water quality issues related to the Mississippi River. UMRBA implemented a Water Quality Coordination Project that aimed to discern underlying reasons for state inconsistencies in assessment and listing and to initiate actions to address inconsistencies (www.umrba.org/wq/wq2002rpt.pdf). For example, one outcome of the project is a Memorandum of Understanding among the five UMRBA states to use a minimum number of common water reaches for purposes of characterizing water quality under CWA section 305(b) and identifying water quality impairments under section 303(d).

Over time, these efforts in the Upper Mississippi River basin should lead to improved consistency in state section 305(b) assessments and section 303(d) listings throughout Mississippi and Missouri basins. In addition to these ongoing efforts, EPA will work with the

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[48] U.S. Environmental Protection Agency. 2003. *EPA's Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d) and 305(b) of the Clean Water Act, July 2003*. http://www.epa.gov/owow/monitoring/repguid.html).

petition states during the 2006 reporting and listing cycle (now underway) to resolve or explain, where possible, inconsistencies in the listing of impaired waters on the Mississippi and Missouri Rivers. Examples cited by the petitioner, including the fact that Arkansas and Kentucky did not include the Mississippi River on their 1998 section 303(d) list and that Kansas did not list the Missouri River in 1998, will be given particular consideration. EPA will continue through successive listing cycles to use any new sources of water quality data for the affected river segments, such as data generated through the Great Waters Initiative, to work with states in refining their impaired water lists. Therefore, EPA concludes it is unnecessary for EPA to federally promulgate monitoring requirements in water quality standards for the petition area to meet the requirements of the CWA under CWA section 303(c)(4)(B).

Conclusion

For the foregoing reasons, EPA denies the petition’s request for EPA to publish water quality standards for the petition area, at this time.

ATTACHMENT A – WATER QUALITY STANDARDS FOR PETITION STATES: LIST AND CITATIONS

State	State Regulation Information
Arkansas	Arkansas Pollution Control and Ecology Commission; Regulation 2 - Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas; (October 28, 2002); Effective under Clean Water Act - January 23, 2003. http://www.epa.gov/ost/standards/wqslibrary/ar/ar.html
Illinois	Title 35: Environmental Protection; Subtitle C: Water Pollution; Chapter 1: Pollution Control Board Parts 301 Introductions & Park 302 Water Quality Standards (August 26, 1999) http://www.epa.gov/ost/standards/wqslibrary/il/il.html
Iowa	567 Iowa Administrative Code Chapter 61 – Water Quality Standards Effective under Clean Water Act – June 16, 2004 http://www.epa.gov/ost/standards/wqslibrary/ia/ia.html
Kansas	Kansas Department of Health and Environment; Division of Environment; Bureau of Environmental Field Services Kansas Surface Water Register (December 15, 2003) Effective Under Clean Water Act–To be acted upon June 2004 Kansas Administrative Regulations Title 28, Article 16 – Surface Water Quality Standards (September 25, 2003) Effective Under the Clean Water Act – November 3, 2003 http://www.epa.gov/ost/standards/wqslibrary/ks/ks.html
Kentucky	Natural Resources and Environmental Protection Cabinet; Department for Environmental Protection; Division of Water Kentucky Administrative Regulations, Title 401, Chapter 5 Effective Under the Clean Water Act – December 8, 1999 http://www.epa.gov/ost/standards/wqslibrary/ky/ky.html
Missouri	Code of State Regulations Title 10 - Rules of Department of Natural Resources; Division 20 – Clean Water Commission; Chapter 7 – Water Quality 10 CSR 20-7 (10/31/99) http://www.epa.gov/ost/standards/wqslibrary/mo/mo.html
Nebraska	Nebraska Department of Environmental Quality Title 117 – Nebraska Surface Water Quality Standards (12/31/02) Effective Under the Clean Water Act – August 8, 2003 http://www.epa.gov/ost/standards/wqslibrary/ne/ne.html
Tennessee	Rules of the Tennessee Department of Environment and Conservation; Division of Water Pollution Control Chapter 1200-4-3 General Water Quality Criteria (October 1999) Effective Under the Clean Water Act – October 11, 1999 http://www.epa.gov/ost/standards/wqslibrary/tn/tn.html

Attachment B -- EPA analysis of State Water Quality Standards in the Petition Area
(Mississippi River)

NOTE: ***Spreadsheet reflects applicable numeric criteria only.***
Numeric criteria reflected are most stringent criteria applicable to segment.

STATE		DESIGNATED USE											NUMERIC WATER QUALITY CRITERIA									
EPA's most recent 304(a) recommendations next to pollutant label	**Outstanding State Resource Water**	**Primary Rec**	**Secondary Rec**	**Aquatic Life**	**Aesthetics**	**Fish Consumption**	**Drinking Water/Domestic Water Supply**	**Agriculture**	**Irrigation**	**Livestock & Wildlife watering**	**Naviagation**	**Industrial**	**chlordane (CCC = .0043 µg/l, water + organism = .00080 µg/l, organism only = .00081 µg/l) MCL=.002mg/L or 2 µg/l**	**atrazine 1500 µg/l freshwater, 760 µg/l saltwater, MCL = 3 ppb or 3 µg/l**	**Total PCBs (CCC = .014 µg/l, HH = .000064 µg/l updated) MCL = .5 ppb or .5 µg/l**	**e.coli (126 / 100 ml)**	**enterococci (33 per 100 ml)**	**DO (5 mg/l 1 day minimum)**	**Ammonia (1999 update, pH/temp. dependent)**	**Phosphorus (ecoregional based)**	**Nitrogen (ecoregional based)**	**Sediments (narrative. Sedimentation criteria in development)**
IA (effective 6/16/04)																						
Skunk River to Iowa River		X		Significant Resource Warm Water (Class B(WW))				X	X	X		X	C = .004 µg/l* A = 2.5 µg/l* HH (fish consumption) = .006 µg/l *		C = .014 µg/l * A = 2 µg/l * HH (fish consumption) = .0004 µg/l *	E. coli = 126/100 ml* (geometric) Mar 15 - Nov 15, 235/100 ml* (single sample max)		no less than 5 mg/l (at any time)				Turbidity shall not be increased by more than 25 NTU by any point source discharge
IA-MO state line to confluence w/ Skunk R.		X		Significant Resource Warm Water (Class B(WW))				X	X	X		X	C = .004 µg/l* A = 2.5 µg/l* HH (fish consumption) = .006 µg/l *		C = .014 µg/l * A = 2 µg/l * HH (fish consumption) = .0004 µg/l *	E. coli = 126/100 ml* (geometric) Mar 15 - Nov 15, 235/100 ml* (single sample max)		no less than 5 mg/l (at any time)				Turbidity shall not be increased by more than 25 NTU by any point source discharge
Burlington Water works							X	X	X	X		X	PWS = .021 µg/l *	PWS = 3 µg/l *	PWS = .0017 µg/l*						Nitrate as N = 10 mg/l Nitrate + Nitrite as N = 10 mg/l Nitrite as N = 1 mg/l	Turbidity shall not be increased by more than 25 NTU by any point source discharge
Koekuk Municipal Water Works Intake							X	X	X	X		X	PWS = .021 µg/l *	PWS = 3 µg/l *	PWS = .0017 µg/l*						Nitrate as N = 10 mg/l Nitrate + Nitrite as N = 10 mg/l Nitrite as N = 1 mg/l	Turbidity shall not be increased by more than 25 NTU by any point source discharge
Fort Madison Municipal Water Works Intake							X	X	X	X		X	PWS = .021 µg/l *	PWS = 3 µg/l *	PWS = .0017 µg/l*						Nitrate as N = 10 mg/l Nitrate + Nitrite as N = 10 mg/l Nitrite as N = 1 mg/l	Turbidity shall not be increased by more than 25 NTU by any point source discharge
IL(effective 8/26/99)	Designated General Use Water (protects for multiple uses)																					
Mississippi River		X^	X	X	X			X		X		X	Narrative w/Translator A = 2.4 µg/l C = .0043 µg/l noncancer = .72 ng/l	A = 280 µg/l ## C = 12 µg/l ##	HH = .015 ng/L	Fecal = 200 (geometric)* nor 400* in 10% of 30 day samples		no less than 5 mg/l (at any time) or less than 6 mg/l 16 of 24 hours		.05 mg/l* in reservoir/lake 8.1 hectares (or entering stream)		
Mississippi R. at Drinking Water/Food Processing Intakes		X^	X	X	X		Public and Food Processing Water Supply	X		X		X	.003 mg/l*	A = 280 µg/l ## C = 12 µg/l ##	HH = .015 ng/L (fish consumption only)	Fecal = 2000 (geometric)*		no less than 5 mg/l (at any time) or less than 6 mg/l 16 of 24 hours		.05 mg/l* in reservoir/lake 8.1 hectares (or entering stream)	Nitrate-Nitrogen = 10 mg/l*	
MO (effective 10/31/99)																						
State Line to Ohio R.			X	WW & HH fish consumption		X	X		X	X		X	HH (fish consumption) = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	HH = .000045 µg/l*			5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	
Ohio R. to Missouri R.			X	WW & HH fish consumption		X	X		X	X		X	HH (fish consumption) = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	HH = .000045 µg/l*			5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	
Missouri R. to Des Moines R.		X	X	WW & HH fish consumption		X	X			X		X	HH (fish consumption) = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	HH = .000045 µg/l*	Fecal = 200*		5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	
KY (12/8/99)																						
Mississippi R. - Confluence w/ Ohio R. to River Mile 947.0		X	X	Warm Water Aquatic Habitat									(Proposing to adopt 2002 EPA HH recommendations) C = .0043 µg/l* A = 2.4 µg/l* HH (fish consumption) = 0.0022 µg/l*		C = .0014µg/l* A = LC1* or 1/3 LC50* or .3 acute toxicity units* HH (fish consumption) = .000079 µg/l*	Fecal = 200 (geometric, not less than 5 samples/month)* nor <400* in more 20% or more of all samples in month		Daily average = 5.0 mg/l (no less than)** Minimum = 4.0 mg/l(no less than)*	un-ionized = 0.05 mg/l*			
Mississippi R. - River mile 947.0 to 945.0	X	X	X	Warm Water Aquatic Habitat									"		"	"	"	"	"			
Mississippi R. - River mile 945.0 to KY/TN state line		X	X	Warm Water Aquatic Habitat									"		"	"	"	"	"			

Attachment B -- EPA analysis of State Water Quality Standards in the Petition Area (Mississippi River)

STATE		DESIGNATED USE											NUMERIC WATER QUALITY CRITERIA									
EPA's most recent 304(a) recommendations next to pollutant label	**Outstanding State Resource Water**	**Primary Rec**	**Secondary Rec**	**Aquatic Life**	**Aesthetics**	**Fish Consumption**	**Drinking Water/Domestic Water Supply**	**Agriculture**	**Irrigation**	**Livestock & Wildlife watering**	**Naviagation**	**Industrial**	**chlordane (CCC = .0043 µg/l, water + organism = .00080 µg/l, organism only = .00081 µg/l) MCL=.002mg/L or 2 µg/l**	**atrazine 1500 µg/l freshwater, 760 µg/l saltwater, MCL = 3 ppb or 3 µg/l**	**Total PCBs (CCC = .014 µg/l, HH = .000064 µg/l updated) MCL = .5 ppb or .5 µg/l**	**e.coli (126 / 100 ml)**	**enterococci (33 per 100 ml)**	**DO (5 mg/l 1 day minimum)**	**Ammonia (1999 update, pH/temp. dependent)**	**Phosphorus (ecoregional based)**	**Nitrogen (ecoregional based)**	**Sediments (narrative. Sedimentation criteria in development)**
AR (effective 1/23/03)																						
Mississippi River		X	X	Perrenial Delta Fishery			X		X			X	C = .0043 µg/l** A = 2.4 µg/l* HH = 5 ng/l		C = .0140 µg/l** HH = .4 ng/l	fecal = 200* (geometric) nor 400* in more than 10% of 30 day samples		5 mg/l (no less than)		TP = 100 µg/l***	10 mg/l effluent limit for dischargers near domestic water supply uses #	Turbidity = 50 NTU
TN (effective 10//11/99)																						
Mississippi R. Mile 741.0 to 820.0		X		X			X		X	X	X	X	(Adopted 2002 EPA HH recommendations, pending approval) C = .0043 µg/l A = 2.4 µg/l 2 µg/l* (PWS) water+organism = .0057 µg/l, organism only = .0059 µg/l	3 µg/l* (PWS)	C = .014 µg/l (each aroclor) 0.5 µg/l* (PWS) water+organism = .00044 µg/l total, organism only = .00045 µg/l total	Fecal = 200* , E.coli = 126 *(geometric based on 10 samples)		5 mg/l (no less than)				
Mississippi R. Mile 820.0 to TN/KY state line (Mile 905.0)		X		X			X		X	X	X	X	(Adopted 2002 EPA HH recommendations, pending approval) C = .0043 µg/l A = 2.4 µg/l 2 µg/l* (PWS) water+organism = .0057 µg/l, organism only = .0059 µg/l	3 µg/l* (PWS)	C = .014 µg/l (each aroclor) 0.5 µg/l* (PWS) water+organism = .00044 µg/l , organism only = .00045 µg/l	Fecal = 200* , E.coli = 126 *(geometric based on 10 samples)		5 mg/l (no less than)				

* Shall not exceed
** 24 hour average
*** As a guideline, shall not exceed
^Protects for Primary "for all General Use waters whose physical configuration permits
Based on Arkansas Water Quality Planning and Management: State Continuing Planning Process (1999)
Based on Narrative Procedure to derive Numeric Criteria

Attachment B -- EPA Analysis of State Water Quality Standards in the Petition Area
(Missouri River)

NOTE: ***Spreadsheet reflects applicable numeric criteria only.***
Numeric criteria reflected are most stringent criteria applicable to segment.

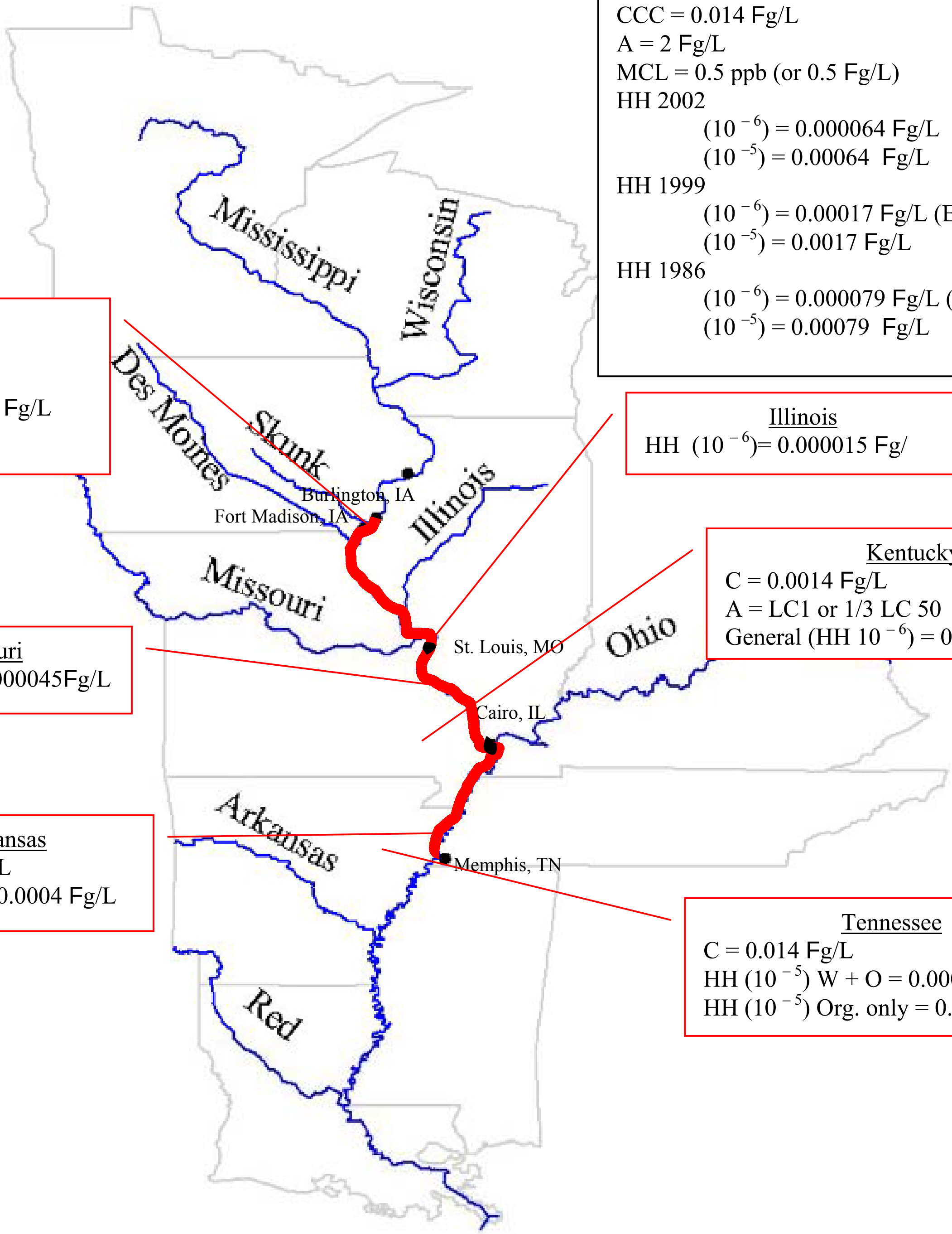
STATE	DESIGNATED USE										NUMERIC WATER QUALITY CRITERIA									
	Primary Rec	Secondary Rec	Aquatic Life	Aesthetics	Food Procurement/ Fish consumption	Public/Domestic Water Supply	Agricultural	Irrigation	Livestock & Wildlife watering	Industrial	chlordane (CCC = .0043 µg/l, water + organism = .00080 µg/l, organism only = .00081 µg/l) MCL=.002mg/L or 2 µg/l	atrazine 1500 µg/l freshwater, 760 µg/l saltwater, MCL = 3 ppb or 3 µg/l	Total PCBs (CCC = .014 µg/l, CMC = 2 µg/l, HH = .000064 µg/l updated) MCL = .5 ppb or .5 µg/l	e.coli (126 per 100 ml)	enterococci (33 per 100 ml)	DO (5 mg/l 1 day minimum)	Ammonia (1999 update, pH/temp. dependent)	Phosphorus (ecoregional based)	Nitrogen (ecoregional based)	Sediments (narrative. Sedimentation criteria in development)
IA (effective 6/16/04)																				
IA-MO state line to confluence w/ Big Sioux R.	X		Significant Resource Warm Water (Class B(WW))				X	X	X	X	C = .004 µg/l * A = 2.5 µg/l* HH = .006 µg/l*		C = .014 µg/l* A = 2 µg/l* HH = .0004 µg/l*	E. coli = 126/100 ml* (geometric) Mar 15 - Nov 15, 235/100 ml* (single sample max)		no less than 5 mg/l (at any time)				Turbidity shall not be increased by more than 25 NTU by any point source discharge
City of Council Bluffs Water Works Intake						X	X	X	X	X	PWS = .021 µg/l*	PWS = 3µg/l*	PWS = .0017µg/l*						Nitrate as N = 10 mg/l Nitrate + Nitrite as N = 10 mg/l Nitrite as N = 1 mg/l	Turbidity shall not be increased by more than 25 NTU by any point source discharge
NE (effective 8/8/03)	Water quality criteria to protect downstream beneficial uses shall be applicable to all surface waters, whether or not those beneficial uses are assigned to a given water body.																			
Platte R. to NE-KS border	X		Class A Warm Water	X		X	X			X	C = .0043 µg/l** A = 2.4 µg/l* PWS = 2 µg/l*	C = 12 µg/l (4 day average) A = 330 µg/l (1 hr average) PWS = 3 µg/l*	C = .0017 µg/l** A = 2 µg/l* PWS = .5 µg/l*	fecal = 200 (geometric mean)* or 400 (no more than 10% of samples shall equal or exceed) E.coli = 126/100ml* (5 samples, 30-day period)		1 day min no less than 5 mg/l (April 1 - Sep. 30 - early life stages) 1 day min no less than 3 mg/l (Oct. 1 - Mar. 31)			(AG) Nitrate + Nitrite = 100 mg/l* (PWS) Nitrate-nitrogen = 10 mg/L* (PWS) Nitrite-Nitrogen = 1 mg/L*	
Big Sioux R. to Platte R.	X		Class A Warm Water	X		X	X			X	C = .0043 µg/l** A = 2.4 µg/l* PWS = 2 µg/l*	C = 12 µg/l (4 day average) A = 330 µg/l (1 hr average) PWS = 3 µg/l*	C = .0017 µg/l** A = 2 µg/l* PWS = .5 µg/l*	fecal = 200 (geometric mean)* or 400 (no more than 10% of samples shall equal or exceed) E.coli = 126/100ml* (5 samples, 30-day period)		1 day min no less than 5 mg/l (April 1 - Sep. 30 - early life stages) 1 day min no less than 3 mg/l (Oct. 1 - Mar. 31)			(AG) Nitrate + Nitrite = 100 mg/l* (PWS) Nitrate-nitrogen = 10 mg/L* (PWS) Nitrite-Nitrogen = 1 mg/L*	
MO (10/31/99)																				
Mouth to Gasconade R.		X	WW & HH fish consumption			X		X	X	X	HH = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	C = .000045 µg/l*			5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	
Gasconade R. to Chariton R.		X	WW & HH fish consumption			X		X	X	X	HH = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	C = .000045 µg/l*			5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	
Chariton R. to Kansas R.		X	WW & HH fish consumption			X		X	X	X	HH = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	C = .000045 µg/l*			5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	
Kansas R. to State Line		X	WW & HH fish consumption			X		X	X	X	HH = .00048 µg/l* PWS = 2 µg/l*	PWS = 3 µg/l*	C = .000045 µg/l*			5 mg/l (no less than)			PWS Nitrate-Nitrogen = 10 mg/L	

Attachment B -- EPA Analysis of State Water Quality Standards in the Petition Area
(Missouri River)

STATE	DESIGNATED USE										NUMERIC WATER QUALITY CRITERIA									
	Primary Rec	Secondary Rec	Aquatic Life	Aesthetics	Food Procurement/ Fish consumption	Public/Domestic Water Supply	Agricultural	Irrigation	Livestock & Wildlife watering	Industrial	chlordane (CCC = .0043 µg/l, water + organism = .00080 µg/l, organism only = .00081 µg/l) MCL=.002mg/L or 2 µg/l	atrazine 1500 µg/l freshwater, 760 µg/l saltwater, MCL = 3 ppb or 3 µg/l	Total PCBs (CCC = .014 µg/l, CMC = 2 µg/l, HH = .000064 µg/l updated) MCL = .5 ppb or .5 µg/l	e.coli (126 per 100 ml)	enterococci (33 per 100 ml)	DO (5 mg/l 1 day minimum)	Ammonia (1999 update, pH/temp. dependent)	Phosphorus (ecoregional based)	Nitrogen (ecoregional based)	Sediments (narrative. Sedimentation criteria in development)
KS (effective 11/3/03)																				
Missouri R. (HUC 10240005, Seg. 1)	Class B	X	Special Aquatic Life Use (applicable criteria same for all aquatic life use designations. Only use name differs)		X	X		X	X	X	C = .0043 µg/l* A = 2.4 µg/l* HH (fish consumption) = .00048 µg/l* (3 µg/l for LWW) PWS = .00057 µg/l (EPA)	C = 3 µg/l* A = 170 µg/l* PWS = 3 µg/l*	C = .014 µg/l* A = 2 µg/l* HH (fish consumption) = .0000079 µg/l* PWS = .00017 µg/l (EPA)	E.coli (geometric mean)* = 262/100 mL		not less than 5 mg/l		Elemental P = .1 µg/l	Nitrate as N = 10 mg/l (PWS) Nitrite + Nitrate as N = 10 mg/l (PWS) or 100 mg/l (LWW)	
Missouri R. (HUC 10240005, Seg. 19)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240005, Seg. 2)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240005, Seg. 21)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 1)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 11)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 13)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 15)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 19)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 2)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 4)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 5)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 7)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 9)	"	X	Special Aquatic Life Use		X	X		X	X	X	"	"	"	"	"	"		"	"	
Missouri R. (HUC 10240011, Seg. 9099)	"	X	Expected Aquatic Life Use		X	X	X	X	X	X	"	"	"	"	"	"		"	"	

* Shall not exceed
** 24 hour average

ATTACHMENT C
PCB CRITERIA ON MISSISSIPPI RIVER



EPA's Recommendations
CCC = 0.014 Fg/L
A = 2 Fg/L
MCL = 0.5 ppb (or 0.5 Fg/L)
HH 2002
(10^{-6}) = 0.000064 Fg/L (EPA's #)
(10^{-5}) = 0.00064 Fg/L
HH 1999
(10^{-6}) = 0.00017 Fg/L (EPA's #)
(10^{-5}) = 0.0017 Fg/L
HH 1986
(10^{-6}) = 0.000079 Fg/L (EPA's #)
(10^{-5}) = 0.00079 Fg/L

Iowa
C = 0.014 Fg/L
A = 2 Fg/L
HH (10^{-5}) = 0.0004 Fg/L
PWS = 0.0017 Fg/L

Illinois
HH (10^{-6})= 0.000015 Fg/

Kentucky
C = 0.0014 Fg/L
A = LC1 or 1/3 LC 50
General (HH 10^{-6}) = 0.000079 Fg/L

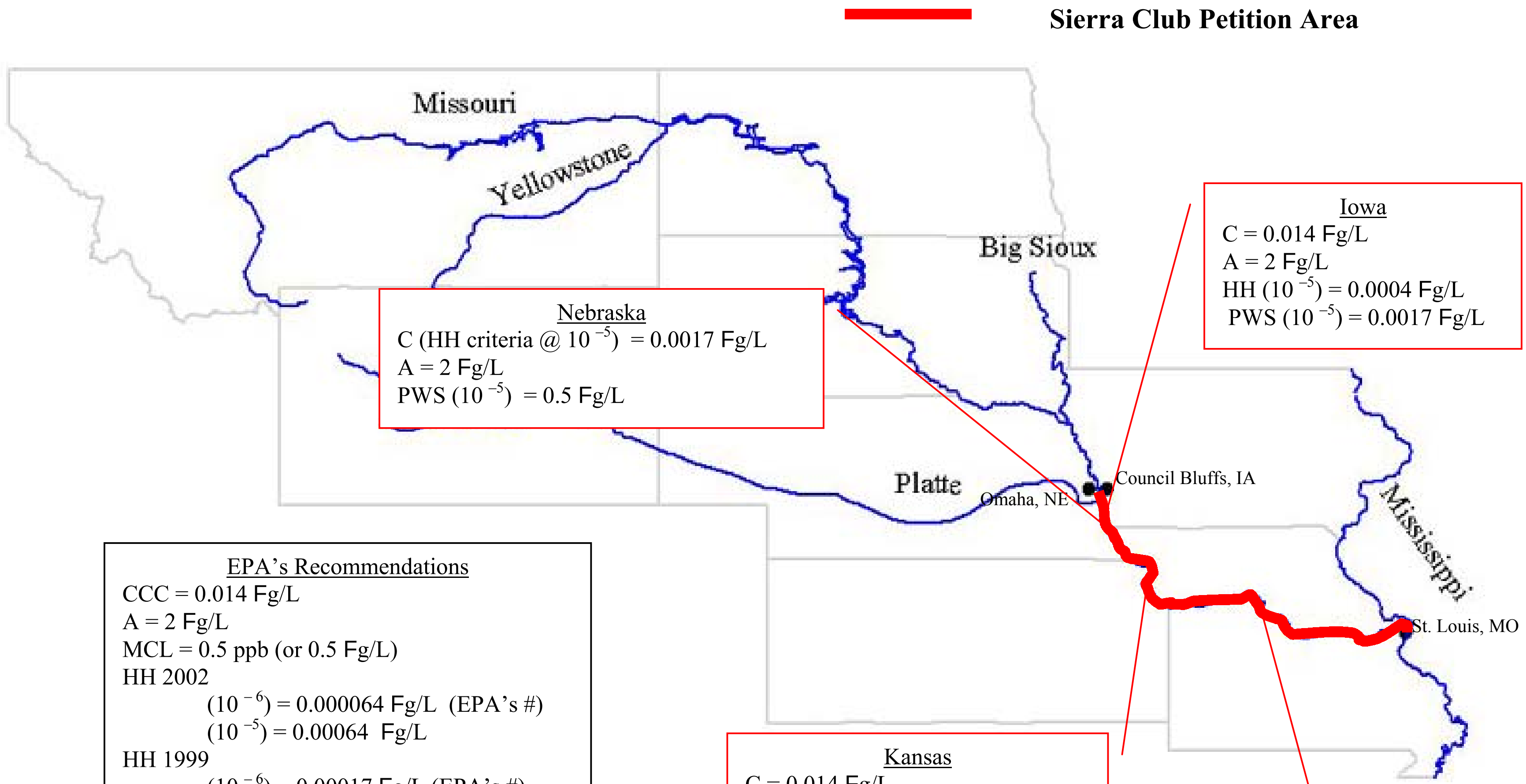
Missouri
HH (10^{-6})= 0.000045Fg/L

Arkansas
C = 0.014 Fg/L
HH (10^{-5}) = 0.0004 Fg/L

Tennessee
C = 0.014 Fg/L
HH (10^{-5}) W + O = 0.00044 Fg/L
HH (10^{-5}) Org. only = 0.00045 Fg/L

▬ **Sierra Club Petition Area**

ATTACHMENT D
PCB CRITERIA ON MISSOURI RIVER



<u>Nebraska</u>
C (HH criteria @ 10^{-5}) = 0.0017 Fg/L
A = 2 Fg/L
PWS (10^{-5}) = 0.5 Fg/L

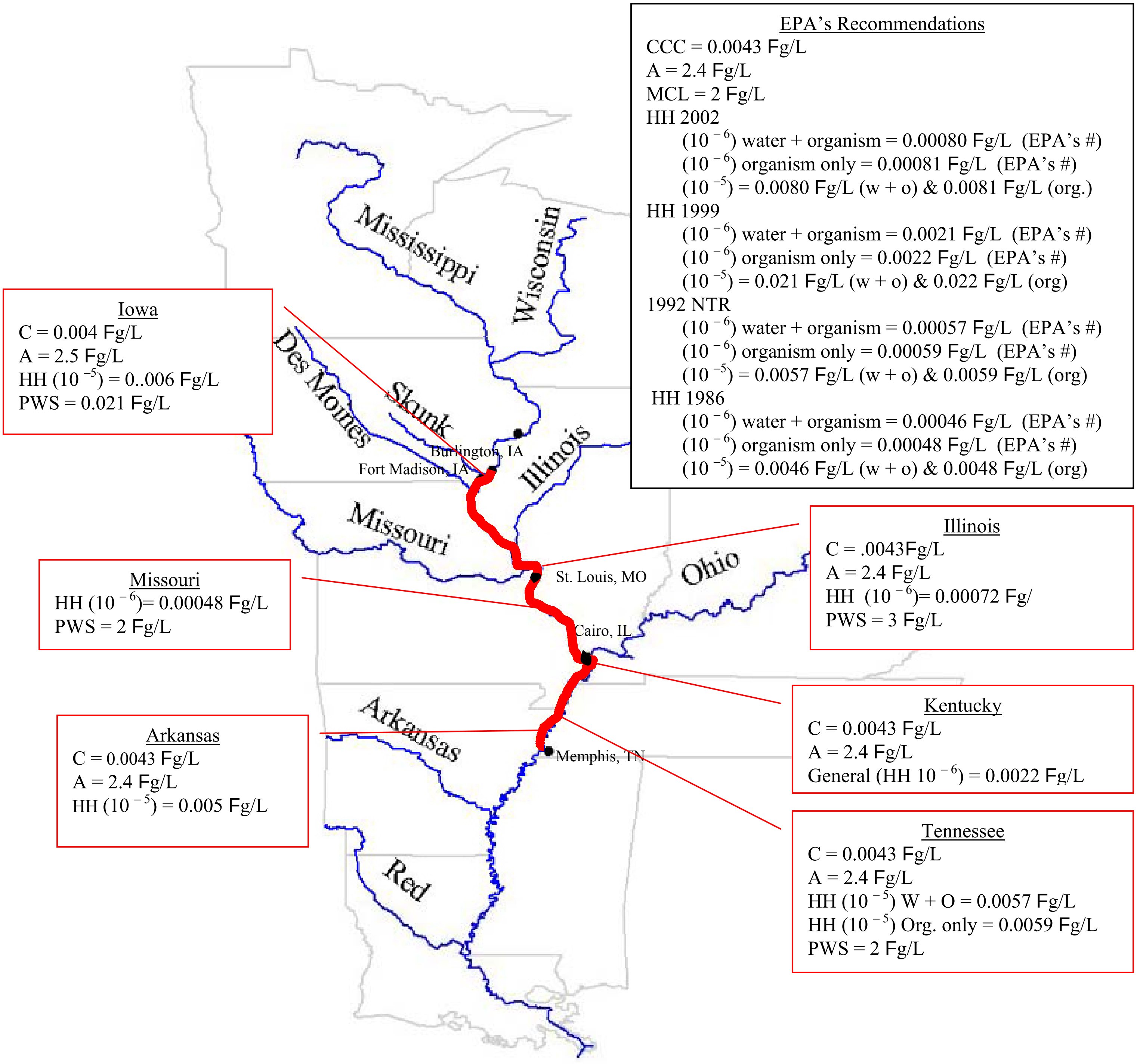
<u>Iowa</u>
C = 0.014 Fg/L
A = 2 Fg/L
HH (10^{-5}) = 0.0004 Fg/L
PWS (10^{-5}) = 0.0017 Fg/L

<u>EPA's Recommendations</u>
CCC = 0.014 Fg/L
A = 2 Fg/L
MCL = 0.5 ppb (or 0.5 Fg/L)
HH 2002
(10^{-6}) = 0.000064 Fg/L (EPA's #)
(10^{-5}) = 0.00064 Fg/L
HH 1999
(10^{-6}) = 0.00017 Fg/L (EPA's #)
(10^{-5}) = 0.0017 Fg/L
HH 1986
(10^{-6}) = 0.000079 Fg/L (EPA's #)
(10^{-5}) = 0.00079 Fg/L

<u>Kansas</u>
C = 0.014 Fg/L
A = 2 Fg/L
HH fish (10^{-6}) = 0.0000079 Fg/L
PWS (10^{-6}) = 0.00017 Fg/L
(EPA promulgation)

<u>Missouri</u>
HH = 0.000045 Fg/L

ATTACHMENT E
CHLORDANE CRITERIA ON MISSISSIPPI RIVER



EPA's Recommendations
CCC = 0.0043 Fg/L
A = 2.4 Fg/L
MCL = 2 Fg/L
HH 2002
(10^{-6}) water + organism = 0.00080 Fg/L (EPA's #)
(10^{-6}) organism only = 0.00081 Fg/L (EPA's #)
(10^{-5}) = 0.0080 Fg/L (w + o) & 0.0081 Fg/L (org.)
HH 1999
(10^{-6}) water + organism = 0.0021 Fg/L (EPA's #)
(10^{-6}) organism only = 0.0022 Fg/L (EPA's #)
(10^{-5}) = 0.021 Fg/L (w + o) & 0.022 Fg/L (org)
1992 NTR
(10^{-6}) water + organism = 0.00057 Fg/L (EPA's #)
(10^{-6}) organism only = 0.00059 Fg/L (EPA's #)
(10^{-5}) = 0.0057 Fg/L (w + o) & 0.0059 Fg/L (org)
HH 1986
(10^{-6}) water + organism = 0.00046 Fg/L (EPA's #)
(10^{-6}) organism only = 0.00048 Fg/L (EPA's #)
(10^{-5}) = 0.0046 Fg/L (w + o) & 0.0048 Fg/L (org)

Iowa
C = 0.004 Fg/L
A = 2.5 Fg/L
HH (10^{-5}) = 0..006 Fg/L
PWS = 0.021 Fg/L

Illinois
C = .0043Fg/L
A = 2.4 Fg/L
HH (10^{-6})= 0.00072 Fg/
PWS = 3 Fg/L

Missouri
HH (10^{-6})= 0.00048 Fg/L
PWS = 2 Fg/L

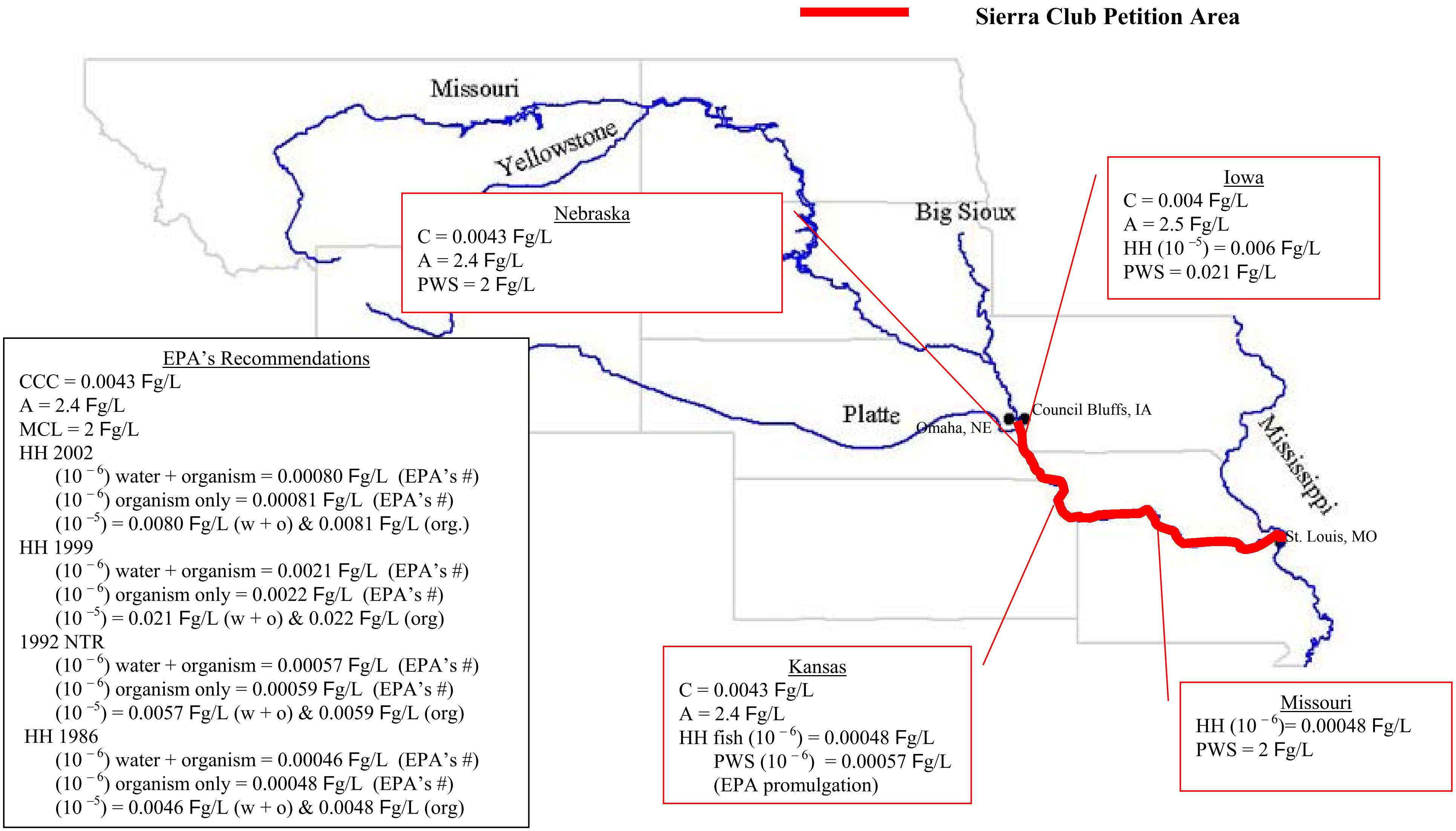
Kentucky
C = 0.0043 Fg/L
A = 2.4 Fg/L
General (HH 10^{-6}) = 0.0022 Fg/L

Arkansas
C = 0.0043 Fg/L
A = 2.4 Fg/L
HH (10^{-5}) = 0.005 Fg/L

Tennessee
C = 0.0043 Fg/L
A = 2.4 Fg/L
HH (10^{-5}) W + O = 0.0057 Fg/L
HH (10^{-5}) Org. only = 0.0059 Fg/L
PWS = 2 Fg/L

🟥 **Sierra Club Petition Area**

ATTACHMENT F
CHLORDANE CRITERIA ON MISSOURI RIVER



Nebraska
C = 0.0043 Fg/L
A = 2.4 Fg/L
PWS = 2 Fg/L

Iowa
C = 0.004 Fg/L
A = 2.5 Fg/L
HH (10^{-5}) = 0.006 Fg/L
PWS = 0.021 Fg/L

EPA's Recommendations
CCC = 0.0043 Fg/L
A = 2.4 Fg/L
MCL = 2 Fg/L
HH 2002
(10^{-6}) water + organism = 0.00080 Fg/L (EPA's #)
(10^{-6}) organism only = 0.00081 Fg/L (EPA's #)
(10^{-5}) = 0.0080 Fg/L (w + o) & 0.0081 Fg/L (org.)
HH 1999
(10^{-6}) water + organism = 0.0021 Fg/L (EPA's #)
(10^{-6}) organism only = 0.0022 Fg/L (EPA's #)
(10^{-5}) = 0.021 Fg/L (w + o) & 0.022 Fg/L (org)
1992 NTR
(10^{-6}) water + organism = 0.00057 Fg/L (EPA's #)
(10^{-6}) organism only = 0.00059 Fg/L (EPA's #)
(10^{-5}) = 0.0057 Fg/L (w + o) & 0.0059 Fg/L (org)
HH 1986
(10^{-6}) water + organism = 0.00046 Fg/L (EPA's #)
(10^{-6}) organism only = 0.00048 Fg/L (EPA's #)
(10^{-5}) = 0.0046 Fg/L (w + o) & 0.0048 Fg/L (org)

Kansas
C = 0.0043 Fg/L
A = 2.4 Fg/L
HH fish (10^{-6}) = 0.00048 Fg/L
PWS (10^{-6}) = 0.00057 Fg/L
(EPA promulgation)

Missouri
HH (10^{-6})= 0.00048 Fg/L
PWS = 2 Fg/L

ATTACHMENT G
PETITION STATES' CWA SECTION 303(D) IMPAIRED WATERS LISTINGS FOR MISSISSIPPI AND MISSOURI RIVER

(As Of March 2004)

Mississippi River

	Segment	Location	Impairment	Use impaired
Iowa				
	IA-1-NEM-0010_2	L&D 15 to L&D 14	arsenic	Drinking water
	IA01-NEM-0010_4	Wapsipinicon R. to L&D 13	organic enrichment	Aquatic life
	IA-03-SKM-0010_1	MO state line to outfall of Ft. Madison WWTP	arsenic	Drinking water
Illinois				
	ILI01_I 05	Mississippi River South	PCBs	Overall use, drinking water supply, fish consumption, aquatic life, primary contact (swimming)
	ILJ81_J 01		PCBs	Overall use, drinking water supply, fish consumption, aquatic life
	ILJ83_J 05		PCBs, Siltation, Suspended Solids, Metals, Nutrients, Phosphorus, Total Ammonia-N, Nitrates	Overall use, fish consumption, aquatic life, primary contact (swimming)
	ILJ83_J 06		PCB siltation, flow alterations, habitat, nutrients	Overall use, fish consumption, aquatic life

	Segment	Location	Impairment	Use impaired
	ILJ03_J 11		Nonpriority Organics, Siltation, Habitat Alteration, Suspended Solids, Priority Organics	Overall use, drinking water supply, fish consumption, aquatic life
	ILK04_K 22		PCBs, Pathogens, Organic Enrichment, Priority Organics	Overall u7se, drinking water supply, fish consumption, aquatic life, primary contact (swimming)
	ILK03_K 17		PCBs, Organic Enrichment, Priority Organics	Overall use, drinking water supply, fish consumption, aquatic life
	ILK06_K 21		PCBs, Organic Enrichment, Priority Organics	Overall use, fish consumption, aquatic life
	ILM02_M 06		PCBs	Overall use, fish consumption, aquatic life
	ILM03_M 03		PCBs	Overall use, fish consumption, aquatic life
	ILM04_M 04		PCBs	Overall use, fish consumption, aquatic life, primary contact (swimming)
	ILM05_M 05		PCBs	Overall use, drinking water supply, fish consumption, aquatic life

	Segment	Location	Impairment	Use impaired
	ILM10_M 10		PCBs	Overall use, fish consumption, aquatic life, primary contact (swimming)
	ILI84_I 84		PCBs	Overall use, fish consumption, aquatic life, primary contact (swimming)
Missouri				
	WBID 1707	Ohio R to Missouri R. @ Herculaneum (5 mi)	lead, zinc	Aquatic life
	WBID 3152	Ohio R. to state line	chlordane, PCBs	Aquatic life (fish consumption)
	WBID 1707	Missouri R. to Ohio R.	chlordane, PCBs	Aquatic life (fish consumption)
	WBID 1	Des Moines R. to Missouri R.	chlordane, PCBs	Aquatic life (fish consumption)
Kentucky	No 303(d) listings			
Tennessee				
	TN08010100001 - 0200	BLUE BANK BAYOU	Nutrients. siltation	Fish and aquatic life use
	TN08010100001 –1000	MISSISSIPPI RIVER	PCBs, dioxin, chlordane, nitrate, siltation, other habitat alterations	Fishing advisory originally due to chlordane

	Segment	Location	Impairment	Use impaired
	TN08010100001 - 1100	MCKELLAR LAKE	PCBs, chlordane, dioxin, siltation, organic enrichment/low DO, pathogens	Fishing advisory originally due to chlordane.
	TN08010100001 - 2000	MISSISSIPPI RIVER	PCBs, dioxin, chlordane, nitrate, siltation, other habitat alterations	Fish and aquatic life use.
	TN08010100001 - 3000	MISSISSIPPI RIVER	PCBs, dioxin, chlordane, nitrate, siltation, other habitat alterations	Fish and aquatic life use
	TN08010100001 - 4000	MISSISSIPPI RIVER	PCBs, dioxin, chlordane, nitrate, siltation, other habitat alterations	Documented habitat for a federally listed fish: the pallid sturgeon (Scaphirhynchus albus).
	TN08010100001 - 5000	MISSISSIPPI RIVER	PCBs, dioxin, chlordane, nitrate, siltation, other habitat alterations	Fish and aquatic life use.
	TN08010100POPLARTLK	POPLAR TREE LAKE	Nutrients	No recent data on this 125 acre lake.
Arkansas	No 303(d) listings			

Missouri River

	Segment	Location	Impairment	Use impaired
Iowa				
	IA06-WEM-0020_2	Council Bluffs water supply intake to Boyer R.	arsenic	Drinking water
	IA06-WEM-0020_2	Council Bluffs water supply intake to Boyer R.	bacteria	Primary contact recreation
Nebraska				
	MT1-10000	Big Sioux R. to Platte R.	fecal coliform	Primary contact recreation
	NE1-10000	Platte R. to Kansas border	fecal coliform	Primary contact recreation
Kansas	No 303(d) listings			
Missouri				
	WBID 1604	Gasconade R. to mouth	chlordane, PCBs	Aquatic life (fish consumption)
	WBID 701	Chariton R. to Gasconade R.	chlordane, PCBs	Aquatic life (fish consumption)
	WBID 356	Kansas R. to Chariton R.	chlordane, PCBs	Aquatic life (fish consumption)
	WBID 226	Iowa sate line to Kansas R.	chlordane, PCBs	Aquatic life (fish consumption)
	WBID 356	Kansas R. to Chariton R.	mercury	Aquatic life (fish consumption)
	WBID 226	Kansas R. to Iowa State line	mercury	Aquatic life (fish consumption)

Spokane River
PCB Source Assessment
2003-2007

April 2011

Publication No. 11-03-013

DEPARTMENT OF
ECOLOGY
State of Washington

06808

Publication and Contact Information

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www.ecy.wa.gov/biblio/1103013.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, DSER0010.

The Activity Tracker Code for this study is 09-234.

For more information contact:

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Cover photo: Spokane Falls (photo by Pat Hallinan)

Spokane River
PCB Source Assessment
2003-2007

by

Dave Serdar, Brandi Lubliner, Art Johnson, and Dale Norton

Toxics Studies Unit
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Waterbody Numbers:

WA-57-1010: Middle Spokane River
WA-54-1010, WA-54-1020: Lower Spokane River
WA-54-9040: Lake Spokane (formerly Long Lake-Spokane River)
WA-55-1010: Little Spokane River

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Abstract

The Spokane River does not meet Washington State human health criteria for polychlorinated biphenyls (PCBs) in edible fish tissue. During 2003 to 2007, the Department of Ecology conducted a series of water quality studies in an effort to assess sources of these legacy pollutants to the river. PCBs were analyzed in river water, industrial and municipal wastewater effluents, stormwater, suspended particulate matter, bottom sediments, sediment cores, and fish tissue. The study area covered the Spokane River from the Idaho border (river mile 96.1) to the mouth at the Columbia River. The lower part of the river flows through the Spokane Tribe of Indians reservation.

Total PCB concentrations in water increased with successive reaches moving downstream from the Idaho border (106 pg/l, parts per quadrillion) to lower Lake Spokane (formerly Long Lake; 399 pg/l), with a corresponding eight-fold increase in loads (477 – 3,664 mg/day), on average. The Washington State PCB human health criterion for surface water is 170 pg/l. Although PCB concentrations in Spokane River fish are generally much lower than historical levels, fish in most areas did not meet the state's human health criterion in edible tissue (5.3 ng/g, parts per billion).

Overall, PCB loading to Washington reaches of the river can be divided into the following source categories; City of Spokane stormwater (44%), municipal and industrial discharges (20%), and Little Spokane River (6%). In addition, PCB loading from Idaho at the state line represented 30% of the overall loading.

A PCB loading scenario was proposed to meet the Spokane Tribe human health water quality criterion for total PCBs (3.37 pg/l, equivalent to 0.1 ng/g in tissue). The scenario requires a 95% PCB load reduction at the Idaho border, a 97% load reduction in the Little Spokane River, and ≥99% reductions in municipal, industrial, and stormwater discharges. A food web bioaccumulation model indicated that PCB loads in water and PCB concentrations in sediment would require large reductions to meet the Spokane Tribe criterion.

Acknowledgements

The authors of this report thank the following people for their contribution to this study:

- Pat Blau (Kaiser Trentwood), Rick Fink (Inland Empire), Dan Grogg (Liberty Lake Wastewater Treatment Plant), and Tim Pelton (Spokane Wastewater Treatment Plant) permitted sampling of their facilities.
- Gary Bussiere and Michael Coster (City of Spokane) arranged and conducted stormwater sampling.
- Bob Hughes (Plante Ferry Park), Dennis Dalton, Jack Hartt, and Mark Nickelson (Riverside State Park), Brett Walker (Washington Department of Natural Resources Long Lake Campground), Mark Bloss and Larry Ford (Avista Long Lake and Little Falls Dam), and Mark Cleveland (Upriver Dam) provided access to the Spokane River.
- John Sneva and Lucinda Morrow (Washington Department of Fish and Wildlife) aged fish specimens.
- Jim Huckins and David Alvarez (U.S. Geological Survey) provided advice on interpreting semipermeable membrane devices data.
- Larry Gadbois (Environmental Protection Agency) reviewed the report.
- Staff from the Washington State Department of Ecology (* formerly with Ecology):
    - John Roland of Ecology's Eastern Regional Office (ERO) provided valuable advice from project inception through completion.
    - John Roland, David Moore, Patrick Hallinan, Arianne Fernandez, and Brendan Dowling reviewed the project report for ERO.
    - Nigel Blakley*, Brandee Era-Miller, Richard Jack*, Aspen Madrone, Dale Norton, Jim Ross, Lawrence Sullivan*, and Sandra Treccani assisted with sampling.
    - Steve Golding* conducted sampling at NPDES permitted facilities.
    - Chad Wiseman* identified benthic organisms in fish stomachs.
    - Nigel Blakley* assisted with food web modeling.
    - Casey Deligeannis and Keith Seiders helped prepare tissue samples.
    - Pam Covey* and Will White* tracked and transported samples for laboratory analysis.
    - Karin Feddersen managed outside laboratory contracts.
    - Heidi Chuhran, Kamilee Ginder, Meredith Jones, Randy Knox, Myrna Mandjikov, Jamie Martin, Bridget Mason, Dean Momohara, and Aileen Richmond analyzed samples at Manchester Environmental Laboratory.
    - David Sternberg reviewed the project report for the Toxics Cleanup Program.
    - Dale Norton supervised this project.
    - Joan LeTourneau, Cindy Cook, and Gayla Lord edited and formatted the final report.

Executive Summary

Section 303(d) of the federal Clean Water Act requires states to prepare a list every two years of waterbodies that do not meet water quality standards. In Washington, the 303(d) list is compiled by the Washington State Department of Ecology (Ecology). The Clean Water Act requires that waterbodies on the 303(d) list be cleaned up by pollution-control programs or that a Total Maximum Daily Load (TMDL) be developed for the pollutants of concern. A TMDL determines the amount of pollutant that can be discharged to a waterbody and still meet standards (loading capacity) and allocates that load among the various sources."

Fifteen waterbody segments of the Spokane River and Lake Spokane (also known as Long Lake), and one segment of the Little Spokane River are on the 2008 303(d) list for not meeting (exceeding) Washington State's human health water quality criterion for polychlorinated biphenyls (PCBs) in edible fish tissue (Table ES-1). PCBs are legacy pollutants no longer produced or no longer put into new use in the United States. PCBs had numerous industrial applications as insulating fluids, plasticizers, in inks, and carbonless paper, and as heat transfer and hydraulic fluids. Environmental Protection Agency (EPA) has classified these compounds as probable human carcinogens.

Table ES-1. 303(d) Listings for Total PCBs in the Spokane River.

Waterbody	Reach	Waterbody Number	Watercourse Number	Listing ID
Spokane River	Idaho Border to Latah Creek	WA-57-1010	QZ45UE	14397 14398 8201 8207 8202 14402
Spokane River	Latah Creek to Ninemile Dam	WA-54-1010	QZ45UE	14400 14385 9033
Little Spokane River	Near mouth	WA-55-1010	JZ70CP	9051
Lake Spokane (Long Lake)	Ninemile Dam to Lake Spokane Dam	WA-54-9040	QZ45UE	9021 36441 9015 36440
Spokane River	Lake Spokane Dam to Mouth	WA-54-1020	QZ45UE	9027

Ecology conducted the water quality studies described in this report from 2003 to 2007 to assess PCB sources to the Spokane River. The goal of these efforts was to quantify PCB contamination and identify necessary reductions in sources and the receiving waters to meet applicable PCB water quality criteria in the Spokane River. The studies analyzed PCBs in river water, industrial and municipal effluents, stormwater, suspended particulate matter, bottom sediments, sediment cores, and fish tissue.

The Spokane River, shown in Figure ES-1, begins in northern Idaho at the outlet of Lake Coeur d'Alene and flows west 112 miles to the Columbia River (Lake Roosevelt). The study area covered the Spokane River from the Idaho border (river mile 96.1) to the Columbia. The watershed encompasses over 6,000 square miles (15,500 km^2) in Washington and Idaho. The river flows through the smaller cities of Post Falls and Coeur d'Alene in Idaho and large urban areas of the Spokane Valley and Spokane in Washington. Other cities in the watershed include Liberty Lake, Deer Park, and Medical Lake Washington as well as Wallace and Kellogg Idaho upstream from Lake Coeur d'Alene. The Spokane Tribe of Indians reservation lies along the north bank of the lower river (Spokane Arm of Lake Roosevelt).

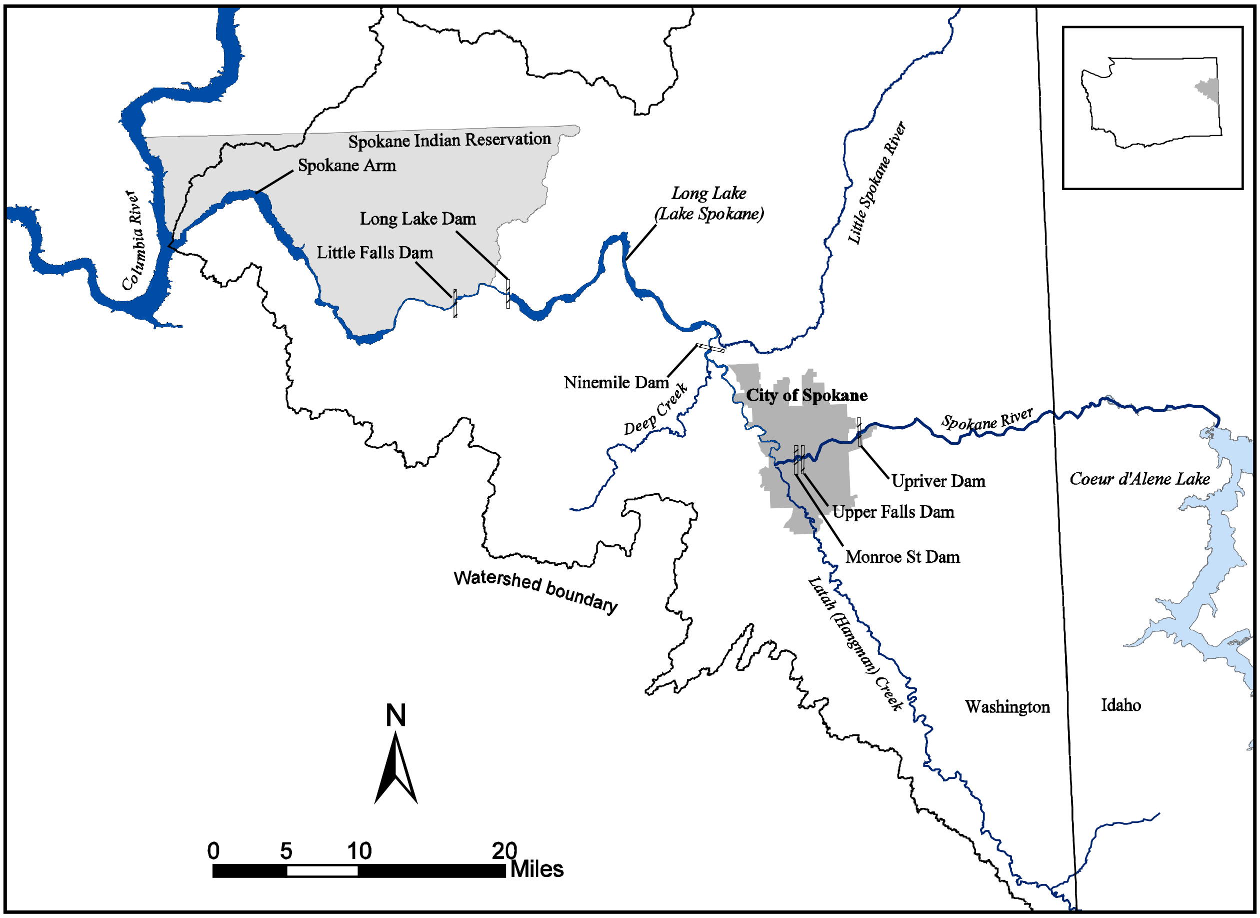

Figure ES-1: Spokane River Basin.

The Spokane Tribe human health PCB water quality criterion of 3.37 pg/l (parts per quadrillion) was used as the basis for calculating necessary PCB load reductions. The criterion is equivalent to 0.1 ng/g (parts per billion) in edible fish tissue. Although this criterion only applies to the Spokane Arm and lower half of the Little Falls reservoir, it cannot reasonably be met within these bounds unless PCB concentrations in upstream reaches are reduced to levels near the criterion. Washington State's human health criteria for PCBs is 170 pg/l (5.3 ng/g in fish tissue), the difference primarily being due to assumptions about human consumption rates of fish.

A PCB loading scenario is proposed to meet the Spokane Tribe human health criterion. The scenario requires a 95% PCB load reduction at the Idaho border, a 97% load reduction in the Little Spokane River, and ≥99% reductions in municipal, industrial, and stormwater discharges. Based on the loads estimated in this report, the largest current contributor of PCBs to the river (44%) is the City of Spokane's partially combined sewer-stormwater system. This is the most important source to reduce.

A food web bioaccumulation model used to predict PCB concentrations in fish tissue from the levels in water and sediments indicates that reductions of ≥99% would be required to meet the Spokane Tribe's fish tissue criterion where the Spokane River enters the reservation. Even with large reductions in PCBs, it seems unlikely that the Spokane tribal target (0.1 ng/g) in fish tissue is achievable. This concentration is approximately an order of magnitude lower than the median level (1.4 ng/g) reported in fish tissue from background areas of Washington in a 2010 statewide study conducted by Ecology (Johnson et al., 2010). Despite the extremely low tribal criteria, it is clear that further reductions in PCB loading are achievable. Implementing an adaptive management narrative limit in National Pollutant Discharge Elimination System (NPDES) permits might be a productive approach to establish a set of achievable targets for toxic chemical reductions.

Recommendations

Even though significant reductions in PCB levels have been measured in the Spokane River over the last two decades, achieving further reductions in PCBs will be a challenging long-term process which will require a strategy that uses a combination of activities to achieve water quality targets. To start meeting this challenge, Ecology has drafted a long-term strategy for reducing PCBs and other toxic chemicals in the Spokane River watershed.

The Spokane River Toxics Reduction Strategy requires coordination across several Ecology programs, including the Spokane River Urban Waters Program (UWP) which was formed in 2007. The primary purpose of this program is to identify and eliminate toxic chemicals at their source. The UWP also works cooperatively with local governments including the City of Spokane and the Spokane Regional Health District.

Under the reduction strategy, source identification and control will largely be carried out by the UWP. The strategy uses a three-pronged approach (prevention, management, and cleanup) to reduce sources. Priority is placed on using a systematic step-wise process for identifying potential PCB sources within a conveyance system, then reducing and/or eliminating sources as they are located.

The conceptual approach to reduce PCBs discharged to the Spokane River should continue to focus on:

1. Identifying PCB sources and reducing or eliminating them from stormwater and wastewater effluents.
2. Examining treatment alternatives for effluent PCB removal.
3. Implementing necessary treatment plant controls.
4. Characterizing PCB transport through groundwater.

Implementation of an adaptive management approach using narrative limits in NPDES permits should be explored as an option to establish a set of achievable targets for toxic chemical reductions. In addition, source reduction efforts should be coupled with an ongoing effectiveness monitoring program to evaluate progress in reaching water quality targets.

The 303(d) List

The federal Clean Water Act established a process to identify and clean up polluted waters. The Clean Water Act requires each state to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards include (1) designated uses for aquatic life, recreation, water supply, and harvesting (fish consumption) and (2) criteria, usually numeric criteria, to protect those uses.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list and is prepared by the Washington State Department of Ecology (Ecology). To develop the list, Ecology compiles its own ambient water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before being used to develop the 303(d) list. The 303(d) list is part of the larger Water Quality Assessment (www.ecy.wa.gov/programs/wq/303d/index.html).

The last comprehensive freshwater and marine water 303(d) list for Washington was prepared in 2008. Listing updates are now staggered, with the marine list completed in 2010 and the freshwater list scheduled to be completed in 2012. The next opportunity to evaluate compliance with water quality standards in the Spokane River will be in 2012.

The Clean Water Act requires that waterbodies on the 303(d) list be cleaned up by pollution-control programs or that a TMDL be developed. A pollution-control program needs to address the sources of pollution and have a monitoring and enforcement component. A TMDL identifies pollution problems in the watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. When developing a pollution-control program or a TMDL, Ecology works with the local communities and other relevant stakeholders to identify all actions that need to occur to address the sources of pollution. A monitoring plan to assess the effectiveness of those implementation actions is also developed. That monitoring plan is used to determine success or the next steps needed.

Spokane River PCB Listings

The Spokane River begins in northern Idaho at the outlet of Lake Coeur d'Alene and flows west 112 miles to the Columbia River. Within Washington this includes Water Resource Inventory Areas (WRIAs) 54, 55, 56, and 57 (Figure 1). The designated uses for this area include aquatic life uses, recreation, fish consumption, and Spokane Tribe of Indians ceremonial, spiritual, and cultural uses (see *Water Quality Standards and Designated Uses* section).

Elevated levels of polychlorinated biphenyls (PCBs) are found in Spokane River water, sediments, fish tissue, and effluents being discharged to the river. Ecology first documented PCB contamination in Spokane River fish in the early 1980s (Hopkins et al., 1985), and numerous investigations have evaluated the extent of the contamination (e.g., Ecology, 1995; Johnson, 1997; Johnson, 2001; Anchor, 2004). One location behind Upriver Dam required clean-up of PCBs in bottom sediments under the Model Toxics Control Act (MTCA, WAC 173-340). Cleanup was completed in January 2007, and long-term monitoring for PCBs at this site began in the fall of 2008.

Most of the Spokane River fish analyzed for PCBs fail to meet (exceeded) state surface water quality standards established to protect beneficial uses of surface waters, such as fish consumption. Fish consumption advisories have been issued for parts of the river (Spokane Regional Health District and Washington State Department of Health, 2003).

Fifteen waterbody segments of the Spokane River and Lake Spokane (also known as Long Lake, herein referred to as Lake Spokane) and one segment of the Little Spokane River are on the 2008 303(d) list for exceeding human health water quality criteria for PCBs (Table 1; www.ecy.wa.gov/programs/wq/303d/index.html).

Table 1. 303(d) Listings for Total PCBs in Spokane River Fish Tissue for 2008.

Waterbody	Reach	WB number	Watercourse Number	Listing ID
Spokane River	Idaho Border to Latah Creek	WA-57-1010	QZ45UE	Spokane River
	Latah Creek to Ninemile Dam	WA-54-1010		
Little Spokane River	Near mouth	WA-55-1010	JZ70CP	Little Spokane River
Lake Spokane (Long Lake)	Ninemile Dam to Lake Spokane Dam	WA-54-9040	QZ45UE	Lake Spokane (Long Lake)
Spokane River	Lake Spokane Dam to Mouth	WA-54-1020	QZ45UE	Spokane River

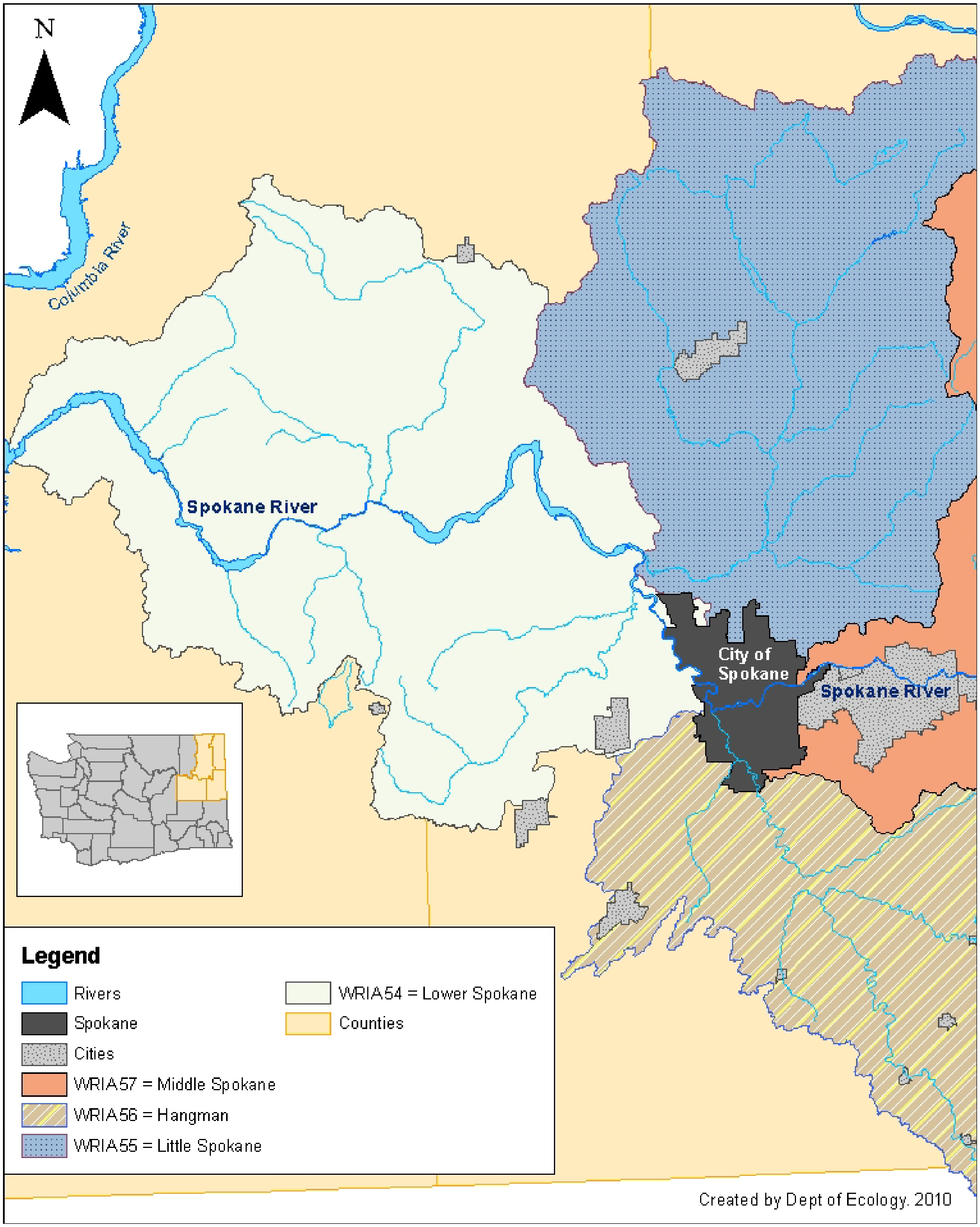

Figure 1. Location Map of Spokane River Showing Water Resource Inventory Areas.

The Spokane River and Lake Spokane have other water quality criteria exceedances that are not addressed in this source assessment. Table 2 shows the 303(d) listings for parameters other than PCBs that occur in the study area.

Table 2. Additional 303(d) Listings Not Addressed in this Report.

Waterbody	Parameter	Medium	Listing ID	Township	Range	Section
Spokane River	Temperature	Water	3737	25N	46E	06
	Total dissolved gas		15183	27N	39E	20
			15184	27N	39E	14
	Fecal coliform		16853	25N	42E	04
Lake Spokane (Long Lake)	Dioxin	Fish Tissue	42410	27N	41E	22
Spokane River			42411	26N	42E	20
			51586	26N	42E	28
			51587	25N	44E	03
Lake Spokane (Long Lake)	Dissolved oxygen	Water	40939	27N	40E	15
Spokane River			15188	26N	42E	17
			17523	25N	43E	02
			15187	25N	43E	18
			11400	25N	46E	06

The listings for dioxin in Spokane River and Lake Spokane fish are based on rainbow trout and mountain white fish collected by Ecology between 2001 and 2005 (Seiders et al., 2004, 2006, 2007). The listings are either for marginal exceedances of the human health criterion for 2,3,7,8-TCDD (dioxin) or for exceedances due to other polychlorinated dioxins and furans (PCDDs/PCDFs). These listings were not addressed in the present series of studies.

Ecology plans to address dioxin listings on a larger scale (possibly region- or state-wide) in the future. Because dioxins are often carried via air and can pollute sizeable areas not necessarily limited to watersheds, a larger TMDL footprint will likely be more effective and efficient at determining sources and subsequent evaluation of possible controls.

A TMDL for lead, cadmium, and zinc was completed for the Spokane River in 1999 (Pelletier and Merrill, 1998; Butkus and Merrill, 1999).

Water Quality Standards and Designated Uses

Applicable water quality criteria for PCBs to protect human health were promulgated by the U.S. Environmental Protection Agency (EPA) in the National Toxics Rule (NTR). The Washington State Water Quality Standards for Surface Waters (WAC 173-201A-240) contain aquatic life criteria for PCBs, and the Spokane Tribe of Indians' Surface Water Quality Standards (Resolution 2003-259) contain both human health and aquatic life-based PCB criteria. These regulations and other guidance are discussed separately below. The applicable numeric criteria are shown in Table 3.

Table 3. Water and Fish Tissue Criteria or Thresholds for Total PCBs [a] (pg/l: picograms per liter; parts per quadrillion; ng/g: nanograms per gram; parts per billion).

Regulation or Guidance	Aquatic Life - Water		Human Health [bc]		Fish Tissue Consumption Rate (kg/day)
	(chronic) (pg/l)	(acute) (pg/l)	Water (pg/l)	Tissue (ng/g)	
National Toxics Rule (40 CFR 131)	--	--	170	5.3	0.0065
Washington Water Quality Standards (Ch. 173-201A WAC)	1.4 x $10^{4(d)}$	2 x $10^{6(d)}$	--	--	--
Spokane Tribe Water Quality Standards (Resolution 2003-259)	1.4 x $10^{4(e)}$	2 x $10^{6(f)}$	3.37	0.1	0.0863
EPA National Recommended Water Quality Criteria (EPA, 2002)	--	--	64	2.0	0.0175
EPA Screening Value for Recreational Fishers (EPA, 2000a)	--	--	--	2.0	0.0175
EPA Screening Value for Subsistence Fishers (EPA, 2000a)	--	--	--	0.245	0.142

[a] total PCBs (sum of detected Aroclors, homologue groups, or congeners).

[b] based on a one-in-a-million (10^{-6}) excess lifetime cancer risk.

[c] for consumption of organisms and water.

[d] 24-hr average not to be exceeded.

[e] A one-hour average not to be exceeded more than once every three years on average.

[f] A four-day average not to be exceeded more than once every three years on average.

Regulations

National Toxics Rule

Criteria for the protection of human health were issued to the state in the NTR (40 CFR 130.36). Promulgated by EPA in 1992, and subsequently amended for PCBs in 1999, the NTR establishes numeric, chemical-specific water quality criteria for most priority pollutants. In fresh waters, human health criteria take into account the combined exposure of both drinking the water and eating fish and shellfish that live in the water. Criteria are calculated such that the upper-bound excess cancer risk is less than or equal to one in one million (10^{-6} risk level). Criteria for non-carcinogens are calculated such that effects should not be seen at exposures reflecting standard EPA exposure parameters (see equation below).

NTR human health criteria for PCBs (170 pg/l (parts per quadrillion) for a 10^{-6} risk level) were derived primarily to protect people from contaminated fish, the predominant exposure pathway. Exposure through water consumption is negligible, representing approximately 1% of the total PCB intake. The human health criteria are calculated using the following equation:

Equation 1. $$\boldsymbol{HHC = \frac{RF \times BW \times (10^{9}\ pg/mg)}{q1^{*} \times [WC + (FC\ x\ BCF)]}}$$

Where:

- HHC = human health criteria.
- RF (risk factor) = the acceptable level of cancer risk. Washington’s acceptable upper-bound excess cancer risk is one in a million (10^{-6}) for a lifetime exposure.
- BW (body weight) = the average body weight of the consumer. The NTR uses an average consumer body weight of 70 kg.
- q1* (cancer slope factor) = the cancer potency of each chemical. The NTR uses a q1* of 2 per mg/kg-day for PCBs.
- WC (water consumption) = the average daily consumption of water by a consumer. The NTR uses a water consumption rate of 2 L/day.
- FC (fish consumption) = the average fish tissue consumption by a consumer. The NTR uses a fish tissue consumption rate of 0.0065 kg/day.
- BCF (bioconcentration factor) = the concentration of a chemical in tissue accumulated through gill and skin divided by the concentration in the water column. The NTR uses a BCF of 31,200 L/kg for PCBs.

The water quality criterion can be converted to an equivalent fish tissue criterion using the BCF in Equation 2, where Cw is the concentration in water and Ct is the concentration in tissue:

Equation 2. $$\boldsymbol{BCF = \frac{C_t}{C_W}}$$

NTR-equivalent fish tissue concentrations may then be calculated by $C_t = BCF \times C_w$. The calculated NTR-equivalent concentration for PCBs in edible tissue (C_t) is 5.3 ng/g (parts per billion; Table 3).

The values used by EPA to derive the NTR human health criteria are not always used by public health agencies to establish fish consumption advisories in Washington and other NTR states. The Washington State Department of Health (WDOH), which has primary responsibility for assessing the need for fish consumption advisories, examines local information about higher fish consumption rates, and sub-populations at increased risk. Additionally, differences are present in the use of chemical toxicity factors and health effect endpoints. For example, water quality criteria for PCBs are based on protection against cancer, while state fish advisories for PCBs are based on protection against non-cancer effects.

Washington State

Water quality standards for surface waters of Washington State are contained in Chapter 173-201A of the Washington Administrative Code (WAC), last amended in 2006 and approved by EPA in 2008. The numeric criteria to protect aquatic life from PCB exposure is found in WAC 173-201A-240. The acute exposure criterion for PCBs in freshwater is 2 x 10^6 pg/l. The chronic exposure criterion is 1.4 x 10^4 pg/l (Table 3).

The standards also include a provision that "Toxic substances shall not be introduced above natural background levels in waters of the state which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent on those waters, or adversely affect public health as determined by the department (WAC 173-201A-240(1)."

Designated uses (defined in WAC 173-201A-200(1)) in the Spokane River, from its mouth to the Idaho border include:

- Core summer habitat
- Spawning/rearing
- Recreation
- Water supply
- Harvesting
- Other miscellaneous uses

Spokane Tribe

The Spokane Tribe of Indians (Spokane Tribe) Surface Water Quality Standards (Resolution 2003-259) are similar to the Washington State Water Quality Standards in terms of narrative and numeric criteria. They apply to the westernmost part of the river defined by a line bisecting the Spokane Arm and Little Falls reservoir from river mile (RM) 32.5 to RM 0 (see Figure 2). The Tribal standards consider the Spokane River and most of its tributaries to be Class A surface water, with the exception of Blue Creek, Orazada Creek, and Sand Creek which are all Class AA tributaries to the Spokane Arm between RM 8 and RM 13. Designated uses for Spokane Tribe Class A and AA waters are similar to the Washington State standards, but also include primary contact (Washington waters are also designated for primary contact), ceremonial and spiritual, and cultural uses.

The Spokane Tribal narrative section for toxic pollutant standards is nearly identical to that of Washington State, including the adoption of a 10^{-6} risk level of for carcinogens. However, the Tribal numeric human health criteria are substantially lower (more restrictive) than those issued to Washington in the NTR (3.37 vs. 170 pg/l) due to different values used to derive the human health criteria. Tribal standards employ an aquatic organism consumption rate of 0.0863 kg/day, as opposed to the 0.0065 kg/day fish consumption rate in the NTR. In addition, the Spokane Tribe PCB criteria include an older cancer slope factor of 7.7 per mg/kg-d. Using the same approach used to derive an NTR-equivalent tissue value as described above in Eq. 2, the Spokane Tribe human health criteria of 3.37 pg/l translates to an equivalent edible tissue concentration of 0.1 ng/g.

Guidance

EPA Recommended National Water Quality Criteria

In 2002, EPA recommended new national water quality criteria including a new human health criterion for PCBs based on an upward revision of the fish consumption rate to 0.0175 kg/day (EPA, 2002). All other factors used to derive the recommended criterion (RF, BW, q1*, WC, and BCF) remained unchanged. The resulting recommended criterion for PCBs is 64 pg/l for water. The equivalent fish tissue concentration for this criterion is 2.0 ng/g (Table 3).

EPA Screening Values for Fish Advisories

Other threshold values which have no regulatory standing but are often used to assess potential public health risk are the EPA (2000a) tissue screening values (Table 3) used to evaluate fish advisories. Tissue screening values are derived in the same manner as NTR criteria and EPA's 2002 recommended national criteria, with adjustments only to the fish consumption rates. The screening value for recreational fishers is 2.0 ng/g, based on a consumption rate representing the 90th percentile of sport fishers (0.0175 kg/day). The screening value for subsistence fishers (0.24 ng/g) is based on a 99th percentile consumption rate (0.142 kg/day).

Watershed Description

Hydrology

The Spokane River begins in northern Idaho at the outlet of Coeur d'Alene Lake and flows west 112 miles to the Columbia River (Franklin D. Roosevelt Lake) (Figure 2). The watershed encompasses over 6,000 square miles (15,500 km^2) in Washington and Idaho. The river flows through the smaller cities of Post Falls and Coeur d'Alene in Idaho and large urban areas of the Spokane Valley and Spokane in Washington. Other cities in the basin include Liberty Lake, Deer Park, and Medical Lake Washington as well as Wallace and Kellogg Idaho upstream from Lake Coeur d'Alene.

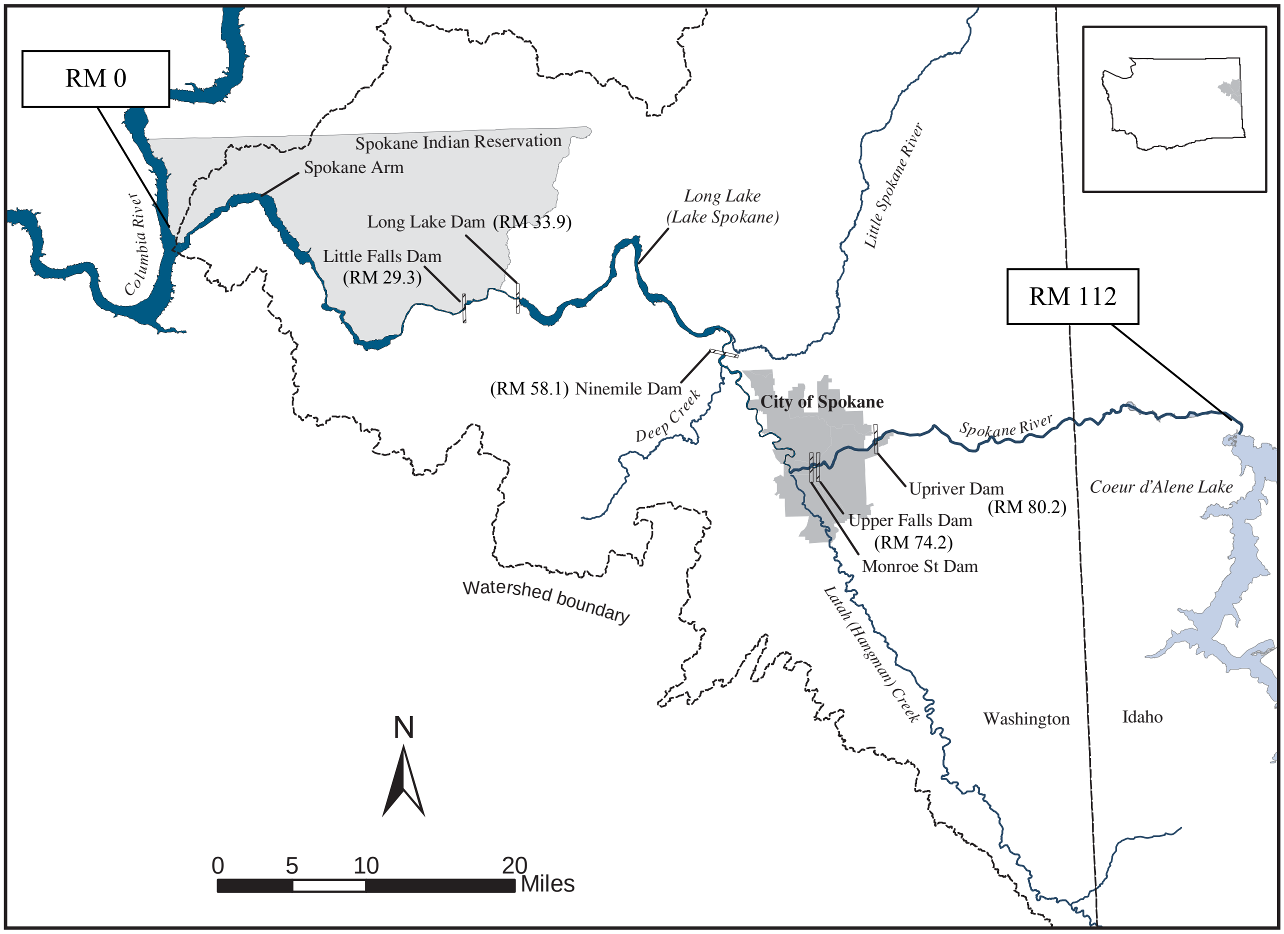

Figure 2. Spokane River Basin.

There are seven dams along the Spokane River:

1. Post Falls Dam (RM 100.8).
2. Upriver Dam (RM 80.2).
3. Upper Falls Dam (RM 74.5).
4. Monroe Street Dam (RM 74.0).
5. Ninemile Dam (RM 58.1).
6. Lake Spokane (Long Lake) Dam (RM 33.9).
7. Little Falls Dam (RM 29.3).

The dams create a series of pools which vary in length, the largest being 23-mile long Lake Spokane. Downstream from Lake Spokane, the Spokane River forms the southern boundary of the Spokane Tribe of Indians reservation from Chamokane Creek (RM 32.5) to the Columbia River at RM 639.0. The reservation occupies approximately 160,000 acres and is home to 2,441 tribal members (as of 2006).

The flow regime in the Spokane River is dictated largely by freezing temperatures in the winter followed by spring snowmelt. Figure 3 shows the harmonic mean flow at four points in the Spokane River. The harmonic mean is recommended by EPA (1991a) for use in assessing a river's loading capacity for long-term exposure to carcinogens such as PCBs. This is the appropriate measure of central tendency when dealing with rates, in this case rates of flow. Harmonic mean is discussed in more detail later in this report (see *Instream Loads*).

The annual mean flow for 1969-2002 was approximately 61,000 L/sec (2,154 cfs) where the Spokane River crosses the Idaho border. Flows increased to 82,000 L/sec (2,895 cfs) downstream of Spokane, reflecting the influx of groundwater through this river reach. Prior to 1969 there were un-quantified agricultural diversions for irrigation from the Spokane River in the vicinity of Post Falls.

Sediment

Downstream of Spokane the river corridor is largely undeveloped. The two major tributaries – Latah Creek (formerly Hangman Creek) and Little Spokane River – enter the Spokane River at RM 72.2 and RM 56.3, respectively. Latah Creek has an extremely flashy flow regime, responding rapidly to rainfall or snowmelt and is prone to erosion of its banks, thus delivering substantial sediment loads to the Spokane River (SCCD, 2002). In comparison, the Little Spokane River has an order of magnitude higher mean flow than Latah Creek, but carries slightly lower sediment loads.

One particular macro characteristic of the Spokane River is the general lack of fine depositional sediments in most of the river. Lake Coeur d'Alene acts as a settling basin for sediments transported in the upper watershed, and there are no tributaries to the river between the outlet of the lake and Latah Creek. Spokane River is essentially a free-stone stream environment. Although the dams break the river into a series of pools, there are few areas of placid water above Lake Spokane. The river velocities are high enough and the sediment load low enough to scour the bed or prevent settling of significant fine particulate matter, even immediately behind the dams. As a result, almost the entire riverbed upstream of Lake Spokane (the largest reservoir) is composed of gravel, cobble, and boulders with the finer sediment reserved for limited locations behind the dams, interstitial spaces within the river bed, isolated shoreline deposits, and certain fluvial bar features. One notable exception is the narrow band of fine, organic carbon rich sediments found near the Upriver Dam reservoir that constituted the MTCA cleanup site, previously mentioned.

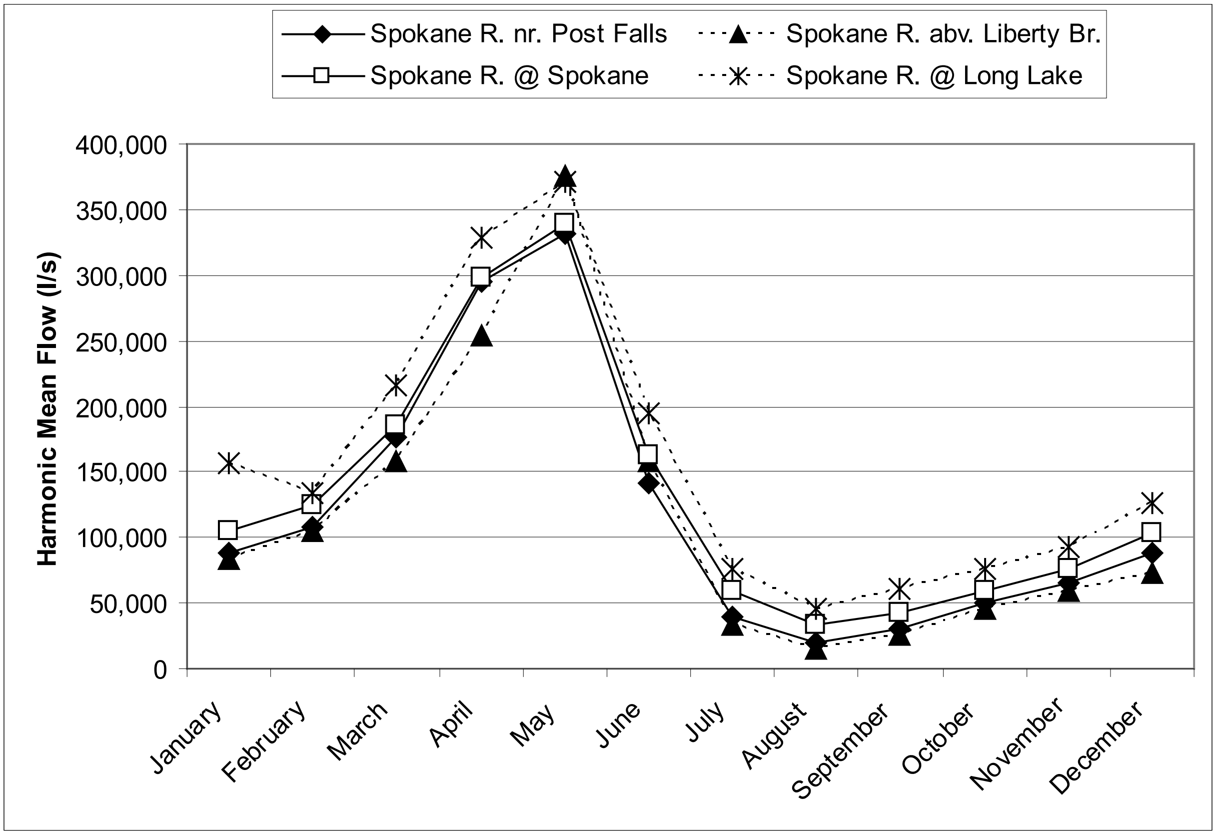

Figure 3. Spokane River Monthly Harmonic Mean Flows for Water Years 1969-2002.

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PCB Contamination of the Spokane River

Uses, Structure, and Analysis

PCBs were first produced for commercial use in 1929. Production continued until a 1979 ban on all PCB manufacturing, processing, and distribution due to evidence that PCBs build up in the environment and concerns about possible human carcinogenicity (Sittig, 1980). Principal uses were as heat transfer fluids, plasticizers, wax and pesticide extenders, lubricants, and fluids for hydraulic machinery, vacuum pumps, and compressors.

There are 209 individual forms of PCBs, known as congeners. The naming system for congeners is based on the number and location of chlorine atoms on the biphenyl rings (Figure 4).

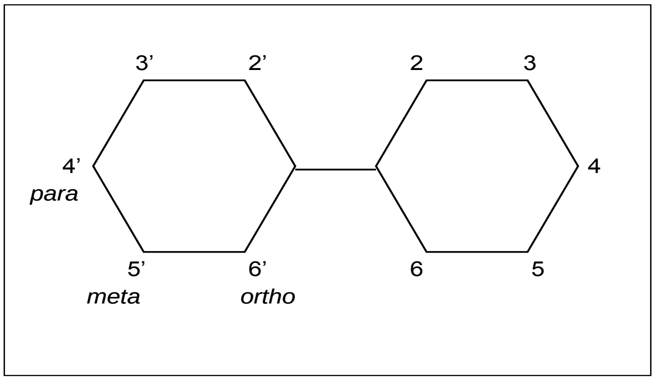

Figure 4. Generic PCB Molecular Structure and Numbering System.

In the U.S., PCBs were produced almost exclusively as Aroclors, the trade name for congener mixtures containing 21 to 68% chlorine by weight. The names given to the different Aroclors reflect this composition; Aroclor [PCB]-1248, for instance, contains approximately 48% chlorine by weight (12 refers to the number of carbon atoms in the biphenyl ring). Many different commercial Aroclor mixtures have been quantified as to their congener composition by Frame et al. (1996).

PCBs can be analyzed as individual congeners or Aroclor-equivalents. Congeners are usually analyzed by high-resolution gas chromatography/mass spectrometry (GC/MS) methods that are more costly, but more sensitive and thus give lower detection limits than the gas chromatography/electron capture (GC/ECD) method typically employed for Aroclor mixtures. Most of the historical fish tissue data for Washington State is from Aroclor analysis.

Much of the 600 million kg of PCBs used domestically has found its way into the environment through improper disposal or by leakage of sealed systems (Sittig, 1980). Loss to the environment through PCB use in open systems such as hydraulic fluids in die cast machinery, heat transfer systems, and specialty inks was also not uncommon (EPA, 2000a). Their primary uses are associated more with heavy industry or urban centers rather than agriculture (EPA, 1992). Direct application to the environment occurred on a lesser scale through use as pesticide extenders or oil mixtures applied to roads for dust control. Many of the same properties that made PCBs commercially desirable – their stability and resistance to degradation – make them extremely persistent in the environment. They have become one of the most ubiquitous of all environmental contaminants.

Environmental Fate

The persistence of PCBs increases with the degree of chlorination. Mono-, di- and tri-chlorinated biphenyls biodegrade relatively rapidly, tetrachlorinated biphenyls biodegrade slowly, and higher chlorinated biphenyls are resistant to biodegradation.

In soils, PCBs experience tight adsorption which generally increases with the degree of chlorination of the PCB. PCBs generally do not leach significantly in aqueous soil systems; the higher chlorinated congeners have a lower tendency to leach than the less chlorinated congeners. Vapor loss of PCBs from soil surfaces appears to be an important fate mechanism with the rate of volatilization decreasing with increasing chlorination.

In water, adsorption to sediment and suspended matter are important fate processes; PCB concentrations in sediment and suspended matter are typically much greater than in the water column. Although adsorption can immobilize PCBs (especially the higher chlorinated congeners) for relatively long periods of time, eventual re-solution into the water column has been shown to occur. The PCB composition in water will be enriched in the lower chlorinated PCBs because of their greater water solubility, and the least water soluble PCBs (highest chlorine content) will tend to remain adsorbed.

However, strong PCB adsorption to sediment significantly competes with volatilization, with the higher chlorinated PCBs having longer half-lives than the lower chlorinated PCBs. Lower chlorinated PCBs and ortho-substituted congeners are more volatile than the highly chlorinated PCBs. Henry's Law constants generally range from approximately 1 to 400 Pa m^3/mol (Pascals cubic meter/mole), indicating volatilization is an important transport process for PCBs in the environment. PCB volatilization from water, particularly at falls or dams, and from exposed contaminated soils can be an important transport process for PCBs and, in the absence of adsorption, PCBs volatilize relatively rapidly from water.

Losses of PCBs from the Great Lakes have been estimated by Eisenreich et al. (1992) as 66% via volatilization, 27% via sedimentation, and 7% through the outflow to other waterbodies. Dam spillways may cause significant transformations of an Aroclor mixture, with differential loss of constituent congeners (McLachlan et al., 1990). The dams along the Spokane River likely modify the dissolved and particulate fractions of PCBs as water moves downstream.

The combination of differential solubility, variable octanol-water partitioning coefficients (K_{ow}), and volatilization leads to weathering of Aroclor mixtures. In environmental samples, these physical and chemical processes change the composition of released PCB mixtures over time. Thus, sediment and water samples rarely have congener patterns which match a commercial Aroclor due to weathering. If released to the atmosphere, PCBs will primarily exist in the vapor-phase; the tendency to become associated with the particulate-phase will increase as the degree of chlorination increases. Physical removal of PCBs from the atmosphere is accomplished by wet and dry deposition.

PCBs accumulate in the lipids (fats) of fish and other animals. Lipid solubility increases with the degree of chlorination (Mabey et al., 1982), reflected in their high K_{ow}. The range of log K_{ow} is from approximately 4.6 for monochlorinated congeners to 8.2 for decachlorobiphenyl. Peak bioaccumulation occurs between log K_{ow} 6.5 and 7.0 (Fisk et al., 1998), those congeners with 5 or 6 chlorines. It is believed that congeners with log $K_{ow} > 7.0$ are too large to be efficiently assimilated in the fish digestive tract.

All known aerobic and anaerobic biotic processes act to de-chlorinate PCBs (ATSDR, 1997). Substitution of either a hydrogen or chlorine atom is generally required by an organism to excrete a PCB molecule. Congeners which do not have chlorines in meta positions can be metabolized and excreted. Organisms preferentially metabolize and excrete different PCB congeners depending on their resistance to substitution. Substitution is generally more difficult for the richly chlorinated congeners, leading to preferential bioaccumulation of heavier, but not the heaviest, congeners.

Historical Data on PCBs in the Spokane River

Ecology has analyzed PCBs in a variety of water, sediment, and fish tissue samples collected from the Spokane River over the past two decades. Additional data have been collected by or in cooperation with the U.S. Geological Survey (USGS) and various NPDES dischargers. More recent work has focused attention on characterizing PCB contaminated sediments behind Upriver Dam. The various data collection efforts going back to 1980 are listed in Table 4.

PCBs were first analyzed in the Spokane River during Ecology statewide screening-level surveys of contaminants in fish from rivers and lakes (Hopkins et al., 1985; Hopkins, 1991; Serdar et al., 1994). Spokane River fish almost always had high PCB concentrations. For instance, total PCBs in whole fish ranged up to 2,300 ng/g (parts per billion) in northern pikeminnow (*Ptychocheilus oregonensis*) collected in 1983. Fillets from mountain whitefish (*Prosopium williamsoni*) and bridgelip sucker (*Catostomus columbianus*) from Riverside State Park in the City of Spokane were also elevated with total PCB concentrations of 230 and 370 ng/g, respectively. Largescale suckers (*Catostomus macrocheilus*) sampled from Lake Spokane had a whole body concentration of 720 ng/g.

In 1993, Ecology expanded its investigation of PCBs in the Spokane River by analyzing multiple fish species and sediments at reaches encompassing the entire river. Johnson et al. (1994) confirmed the high PCB levels seen earlier and found the highest fish tissue and sediment levels in the reach above Upriver Dam (up to 2,800 ng/g in whole largescale suckers and 3,200 ng/g in sediments) with levels gradually declining downstream.

Table 4. Summary of PCB Data Collected on the Spokane River, 1980-2007.

Investigator	Sample Type	Year Collected	Purpose
Ecology (Hopkins et al., 1985)	Fish tissue	1980-1983	Statewide survey of contaminants in rivers
Ecology (Hopkins, 1991)	Sediment	1989	Statewide survey of contaminants in rivers
Ecology (Serdar et al., 1994)	Fish tissue[1,2] Sediment	1992	Statewide survey of contaminants in lakes
Ecology (Johnson, et al., 1994)	Tissue Sediment	1993	Survey for PCBs in the Spokane River
Ecology (Davis et al., 1995)	Fish tissue		Statewide survey of pesticides and PCBs
Ecology (Ecology, 1995)	Fish and crayfish, tissue, sediment, surface water, effluent, sludge	1994	Synoptic survey of PCBs in the Spokane River
Hart Crowser, 1995	Effluent		Sampled Kaiser Trentwood effluent coincidental with Ecology sampling
Ecology (Huntamer, 1995)	Sediment		Microscopic examination and PCB analysis of sediments behind Upriver Dam
Ecology (Golding, 1996)	Effluent Sludge	1995	Follow-up to effluent and sludge sampling conducted during 1994 synoptic survey
Ecology (Johnson, 1997)	Fish tissue	1996	Survey to determine PCB levels in Spokane River fish
Ecology and USGS (Johnson, 2000)	Fish and crayfish tissue	1999	Survey to determine PCB levels in Spokane River fish
Ecology (Johnson and Norton, 2001)	Sediment	2000	Chemistry and bioassays of Spokane River
Ecology (Golding, 2001)	Surface water Effluent		Survey of PCBs in Kaiser Trentwood effluents and receiving waters
Ecology (Golding, 2002)	Effluent	2001	Survey of PCBs in industrial and WWTP effluents
Ecology (Jack and Roose, 2002)	Fish tissue		Intensive survey of PCBs in Lake Spokane fish
Exponent and Anchor, 2001	Sediment		Survey of PCBs in sediments behind Upriver Dam
SAIC, 2003a	Effluent Sludge	2002	Survey of PCBs in effluent and sludge from Inland Empire
SAIC, 2003b	Fish tissue		Intensive survey of PCBs in Lake Coeur d'Alene fish
Anchor Environmental (Anchor, 2004)	Surface water Groundwater	2003	Remedial investigation of PCBs in the vicinity of Upriver Dam MTCA site
Merill and Bala, 2004	Effluent	2002-2003	Bi-weekly monitoring of PCBs in Kaiser Trentwood effluent
Kaiser (Kaiser, 2005)	Effluent	2004-2005	PCBs in Kaiser Trentwood effluent
Merill and Bala, 2004	Effluent	2002-2003	Bi-weekly monitoring of PCBs in Kaiser Trentwood effluent
Ecology (Serdar and Johnson, 2006)	Fish tissue	2005	Synoptic survey of PCBs in Spokane River fish
Ecology (Seiders, Deligeannis, and Kinney, 2006)	Surface water Fish tissue		Statewide survey of toxic contaminants in waters and fish, including Spokane River
Parsons, 2007	Stormwater	2007	Survey of PCBs in Spokane stormwater

WWTP: wastewater treatment plant.

In 1994, Ecology further increased the number of organisms and locations analyzed for PCBs in the Spokane River. Results again confirmed the pattern of contamination among sites seen in 1993. The 1994 study also found that Little Spokane River fish had higher than expected PCB levels. Crayfish had low accumulations of PCBs.

The 1994 samples also included bottom sediments and potential industrial/municipal sources of PCBs to the river. This helped define the extent of contamination behind Upriver Dam, largely by delineating the area of depositional material. Nearly the entire river was surveyed for the presence of significant bulk fine sediment deposits between the state line and Lake Spokane, but the "hot spot" behind Upriver Dam was the only sediment deposit found during that study.

Perhaps the most important findings from 1994 were the characterizations of PCB sources to the river. Sewage treatment plants, industrial facilities, and industrial sites along the river were sampled to assess their relative contribution of PCBs. Results showed that sources upstream of the Idaho border were negligible, but downstream there was a substantial ongoing PCB source at the Kaiser Trentwood aluminum plant, potentially significant sources such as the Liberty Lake wastewater treatment plant (WWTP) and the former Inland Metals site, and a historically large source from the Spokane Industrial Park, which now discharged to the Spokane WWTP. Low PCB concentrations were found at a Washington Water Power yard, located just above the river bank, ruling this site out as a potentially significant source. PCB discharges from industrial and municipal treatment plants are discussed in more detail later in this section of the report.

Ecology analyzed more fish in 1996, specifically to determine if the trend toward decreasing PCB concentrations continued. The three species used most often for comparisons in the Spokane River – rainbow trout, mountain whitefish, and largescale suckers – all showed substantial decreases in PCB concentrations from earlier data (Table 5). However, PCB levels continued to remain high relative to other areas in the state.

Since 1999, surveys in the Spokane River have verified previous data or further characterized the contamination so that its implications are better understood. The three major areas where study efforts have concentrated in the past decade are:

- Continued sampling of fish to evaluate temporal trends and conduct human health risk assessment.
- Continued monitoring of known PCB sources.
- Characterization of the Upriver Dam cleanup site.

In July 1999, USGS collaborated with Ecology to further document PCB contamination in fish from the mainstem of the Spokane River (USGS, 1999; Johnson, 2000). This study found that whole largescale suckers exceeded a criterion of 110 ng/g used to protect fish-eating wildlife (Newell et al., 1987). Concentrations in whole suckers ranged from 120 to 700 ng/g total PCBs. For mountain whitefish and rainbow trout (*Oncorhynchus mykiss*), fillets and whole fish were analyzed. Peak concentrations were found in rainbow trout in the vicinity of RM 85 (Plante Ferry) and in mountain whitefish in the vicinity of RM 63 (Ninemile). Maximum concentrations were about 1,600 ng/g for both species.

Table 5. Summary of Total PCB Concentrations in Fish Tissue from the Spokane River (mean concentrations in ng/g, ww).

Location and Tissue Type	Total PCB Concentrations Measured by:					
	Aroclor Analysis					Congener Analysis
	1993[a]	1994[b]	1996[c]	1999[d]	2001[e]	2005[f]
Rainbow trout - fillet						
State line	--	--	--	106	--	55
Plante Ferry	918	424	799	891	--	153
Above Monroe Dam*	--	145	76	226	--	73
Ninemile	490	371	76	143	--	
Mountain whitefish - fillet						
Above Monroe Dam	--	568	381	339	--	234
Ninemile	522	139	444	632	--	139
Little Spokane	--	222	145	--	--	--
Upper Lake Spokane	--		--	--	73	43
Lower Lake Spokane	780	113	--	--	--	76
Largescale suckers - whole						
State line	--	--	--	120	--	56
Plante Ferry	2,005	531	530	283	--	122
Above Monroe Dam	--	201	116	445	--	1,823
Ninemile	1,210		345	680	--	--
Little Spokane	--	440	366	--	--	--
Upper Lake Spokane	--	--	--	--	265	327
Lower Lake Spokane	410	820	--	--	357	254

--no data
[a] Johnson et al., 1994
[b] Ecology, 1995
[c] Johnson, 1997
[d] Johnson, 2000
[e] Jack and Roose, 2002
[f] Serdar and Johnson, 2006
*Same reach as Mission Park

In 2001, Ecology, WDOH, and the Washington Department of Fish and Wildlife (WDFW) collaborated in the collection of five species to evaluate PCB concentrations in Lake Spokane fish tissues (Jack and Roose, 2002). In general, largescale suckers and mountain whitefish had the highest PCB concentrations. Total PCBs in whole suckers ranged from 160 to 340 ng/g, while mountain whitefish fillets ranged from 60 to 89 ng/g. The greater uptake and retention of PCBs in suckers is likely influenced by their relatively high lipid content, benthic (bottom feeding) habits, limited capabilities for PCB excretion, and longevity. Largescale suckers analyzed from Lake Spokane were up to 24 years old (Jack and Roose, 2002). Fish consumption advisories were issued in 2003 and are further discussed below.

In 2005, another intensive study was conducted to expand and update the information on chemical contaminants in Spokane River fish (Serdar and Johnson, 2006). Fish from six locations between the Washington/Idaho state line and lower Lake Spokane were collected. Samples of fillets and whole fish were analyzed for PCBs, polybrominated diphenyl ether flame retardants (PBDEs), arsenic, cadmium, lead, and zinc. A subset of samples was also analyzed for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs).

Compared to historical levels, PCB concentrations appeared to have decreased in all parts of the Spokane River except the Mission Park reach. Relative to other parts of the state, Spokane River fish were within the mean and median for fillet PCB concentrations. However, whole fish results for Mission Park and Lake Spokane were at or above the upper end of the range of whole fish statewide.

Spokane River fish also substantially exceeded statewide comparisons for concentrations of PBDEs, zinc, lead, and cadmium (whole fish samples only). The Urban Waters Program at Ecology is currently pursuing sources of PBDEs to the river. Metals contamination of the Spokane River is from historic mining in Idaho's Silver Valley and has been the subject of many past studies. As previously mentioned, a TMDL has been established for lead, cadmium, and zinc in the Spokane River.

Ecology's Washington State Toxics Monitoring Program also sampled fish from the Spokane River in 2003-04 for a suite of toxic compounds. PCBs were not analyzed due to concurrent intensive PCBs surveys on the river. A recommendation from this effort was to list the Spokane River as impaired on the 303(d) list for 2,3,7,8-TCDD (dioxin) (Seiders et al., 2006).

Table 5 provides a comparison of the total PCB concentrations from the various Ecology studies.

Fish Consumption Advisories

Based on the elevated PCB and lead levels in Spokane River fish, WDOH and the Spokane Regional Health District issued an advisory in 2003 to avoid or limit consumption of fish in parts of the Spokane River (www.doh.wa.gov/ehp/oehas/fish/consumpadvice.htm#Spokane%20River). The health departments later concluded that the advisory would also be protective for PBDEs. The advisory, updated in April 2008 based on fish tissue samples collected for the present 2003-07 study, is summarized in Table 6.

Table 6. April 2008 Spokane River Fish Consumption Advisories.

Location	Species	Consumption Advice
Spokane River – All Areas	All Species	Do not eat the fish head or entrails.
Idaho Border to Upriver Dam	All Species	Do not eat
Upriver Dam to Ninemile Dam	Largescale Sucker	Do not eat
	All Other Species	One meal per month
Lake Spokane (Long Lake)	Largescale Sucker	One meal per month
	Brown Trout	
	Largemouth Bass	Two meals per month
	Smallmouth Bass	
	Rainbow Trout	Two meals per week
	Yellow Perch	

National Pollutant Discharge Elimination System (NPDES) Permits

Ecology has issued NPDES wastewater discharge permits to a variety of industrial and municipal facilities in the Spokane River basin. Some of these facilities have discharged PCBs in the past. Ecology-directed MTCA sediment cleanup actions upstream of Upriver Dam identified the Kaiser Trentwood facility and the Spokane Industrial Park as the most prominent historic sources of PCB releases in that portion of the river. Recent studies have confirmed the presence of PCBs in the waste streams of some permitted Spokane River dischargers. Appendix A lists the permitted discharges to the greater Spokane watershed by WRIA and permit number.

The NPDES permits in Appendix A are coded based on the type of discharge to waters of the state. Those permit numbers beginning with ST are for the discharge of municipal and industrial effluents to ground or industrial effluents to municipal sewer systems. The City of Spokane WWTP receives effluent from a number of these industrial dischargers. Permit numbers beginning with WAG are general NPDES permits. "WA" permits are those allowing discharge of effluents to surface waters.

In addition to the industrial and municipal discharges in Appendix A, the City of Spokane has a partially combined sewer-stormwater system. Spokane is permitted for stormwater discharges under the NPDES Phase II program. A combined sewer is a conjoined system of (1) stormwater collection from areas such as roofs and parking lots and (2) raw sewage. During heavy rain or snowmelt events, the influx of stormwater to the combined system may overwhelm its carrying capacity. At that time, a combined sewer overflow (CSO) event occurs, and a portion of the stormwater-sewage mixture bypasses the local WWTP and discharges directly to the river.

There are a total of 24 CSO points within the City of Spokane (City of Spokane, 2002). These sewers may discharge during high-flow periods or inadvertently during maintenance activities. Because of the variety of previous uses of PCBs, they may be discharged to the river during these overflow events. Some of the stormwater is delivered directly to the river through storm sewers and into ground via drywells or infiltration basins.

Historic NPDES Effluent PCB Concentrations

Some of the NPDES-permitted effluents discharged to the Spokane River have been sampled for PCBs by Ecology and others (Table 7). Ecology (1995), Golding (1996, 2001, 2002), and SAIC (2003a) report effluent data from July 1994 through June 2002 (Table 7). These samples were analyzed by both Aroclor-equivalents and congener-specific methods. While the methods may not be directly comparable to each other, these data are included to illustrate the range of loads and potential variability from these sources.

Historic PCB loads from the Kaiser Trentwood aluminum mill were consistently higher than other facilities by about an order of magnitude, although loads appear to have declined from 1994 to 2001. Kaiser also monitored PCBs in their outfall bi-weekly in 2002 and 2003 (Merrill and Bala, 2004). The median concentration of total PCBs in 2002 was 2,700 pg/l (140 mg/day), decreasing to 1,200 pg/l (90 mg/day) in 2003.

PCB concentrations in Kaiser effluent during 2002-2003 were generally consistent, with variability expressed by peaks – an order of magnitude increase from normal levels – occurring at two to five month intervals. The monitoring result for 4/9/2002 showed an unusually high PCB level in the effluent, 2.2×10^6 pg/l (0.125 kg/day), which persisted for a maximum of three weeks before returning to typical levels. PCB levels jumped again in November 2002 when four consecutive monitoring events from 11/18/2002 to 12/29/2002 found effluent concentrations of 2.6×10^7 pg/l, 3.2×10^6 pg/l, 4.8×10^7 pg/l, and 3.4×10^6 pg/l. Assuming an average daily load of 0.99 kg/day for a period of six weeks (one week prior to discovery until one week following the last elevated measurement), approximately 53 kg total PCB was delivered to the Spokane River from the Kaiser facility during this period.

Table 7. Summary of Spokane Area PCB Point Source Data.

Source	Date	Method	Total PCBs (pg/l)	Identified Aroclor	Effluent Flow (ML/day)	PCB Load to River (mg/Day)
Kaiser Trentwood	08/1/94 [a]	Aroclor	21,000	PCB-1248	109	2,290
	12/5/95 [b]		29,000		67.8	1,970
			34,000			2,300
	12/6/95 [b]		25,000		68.5	1,710
			29,000			1,990
	08/14/00 [c]		53,000		96.1	5,100
			900 U	NA	96.1	0
	08/15/00 [c]		900 U			0
			25,000	PCB-1248		2,400
	05/1/01 [d]		10,174 NJ	NA	62.1	630
	05/2/01 [d]		5,165 NJ			320
Spokane WWTP	05/1/01 [d]	congener	1,813 NJ	NA	142	260
	05/2/01 [d]		1,767 NJ			250
Liberty Lake WWTP	05/1/01 [d]	congener	1,917 NJ	NA	2.46	4.7
	05/2/01 [d]		1,543 NJ			3.8
Inland Empire Paper	05/1/01 [d]	congener	2,436 NJ	NA	16.3	40
	06/5/02–a.m. [e]		5,484		20.0	110
	06/5/02–p.m. [e]		4,305		18.0	78
Spokane Industrial Park	07/31/94 [a]	Aroclor	9,000 U	NA	*	*
	08/4/94 [a]		31,000 U			
	05/1/01 [d]	congener	9,371 NJ			
	05/2/01 [d]		7,108 NJ			

Bold: Analyte detected
NJ: There is evidence that the analyte is present. Associated numerical result is an estimate.
U: Analyte not detected at or above the reported value.
NA: not applicable
ML/day: 0.264 MGD (million gallons per day)
* Currently discharges to Spokane WWTP; formerly discharged to Spokane River.
[a] Ecology, 1995
[b] Golding, 1996
[c] Golding, 2001
[d] Golding, 2002
[e] SAIC, 2003a

PCB levels in effluent samples collected from the Spokane WWTP, Liberty Lake WWTP, and Inland Empire Paper in 2001-2002 ranged from 1,543 to 5,484 pg/l. Higher concentrations of 7,108 and 9,371 pg/l were reported in effluent from the Spokane Industrial Park analyzed in 1994. This facility now discharges to the Spokane WWTP.

PCBs Behind Upriver Dam, 1995-2004

As mentioned previously, bulk fine sediment deposits are sparse in the Spokane River upstream of Lake Spokane, with the exception of scattered shoreline, bar feature, and lower energy zones. Two notable exceptions are the narrow bands of silt and organically-enriched sediments deposited behind Upriver Dam (Figure 5).

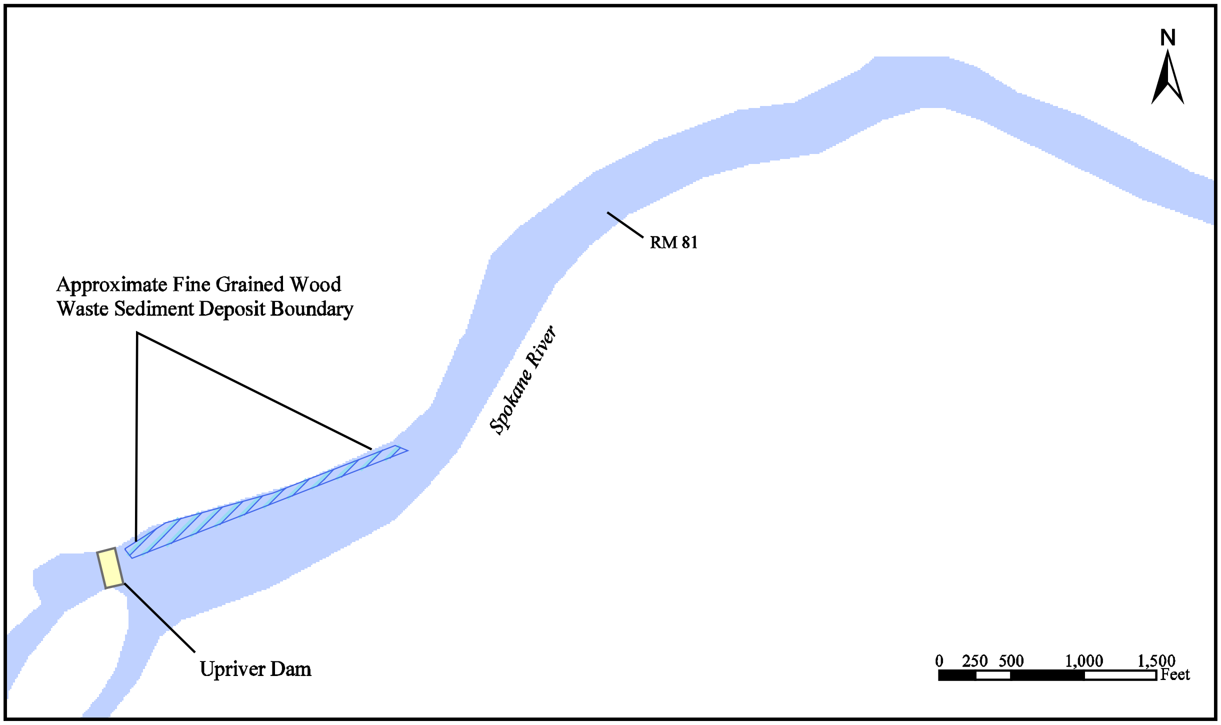

Figure 5. Location of Fine-Grained Wood Waste Sediment Deposit Behind Upriver Dam.

Following discovery of PCB contamination behind Upriver Dam in 1993 and confirmation of high PCB levels in 1994, subsequent sampling consisted mainly of defining the boundary of contamination and distribution of fine sediments upstream of the dam. Sediments within a band located immediately behind the dam generally showed PCBs at 1,000-5,000 ng/g dry weight (dw) and in some samples contained >10% total organic carbon, gradually becoming sandier at the margins (Ecology, 1995; Johnson and Norton, 2001). Huntamer (1995) conducted a microscopic analysis of the organic-enriched sediments and found them to be largely composed of wood particles, consistent with un-aided visual observation made earlier. Huntamer also observed charcoal which he speculated may have originated from recent wildfires in the area.

In February 2003, Ecology entered into a Consent Decree with Kaiser and Avista (formerly Washington Water Power) to evaluate site conditions at Upriver Dam. The remedial investigation (RI) and feasibility study (FS) (Anchor 2005a and 2005b) required under the Consent Decree informed decisions that led to the completion of a cleanup under MTCA. Aside from sediment characterization, the RI/FS addressed other components of the aquatic ecosystem associated with the Upriver Dam contamination, such as sampling PCBs in the water column and in hydraulically-connected groundwater wells, as well as bathymetric surveys of the reach.

Groundwater monitoring in the area indicates there is localized loss of surface water to the aquifer due to the hydraulic difference between the reservoir pool and the river surface downstream of the dam. Monitoring wells located downgradient of the dam showed low PCB concentrations (9-116 pg/l), which were in the range of associated field and laboratory blanks (10-226 pg/l), suggesting the presence of PCBs was due to sampling or lab contamination rather than PCB movement from the reservoir to groundwater (Anchor, 2004).

Surface water sampling was conducted both upstream and downstream of the Upriver Dam site as part of the RI/FS. During the RI/FS, upstream surface water samples and surface water samples collected at the Upriver Dam site (120 and 110 pg/l respectively) exceeded the EPA National Recommended Water Quality Criterion of 64 pg/l. As being an applicable, relevant, and appropriate requirement (ARAR) under MTCA, the 64 pg/l criterion was selected as the surface water criterion at the Upriver Dam site.

Numerous sediment samples were analyzed in and around the known area of contamination as part of the RI/FS. Samples were also collected upstream in backwaters identified as potential depositional areas. Results identified a second significant fine sediment deposit above Upriver Dam at RM 83.4 (Donkey Island) and corroborated earlier findings that deposited fine material and elevated PCB concentrations are absent outside the known areas of bulk fine sediment accumulation.

The Cleanup Action Plan by Ecology (2005) identified a sediment cleanup value of 62 µg/kg total PCBs as protective of human health and the river ecological community. The 62 µg/kg PCB sediment cleanup value was derived for the protection of aquatic life inhabiting the upper layer (0 - 10 cm) of the sediment. The selected sediment cleanup level is based on the lowest apparent effects threshold (AET) suggested for use in freshwater sediments (Michelson, 2003).

The Upriver Dam cleanup was completed in January 2007. A sediment cap was placed over the primary contaminated area on the river bed behind Upriver Dam (Deposit 1) using an excavator on a floating barge. A second smaller area of contaminated sediment was excavated in the Donkey Island area just east of Argonne Road (Deposit 2). The sediment cap that was placed at Deposit 1 was required to be 13 inches in depth. Of the 13 inches, 4 inches were bituminous coal, followed by 6 inches of clean sand, and then armored with 3 inches of gravel. The total size of the cap at Deposit 1 encompassed approximately 3.5 acres. Deposit 2 covered approximately 0.2 acres of contaminated sediment that was excavated as part of the remedial action. The estimated amount of contaminated sediment that was excavated at Deposit 2 is 600 cubic yards.

The first scheduled monitoring event at Deposit 1 to check the integrity of the sediment cap and sample the sediments for PCBs began in the fall of 2008. The results of the 2008 monitoring event found that the cap was fully intact with an additional 1 to 2 feet of deposited sand and woody material on top of the cap. The additional material is suspected to be as a result of the high spring-runoff flows that occurred in 2008. The core samples that were taken of the cap and the grab samples of the newly deposited sand did not detect PCBs higher than the cleanup value.

2003-2007 PCB Source Assessment

Goals

Sampling for the Spokane River PCB source assessment study was initially conducted by the Ecology Environmental Assessment Program from September 2003-July 2004. Additional fish and stormwater samples were collected in late 2005 and early 2007, respectively. The overall goal of this effort was to quantify PCB contamination and identify necessary reductions in sources and the receiving waters to meet applicable PCB water quality criteria for the Spokane River.

Objectives

Specific objectives of the study were to:

1. Obtain representative data on PCB concentrations and ancillary parameters in the Spokane River water column, NPDES permitted discharges, bottom sediments, and fish tissue.
2. Assess trends and natural recovery rates for PCBs in Spokane River sediments.
3. Determine the Spokane River's loading capacity for PCBs.
4. Evaluate a food web bioaccumulation model to predict PCB concentrations in Spokane River fish.

The first objective was addressed by sampling PCBs in industrial and municipal effluent, surface water, suspended particulate matter, stormwater, surface and sub-surface sediments, and fish tissue.

The second objective was achieved by analyzing PCBs in sediment cores.

Water column PCB measurements from semi-permeable membrane devices, a passive sampling technique, were used to assess the loading capacity of the Spokane River. Estimates of the PCB load reductions needed to meet the more stringent human health criteria of the Spokane Tribe were based on loading capacity and on current estimates of PCB discharges in effluent and stormwater.

The Arnot-Gobas food web bioaccumulation model (Arnot and Gobas, 2004) was employed to estimate site-specific critical PCB concentrations in water and sediment. Needed load reductions to meet water quality criteria were then estimated using PCB loading capacities derived from the model.

Field Data Collection

Sampling Locations

Sampling station locations for the source assessment study are shown in Figures 6-10. Coordinates and a description of each station location are in Appendix B.

For the purpose of this report, “Stations” are identical to the “User Location ID” in Ecology’s Environmental Information Management (EIM) database (available on the internet at www.ecy.wa.gov/eim/). All of the data for this project are available through EIM under the User Study ID named “DSER0010”, with two exceptions:

1) The Ninemile rainbow trout fillet data are under the User Location ID “Spokane-F” or the User Study ID “WSTMP03T”.
2) The 2007 stormwater data from the Parsons, (2007) study were entered into EIM under the User Study ID “brwa0004”.

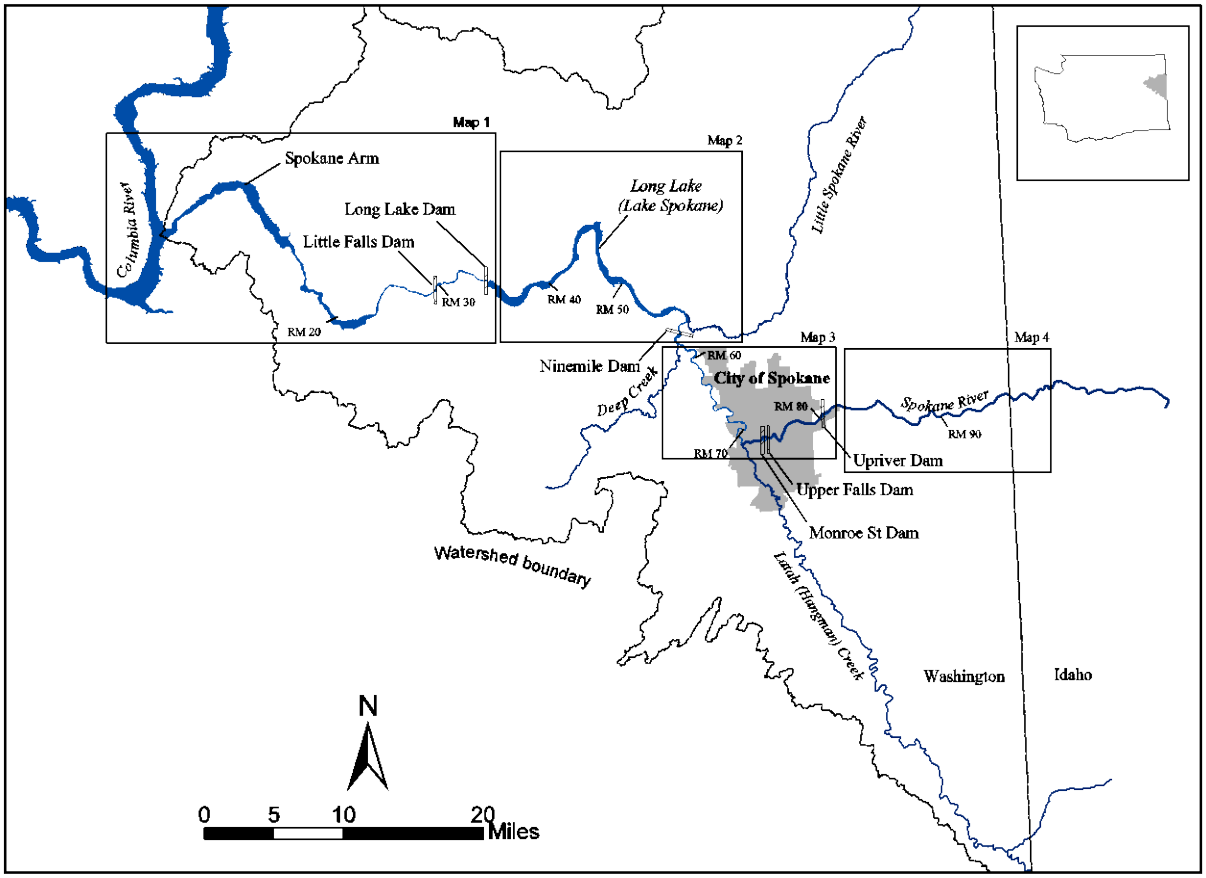

Figure 6. Sampling Maps for Spokane River PCB Source Assessment Study.

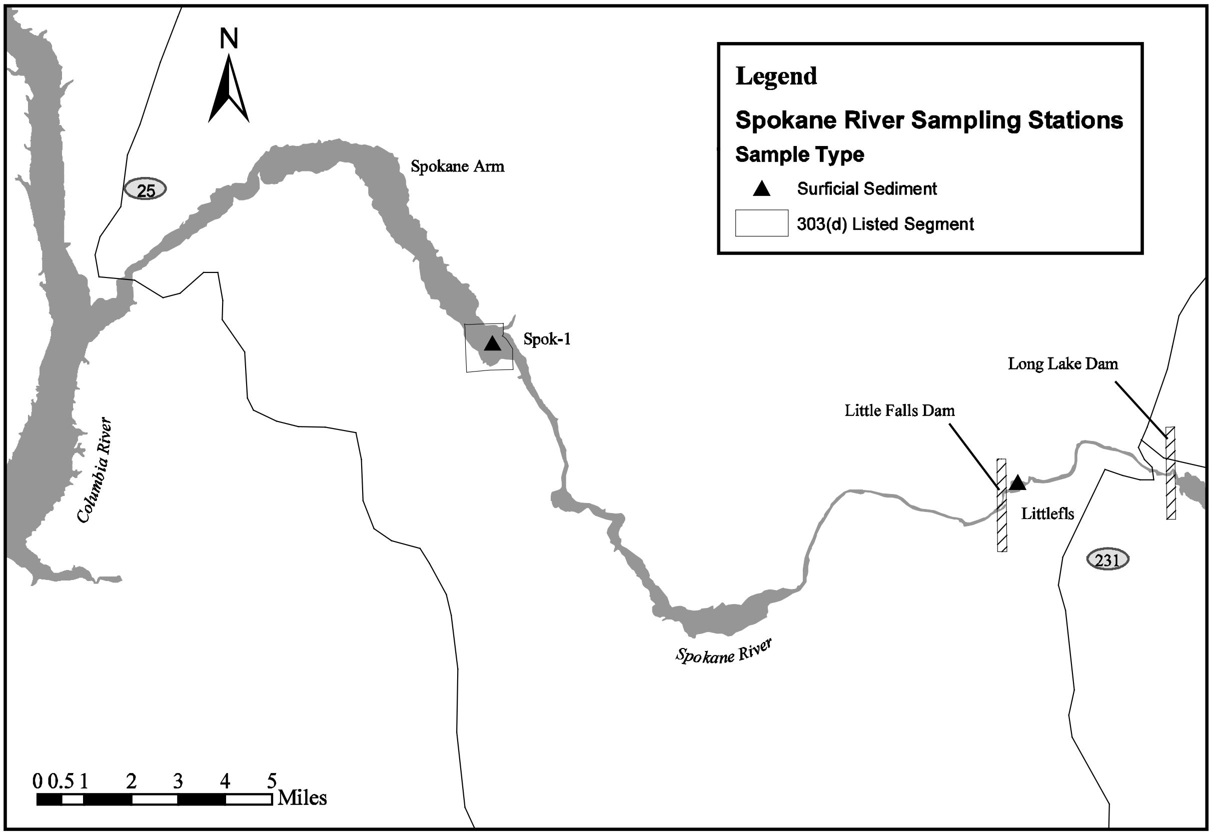

Figure 7. Sampling Map 1: Spokane River Mouth to Long Lake (Lake Spokane) Dam.

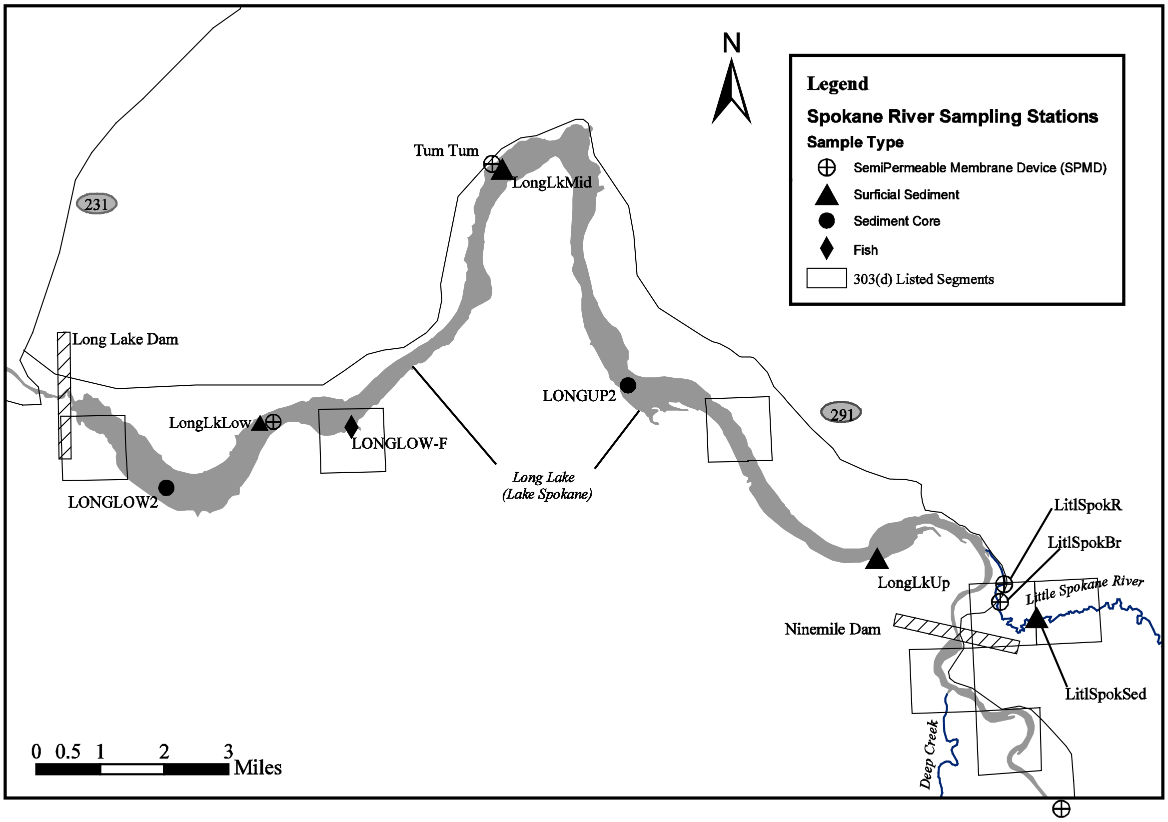

Figure 8. Sampling Map 2: Long Lake (Lake Spokane) Dam to Ninemile Dam.

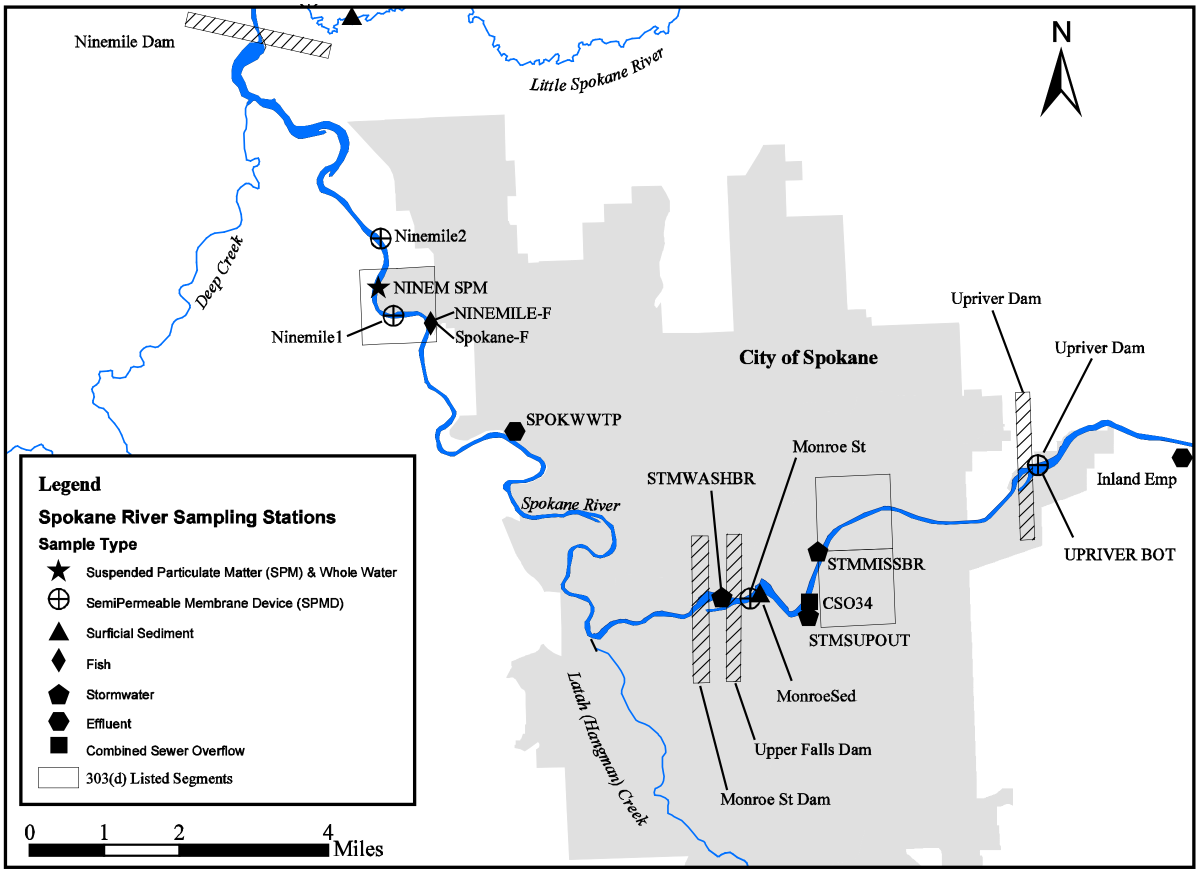

Figure 9. Sampling Map 3: Ninemile Dam to Upriver Dam.

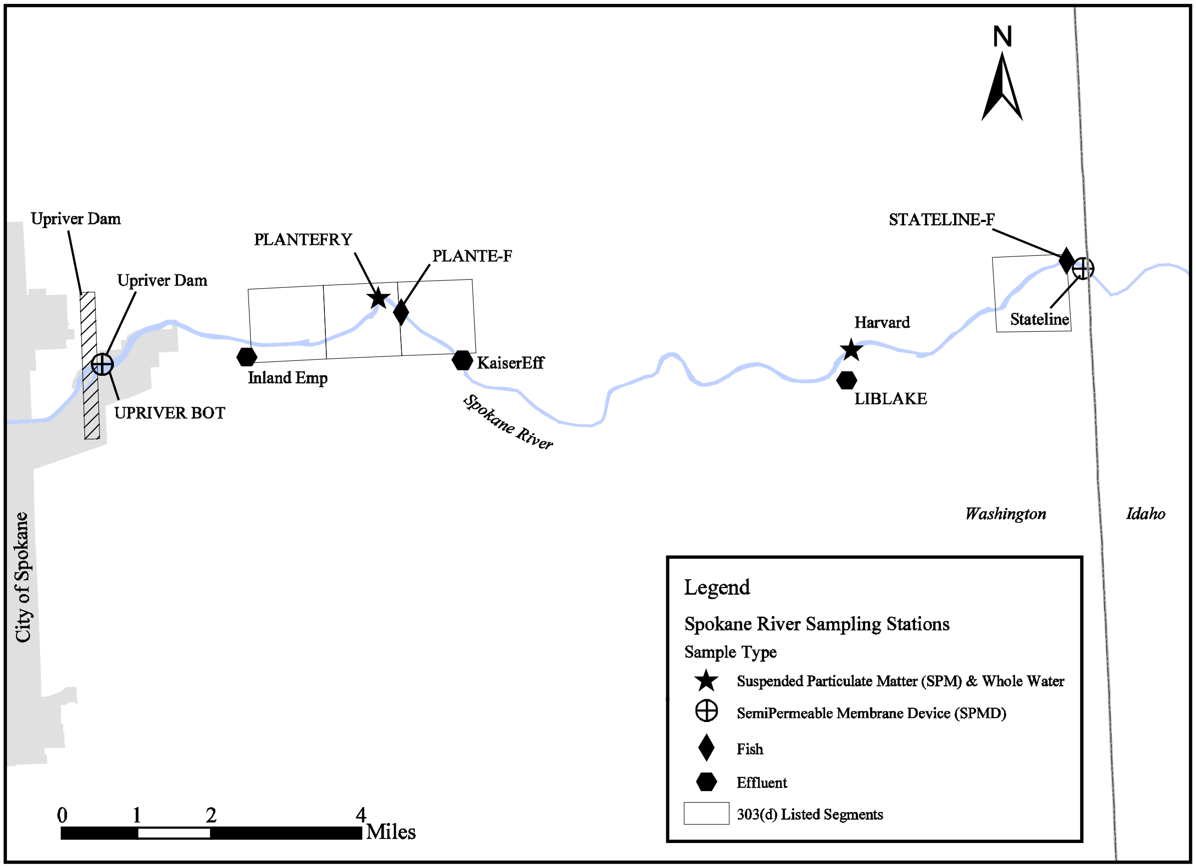

Figure 10. Sampling Map 4: Upriver Dam to Idaho Border.

Surface Water

Semipermeable Membrane Devices

Surface water at five Spokane River and one Little Spokane River locations was sampled using semipermeable membrane devices (SPMDs) obtained from Environmental Sampling Technologies (EST). SPMDs are passive samplers which consist of a 91 x 2.5 cm lay-flat polyethylene membranes filled with 1 mL triolein, a synthetic lipid that mimics biological uptake of dissolved organic compounds like PCBs. Membranes are mounted on “spider carriers” that hold the membranes during deployment and placed inside perforated stainless steel canisters, up to five membranes per can. The chemical residues accumulated in an SPMD can be used to calculate the ambient water column concentration for the chemicals of interest. Detailed information on SPMDs is in Appendix C. Table 8 shows locations where SPMDs were deployed.

Table 8. Locations and Dates of SPMD Deployments.

Location	Station	RM	Dates
State line	Stateline	96.1	10/1 - 10/29/2003 1/28 - 2/24/2004 4/14/04 - 5/12/2004
Behind Upriver Dam at mid-depth	Upriver Dam	80.3	10/1 - 10/29/2003 1/28 - 2/25/2004 4/14 - 5/12/2004
Behind Upriver Dam near bottom	UPRIVER BOT	80.3	10/1 - 10/29/2003 1/28 - 2/25/2004 4/14 - 5/12/2004
Behind Monroe St./Upper Falls Dam	Monroe St	74.8	10/2 - 10/29/2003 1/28 - 2/25/2004 4/14 - 5/12/2004
Ninemile Dam Pool upstream of Plese Flats	Ninemile1	63.6	10/1 - 10/29/2003 1/28 - 2/24/2004*
Ninemile Dam Pool near Sevenmile Bridge	Ninemile2	62.4	4/14 - 5/12/2004
Tum Tum	Tum Tum	44.2	1/29 - 2/24/2004
Lower Lake Spokane	LongLkLow	38.4	10/2 - 11/4/2003 4/13 - 5/11/2004
Little Spokane River at Rt. 291 bridge	LitlSpokBr	1.1	1/29 - 2/24/2004 4/14 - 5/12/2004
Little Spokane River ½ mile upstream of mouth	LitlSpokR	0.5	10/2 - 10/30/2003

*SPMD lost.

Canisters were deployed in the middle of the water column at Stateline, behind Upriver Dam, behind Upper Falls Dam (Monroe St.), upstream of Seven Mile Bridge (Ninemile), in Lake Spokane, and in the Little Spokane River near the mouth. In addition to the mid-depth SPMDs, deployments were also done approximately one foot above the bottom at the Upriver Dam site. The project plan called for one additional SPMD deployment in the lower two miles of Deep Creek, but the creek was too shallow for the sampler (Jack et al., 2003).

SPMD deployments occurred during October 2003, January-February 2004, and April-May 2004. These periods were selected to represent a range of river conditions: low flow in October, moderate flow in February, and high flows during spring runoff. Exposure periods were generally 28 days.

On arriving at the sampling site, the cans were opened, spider carriers were slid into the canisters, and the device was suspended in the water column. Because SPMDs are potent air samplers, the procedure was done as quickly as possible, typically one minute or less. Air exposure times were recorded for each event. Three SPMD membranes were used in each canister, with two canisters per sampling site. The dual canisters were used to minimize the risks of loss or vandalism. If both canisters were successfully recovered, the six membranes were combined for extraction. During each deployment period, one of the SPMD pairs from Upriver Dam was analyzed separately as a replicate. The dual canisters were deployed several meters apart at each station.

In some cases, alternative site selection was necessary due to variable flows or ice. The Lake Spokane SPMD was moved upstream to Tum Tum in January-February because the lower lake was frozen. The April deployment at Ninemile was moved downstream due to high flows, and the Little Spokane site was moved upstream from its original location for February and April sampling to improve accessibility. One of the two canisters was lost at Ninemile during October and at Stateline in April-May. In both instances the single canister (with three membranes each) contained enough material for complete analysis without compromising data quality. Both canisters were lost from Ninemile during January-February, the only event with lost data.

The SPMD retrieval procedure was essentially the opposite of deployment. Cans holding the SPMDs were sealed and shipped back to EST for extraction. EST then shipped the extracts to an accredited contract laboratory, Pace Analytical Services Inc., for PCB analysis.

A trip/field blank was prepared for each SPMD deployment by exposing dedicated membranes to air for the average time sample membranes were exposed. Trip blank membranes were treated the same as other membranes before and after sampling.

Temperature was monitored at 30-minute intervals throughout each deployment using a Tidbit® or I-button® temperature logger attached to the SPMD canister. At the beginning and end of each deployment period, grab samples for total organic carbon (TOC), dissolved organic carbon (DOC), and total suspended solids (TSS) were collected.

Suspended Particulate Matter and Whole River Water

Suspended particulate matter and whole water samples were collected at several locations to further assess water column PCB concentrations. Since hydrophobic organic chemicals like PCBs preferentially sorb to suspended particles, concentrations are more readily detectable, making it a useful surrogate for whole water. Suspended particles were collected using Sedisamp II continuous-flow centrifuges (model 101IL) in a manner described by Serdar et al. (1997) and previously used to collect particles in the Spokane River (Ecology, 1995). Table 9 shows locations and dates for sampling.

Table 9. Locations and Sampling Dates for Suspended Particulate Matter and Whole River Water.

Location	Station	RM	Dates (2003)
Harvard Road	Harvard	92.8	10/20 – 10/22
Plante Ferry Park	PLANTEFRY	84.8	10/28 – 10/30
Ninemile Pool at Plese Flats	NINEM SPM	63.2	11/3 – 11/5

A peristaltic pump set at a rate of 3-4 L/min. was used to draw water from an intake strainer situated in the middle of the water column approximately 10-20 meters offshore. All tubing and fittings were Teflon®, except for Silastic® tubing used at the pump head, and all centrifuge bowl parts in contact with samples were high quality stainless steel.

Water samples for TSS were collected from the centrifuge intake and outlet water each day to estimate particle removal efficiency. TOC and DOC samples were also collected during suspended particle sampling. Aliquots of intake water were periodically collected to provide a composite sample of whole river water for PCB analysis. Once sufficient material was obtained, the centrifuges were disassembled. Then the particulate matter was removed using a Teflon® spatula, and the particulate matter placed in appropriate sample containers. All samples were stored on ice in locked coolers while in the field.

Total mass of particulate matter collected was 9-17 g (dry weight), extracted from 8,700-9,600 L of river water. TSS concentrations in whole river water averaged 1-2 mg/L, and no TSS was detectable in the centrifuge outlet water at a reporting limit of 1 mg/L. Based on the average TSS values in the river and the dry weight of the particulate matter collected, the centrifuge extraction efficiencies were 71-89%, which is in the range of typical values using these centrifuges in similar water conditions (Yake, 1993). Ancillary data for suspended particulate samples are in Appendix D.

Effluents

Industrial and Municipal Wastewater Effluent

Final effluent from wastewater streams of four facilities were collected during unannounced visits on three occasions (Table 10). Samples were composites from two consecutive days, except at Kaiser Trentwood where final effluent was collected as discrete samples each day. Composite grab samples were also collected at the Kaiser wastewater stabilization lagoon and at the outlet of bed filters to assess the effect of particle removal on PCB concentrations.

Table 10. Outfall Locations and Dates of Industrial and Municipal Wastewater Effluent Samples.

Facility	Station	RM	Dates
Liberty Lake Sewer District WWTP	LIBLAKE	92.7	10/21– 22/2003 2/2 – 3/2004 4/26 – 27/2004
Kaiser Trentwood - Effluent	KaiserEff	86.0	10/21 – 22/2003 2/2 – 3/2004 4/26 – 27/2004
Kaiser Trentwood - Lagoon	KaiserLag	--	10/21 – 22/2003 2/2 – 3/2004 4/26 – 27/2004
Kaiser Trentwood - Below Filter	KaiserFilt	--	10/21 – 22/2003 2/2 – 3/2004 4/26 – 27/2004
Inland Empire Paper Company	Inland Emp	82.5	10/21 – 22/2003 2/2 – 3/2004 4/26 – 27/2004
City of Spokane WWTP	SPOKWWTP	67.4	10/21 – 22/2003 2/2 – 3/2004 4/26 – 27/2004

Samples were obtained by dipping a pre-cleaned glass container into the waste stream, either by hand or a stainless steel pole. Two-day composites included two quart grabs per day (morning and afternoon). A transfer blank was also collected during each round of sampling by pouring deionized water prepared at Manchester Environmental Laboratory into sample containers while on site. TSS samples were also collected as two-day grab composites at all facilities. Samples were placed on ice while in the field and maintained in coolers for transport with a chain-of-custody record.

Urban Stormwater

2004 Sampling

Three storm drains and one CSO were sampled during June 2004 (Table 11). Sampling was conducted by City of Spokane personnel during a runoff event produced by approximately 0.5 inches of rain in a 24-hour period. This event represented approximately one-half of the total precipitation for the month.

The storm-drain and CSO sites were selected by City of Spokane personnel based on recommendations by Ecology that the sites should be heavily developed with industrial land use preferred, outfalls should be upstream of the Monroe St. Dam, and at least one should be a CSO outfall.

Table 11. Outfall Locations and Date of 2004 Storm Drain and CSO Samples.

Drain	Station	RM	Date
Mission Ave. and Perry St.	STMMISSBR	76.5	6/10/04
CSO at Erie St.	CSO34	75.8	
Superior St. near Cataldo St.	STMSUPOUT	75.7	
Washington St. Bridge	STMWASHBR	74.3	

The plan called for five storm drain/CSOs sampled during two runoff events, but a lack of precipitation, poor timing, and interference with other priorities of the City's stormwater sampling program precluded the successful completion of the plan.

2007 Contracted Sampling

In 2007 Ecology commissioned Parsons Inc. to conduct a Spokane stormwater study that sampled 14 sites including the four previously sampled storm drains/CSO. Stormwater sites were selected to be within the city limits and to discharge stormwater directly to the Spokane River. Parsons' subcontractor, TerraGraphics Environmental Engineering Inc., collected stormwater grab samples for PCBs and TSS during three storm events in May and June of 2007. The storm-event rainfall measured ranged from 0.29 to 0.86 inches and was preceded by more than four days of dry weather (Parsons, 2007).

Stormwater sampling locations for the Parsons study are described in Table 12.

Table 12. 2007 Stormwater Sampling Locations

Location ID	City Manhole Identifier	Latitude†	Longitude†	Location Description
STMWTR_ HWY291	0106436ST	47.73423	-117.507	Near the southwest corner of the intersection of Parkway Road and Ninemile Road (Hwy 291).
STMWTR_ 7TH	2000318ST	47.64898	-117.445	Next to light pole on southeast side of curb at intersection of 7th Street and Inland Empire. This is a combined sewer overflow (CSO 26).
STMWTR_ HSTREET	0400621ST	47.69031	-117.464	In the middle of H Street next to the alley north of Glass and south of Northwest Boulevard. This is a combined sewer overflow (CSO 07).
STMWTR_ COCHRAN	0501142ST	47.68353	-117.448	In the middle of Cochran Street, north of Grace Avenue west of TJ Meenach Drive Southern (and downstream) of two manholes.
STMWTR_ LINCOLN	0906615IN	47.66256	-117.425	Catch basin in sidewalk east of Lincoln Street next to Anthony's Restaurant, north of Post Street Bridge.
STMWTR_ CLARKE	1900330ST	47.65836	-117.439	Off north side of the curb of Clarke Street, east of Elm Street. This is a combined sewer overflow (CSO 24A).
STMWTR_ HOWARDBR	1000124ST	47.66485	-117.421	Northeast of Howard Bridge (walking bridge), just south of intersection with Mallon Avenue. In the middle of the trail. South of circle, approximately 12 feet east of catch basin, near map sign.
STMWTR_ UNION	1382924ST	47.66148	-117.392	In the middle of the street in front of the Union Gospel Mission, just south of intersection of Erie Street and Trent Avenue.
STMWTR_ RIVERTON	1800130ST	47.66751	-117.389	At the intersection of South Riverton Avenue and Desmet Avenue on the river side of the guardrail.
STMWTR_ GREENE	1680120ST	47.67772	-117.364	South of the Greene Street bridge, located on the sidewalk east of the bridge.
STMWTR_ WASHINGT	1100230ST	47.664	-117.418	North and west of Washington Street bridge. Located where the two paved walking trails converge. Previously named "stmwashbr."
STMWTR_ SUPERIOR	1300136ST	47.66579	-117.393	In the middle of Superior Street, south of Cataldo Avenue. Previously named "stmsupout ."
STMWTR_ ERIECSO	0521966CD	47.66108	-117.393	South of Trent Avenue on Erie Street south of site 4217. Middle of three manhole covers in parking area of park. This is a combined sewer overflow (CSO 34). Previously named "CS034."
STMWTR_ MISSION	1400224ST	47.67227	-117.39	Northeast of the intersection of Perry Street and Mission Avenue near Avista. Previously named "stmmissbr ."

† in decimal degrees
From Parsons, 2007.

Bottom Sediment

Surficial Deposits

Ecology collected surficial (top 2 cm) bottom sediments at several locations in the Spokane River, Little Spokane River, and a reference site. Surface sediment samples were collected from an Ecology boat using a 0.1 m^2 stainless steel van Veen or a 0.01 m^2 Petite Ponar grab sampler. Sediments from the Little Spokane were taken from the right bank using a pipe dredge.
Sites were selected to assess the possibility of high concentrations of PCBs behind Monroe St. Dam, assess the longitudinal PCB concentration gradient in Lake Spokane, evaluate the potential of the Little Spokane River as a significant PCB source, and assess PCB concentrations in previously unexamined Spokane River reaches downstream of Lake Spokane.

The same reference site (Buffalo Lake) selected for an earlier bioassay survey of the Spokane Arm of Lake Roosevelt (Era-Miller, 2004) was used to provide reference sediments for the present 2003-07 study. It is located in a remote area of Okanogan County west of Spokane and receives contamination only through atmospheric deposition. An EPA study conducted during 2002 found low a PCB concentration (5.6 ng/g total PCBs) in largemouth bass fillets from Buffalo Lake (unpublished EPA data).

Table 13 lists locations for surficial sediment sampling. The riverbed behind the Monroe St. Dam in the vicinity of RM 76 and downstream of Little Falls Dam in the vicinity of RM 18-29 was composed almost entirely of gravel and cobble, and therefore no samples were collected.

Table 13. Locations and Dates of Surficial Sediment Samples.

Location	Station	RM	Date
Behind Monroe St./Upper Falls Dam	MonroeSed	74.9	4/14/2004
Lake Spokane (Long Lake)	LongLkUp	54.3	5/11/2004
	LongLkMid	44.3	11/4/2003
	LongLkLow	38.4	11/4/2003
Little Falls Pool	Littlefls	29.9	11/4/2003
Spokane Arm at Porcupine Bay	SPOK-1	12.6	11/6/2003
Little Spokane River	LitlSpokSed	2.3	12/10/2003
Buffalo Lake (reference)	BUFFALO REF	--	11/5/2003

Sediment Cores

Ecology collected sediment cores from the upper and lower reaches of Lake Spokane to assess trends in historic PCB deposition and to estimate sediment recovery rates (Table 14). Cores were collected using a Wildco 50-cm stainless steel gravity box corer fitted with a 13 cm by 13 cm (inner diameter) transparent acrylic liner.

Table 14. Locations and Dates of Sediment Cores.

Location	Station	RM	Date
Upper Lake Spokane	LONGUP2	49.2	6/9/2004
Lower Lake Spokane	LONGLOW2	36.0	11/4/2003

Fish and Crayfish Tissue

Ecology obtained fish and crayfish for PCB analysis from seven locations in the Spokane River from 2003 to 2005 (Table 15). For 2003 and 2004, the goal was to collect rainbow trout (>250 mm) and two size classes of largescale suckers (250-350 mm and <200 mm) at each site except Upriver Dam. Crayfish were collected at Upriver Dam due to interest in their possible accumulation of PCBs at the cleanup site. All biological data on specimens used for analysis are in Appendix E.

The goal for 2005 sampling was to provide high quality representative data to WDOH for use in a human health assessment and in reviewing the current fish consumption advisory stemming from data collected in 1999 and 2001. A secondary objective was to examine contaminant trends within the river system. Rainbow trout were not found during extensive efforts to capture them at Stateline and lower Lake Spokane. Largescale suckers were numerous at all sites except in the Ninemile reach where bridgelip suckers were the dominant species. The smaller size class of largescale suckers was not found at any of the sites sampled, even when various capture methods were employed.

Fish were collected primarily using Ecology's 16' Smith-Root electrofishing boat. Largescale suckers from Lake Spokane were captured using variable mesh gillnet sets on the lake bottom. Specimens were held in the vessel's live well and checked for species identification and desired length. Crayfish were collected using basket-cone style crayfish traps baited with cat food and set on the bottom overnight.

Fish selected for analysis were killed by a blow to the head. Each fish was given a unique identifying number, and its length and weight were recorded. The fish were individually wrapped in aluminum foil, put in plastic bags, and placed on ice for transport to Ecology headquarters, where the samples were frozen pending preparation of the tissue samples.

Crayfish were placed in a pre-cleaned 1 gallon glass jar and held on ice in coolers while in the field. Upon returning to Ecology headquarters, specimens were measured, weighed, and identified using an invertebrate species key. Following identification, specimens were returned to the jar and frozen until resection.

Table 15. Locations and Dates of Fish and Crayfish Samples.

Location	Station ID	RM	Latitude	Longitude	Species	Tissue	Dates
Near state line with Idaho	STATELINE-F	96.0	47.6981	-117.044	Largescale sucker	Whole body	7/14/04[*]
	SPK 96	96.0	47.69832	-117.044			8/22/05[†]
Near Plante Ferry Park	PLANTE-F	85.0	47.69459	-117.239	Rainbow trout	Fillet Gut contents	9/15/03[*]
					Largescale suckers	Whole body Gut contents	
	SPK 85	85.0	47.69498	-117.24	Rainbow trout	Fillet	8/23/05[†]
					Largescale suckers	Whole body	
Behind Upriver Dam	Upriver Dam	80.3	47.6869	-117.325	Crayfish	Tail muscle	5/13/04[*]
Mission Park	SPK 77	77.0	47.67655	-117.382	Mountain whitefish	Fillet	9/28/05-9/29/05[†]
	SPK 75.2	75.2	47.66401	-117.404	Largescale sucker	Whole body	9/28/05[†]
					Rainbow trout	Fillet	
Ninemile reservoir (near Seven Mile Bridge)	Spokane-F	61.7	47.7324	-117.51	Rainbow trout	Fillet	9/16/03[*]
	NINEMILE-F	61.7	47.74299	-117.522	Rainbow trout	Gut contents	
	NINEMILE-F	61.7	47.74299	-117.522	Bridgelip sucker	Whole body Gut contents	7/13/04[*]
	SPK 64.0	64.0	47.72043	-117.501	Rainbow trout	Fillet Whole body	9/29/05[†]
					Mountain whitefish	Fillet Whole body	
					Bridgelip sucker	Fillet Whole body	
Upper Lake Spokane	SPK 55.6	55.6	47.80089	-117.549	Largescale sucker	Whole body	9/27/05[†]
					Smallmouth bass	Fillet	
					Mountain whitefish	Fillet	
	SPK 55.2	55.2	47.80156	-117.558	Brown trout	Fillet	11/3/05[†]
Lower Lake Spokane	SPK 40.1	40.1	47.83472	-117.737	Mountain whitefish	Fillet	11/3/05[†]
		40.8	47.84152	-117.725	Smallmouth bass	Fillet	
	LONGLOW-F	39.4	47.82769	-117.745	Largescale sucker	Whole body	7/13/04-7/14/04[*]

[*] Sampling conducted in support of the present study. See Jack et al. (2003) for Quality Assurance Project Plan.

[†] Serdar and Johnson (2006).

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Sample Preparation

Sample containers and holding times for 2003-2005 are shown in Table 16. The fish and crayfish tissue preparation techniques used are described in Appendix F. See Parsons (2007) for sample preparation, analytical methods, and data quality information for stormwater samples collected in 2007.

Analytical Methods

All PCB congener samples and percent lipid in tissue were analyzed at Pace Analytical Services, Inc., Minneapolis, MN. PCB Aroclors, TOC in sediments, and TOC, DOC, and TSS in water were analyzed at Manchester Environmental Laboratory. SPMD preparation and dialysis was done at Environmental Sampling Technologies (EST), St. Joseph, MO. Radioisotope analysis of sediment cores was done at Teledyne Brown Engineering, Knoxville, TN. Grain size analysis was done at Analytical Resources, Inc., Tukwila, WA.

Table 16 shows analysis methods and reporting limits for sample media.

Table 16. Preparation Methods, Analytical Methods, and Reporting Limits for the Spokane River Samples.

Sample Media	Parameter	Preparation Method	Analytical Method	Reporting Limits
Semipermeable Membrane Device (SPMD)	PCB Congeners	Dialysis and ampulization - EST SOP	GC/HRMS, EPA Method 1668A	100 ng/4 ML dialysate (per congener) translates to approx. 0.1 - 1 pg/l (per congener)
Water	PCB Congeners	--	GC/HRMS, EPA Method 1668A	100 pg/l (per congener)
	TSS	--	EPA Method 160.3	1 mg/L
	TOC	--	EPA Method 415.1	1 mg/L
	DOC	--	EPA Method 415.1	1 mg/L
Sediment (Suspended particulate matter and surficial sediment)	PCB Congeners	Soxhlet extraction	GC/HRMS, EPA Method 1668A	0.05 ng/g (per congener)
Sediment	PCB Congeners	Soxhlet extraction	GC/HRMS, EPA Method 1668A	0.05 ng/g (per congener)
	TOC (104 °C)	--	Combustion	0.1%
	Grain size	--	Sieve and Pipet	±0.5% for each fraction
Sediment (Core)	PCB Aroclors	Soxhlet extraction	GC/ECD, EPA Method 8082	1 - 25 ng/g (per Aroclor)
	TOC (104 °C)	--	Combustion	0.1%
	Pb-210	--	Gamma detection	--
Tissue	PCB Congeners	Soxhlet extraction	GC/HRMS, EPA Method 1668A	0.01 - 0.05 ng/g (per congener)
	% lipids	--	Gravimetric	0.1%

SOP = Standard operating procedure.

Data Quality Assessment

Ecology's Manchester Laboratory reviewed the chemical data for this project. For results generated by Manchester, final data review was performed by the unit supervisor or an analyst experienced with the method. Manchester chemists performed the review for analytical work sub-contracted to commercial laboratories. Quality assurance and quality control at Manchester are described in the *Lab Users Manual* http://aww.ecologydev/programs/eap/forms/labmanual.pdf (Ecology Intranet).

Manchester prepared written case narratives assessing the quality of all data collected. These reviews include a description of analytical methods and an assessment of holding times, initial and continuing calibration and degradation checks, method blanks, surrogate recoveries, internal standard recoveries, matrix spike recoveries, laboratory control samples, and laboratory duplicates. The reviews and the complete Manchester data reports are available from the author on request.

A Quality Assurance Project Plan (Jack, 2003) established measurement quality objectives (MQOs) for accuracy, bias, and reporting limits. To determine if MQOs were met, the project lead compared results on field and laboratory quality control samples to the MQOs. To evaluate whether the reporting limit targets were met, the results were examined for non-detects and to determine if any values exceeded the lowest concentration of interest. Based on these assessments and a review of the laboratory data packages and Manchester's data verification reports, the data were either accepted, accepted with appropriate qualifications, or rejected and re-analyzed or re-sampled where possible.

The precision and accuracy of the 2003-2005 data reported here can be gauged from results on laboratory duplicates, field replicate samples, and standard reference materials, detailed in Appendix G. The relative percent difference (RPD) between duplicate (split) and replicate (separately collected) samples was 20% or better for PCBs in effluents, fish tissue, and sediment. Greater variability was encountered in analyzing PCBs in SPMD extracts, 9-55% RPD. Results from analyzing PCB congeners in a sediment standard reference material agreed within 13% of certified values, on average.

Results and Discussion

Dissolved PCBs in Spokane River Water

Ancillary water quality data collected in concert with SPMD deployments are shown in Table 17. Organic carbon concentrations were low at all sites. DOC constituted approximately 92% of the TOC on average. TSS concentrations were generally ≤3 mg/L with higher values (4-10 mg/L) occurring in February and April.

With a few exceptions, average temperatures were similar at all mainstem locations during each deployment. Stateline and Lake Spokane were approximately 1.5ºC warmer than other sites in October, but Stateline temperatures were slightly colder in February. Lake Spokane temperatures were also the warmest among mainstem sites in February. At Upriver Dam, bottom and middle water column temperatures were nearly identical.

Dissolved PCB concentrations determined from analyzing the SPMD membranes are shown in Table 18. A summary of the PCB residues accumulated in the membranes (raw data) is in Appendix C.

Concentration estimates for dissolved total PCBs ranged from 34 pg/l (parts per quadrillion) at Stateline during February (2004) to a maximum of 656 pg/l at lower Lake Spokane during October (2003). PCBs were composed primarily of tri- through heptachlorobiphenyl congeners. Spokane River total PCBs showed a fairly consistent trend of increasing concentrations moving downstream. Generally, dissolved total PCB concentrations were comparatively low at Stateline and Upriver Dam (34-145 pg/l), intermediate at Monroe St. and Ninemile (76-305 pg/l), and highest at Lake Spokane (78-656 pg/l). Total PCB concentrations in the Little Spokane River were 118-178 pg/l. The PCB mixture in the Little Spokane was enriched in octa, nona, and deca homologues compared to the mainstem Spokane River, suggesting a difference in sources.

There was evidence of seasonal differences in total PCB levels, with concentrations highest during October and lowest during February (Figure 11). Total PCB measured during October and April appeared similar at all reaches except for a large divergence at Lake Spokane. One possible reason for the much higher PCB concentration in Lake Spokane in October is the fall breakdown of stratification, which allowed bottom water enriched in PCBs to mix with the upper water column. This is consistent with SPMD findings for Upriver Dam, discussed below.

Table 17. Ancillary Parameters at SPMD Sites (mg/L).

Station Name	Sample Number	Collection Date	DOC		TOC		TSS		Mean Temp. (ºC)
Stateline	3408971	10/1/03	1.1		1.3		1	U	14.4
	3448107	10/29/03	1.1		1.2		2		
	4058111	1/28/04	1.4		1.3		1	U	3.2
	4094040	2/24/04	1.2		1.3		1		
	4164041	4/14/04	1.2		1.6		3		10.8
	4208134	5/12/04	1		1.2		2		
Upriver Dam	3408966/72*	10/1/03	1.2		1.5		2		12.7
	3448108	10/29/03	1		1.2		1		
	4058112	1/28/04	1.2		1.4		1		3.5
	4094044/5*	2/25/04	1.2		1.3		2		
	4164042/3*	4/14/04	1.6		1.7		3		10.8
	4208135	5/12/04	1		1.1		2		
UPRIVER BOT	--	10/1/03	--		--		--		12.7
	--	10/29/03	--		--		--		
	--	1/28/04	--		--		--		3.6
	4094046	2/25/04	1.1		1.3		2		
	4164044	4/14/04	1.3		1.4		3		9.8
	4208136/7*	5/12/04	1.1		1.1		2		
Monroe St	3408968	10/2/03	1	U	1	U	1	U	12.0
	3448109	10/29/03	1	U	1.1		1		
	4058113	1/28/04	1	U	1.1		2		4.0
	4094047	2/25/04	1.2		1.2		1		
	4164045	4/14/04	1.4		1.3		3		10.8
	4208138	5/12/04	1	U	1.3		2		
Ninemile1	3408967	10/1/03	1	U	1	U	1	U	12.3
	3448110	10/29/03	1.1		1.3		2		
	4058114/5*	1/28/04	1.2		1.3		2		--
	4094041	2/24/04	1.4		1.8		4		
Ninemile2	4164046	4/14/04	1.4		1.4		6		10.8
	4208139	5/12/04	1		1.1		2		
LongLkLow	3408969	10/2/03	1.1		1.1		2		14.4
	3454120	11/4/03	1	U	1	U	2		
	4164040	4/13/04	1.1		1.5		4		10.8
	4208133	5/11/04	1.1		1.3		3		
Tum Tum	4058117	1/29/04	1		1.1		2		4.5
	4094043	2/24/04	2.1		2.6		4		
LitlSpokR	3408970	10/2/03	1	U	1	U	1		
	3448111	10/30/03	1	U	1	U	2		14.4
LitlSpokBr	4058116	1/29/04	1	U	1	U	8		4.5
	4094042	2/24/04	2.7		2.2		10		
	4164047	4/14/04	1.3		1.7		7		
	4208140	5/12/04	1.1		1	U	5		10.8

*Mean of replicate analysis.

U: The analyte was not detected at or above the reported result, equivalent to <1.

Stateline: Spokane River at the Idaho state line just downstream of Interstate 90 bridge.

Upriver Dam: Spokane River upstream of Upriver Dam.

UPRIVER: Spokane River upstream of Upriver Dam, 2 feet from bottom of riverbed.

Monroe St: Spokane River upstream of Monroe Street Dam.

Ninemile1: Spokane River at Riverside State Park.

Ninemile2: Spokane River downstream of boat launch at Plese Flats

LongLkLow: Lower Lake Spokane.

Tum Tum: Lake Spokane near Tum Tum.

LitlSpokR: Little Spokane River at State Route 291 bridge.

Table 18. SPMD Dissolved PCB Concentrations Grouped by Homologues (pg/l), 2003-2004.

Station Name	Sample Number	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
October 2003												
Stateline	474155	0.4	1.5	11	15	56	19	7.9	2.4	0.0	0.0	113
Upriver Dam	474156/7*	0.7	5.5	25	26	32	10	3.7	0.0	0.0	0.0	103
UPRIVER BOT	474158	0.4	5.0	31	48	43	13	4.8	0.7	0.0	0.0	145
Monroe St	474159	0.6	8.6	32	60	65	42	18	3.0	0.0	0.0	231
Ninemile1	474160	0.3	13	63	61	95	49	21	3.1	0.0	0.0	305
LongLkLow	474161	0.7	15	59	269	195	74	32	9.3	2.3	0.0	656
LitlSpokR	474162/3*	0.2	1.0	12	27	33	16	12	11	6.4	0.0	118
February 2004												
Stateline	194130	0.0	0.0	1.8	4.6	14	8.9	5.0	0.0	0.0	0.0	34
Upriver Dam*	194131/2*	0.1	0.6	5.6	12	15	3.7	19	0.0	0.0	0.0	56
UPRIVER BOT	194133	0.0	0.3	10	40	22	4.1	0.8	0.0	0.0	0.0	78
Monroe St	194134	0.0	1.0	9.5	21	20	13	11	0.0	0.0	0.0	76
Ninemile1	--	--	--	--	--	--	--	--	--	--	--	--
Tum Tum	194135	0.0	1.4	12	24	18	8.9	13	0.1	0.0	0.0	78
LitlSpokBr*	194136/7*	0.1	0.4	9.1	35	51	16	12	13	6.9	0.0	143
April 2004												
Stateline	208134	0.0	0.3	8.0	17	60	32	27	2.1	0.0	0.0	145
Upriver Dam	208135	0.0	0.0	2.1	16	14	6.6	4.6	0.9	0.0	0.0	45
UPRIVER BOT*	208136/7*	1.8	1.0	24	78	57	17	11	0.5	0.0	0.0	191
Monroe St	208138	0.1	1.8	21	53	80	40	31	4.0	0.0	0.0	231
Ninemile2	208139	0.5	2.6	25	57	68	40	28	3.9	0.0	0.0	225
LongLkLow	208133	0.6	6.0	25	94	84	34	16	3.3	0.0	0.0	263
LitlSpokBr*	208140/1*	0.4	0.8	18	37	53	19	23	14	10	3.1	178

*Mean of replicate analysis.
Note: Reporting limits were variable, 0.1 – 10 pg/l.

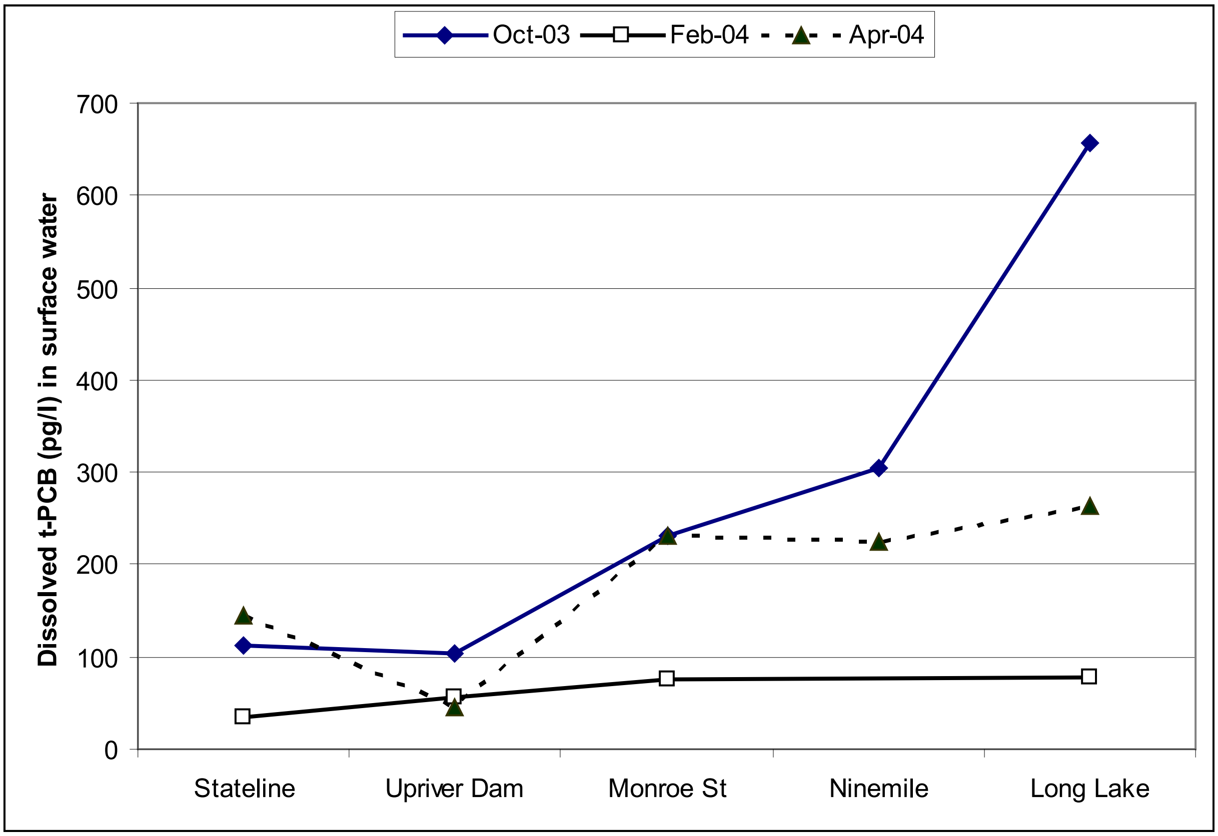

Figure 11. Dissolved Total PCBs in the Spokane River, 2003-2004.

Dissolved PCBs at Monroe Street, Ninemile, and lower Lake Spokane did not meet (exceeded) Washington State's human health water quality criterion of 170 pg/l. During October, the total PCB concentrations at these sites ranged from 231 to 656 pg/l. In April, the concentration range was 231 to 263 pg/l. The Little Spokane River was at the criterion in April (178 pg/l).

The February total PCB concentrations were similar among reaches and low compared to other months. Lower concentrations during this deployment may have been more a result of colder temperatures which reduce the SPMD sampling rate but is not accounted for in calculations used to translate SPMD PCB residues to surface water concentrations (see Appendix C). This may also explain the consistent total PCB concentrations in the Little Spokane River, since February and April temperatures at this location were 2-3ºC warmer. Simple flow dilution does not explain the differences among deployments since Spokane River discharge was highest during April (325 m^3/s at Spokane), lowest during October (49 m^3/s), and intermediate during February (114 m^3/s).

One objective of the SPMD sampling at the Upriver Dam cleanup site was to assess PCB levels at different depths. Samplers deployed 1-2 feet from the bottom had consistently higher concentrations than those at mid-depth (12-13 feet above bottom, Figure 12). The difference was pronounced in April when the bottom sample was four times the mid-column sample, even though the temperature was 1ºC lower (and thus a slightly lower sampling rate) at the bottom. Temperatures at both depths were identical during the other deployments.

At the time of sampling, higher PCB concentrations near the bottom were expected at this site which has PCB contaminated sediments that had yet to undergo state-directed cleanup (see previous Upriver Dam discussion). Although the high level of organic carbon in some of the PCB contaminated sediments theoretically sequesters PCBs, some diffusion to the water column occurs which was captured by the near-bottom SPMDs.

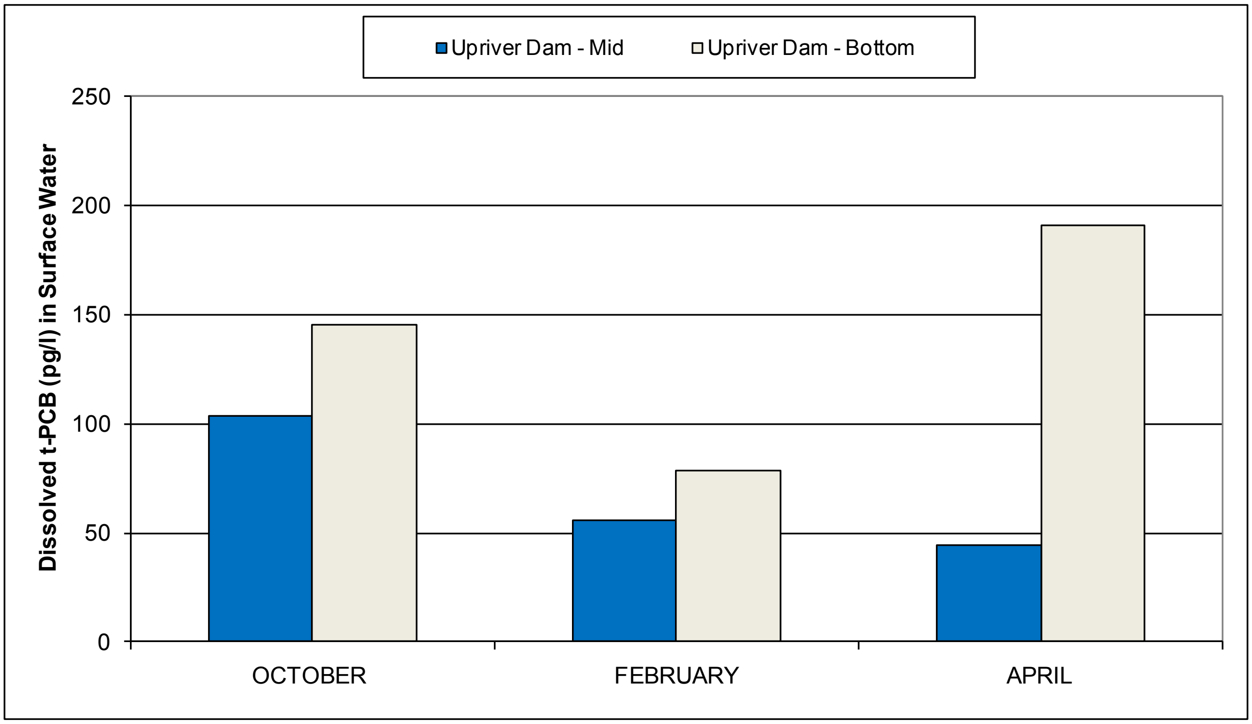

Figure 12. Dissolved Total PCBs at Mid-depth and Near the Bottom at Upriver Dam.

PCBs in Spokane River Suspended Particulate Matter

PCBs were measured in suspended particulate matter (SPM) and whole water from the Spokane River at Harvard Rd., Plante Ferry, and Ninemile during three two-day events in October-November 2003. For each sample collection (Oct 20-21, Oct 28-29, and Nov 3-4), a generator run pump was used to draw water up to a large centrifuge. Whole water samples were pumped to a sample container immediately upstream of the centrifuge. Ancillary water quality parameters included TOC, DOC, and TSS (Appendix D). TOC and DOC values were generally ≤1 mg/L. TSS averaged 1 mg/L at Harvard Road and Ninemile and 2 mg/L at Plante Ferry.

In SPM, PCBs were composed primarily of tetra-, penta-, and hexachlorobiphenyl congeners (Table 19). [Compared to dissolved PCBs which were composed primarily of tri- through heptachlorobiphenyl congeners. See previous discussion on dissolved results for the Spokane River.] Total PCB concentrations in suspended particles from Ninemile (69 ng/g, parts per billion) were an order of magnitude higher than those upstream (7.1-9.6 ng/g). The low TSS concentrations during all three sampling events indicate that differences in total PCB concentrations were not due to sediment entrainment.

For the most part, detection limits in the whole surface water samples were not low enough to afford a useful comparison with the SPM data. No PCBs were detected in the whole water samples collected at Harvard Rd. or Plante Ferry at the 110 pg/l level, and only a low concentration (130 pg/l) of dichlorobiphenyl congeners was detected at Ninemile (Table 19). This is an unusual finding considering the relatively low concentration of this homologue group in SPM and SPMDs.

Earlier (1994) SPM sampling by Ecology (1995) at Plante Ferry yielded much higher PCB concentrations (220 ng/g) using the same collection methods as the present 2003-07 study. Although that result was obtained using an Aroclor rather than congener analysis, river conditions were similar, TSS was low (<1 mg/L), and the sampling site was nearly identical.

To examine the proportion of solid and dissolved phase PCB concentrations in the Spokane River, the following partition formula was applied to the SPM data:

Equation 3. $$\boldsymbol{Fraction\ of\ dissolved\ PCB} = \frac{\mathbf{1}}{(\mathbf{1}+(\boldsymbol{f_s}*\boldsymbol{f_{oc}}*\boldsymbol{K_{oc}}))}$$

Where:

- f_s = fraction of solid in water.
- f_{oc} = fraction of organic carbon in the solid phase.
- K_{oc} = sediment-water partition coefficient normalized for organic carbon.

This formula assumes that PCBs are in equilibrium between the solid and dissolved phases, and the proportion in each phase is governed by the amount of solids in the water and the organic carbon content of the solid material. K_{oc}, the sediment-water partition coefficient normalized for organic carbon, is a field or laboratory-derived constant for each chemical. Values for f_s were from TSS measurements (1 or 2 mg/L; i.e., f_s = 0.000001 or 0.000002). Values for f_{oc} (0.15) and K_{oc} (449,000) are from EPA (1994) and DiToro et al. (1991), respectively, and are the same values used by Ecology (1995) to calculate a dissolved PCB concentration in water from earlier sampling.

Based on sediment-water partitioning, approximately 94% of the PCBs are in the dissolved phase. Dissolved total PCB concentration for Harvard Rd. and Plante Ferry are 142 and 105 pg/l, respectively, similar to results derived from SPMD deployments at Stateline and Upriver Dam during the same period (≈110 pg/l). The theoretical dissolved concentration of total PCBs was 1,020 pg/l at Ninemile, more than three times the concentration measured with SPMDs (305 pg/l) during October (in Table 18).

Table 19. PCB Concentrations Grouped by Homologues in Suspended Particulate Matter (ng/g, dw) and Whole River Water Collected at the Centrifuge Inlet (pg/l) During Three Sampling Events from October to November 2003.

	Station	Sample Number	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
Suspended Particulate Matter													
Spokane R at Harvard Rd	Harvard	3438100	<0.09	0.11	0.51	0.96	2.91	3.40	1.39	0.32	<0.09	0.09	9.60
Spokane R at Plante Ferry Park	PLANTEFRY	3448100	<0.05	0.09	0.41	1.34	2.49	1.98	0.70	0.08	<0.05	0.05	7.09
Spokane R at Riverside State Park	NINEM SPM	3454105	<0.07	0.39	3.71	12.9	24.6	18.6	6.30	1.71	0.39	0.15	68.8
Whole Water Centrifuge Inlet													
Spokane R at Harvard Rd	Harvard	3438100	REJ	<111	<111	<111	<111	<111	<111	<111	<111	<122	<111
Spokane R at Plante Ferry Park	PLANTEFRY	3448100	<109	<109	<109	<109	<109	<109	<109	<109	<109	<120	<109
Spokane R at Riverside State Park	NINEM SPM	3454105	<108	130	<108	<108	<108	<108	<108	<108	<108	<119	130

Detected values are in green highlight.
<: The analyte was not detected at or above the reported result.
REJ: Data are unusable for all purposes.

Figure 13 shows the two-day whole water PCB concentrations estimated from the suspended matter data and illustrates the relative importance of the dissolved PCB component, at least during low-flow conditions. Results also suggest that the analysis of whole surface water samples collected during particulate matter sampling underestimated actual PCB concentrations.

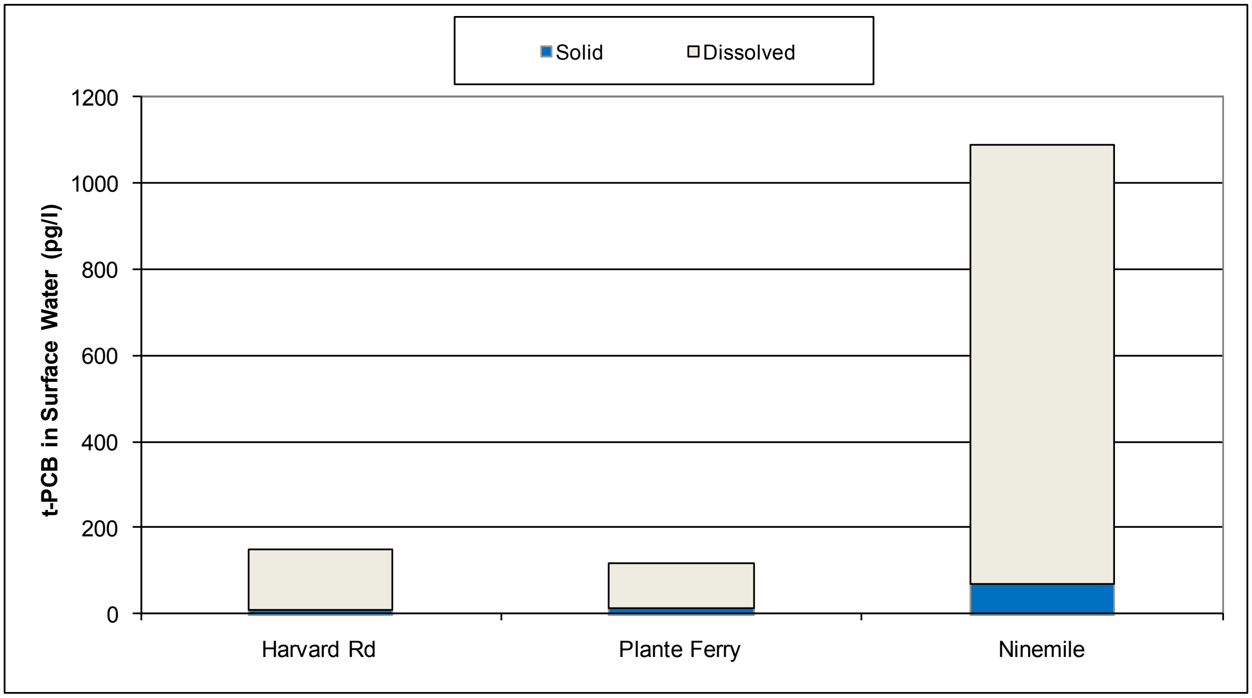

Figure 13. Measured Particle-Bound PCB Concentrations and Theoretical Dissolved PCB Concentrations Based on Suspended Particulate Matter Collected by Three 2-Day Centrifugation Sampling Events of Spokane River Water in October and November 2003.

PCBs in Industrial and Municipal Effluents Discharged to the Spokane River

In late 2003, Kaiser Trentwood installed a black walnut shell filtration system for their process wastewater discharge. Results of 2004-2005 effluent sampling showed an order of magnitude decrease in PCB concentrations and loads compared to 2001, presumably due to the filter and other facility management improvements. Table 20 shows the results of effluent PCB monitoring by Kaiser in 2004-2005 (unpublished).

Table 20. Kaiser Trentwood Effluent Concentrations of Total PCBs (Kaiser, 2005).

Source	Date	Total PCBs (pg/l)*	Effluent Flow (ML/day)	PCB Load to River (mg/day)
Kaiser Trentwood	6/25/04	1,170	63.9	75
	7/7/04	1,230	64.6	79
	7/23/04	1,340	66.2	89
	8/9/04	914	62.4	57
	4/20/05	669	56.2	38
	5/7/05	928	56.1	52
	5/19/05	1,370	59.7	82
	6/11/05	971	56.5	55
	6/14/05	1,130	55.4	63

*sum of detected congeners.

PCBs monitored by Ecology in effluents from four industrial and municipal facilities during three periods – October 2003, February 2004, and April 2004 – are shown in Table 21. Descriptions of the station names and sampling dates were listed in Table 10.

Spokane WWTP was the only facility where PCBs were detected in effluent during all three sampling collections, with an average PCB concentration of 940 pg/l.

Total PCBs in the Kaiser Trentwood effluent were generally <110 pg/l except during October when 330 pg/l was detected on 10/21/2003. Total PCBs were undetected at the 100 pg/l detection limit the following day. Samples from the treatment lagoon at Kaiser showed much higher PCBs (110 – 7,400 pg/l), but these concentrations were reduced substantially by the bed filtration system prior to discharge.

Liberty Lake WWTP had variable concentrations, as did Inland Empire to a lesser degree. Total PCB concentrations at Liberty Lake WWTP were an order of magnitude higher during April than during October and February, while Inland Empire had only one sample with PCBs detected, 670 pg/l total PCBs in October.

Overall, it appears that PCB concentrations in the effluents of the four facilities have decreased substantially since previous sampling. The smallest decrease occurred at the Spokane WWTP where 2003-04 average concentrations were about one-half those during 2001. However, the bulk of this apparent decrease may be due to higher detection limits used for the 2003-2004 samples compared to earlier samples. Effluent samples analyzed by Golding (2002) and SAIC (2003a) typically had detection limits <5 pg/l for individual congeners, and nearly all detected congeners were found at concentrations <100 pg/l. Therefore, the 2003-2004 results are likely all biased low due to the omission of these detections.

The reason for the relatively high level of monochloro-biphenyls in the 2004 Liberty Lake and Spokane WWTP replicate samples is unknown. The poor agreement between the Spokane WWTP replicate samples suggests contamination either from the field or laboratory. These values do not have a significant impact on the PCBs loading scenarios presented later in the report.

Table 21. PCB Concentrations Grouped by Homologues in Industrial/Municipal Effluent (pg/l).

Station Name	Sample ID	TSS mg/L	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
October 2003													
LIBLAKE	3434025	7	<98	161	<98	<98	<98	<98	<98	<98	<98	<98	161
KaiserEff	3434020	1	<100	100 J	228	<100	<100	<100	<100	<100	<100	<110	328 J
KaiserEff	3434023	1	<101	<101	<101	<101	<101	<101	<101	<101	<101	<112	<101
KaiserLag	3434021	3	<102	292 J	911	1,350	<102	<102	<102	<102	<102	<112	2,550 J
KaiserFilt	3434022	1	<100	167 J	104	<100	<100	<100	<100	<100	<100	<110	271 J
Inland Emp	3434026	5	<101	670	<101	<101	<101	<101	<101	<101	<101	<111	670
SPOKWWTP	3434027	6	<99	143	<99	112	218	<99	<99	<99	<99	<108	473
February 2004													
LIBLAKE	4064113	31	<111	<111	<111	<111	<111	<111	<111	<111	<111	<122	<111
KaiserEff	4064105	1	<112	<112	<112	<112	<112	<112	<112	<112	<112	<123	<112
KaiserEff Rep.	4064106	1	<106	<106	<106	<106	<106	<106	<106	<106	<106	<116	<106
KaiserEff	4064107	1	<109	<109	<109	<109	<109	<109	<109	<109	<109	<119	<109
KaiserLag	4064110	5	<106	422	2,580	3,720	647 J	<106	<106	<106	<106	<117	7,370
KaiserFilt	4064109	1	<109	<109	307	125 J	<109	<109	<109	<109	<109	<120	432 J
Inland Emp	4064111	9	<109	<109	<109	<109	<109	<109	<109	<109	<109	<120	<109
SPOKWWTP	4064112	10	<108	<108	<108	123	259	122	<108	<108	<108	<119	504
April 2004													
LIBLAKE	4188205	43	999 NJ	<112	<112	265	<112	<112	<112	<112	<112	<123	1,260 NJ
KaiserEff	4188198	1	<112	<112	<112	<112	<112	<112	<112	<112	<112	<112	<112
KaiserEff	4188199	1	<107	<107	<107	<107	<107	<107	<107	<107	<107	<107	<107
KaiserLag	4188202	1	<104	112 J	<104	<104	<104	<104	<104	<104	<104	<104	112 J
KaiserFilt	4188201	1	<106	<106	<106	<106	<106	<106	<106	<106	<106	<106	<106
Inland Emp	4188203	2	<112	<112	<112	<112	<112	<112	<112	<112	<112	<112	<112
SPOKWWTP	4188204	5	<102	<102	<102	342	588	329	<102	<102	<102	<113	1,260
SPOKWWTP Rep.	4188206	6	865 NJ	<107	<107	360	826	358	<107	<107	<107	<117	2,410 NJ

Detected values are in green highlight.
<: The analyte was not detected at or above the reported result (U or UJ).
NJ: There is evidence that the analyte is present. The associated numerical result is an estimate.
J: The analyte was positively identified. The associated numerical value is an estimate.

PCBs in Stormwater Discharged to the Spokane River

Stormwater sampling during the 2003-04 PCB source assessment study was conducted by City of Spokane personnel during one runoff event on June 10, 2004. Only four locations were sampled, although the sampling plan proposed more sites and storm events. Samples were collected from manholes nearest the outfalls draining the particular stormwater conveyance systems.

Due to the limited data from 2004, a second and larger set of stormwater samples was collected in the spring of 2007 by Parsons, a consultant hired by Ecology. Locations are shown in Figure 14. Results from both the 2004 and 2007 efforts are presented in Tables 22 to 26. The location IDs that correspond to the location descriptions were shown in Tables 11 and 12.

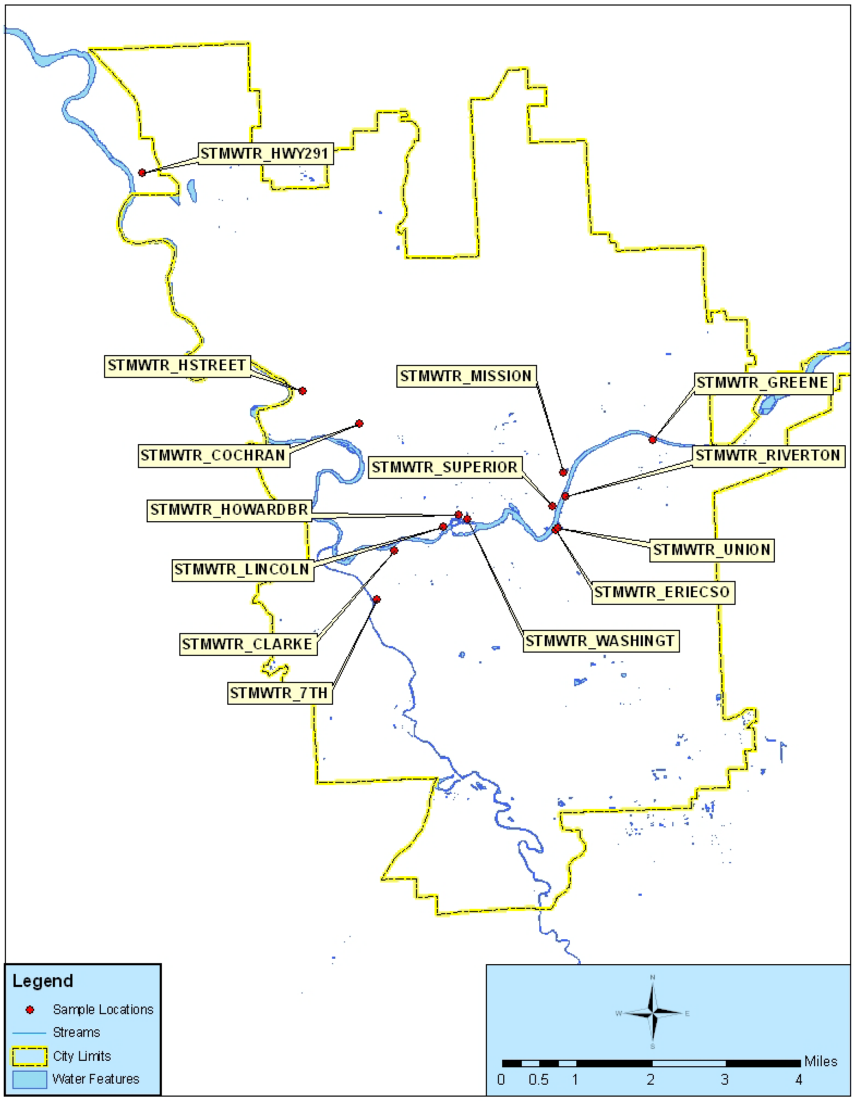

Figure 14. Stormwater Basins in the City of Spokane Sampled for PCBs During 2007 by Parsons.

Table 22. June 10, 2004 Stormwater PCB Concentrations Grouped by Homologues (pg/l).

Location ID*	Sample Number	TSS (mg/L)	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
Stmwtr_Mission (STMMISSBR)	4254001	58	<117	<117	117	5,490	28,800 J	19,200	6,660	1,600	283	254	62,400 J
Stmwtr_ErioeCSO (CSO 34)	4254000	126	<111	<111	685	3,120	10,200	28,500	32,400	7,800	678	<123	83,400
Stmwtr_Superior (STMSUPOUT)	4254003	26	<102	<102	<102	843	1,920	1,270	749	120	<102	<112	4,900
Stmwtr_Washingt (STMWASHBR)	4254002	91	<113	<113	285	2,560	8,380 J	5,290 J	2,530	690	198	<124	19,900 J

Detected values are in green highlight.

* Location ID in parentheses is presented for access to data in EIM. The Location IDs correspond to Table 12, which is the ID given for the 2007 stormwater sampling.

<: The analyte was not detected at or above the reported result (U or UJ).

J: The analyte was positively identified. The associated numerical value is an estimate.

Table 23. May 2, 2007 Stormwater PCB Concentrations Grouped by Homologues (pg/l).

Location ID*	Sample ID	TSS (mg/L)	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
HWY291	07184210	19	76	78	45	483 J	572	408	446	70	<20	<20	2180 J
7TH (CSO 26)	07184211	22	<80	<80	<80	<80	713 J	575	120	<80	<80	<80	1410 J
HSTREET (CSO 7)	07184212	63	<20	120	135	855 J	1,380	973	768	190	54	48	4520 J
COCHRAN	07184213	155	85	578	953	2,430 J	5,770	4,440	2,890	813	293	<20	18,250 J
LINCOLN	07184214	8	<20	<20	88	622 J	1,130	556	315	56	44	<20	2810 J
CLARKE (CSO 24A)	07184215	4	<80	<80	<80	<80	<80	<80	<80	<80	<80	<80	<80[1]
HOWARDBR	07184216	7	<20	102	194	849 J	734	408	309	29	27	42	2700 J
UNION	07184217	67	75	1,960	8,500	21,990	27,660	39,350	42,050	24,860	1,570	160	168,160
RIVERTON	07184218	27	23	336	919	6,570	17,200	10,050	6,050	1,900	99	<20	43,140
WASHINGT	07184221	26	57	295	408	1,700 J	2,800	1,330	1,110	514	82	<20	8,290 J
SUPERIOR	07184222	43	61	440	859	4,970 J	21,340	10,830	2,620	996	84	33	42,230 J
ERIECSO (CSO34)	07184223	40	115	2,960	13,650	29,140	48,120	85,070	78,890	20,190	2,000	296	280,430
MISSION	07184224	34	<100	319 J	381 J	2,990 J	9,720	6,690	2,220	452	<100	<100	22,770 J
SUPERIOR-Replicate	07184225	306	<100	342 J	527	2,350	9,250	6,670	1,410	690	<100	<100	21,230 J
SUPERIOR-Replicate	07184226	27	65	496	971	2,620	6,720	5,310	1,740	1,310	40	<20	19,260

Detected values are in green highlight.

*: In EIM these Locations IDs have the prefix STMWTR_; CSO number in parentheses is not part of the EIM Location ID.

[1]: The Clarke 07184215 Total PCB was revised from 0.062 to <80, post publication in the 2007 Parsons Report. The online report reflects the change.

<: The analyte was not detected at or above the reported result (U or UJ).

J: The analyte was positively identified. The associated numerical value is an estimate.

Table 24. May 21, 2007 Stormwater PCB Concentrations Grouped by Homologues (pg/l).

Location ID*	Sample ID	TSS (mg/L)	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
HWY291	07214210	8	110	105 J	<40	66 J	231	<40	<40	<40	<40	<40	512 J
7TH (CSO 26)	07214211	7	<40	158	51 J	296	342	144	<40	<40	<40	<40	991
HSTREET (CSO 7)	07214212	41	<40	137 J	<40	315 J	801 J	514	305	108	<40	<40	2,179 J
COCHRAN	07214213	12	43 J	135 J	<40	125 J	275 J	95 J	46 J	<40	<40	<40	719 J
LINCOLN	07214214	3	<40	164 J	<40	132 J	353 J	187	<40	<40	<40	<40	836 J
CLARKE (CSO 24A)	07214215	2	<40	101 J	<40	124	<40	<40	<40	<40	<40	<40	225 J
HOWARDBR	07214216	3	<40	122 J	57 J	302 J	317 J	42 J	<40	<40	<40	<40	839 J
UNION	07214217	18	142	373 J	645	1,795 J	3,006 J	4,325	4,631	1,121	62 J	<40	16,099 J
RIVERTON	07214218	14	52 J	<40	47 J	422 J	856 J	997	1,511	356	<40	<40	4,240 J
GREENE	07214219	38	54 J	233 J	828	2,367 J	3,033 J	2,254	2,238	403	<40	<40	11,409 J
WASHINGT	07214221	11	159	132 J	<40	<40	395 J	247	49 J	<40	<40	<40	981 J
WASHINGT-Replicate	07214225	8	108	136 J	<40	169 J	396 J	132	<40	<40	<40	<40	939 J
WASHINGT-Replicate	07214226	9	74 J	80 J	<40	156 J	402 J	239	65 J	<40	<40	<40	1,017 J
SUPERIOR	07214222		196	110 J	<40	155 J	304 J	202	185	<40	<40	<40	1,152 J

Detected values are in green highlight.
*: In EIM these Locations IDs have the prefix STMWTR_
<: The analyte was not detected at or above the reported result (U or UJ).
J: The analyte was positively identified. The associated numerical value is an estimate.

Table 25. June 5, 2007 Stormwater PCB Concentrations Grouped by Homologues (pg/l).

Location ID*	Sample ID	TSS (mg/L)	1-Cl	2-Cl	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	8-Cl	9-Cl	10-Cl	Total PCBs
HWY291	07234710	6	<40	<40	<40	<40	98 J	143	<40	<40	<40	<40	241 J
7TH (CSO 26)	07234711	26	150	121	91 J	702 J	2,708 J	2,382	1,059	382	64 J	48 J	7,707 J
HSTREET (CSO 7)	07234712	46	<40	<40	<40	<40	422 J	266 J	62 J	<40	<40	<40	749 J
COCHRAN	07234713	298	65 J	552	724	2,458 J	5,257	6,301	2,535	1,078	518	110	19,598 J
LINCOLN	07234714	51	<40	215	378	1,187 J	3,163 J	2,818	852	495	255	61 J	9,423 J
CLARKE (CSO 24A)	07234715	92	<40	108	72 J	452 J	1,725 J	1,628	591	196	94 J	<40	4,867 J
HOWARD BR	07234716	67	<40	605	4,404	4,662	2,366 J	1,722	773	210	111	86 J	14,940 J
HOWARD BR-Replicate	07234725	63	<40	528	4,393	4,158	2,549 J	1,222	627	121	122	93 J	13,813 J
HOWARDBR-Replicate	07234726	46	<40	433	3,591	3,302	1,760 J	1,410	566	130	79 J	123	11,393 J
UNION	07234717	65	49 J	511	2,387	5,037	12,488	39,653	36,975	9,056	602	44 J	106,802
RIVERTON	07234718	82	<40	200	500	1,465 J	3,824 J	6,735	5,309	1,222	124	<40	19,380 J
GREENE	07234719	117	<40	295	1,770	3,631	5,599	9,275	5,463	1,315	232	43	27,622
WASHINGT	07234721	158	<40	216	404	1,947 J	2,726 J	2,489	681	318	171	80 J	9,031 J
SUPERIOR	07234222	55	<40	116	109	742 J	1,451 J	1,622	593	227	53 J	<40	4,912 J
ERIECSO (CSO34)	07234223	159	62 J	582	2,094	4,987	10,768	28,081	19,456	6,027	568	62 J	72,686
MISSION	07234224	30	<40	120	152	897 J	3,131 J	3,593	1,884	446	90 J	<40	10,311 J

Detected values are in green highlight.
*: In EIM these Locations IDs have the prefix STMWTR_
<: The analyte was not detected at or above the reported result (U or UJ).
J: The analyte was positively identified. The associated numerical value is an estimate.

Summary statistics for PCB concentrations in City of Spokane stormwater samples from 2004 and 2007 are shown in Table 26. Stormwater PCB concentrations ranged over two orders of magnitude in both data sets from 2004 and 2007. Individual total PCB concentrations varied widely from <80 to 280,000 pg/l in the 2007 Parsons study, and from 4,900 to 83,400 pg/l in 2004.

Table 26. Summary Statistics for Total PCB Concentrations in Spokane Stormwater (pg/l).

Statistic	Stormwater Sampling	
	Ecology in 2004	Parsons in 2007
minimum	4,900	240
10th	9,400	777
25th	16,150	1,118
mean	42,650	23,023
median	41,150	8,000
75th	67,650	19,290
90th	77,100	42,867
95th	80,250	101,684
maximum	83,400	280,430

Parsons provided an in-depth review of the 2007 data in their report (Parsons, 2007). They concluded that:

- Stormwater basins CSO 34 and Union Street showed the highest average concentrations for the three events.
- Total PCB concentrations showed a direct correlation with TSS.
- Sources of PCBs are similar in the stormwater systems, with the exception of the Howard Bridge site. The greater relative abundance of less chlorinated PCBs at Howard Bridge may indicate the presence of a different source.

Post publication of the Parsons report, Union Street was found to drain to the CSO34 (Erie Street) system. Their relative drainage areas are 109 and 1,951 acres, respectively. Thus, Union Street, at <6% of the CSO 34 area, may be largely responsible for the high PCB levels detected at CSO 34.

The Clarke 07184215 total PCB result was revised post publication of the Parsons (2007) report from 0.062 to <80 pg/l.

A wide range of PCB homologues was detected in Spokane stormwater (Tables 22-25) and in particulate samples from the Spokane River (Table 19). A similar homologue range was seen in Spokane River sediment samples (see Table 30). In contrast, a relatively narrow group of dichloro through pentachlorobiphenyl homologues was found in industrial and municipal effluents (Table 21). This finding, coupled with the loading analysis that follows, supports a conclusion that stormwater is a significant PCB source to the Spokane River.

Stormwater Discharges

Streamflow data were not collected during stormwater sampling. Therefore the discharge was estimated using calculations based on rainfall. The average annual stormwater discharge predicted by the Simple Method (www.stormwatercenter.net) was calculated by Parsons (2007). Briefly, the Simple Method uses the equation:

Equation 4. $R = P * Pj * Rv$

where R is annual runoff (inches), P is annual rainfall (inches), Pj is the fraction of annual rainfall events that produce runoff (assumed 0.9), and Rv is a runoff coefficient.

In this method, the runoff coefficient is calculated based on impervious area in the subwatershed (Ia). Watershed imperviousness is a reasonable predictor of Rv (Schueler, 1987), with the relationship best defined as:

Equation 5. $Rv=0.05+0.9Ia$

Geographical data were provided by the City of Spokane Wastewater Management Department. Annual rainfall was estimated to be 18 inches in Spokane, based on data from Ecology's Eastern Washington Stormwater Manual Precipitation Maps (Ecology, 2004 www.ecy.wa.gov/biblio/0410076maps.html). A value of 0.9 was used as the fraction of runoff.

The first step for developing flow estimates using the Simple Method was to determine the area draining to each of the sampling locations. To do so, a shapefile of stormwater boundaries provided by the City of Spokane was merged with the shapefile of areas contributing stormwater to the various CSOs (also provided by the City of Spokane) in a geographic information system. Figure 15 presents the combined stormwater-CSO boundaries for the entire city.

The second step was to determine the impervious areas. Pervious surfaces were determined in each drainage area based on 2007 geographic data. The total impervious area contributing was calculated as the sum of transportation and off-street impervious areas. Percent impervious for all the stormwater basins in the City of Spokane ranged from roughly 12 to 54% for the basins with any development (Parsons, 2007). This stormwater assessment did not take the Census-defined urban areas nor the Urban Growth boundary into account. The Spokane city limits were defined by the 2005 city boundary.

The total PCB average for each sampling station, as well as the calculated impervious fraction, area, and runoff, are shown in Table 27.