LUMMI INDIAN BUSINESS COUNCIL
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January 14, 2020

Annie Sawabini
Department of Ecology
Water Resources Program
PO Box 47600
Olympia, WA 98504-7600

Subject: **Comments on the Draft Amendments to Chapter 173-501 WAC, Instream Resources Protection Program – Nooksack Water Resource Inventory Area (WRIA) 1**

Dear Ms. Sawabini,

I am writing to provide comment on behalf of the Lummi Nation on the proposed draft amendments to Chapter 173-501 WAC, Instream Resources Protection Program-Nooksack Water Resource Inventory Area (WRIA) 1. I am resubmitting the comments (attached) that I submitted on the preliminary draft rule on May 9, 2019 – as a whole, these comments were not adequately addressed in the proposed draft amendments, so are still relevant and should be incorporated. In addition, the evaluation of seasonal impacts associated with the draft rule was incorrectly scaled to accurately characterize seasonal impacts. Please see the attached document titled "*Assessing the Ecological Effects of WRIA 1 Watershed Plan Update*" that characterizes seasonal impacts at appropriate scales.

Thank you for your time and consideration of these comments. If you have any questions about the comments, please contact me [merlej@lummi-nsn.gov, (360) 312-2328] or Kara Kuhlman of my staff [karak@lummi-nsn.gov, (360) 312-2128]

Sincerely,

Merle Jefferson

Merle Jefferson, Sr., Executive Director
Lummi Natural Resources Department (LNR)

cc:
Lawrence Solomon, Lummi Indian Business Council Chairman
Steve Solomon, Lummi Natural Resources Commission Chairman
Kara Kuhlman, LNR Water Resources Manager
Laura Watson, Department of Ecology (Ecology) Director
Mary Verner, Ecology Water Resources Program Manager
Kasey Cykler, Ecology RCW 90.94 WRIA 1 Lead

Enclosures:

1. May 9, 2019 Lummi Nation comments on the Preliminary Draft Rule Language for the Amendment to Chapter 173-501 WAC, Instream Resources Protection Program – Nooksack Water Resource Inventory Area (WRIA 1)
2. Assessing the Ecological Effects of WRIA 1 Watershed Plan Update. Technical Memo Prepared in Support of WRIA 1 Watershed Plan Update 12/5/2018 Interim Work Product

Enclosure 1

May 9, 2019 Lummi Nation comments on the Preliminary Draft Rule Language for the Amendment to Chapter 173-501 WAC, Instream Resources Protection Program – Nooksack Water Resource Inventory Area (WRIA) 1

LUMMI INDIAN BUSINESS COUNCIL
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DEPARTMENT ____________ DIRECT NO. ________

May 9, 2019

Annie Sawabini
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Water Resources Program
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Annie.Sawabini@ecy.wa.gov

Subject: **Comments on the Preliminary Draft Rule Language for the Amendment to Chapter 173-501 WAC, Instream Resources Protection Program – Nooksack Water Resource Inventory Area (WRIA) 1**

Dear Ms. Sawabini,

I am writing to provide comments on behalf of the Lummi Nation on the preliminary draft rule language for the Amendment to Chapter 173-501 WAC, Instream Resources Protection Program – Nooksack Water Resource Inventory Area (WRIA) 1 (preliminary draft rule). As you know, the Lummi Nation has treaty reserved water rights in WRIA-1 and on the Lummi Indian Reservation (Reservation). These rights include, but are not limited to, a federal Indian reserved water right to instream flows sufficient to support treaty fishing rights. In addition, the Lummi Nation also retains a federal reserved water right for consumptive uses necessary to fulfill the purposes of our Reservation.

Regrettably, the state legislature has chosen to ignore the rights of the Lummi Nation in an effort to placate a small but powerful number of special interests groups. The Department of Ecology has thus been placed in the unenviable position of drafting a rule destined to permit actions that will certainly result in the continued impairment of the rights of the Lummi Nation. It is against this backdrop that we provide the following technical comments with respect to your preliminary draft rule

While we appreciate the proposed reduction of the withdrawal limit and the interruptible nature of outdoor water use in the preliminary draft rule, if not coupled with metering – a necessary component for ensuring accountability – establishing compliance with these provisions will be difficult, if not impossible. Furthermore, the draft preliminary rule does not appear to create a net environmental benefit and the certainty of achieving required water offsets is low.

Below are more detailed comments.

1. **Withdrawal Limits:** While the reduction to 500 gallons per day (gpd) and 1/12 acre irrigated non-commercial lawn or garden per connection is an improvement over the currently effective 5,000 gpd maximum and 3,000 gpd annual average limits, we propose that a further reduction in the withdrawal limit – to 350 gpd for both indoor and outdoor use – would provide both a sufficient water supply for rural Whatcom County residents and a higher level of protection of instream flows. Three hundred and fifty (350) gpd has proven to be a reasonable amount of water for indoor and outdoor water use on the Lummi Peninsula pursuant to the settlement

agreement that resolved the *United States, Lummi Nation v. Washington State Department of Ecology, et al*, Civil Action No. C01-0047Z (U.S. District Court, Western District of Washington). Coupled with metering, the 350 gpd withdrawal limit would provide certainty to a conservation-based approach to water management.

2. **Acreage-Based Outdoor Water Use:** There should be a specific limit on the quantity of water allowed to be put to use for outdoor irrigation. As written, there is nothing to prevent residents from overwatering their 1/12 acre of lawn or non-commercial garden. Ecology appears to assume that any excess irrigation water will not be consumptively used (i.e., will become aquifer recharge), this is not universally true. If a gallon per day limit is not established for outdoor water use, we are also concerned with how Ecology will administer and enforce the acreage-based irrigation limits.

3. **Crop Irrigation Requirements:** The Crop Irrigation Requirement (CIR) used in the preliminary draft rule calculations should be nearly 25% higher for pasture/turf based on recent water rights work completed by Ecology contractors (e.g., Protested Report of Examination for Water Right Change, Water Right Number: GWC 2776(A) [G1-*04184C(A)], WR Doc ID 6800738). Without adjustment, Ecology stands to substantially underestimate actual irrigation demand.

4. **Safety Factor:** We agree a safety factor is needed. However, it should be applied to consumptive use estimates that already incorporate known sources of uncertainty. For example, the CIR should be part of the consumptive use estimate to which the safety factor is applied. In addition, the safety factor as applied in the preliminary draft rule does not account for either the 500 gpd indoor water use limit, or, since there is no metering or enforcement, of 3,000 gpd annual average or 5,000 gpd daily maximum use limits.

5. **Interruptible Outdoor Water Use**: We agree with the curtailment of non-subsistence based outdoor water use during a declared drought. That said, the curtailment criterion should be expanded to also be contingent on whether minimum instream flows are being met or not. Where watercourses are gauged, the gage information could be used to determine if minimum instream flows are being met. Where that data is not available, nearby gauged watersheds and/or the Nooksack River gage at Ferndale could be used.

6. **Accountability and Enforcement**: Without metering there is no reliable way to hold residents accountable to the withdrawal limits in the preliminary draft rule. There is also no discussion of how Ecology will enforce the any of the provisions of the preliminary draft rule.

7. **Critical Flow Period:** Establishment of a critical flow period is referenced in the Streamflow Restoration Act (RCW 90.94), but has not yet been defined by Ecology. The critical flow period should be defined as the irrigation season plus the low-flow season— April 1 to November 15.

8. **Offset Projects:** We find many of the water offset projects list in Table 6.1 of the Rule Supporting Document to be problematic.

    a. Most of the listed offset projects were identified for alternative purposes prior to the passage of RCW 90.94, meaning that the preliminary draft rule relies largely on projects unrelated to RCW 90.94 to achieve the goals of RCW 90.94 – thus undermining the goal of streamflow restoration.

b. Many of the offset projects are conceptual or in the early stages of development (i.e., uncertainty of project implementation), rely on coarse-scale estimates of offset quantity (i.e., uncertainty of water replaced), may or may not be implemented effectively (i.e., uncertainty of project effectiveness and lifespan). We find it irresponsible to rely on such a project list to achieve the water-for-water offset required in RCW 90.94.

c. Similarly, the project list does not effectively provide offsets near the projected future points of withdrawal (i.e., projects are out-of-place). To help rectify the inadequate spatial distribution of offset projects relative to impacts of future permit-exempt domestic wells, we strongly recommend that on-site mitigation be added on the project list.

d. The estimated water offset attributed to the Skookum Creek Restoration (No. 19) will take more than 20 years to be realized. As such, the estimated water offset for the Skookum Creek Restoration should be treated like the Stewart Mountain/SF Nooksack Conservation (No. 21) offset, and be removed from the calculated total offsets within WRIA-1.

e. The Managed Aquifer Recharge (MAR) – North Fork Site (No. 8) and Gravel Pits (No. 28) are still only conceptual and the estimated water offsets attributed to these projects should be removed from the calculated total offsets within WRIA-1.

f. Three offset projects require inter-basin transfers (Nos. 24, 44, 45). We are concerned with the "scent" of the water with regards to the homing of salmonids for these three projects. Addressing these concerns needs to be satisfied prior to implementation of these projects.

g. The Bertrand Augmentation (No. 2) and the Middle Fork Porter Creek Phase 4 (No. 23) projects will not provide water throughout the critical flow period (April 1 through November 15).

h. The Coastal South, Lake Whatcom, and Sumas aggregated subbasins do not have any offset projects that will become effective within the 20-year planning period. With the removal of the MAR – North Fork site (No. 8), the North Fork of the Nooksack River will not have any offset projects.

i. With the understanding that resources are limited, monitoring (e.g., surface and ground water, instream resources) should be included on the project list. If monitoring is not included, we will be ill-equipped to assess how conditions are changing and/or what additional management actions are necessary to help protect instream resources.

   j. Considered as a whole, the project list does not provide reliable offsets, particularly where impacts are projected to occur and during the critical flow period (i.e., projects are out-of-place and out-of-time)

9. **Fees:** We are concerned that Ecology has not proposed to increase the permit fee from the $500 required under RCW 90.94. It stands to reason that the fees should be increased to cover the cost of administering the program and to provide at least a portion of the funding needed for water offset and ecological benefit projects. Without sufficient funding, there is a high level of uncertainly that necessary projects will actually be completed.

10. **Metering:** Metering needs to be required. At the December 5, 2018 WRIA 1 Watershed Management Board meeting, several representatives were on the record as generally in favor of mandatory metering (Lummi Nation, Nooksack Indian Tribe, City of Bellingham, and Washington State Department of Fish and Wildlife); the other members present stated a preference for voluntary metering (Whatcom County, PUD No. 1 of Whatcom County). Although consensus on mandatory metering was not achieved, the policy discussions around this topic indicate that several WRIA-1 entities agree that monitoring water use is an important component of responsible water resources management.

11. **Net Ecological Benefit (NEB):** The NEB analysis is insufficient; it does not characterize and quantify potential impacts to instream resources from the projected 20-year new domestic permit-exempt water use at a scale to meaningfully determine if the proposed projects are in-time and in-place. Far more detailed analysis is needed than annualized steady-state water use at the scale of WRIA 1.

    a. Lowland streams where development is likely to occur are already impaired and are important for fish production. These streams should not be subject to further degradation just because they already impacted.

    b. Further temporal analysis is required. For instance, July water use will be greater than the average annualized water use, and will have a proportionally larger impact. Please refer to the December 5, 2018 Interim Work Product developed by Nooksack Natural Resources and Lummi Natural Resources Department technical staff as part of the WRIA-1 planning effort entitled *"Assessing the Ecological Effects of WRIA 1 Watershed Plan Update"* for documentation that contradicts the assertion that impacts to instream resources will be small, regardless of whether they are measurable or not.

12. **Adaptive Management:** The section on adaptive management requires mechanisms to ensure that corrective actions occur where performance goals are not met. We strongly urge Ecology to take into consideration Appendices J and K of the Draft WRIA 1 Watershed Management Plan Update (Draft Project Monitoring and Effectiveness Template, and Draft Monitoring and Adaptive Management Program, respectively). During development of the Draft Monitoring and Adaptive Management Program, we were advocating for a three-year interval and/or as-needed threshold for the two update steps, which did not make it into the draft released to the Planning Unit. The addition of these appendices, with the noted changes, to the Rule Supporting Document would benefit the adaptive management section.

a. Instead of once every five years, self-assessments should be conducted every three years, and/or as needed if growth projections substantially underestimate the actual growth, and/or there is little or no progress on project implementation, and/or if projects are found to not be as effective as intended. This would also provide for an end-of-planning horizon evaluation (under RCW 90.94) in 2038 for the entire effort.

b. In addition to tracking building permits, the number of permit-exempt wells drilled should also be tracked. Wells can be put into use long before the landowner applies for a building permit.

In closing, a 350 gpd limit for indoor and outdoor water use coupled with metering would provide a high level of certainty for the offsets needed and be far easier to effectively administer.

Thank you for your time and consideration of these comments. If you have any questions about the comments, please contact me (merlej@lummi-nsn.gov, (360) 312-2328) or Kara Kuhlman of my staff (karak@lummi-nsn.gov, (360) 312-2128).

Sincerely,

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Lummi Natural Resources Department (LNR)

Cc: Jeremiah Julius, Lummi Indian Business Council Chairman
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Enclosure 2

Assessing the Ecological Effects of WRIA 1 Watershed Plan Update. Technical Memo Prepared in Support of WRIA 1 Watershed Plan Update

12/5/2018 Interim Work Product

Assessing the Ecological Effects of WRIA 1 Watershed Plan Update

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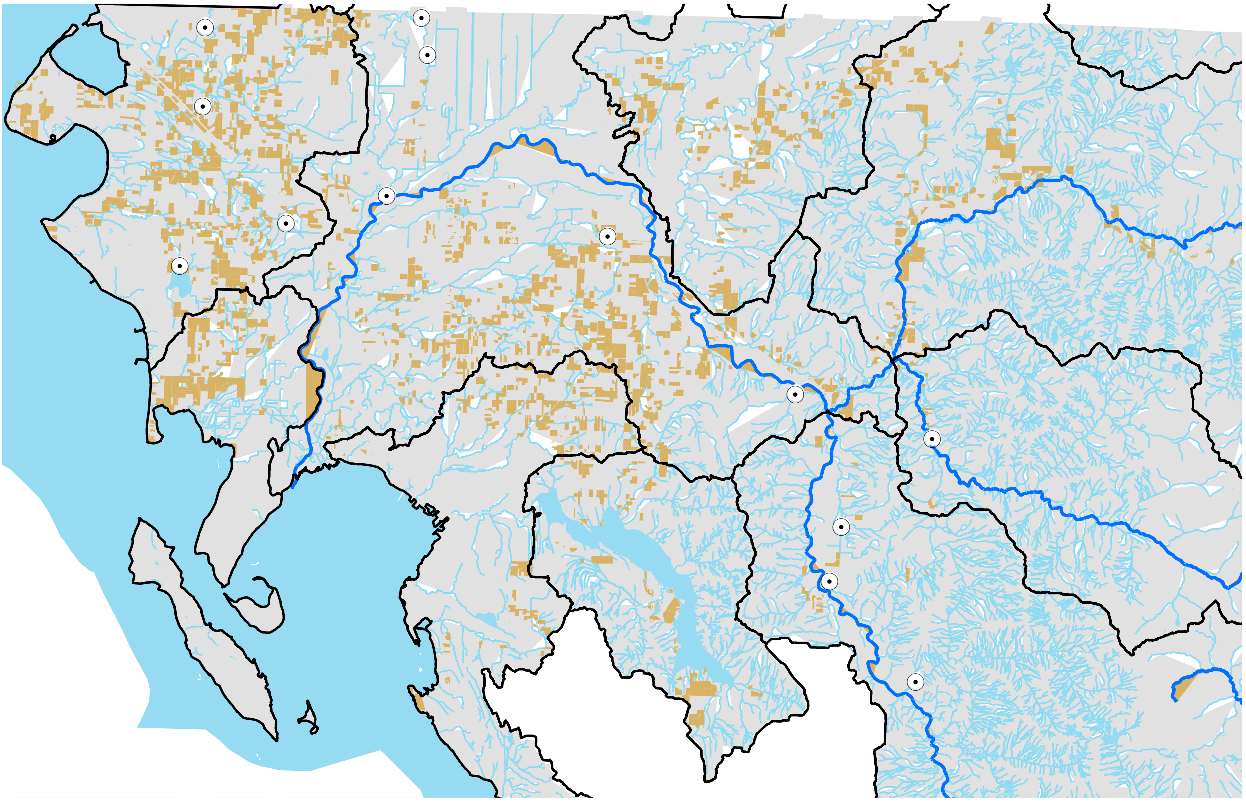
Technical Memo Prepared in Support of WRIA 1 Watershed Plan Update



12/5/2018 Interim Work Product

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DISCLAIMER: Nooksack Indian Tribe and Lummi Nation technical staff performed this work using best available science and readily available methods to evaluate and/or describe potential impacts and a particular suite of planned actions at a temporal and spatial scale relevant to aquatic resources and within the limited timeframe available to conduct the analysis. The report is intended to help inform decision-makers, and should not be misconstrued as representing the policy positions of either the Nooksack Indian Tribe or Lummi Nation.

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Introduction

In January 2018, the Washington State legislature passed ESSB 6091, now codified as RCW 90.94 Streamflow Restoration, which authorizes potential impacts on a closed water body and potential impairment to an instream flow of new domestic groundwater permit-exempt (DGWPE) well withdrawals, provided that applicants pay a $500 fee and restricted water use to no more than 3000 gallons per day annual average. The law also establishes planning requirements specific to water resource inventory areas. For Water Resource Inventory Area (WRIA) 1, the Nooksack Basin[1], the following requirements were established (boldface emphasis added):

- 90.94.020 (4)(a): ***In collaboration with the planning unit, the initiating governments must update the watershed plan to include recommendations for projects and actions that will measure, protect, and enhance instream resources and improve watershed functions that support the recovery of threatened and endangered salmonids.*** *Watershed plan recommendations may include, but are not limited to, acquiring senior water rights, water conservation, water reuse, stream gaging, groundwater monitoring, and developing natural and constructed infrastructure, which includes, but is not limited to, such projects as floodplain restoration, off-channel storage, and aquifer recharge.* ***Qualifying projects must be specifically designed to enhance streamflows and not result in negative impacts to ecological functions or critical habitat.***
- 90.94.020 (4)(b): ***At a minimum, the watershed plan must include those actions that the planning units determine to be necessary to offset potential impacts to instream flows associated with permit-exempt domestic water use.*** *The highest priority recommendations must include replacing the quantity of consumptive water use during the same time as the impact and in the same basin or tributary. Lower priority projects include projects not in the same basin or tributary and projects that replace consumptive water supply impacts only during critical flow periods. The watershed plan may include projects that protect or improve instream resources without replacing the consumptive quantity of water where such projects are in addition to those actions that the planning unit determines to be necessary to offset potential consumptive impacts to instream flows associated with permit-exempt domestic water use.*
- 90.94.020 (4)(c): *Prior to adoption of the updated watershed plan,* ***the department must determine that actions identified in the watershed plan****, after accounting for new projected uses of water over the subsequent twenty years,* ***will result in a net ecological benefit to instream resources within the water resource inventory area****.*

In its *Interim Guidance for Determining Net Ecological Benefit* (Ecology 2018), Ecology further specified that plans should address the following elements:

1. *Characterize and quantify potential impacts to instream resources from the projected 20- year new domestic permit-exempt water use at a scale that allows meaningful determinations of whether the proposed offset is in-time and/or in the same subbasin.*
2. *Describe and evaluate individual offset projects.*

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[1] WRIA 1, the Nooksack Basin, includes the Nooksack River watershed, as well as the watersheds of tributaries to the Fraser River (Chilliwack and Sumas Rivers) and independent tributaries to the Salish Sea from the Canadian border south to Colony Creek in Skagit County.

3. *Explain how the planned projects are linked or coordinated with other existing plans and actions underway to address existing factors impacting instream resources.*
4. *Provide a narrative description and quantitative evaluation (to the extent practical) of the net ecological effect of the plan.*

The purpose of this report is to describe and report on the detailed findings of an assessment of the ecological effects of the WRIA 1 Watershed Plan Update, to address element 4 of the *Interim Guidance*. Specifically, this report evaluates the ecological effects of both the impacts of DGWPE wells in WRIA 1 over the next 20 years (2018-2038) and actions identified to offset those impacts[2]. Consistent with Ecology's guidance, this report is intended to provide the transparent, structured evaluation that will inform determination of net ecological benefit of the WRIA 1 Watershed Plan Update.

Methods

While annualized DGWPE consumptive use was estimated at the aggregated subbasin scale (Dunn and Neff 2018), evaluating the cumulative ecological effects of DGWPE consumptive use and plan actions requires understanding effects at finer spatial and temporal scales. As such, this assessment begins with estimates of the finer-scale spatial and temporal distribution of DGWPE well consumptive use impacts relative to selected actions to offset those impacts, followed by a discussion of the ecological implications of both cumulative streamflow effects and other ecological effects to instream resources. This analysis is based on water use scenarios and options for the projected number of new DGWPE wells that are described by RH2 (Bucknell et al. 2018; Dunn and Neff 2018) and does not incorporate variation described in the analyses of uncertainty around consumptive use impacts or actions. Spatial and temporal analysis methods are described below.

Spatial Distribution of Impacts and Actions

Consumptive Impacts

Evaluation of the spatial distribution of consumptive use impacts is based on the following assumptions:

- Groundwater flow paths match surface topography.
- 100% of consumptive use from DGWPE wells results in flow deficit to closest stream segment.
- There is synchrony in timing of streamflow deficit (including for streams segments downstream).

For the WRIA 1 Watershed Plan update, BERK Consulting developed a scenario for rural growth (i.e. growth outside of urban growth areas) in WRIA 1 over the next twenty years (2018-2038) that was based on work they had completed to support the 2016 Whatcom County Comprehensive Plan update (Ramsey & Silver 2018). The BERK growth scenario allocated growth at the parcel scale based on available land capacity and other factors that influence the distribution of new development. Geospatial data[3] were obtained from Whatcom County (Figure 1) showing parcels attributed with population growth, number of new households, and other growth statistics. There were discrepancies between these data (population growth 9388) and the projections used for consumptive use estimates (9932;

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[2] The actions evaluated in this report are those identified in *Watershed Staff Team Suite of Projects Pending Net Ecological Benefit (NEB) Evaluation*, dated October 4, 2018, and distributed for the October 24, 2018, WRIA 1 Planning Unit meeting.

[3] *WRIA1_GrowthLayers_20180802.gdb* (*PreferredAlt_NonUGA_GrowthOnly_NoLummiEliza_Final_2018_0802*) provided by Cliff Strong (Whatcom County PDS) via email, August, 8, 2018.

Ramsey and Silver 2018), since growth data are for rural growth in Whatcom County only and do not include Skagit County and there were continued adjustments in the calculation of new growth that may not be reflected in the geospatial data. These data represent a plausible scenario for the general spatial distribution of rural growth across WRIA 1, although the number of buildable parcels in Whatcom County far exceeds the projected number of new housing units needed to accommodate growth over the next twenty years and actual growth pattern may vary accordingly.

Since some new rural development can be served by existing water associations and water districts, a subset of BERK's projected rural growth is expected to use DGWPE wells. RH2 developed 5 options for estimating the number of new DGWPE connections (Dunn and Neff 2018), and option 4 was selected by the WRIA 1 Watershed Staff Team and the WRIA 1 Planning Unit, for an estimate of 2150 new DGWPE connections in WRIA 1 for the planning period. Time and data constraints prevented development of a new spatially- explicit growth scenario that would be consistent with option 4. Instead, aggregated subbasin-specific consumptive water use estimates developed by RH2 (Dunn & Neff 2018) were assigned to the BERK parcels as follows: (1) calculate the per household consumptive use by subbasin (i.e. the aggregated subbasin-specific consumptive use estimates divided by the number of households associated with the growth parcels in each subbasin); and (2) assign consumptive use to parcels (i.e. multiply the subbasin-specific per household consumptive use by the number of new households in the parcel). Because the growth scenario does not necessarily reflect the number and location of new DGWPE wells (i.e. for parcels that may fall within water district and water association service areas), the results may not be accurate on a parcel-by-parcel basis. However, total consumptive use by subbasin is equivalent to that estimated by Dunn and Neff (2018) RH2 and the results represent a reasonable approximation of the spatial distribution of consumptive use.

Parcel-level consumptive use was attributed to adjacent stream segments and accumulated downstream as follows:

- Geometric network creation.
  - A 2013 SSHIAP (Salmon and Steelhead Habitat Inventory and Assessment Program) stream layer dataset, edited to remove braids, was used to create a geometric network. Data were edited to enforce flow direction such that each line's geometry pointed in a downhill direction. Topology rules were applied, and the data further manually edited to remove any self intersecting lines and to ensure no dangles or unconnected lines existed in any given river system.
  - Growth polygons (parcels) from the BERK dataset were converted to points using the geometric center (centroid) of each polygon. A near table was generated resulting in coordinates that listed the polygon centroid location and the intersecting coordinates of the closest line based on Euclidian distance. A new feature layer was created from these coordinates and appended to the stream line work. Data were then edited to split the lines at each line intersection. These split data were used to create a geometric network data model inside of an ArcGIS 10.5 geodatabase-feature-class-feature-dataset and flow direction was assigned to the network based on the existing line geometry.
- Flag Creation.
  - Both start and end vertices were generated from the split line work as two separate spatial datasets. Any end nodes that were not coincident with a start node were

exported to a new dataset called *flags*. Flags was edited using ArcGIS Toolbox tools to remove spatially duplicate flags.
- Python Script Development.
    - A Python v2.7 tool was developed to automate upstream tracing and summation of the consumptive use estimates for each scenario. This tool used a search cursor to select each flag. The selected flag served as an input into an upstream accumulation trace of the geometric network (all upstream line connections). The resulting line selection was used to select all growth points that intersected the selection. The growth points selection was exported to a Numeric Python Library (NUMPY) array for summation. The tool then selected the currently evaluated flag's intersecting downstream line and populated a text file with the summed consumptive use values for that upstream accumulation trace. The text file was joined to the line work based on line object ID and exported to a new feature class.
- Screening out of segments coincident with lakes
    - Stream segments coincident with lakes over 23 acres in area were removed using the ArcGIS erase function, and segment lengths recalculated to facilitate length summarization.

Consumptive water use estimates were spatially distributed for the following water use scenarios:

- Scenario 4. One home; outdoor irrigation varies by aggregated subbasin (0.064 to 0.322 acres) and is based on aerial photography-based irrigated acreage analysis (modified means) of new homes constructed and served water by a DGWPE well between 2000 and 2014.
- Scenario 5A. One home, ½ acre of outdoor irrigation, plus excess water use up to 3000 gallons per day (maximum annual average withdrawal limit).
- Scenario 6. One home, ½ acre of outdoor irrigation, plus excess water use up to 5000 gallons per day (maximum daily withdrawal limit).

Scenario 4 was the water use scenario selected by the WRIA 1 Watershed Staff Team and the WRIA 1 Planning Unit as representing a reasonable planning-level estimate of DGWPE well consumptive water use across WRIA 1. Scenarios 5A and 6 were also evaluated to buffer against the considerable uncertainty in estimating consumptive water use, and because both scenarios represent legally and currently permissible water use scenarios—the 3000 gpd average annual limit allows for use of 5000 gpd (daily)[4]. In addition, RH2's consumptive use estimates (Dunn & Neff 2018), when converted to cubic feet per second, represent annually-averaged estimates and thus underestimate peak seasonal consumptive use (see Table 2).

Actions to Offset Impacts

The suite of projects evaluated for ecological effects were those identified in the *Watershed Staff Team Suite of Projects Pending Net Ecological Benefit (NEB) Evaluation* (dated 10/4/2018 and distributed to WRIA 1 Planning Unit 10/24/2018). A shape file with approximate project locations[5] was obtained from

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[4] For example, if five hundred (500) gpd is withdrawn from Oct. 20 through the end of March, five thousand (5,000) gpd can be withdrawn from April 1 through October 19 without exceeding the three thousand (3,000) gpd annual average.

[5] *Potential Projects_44.shp*.

RH2. Streamflow impacts from these projects were incorporated into the stream feature class described above by adding a table attribute for each project with an estimated offset[6], then selecting and assigning offset amount to stream segments downstream of the project location (see Appendix A for how offset was assigned for each project). If a range of offset was estimated, the lower end of the range was used. For interbasin transfers (# 24 Birch Bay Water & Sewer District Deep Wells; #45: PUD #1: Lake Terrell), the stream system in the receiving basin closest to project location was assumed to benefit from offset. The offset associated with #21 Stewart Mountain/SF Conservation Site was assumed to benefit three subbasins (South Fork Nooksack, Lower Nooksack, Lake Whatcom) proportional to the acquisition area in each subbasin, so offset was distributed accordingly; it is worth noting that this project had the greatest estimated offset among all projects, and there is a great deal of uncertainty in the offset estimate. For the two projects that would increase diversion of streamflow from the Lower Nooksack River (#44 PUD #1: Vista Road Project; #45 PUD #1: Lake Terrell), the associated flow deficit was attributed to Nooksack River segments downstream of Plant 2[7]. Actions lacking quantification of offsets (WRIA 1-wide Conservation Program, MAR Feasibility Study, Purchase of Development Rights Program, Glacier WD Groundwater Study and Augmentation, NF Maple Reach Restoration) were not included in quantitative analyses but are discussed qualitatively in results.

Net streamflow impact was calculated at the stream segment level by summing any project offsets, subtracting the accumulated streamflow deficit from DGWPE consumptive use, and converting to cubic feet per second (cfs) using the factor 0.00138128 cfs/acre-foot·year^{-1}. Only streams with net streamflow impact (positive or negative) were used in subsequent analysis (Figure 2).

Hydrologic Context

It is important to understand the net streamflow impact in the context of existing hydrologic regime. Estimates of existing streamflow regime are available at 337 point locations (generally corresponding to drainage outlets and other points of interest) throughout WRIA 1 based on hydrologic modeling conducted in 2007 to support the WRIA 1 Watershed Management Project (Bandaragoda and Greenberg 2013); 138 of these locations are associated with streams affected by projected consumptive use and offset actions. Hydrologic data in the form of geospatial and corresponding tabular data with exceedance flows by percentile and month[8] were assembled and made available through the 2013 Data Integration Project (Bandaragoda and Greenberg 2013). While the hydrology modeling was subsequently updated and refined in 2012 (Bandaragoda et al. 2012), 2012 model data were only available for 37 nodes so the older hydrology modeling was used. The 50th percentile and 95th percentile exceedance flows for July were selected as the streamflows of greatest interest, even though streamflows are lowest in most locations throughout the Nooksack Basin lowlands in September or October. According to monthly crop irrigation requirements from the Washington Irrigation Guide (NRCS 1992), July is the month of peak irrigation. The 50th percentile July streamflow is an indicator of

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[6] Estimated offset has not been quantified for the following projects: North Fork Maple Reach Restoration Phase 1, Glacier WD Groundawter Study and Augmentation, WRIA 1-Wide Conservation Program, MAR Feasibility Study, and Purchase of Development Rights Program.

[7] The authors acknowledge that the PUD has sufficient water rights to accommodate the proposed interbasin transfers, but have deemed it important to account for the negative ecological impact to the Lower Nooksack River.

[8] WRIA1DataIntegration2013.gdb, Wria1_337_nodes); Existing_ExceedanceTables_337nodes_cfs.xls

relatively normal July conditions, while the 95th percentile July streamflow represents a less common extreme low flow, since only 5% of July streamflows fall below that streamflow.

Net streamflow impact data were spatially joined to 2007 hydrology nodes. Since the stream dataset used for net streamflow impact differed from that associated with the 2007 hydrology nodes[9], all nodes were reviewed to verify assignment accuracy of spatial joins. Nodes without a net streamflow change (positive or negative) were deleted and excluded from further analysis; see Figure 2 for the resulting analysis nodes. The 50th percentile and 95th percentile exceedance flows for July were subsequently joined to the 2007 hydrology nodes. July was selected as the most relevant month, since crop irrigation requirements peak in July (NRCS 1992; see also temporal analyses below). The 50th percentile exceedance flow was selected to represent the average flow for July, and the 95% percentile exceedance flow to represent a less common extreme low flow (i.e. the flow level at which only 5% of streamflows would equal or fall below it). Net flow impact for each node was then calculated for the three water use scenarios (Scenario 4, 5A, 6) as a proportion of the two July exceedance flows.

Temporal Analyses

Temporal patterns, both seasonal (intra-annual) and over the 20-year planning period (interannual), of project streamflow benefits relative to projected impacts were evaluated.

Seasonal Pattern

Appendix A of RH2's consumptive use memo (Dunn and Neff 2018) estimates the total annual consumptive water use associated with DGWPE wells in acre-feet per year. Annual consumptive use can be converted to cubic feet per second, but the result is an annual average. Although indoor domestic use is consistent through the year, total and consumptive outdoor use vary seasonally. Seasonal variation in streamflow impact was evaluated in each subbasin on a monthly basis by calculating monthly consumptive water use and comparing to the sum of project offsets provided by month.

Since RH2's calculations for consumptive use (Dunn and Neff 2018) were not available, new calculation worksheets were developed based on methods and results described in the RH2 memo and which duplicated RH2's total annual consumptive use estimates. Monthly consumptive use estimates were then calculated by replacing annual crop irrigation requirements (CIR) with monthly CIR values from the Washington Irrigation Guide (NRCS 1992), which provides both annual and monthly crop irrigation requirements for three climate stations in WRIA 1: Bellingham, Blaine, and Clearbrook. The method for developing subbasin-specific estimates of monthly CIR requirements was consistent with that used by RH2 (Table 7 in Dunn & Neff 2018). Consistent with RH2's estimates, CIRs for pasture/turf were used. To ensure calculation accuracy, monthly consumptive use estimates were aggregated into annual consumptive use estimates by subbasin and scenario and compared to RH2's respective annual consumptive use estimates. All calculations were within 0.41% of RH2's estimates, and many were within 0.01% Monthly consumptive water use was calculated for the following scenarios (all based on option 4 for the number of new DGWPE connections):

- Scenario 4. One home; outdoor irrigation varies by aggregated subbasin (0.064 to 0.322 acres) and is based on aerial photography-based irrigated acreage analysis (modified means).
- Scenario 5B. One home, ½ acre of outdoor irrigation.

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[9] WRIA1DataIntegration2013.gdb, TopnetWMStreamNetwork

- Scenario 5A. One home, ½ acre of outdoor irrigation, plus excess water use up to 3000 gallons per day (maximum annual average withdrawal limit). Monthly fraction of annual indoor and outdoor water use from Scenario 5B was used to calculate the monthly total water use that would average to 3000 gallons per day annual average. Monthly total water use was not constrained to the 5000 gallons per day maximum daily withdrawal limit, and exceeded 8000 gallons per day during July when CIRs are highest.
- Scenario 5A Alternative: One home, ½ acre of outdoor irrigation, plus excess water use up to 3000 gallons per day (maximum annual average withdrawal limit). Monthly total water use from Scenario 5A was constrained to not exceed maximum daily withdrawal limit of 5000 gallons per day; excess monthly total water use was distributed to other months proportionally to monthly fraction of annual indoor and outdoor water use from Scenario 5B to maintain annual average of 3000 gallons per day. This process often required multiple iterations so that no months exceeded 5000 gallons per day total water use.

Scenario 6, which assumes daily withdrawals up to the maximum daily withdrawals limit (5000 gallons per day) was not evaluated as consumptive use would vary little over the year.

Projects were categorized by status (“conceptual”, “in design”, “seeking funding”, “underway”) and offsets were attributed based on RH2 Task 2 Memo Appendix A (Time of Year Water Replaced; Bucknell et al. 2018). Lacking information about seasonal variation in project offset, 100% of the estimated offset was assumed to be provided in a month as long as that month was included in the “Time of Year Water Replaced”. As described under *Spatial Analysis*, the offset for the Stewart Mountain/SF Nooksack Conservation Sale (#21) project was proportionally applied to subbasins based on area of the acquisition area in each subbasin, and the negative flow impacts to the Lower Nooksack subbasin of the PUD #1 Vista Rd. and Lake Terrell Projects (#44, #45) were accounted for in that subbasin.

Finally, monthly consumptive use estimates by scenario and project offsets by status were plotted against month of year for each subbasin and WRIA 1 in aggregate. The net streamflow impact (monthly project offsets in the subbasin minus monthly consumptive use estimates) were also plotted by month for each subbasin and WRIA 1.

Planning Period

RH2’s DGWPE consumptive use estimates (Dunn and Neff 2018) represent the total use after twenty years of growth. To compare the change in consumptive use over the twenty year planning period with project offsets, the number of connections by subbasin and year were back-calculated using the 1.28% average annual growth that was the basis of the population growth estimates. Aggregated subbasin consumptive use (using option 4 for number of new DGWPE connections) by scenario were then scaled to the number of connections in each year. Projects were categorized by status (conceptual, in design, seeking funding, underway) based on RH2 Task 2 Memo Appendix A (Bucknell et al. 2018). For each subbasin and for WRIA 1 in aggregate, consumptive use estimates were plotted by year against project offsets by status for the water use scenarios used in the spatial analysis: Scenario 4, Scenario 5A, and Scenario 6.

As with the spatial analysis, actions lacking quantification of offset (WRIA 1-wide Conservation Program, MAR Feasibility Study, Purchase of Development Rights Program, Glacier WD Groundwater Study and

Augmentation, NF Maple Reach Restoration) were not included in the quantitative temporal analyses but are discussed qualitatively in results

Results

Spatial Analysis

Table 1 summarizes the length of stream with net positive and net negative streamflow impact for each scenario. The total length of stream with net negative impact increases slightly from scenario 4 to scenario 5A and scenario 6.

Table 1. Length of affected streams by water use scenario.

Water Use Scenario	Net streamflow benefit (miles of stream)	Net streamflow deficit (miles of stream)
4	118	501
5A	90	529
6	83	536

Magnitude of Impact

The estimated magnitude of streamflow impact (annually-averaged) from consumptive use associated with new DGWPE wells over the next 20 years for water use scenarios 4, 5A, and 6- as well as the net streamflow impact with offset actions –is shown in Figures 3 through 5. For water use scenario 4 (Figure 3, upper panel), annually-averaged streamflow impact from DGWPE consumptive use (annually-averaged) is less than 0.3 cubic feet per second (cfs) throughout WRIA 1. Streamflow impact accumulates downstream, so it is greatest for the lower Nooksack River and, to a lesser extent, larger tributaries in the lower Basin. With offsets accounted for (Figure 3, lower panel), net streamflow benefit is greatest for the lower Nooksack River (from 6 cfs near the Forks to >11 cfs near the mouth), followed by the South Fork (>6 cfs at mouth), and Bertrand Creek (>2.5 cfs at mouth). The Middle Fork, as well as Dakota, Tenmile, Whatcom, Terrell, and California Creeks also show a net streamflow benefit of 0.5 cfs or less. A number of streams show a net streamflow deficit, although net deficit is less than 0.1 cfs.

For water use scenario 5A (Figure 4, upper panel), annually-averaged streamflow impact from consumptive use (annually-averaged) increases in the Nooksack River from about 0.5 cfs near the Forks to 2 cfs downstream of Ferndale. Outside of the lower Nooksack, streamflow impact from consumptive use is greatest (0.5 to 1 cfs) in Dakota and lower Squalicum Creeks. Throughout most of the affected area, streamflow impact from consumptive use is <0.1 cfs. Accounting for project offsets (Figure 4, lower panel), net streamflow benefit is again greatest for the Nooksack River, which benefits from projects improving streamflow in its tributaries; net streamflow impact is from just under 6 cfs at the Forks confluence to just over 12 cfs at the mouth. Net streamflow benefit is also evident in the South Fork, and Bertrand and Whatcom Creeks, as well as in stream segments in the Dakota Creek, Terrell, Tenmile, and California Creek watersheds, although benefits in those watersheds are negated downstream by consumptive use impacts and creek mouths all show net streamflow deficit.

For water use scenario 6 (Figure 5, upper panel), annually-averaged streamflow impact from consumptive use increases in the lower Nooksack River from around 0.8 cfs near the Forks confluence to

3.6 cfs at the mouth. Streamflow impact near the mouth exceeds 1 cfs in Dakota and Squalicum Creeks and exceeds 0.5 cfs in the lower North Fork, and in the Sumas River and lower Whatcom, California, and Terrell creeks. For this water use scenario, with offsets accounted for, only the lower Nookasck River, Bertrand Creek, the South Fork Nooksack River, and tributary segments of the Dakota Creek, Terrell, California, Lake Whatcom, and other smaller watersheds, show a net streamflow benefit. Net streamflow deficit is greatest (>0.85 cfs) in Dakota, Tenmile, and Squalicum Creeks, followed by the North Fork and Sumas River and California Creek (>0.5 cfs). Similar to water use scenarios 4 and 5A, net streamflow deficit throughout much of the affected area is <0.1 cfs.

Hydrologic Context

In addition to evaluating the absolute magnitude of net streamflow impact, it is important to understand the relative impact, or the magnitude of flow impact relative to the existing streamflow regime. As described in *Methods*, the 50th percentile and 95th percentile exceedance flows for July were selected as the streamflows of greatest interest, because July is the month of peak irrigation and thus consumptive use impact (see section *Temporal Analyses: Seasonal Pattern* below). The 50th percentile July streamflow is an indicator of relatively normal July conditions, while the 95th percentile July streamflow represents a less common extreme low flow, since only 5% of July streamflows fall below that streamflow. Figures 6 and 7 present the net streamflow impact of DGWPE well consumptive and offset actions as a percentage of the 50th and 95th percentile July streamflows at locations (nodes) for which we have hydrologic modeling data.

For water use scenario 4, and assuming relatively normal July streamflows, relative net streamflow deficit (Figure 6) is greatest for Silver and Deer Creeks where the estimated deficit exceeds average July flows. For water use scenarios 5A, relative net streamflow deficit also exceeds 50th percentile July streamflows in Tenmile and lower Squalicum Creeks. The Dakota Creek system is also vulnerable, with relative net streamflow deficit >50% of 50th percentile streamflow at 3 of 15 locations and 25-50% of 50th percentile July streamflow at 4 of 15 locations. Under water use scenario 6, relative net streamflow deficit exceeds the 50th percentile July streamflow at the same locations as in scenarios 4 and 5A, as well as 3 locations in the Dakota drainage, lower Squalicum Creek and Onion Creek, a tributary to Lummi Bay. Other locations in the Squalicum and Dakota Creek watersheds are vulnerable, with relative net streamflow deficit of at least 25%. Wiser Lake Creek, Sumas River, and a tributary to Bellingham Bay are also vulnerable in this water use scenario. Under even lower flow conditions (i.e. 95th percentile July streamflows), relative net streamflow deficit constitutes a higher proportion of streamflow, especially at higher water use scenarios (Figure 7).

Relative net streamflow impact (positive or negative) is less than 10% for most of the 138 hydrologic modeling nodes in WRIA 1 that are affected by DGWPE consumptive impacts and/or offset actions (Figure 8). Under normal July streamflows (e.g. 50th percentile July streamflow; Figure 6, upper panel), relative net streamflow deficit is less than 10% for 64% of nodes under water use scenario 4, 59% of nodes under water use scenario 5A, and 54% of nodes under water use scenario 6. Relative net streamflow deficits are greater than 10% for 2.9%, 17%, and 24% under water use scenarios 4, 5A, and 6, respectively; significant deficits (>50% of 50th percentile flows) are evident for a smaller proportion (Scenario 4 – 2.1%, Scenario 5A – 5.8%, Scenario 6 – 8.0%). Relative net streamflow benefit is evident for 10% of nodes under water use scenario 4 and only 4.3% under scenarios 5A and 6. At times of abnormally low streamflow (e.g. 95th percentile July flows), relative net streamflow deficits increase

(Figure 8, lower panel), with 4.4%, 17%, and 28% of nodes with greater than 10% net streamflow deficit under scenarios 4, 5A, and 6.

Temporal Analysis

Seasonal

The spatial analysis described above is based on estimates of annually-averaged consumptive use. The actual pattern of consumptive use is expected to vary through the year with seasonal changes in irrigation. According to monthly crop irrigation requirements in the *Washington Irrigation Guide*, irrigation season is April to September (NRCS 1992) for pasture/turf under the cooler climatic conditions than are occurring now or predicted for the future (i.e. 1951-1980 is the period used to develop the CIR and was predominantly in the cool-phase of the Pacific Decadal Oscillation (PDO)). Table 2 shows estimates of per-household monthly consumptive water use for two subbasins, one with the highest annual crop irrigation requirement and highest irrigated acreage in scenario 4 (Coastal West) and another with a low annual crop irrigation requirement and lowest irrigated acreage in scenario 4 (Middle Fork). Both indicate that peak household monthly consumptive water use (which occurs in July) can be over 3-fold greater than the annually-averaged estimate. Household monthly consumptive use also exceeds the annual average through much of the irrigation season, from April or May through August or September, depending on water use scenario.

Accordingly, aggregating across WRIA 1, DGWPE well consumptive use exhibits a strong seasonal pattern, peaking in July and trailing off before and after (Figure 9, upper panel). Lowest consumptive use is from October through March, when monthly crop irrigation requirement is zero (based on average conditions during the 1951-1980 period). Comparing across water use scenarios, monthly consumptive water use is higher in scenario 5B relative to scenario 4 April through September, but equivalent outside the irrigation season. The seasonal patterns for Scenario 5A varies depending on whether the maximum daily limit of 5000 gallons per day is applied. Constraining water use to 5000 gallons per day or less while maintaining the 3000 gallon per day average (Scenario 5A) would lessen the peaks but increase consumptive water use September through May relative to the alternative (Scenario 5A-Alt). Even if average per-household water use across WRIA 1 is more consistent with scenario 4, for DGWPE well users using greater amounts of water (up to legal limits, i.e. consistent with Scenarios 5A and 5B), Figure 7 indicates what the localized impacts would be relative to the lower water use scenario for the month of July.

To the extent that action offsets have been quantified, the vast majority of offsets are associated with projects that are in conceptual status and thus lower in implementation certainty (Figure 9, upper panel). A small proportion of offsets are associated with projects that are underway. Although there is some seasonal variation in offsets and the quantified offset was applied year-round, most projects were characterized as having year-round timing of benefit, which may overrepresent the offset in some months. If fully implemented and effective, projects will offset total WRIA 1 consumptive water use in all months and for all three scenarios evaluated, except in June through August for the Scenario 5A Alternative where maximum daily use is not constrained to 5000 gallons per day or less (Figure 9, lower panel). As described in *Spatial Analysis* above, however, it is important to remember that a considerable length of streams will not benefit from offset projects.

Evaluated at the subbasin scale (see Appendix B), the pattern is more nuanced. Offsets far exceed total consumptive water use throughout the year for all four scenarios evaluated in the Lower Nooksack and

South Fork subbasins, although most offsets are associated with projects that are in conceptual status. With water use scenario 4, offsets exceed monthly consumptive use throughout the year for Coastal North, Lake Whatcom, Lower Nooksack, Middle Fork Nooksack and South Fork Nooksack subbasins. In Coastal West, monthly consumptive use exceeds offsets May through September. For water use scenario 5B, there is a seasonal net deficit for Coastal North, Coastal West, and Middle Fork. Seasonal net deficit also is evident through much of the irrigation period in Coastal North, Coastal West, and Middle Fork and Lake Whatcom subbasins for both Scenario 5A alternatives. As with other subbasins, offsets are largely associated with conceptual projects. No offsets have been quantified for the Coastal South, North Fork and Sumas basins.

Table 2. Comparison of annually-averaged household water use with peak monthly household water use for different water use scenarios for two aggregated subbasins (units in gallons per day).

Aggregated Subbasin	Water Use Scenario	Annually-Averaged	Peak Monthly (July)	
		Household consumptive water use (gpd[1])	Household total water use (gpd)	Household consumptive water use (gpd)
Coastal West	4[2]	428	1870	1388
	5B[3]	657	2818	2147
	5A[4]	2062	5000	3647
	5A-Alternative[5]	2062	8859	6299
	6[6]	3437	5000	3647
Middle Fork	4	85	478	275
	5B	559	2688	2043
	5A	2013	5000	3594
	5A-Alternative	2013	9676	6732
	6	3355	5000	3594

[1] Calculated by dividing estimate from Dunn & Neff (2018) Appendix A by number of connections and converting to gallons per day.

[2] 0.064 acres irrigated

[3] 0.5 acres irrigated

[4] Annual average water use 3000 gallons per day: 0.5 acres irrigated, assume excess water use 68% consumptive, constrain monthly water use to no more than 5000 gallons per day.

[5] Same as above but without application of 5000 gallons per day limit.

[6] Maximum daily water use 5000 gallons per day: 0.5 acres irrigated, assume excess water use ~68% consumptive

Planning Period (2018-2038)

Consumptive water use has been estimated for 20 years of new DGWPE well connections, but consumptive water use will increase over time (Figure 10). Assuming water use scenario 4 and an annual population growth rate over the 20-year planning period consistent with projections, and assuming that project offsets accrue within the planning period, offsets associated with projects underway would exceed consumptive use until 2031, when they would be outpaced by consumptive use. If most of the offset associated with conceptual projects is realized, even the higher water use scenarios of 5A and 6 are offset at the WRIA 1 scale. It is important to note that two projects (#19, #21) require mature forest to provide full benefit and thus offsets associated with those projects, which comprise 71% of the offset quantified for WRIA 1, are not expected to fully accrue within the planning period

At the aggregated subbasin scale, the spatial distribution of growth may vary over time and, thus, rate of increase in consumptive use over time within subbasins is likely more variable than at the broader WRIA 1 scale. Nonetheless, it is clear that within many subbasins (Appendix C), an offset gap is likely early on because no or few projects are underway while growth is proceeding. There is also a potential for an offset gap later in time if growth outpaces implementation.

Ecological Implications

Viability of salmonids and other instream resources in freshwater is a function of both habitat conditions (physical habitat characteristics and water quality) and the ecosystem processes that form and maintain those conditions, including hydrology, sediment dynamics, riparian, floodplain-channel interactions, habitat connectivity, organic matter, and nutrient supply (PSRITT 2015). While the focus of this assessment is an evaluation of the cumulative effects of DGWPE consumptive use impacts and projects on hydrologic regime, it is important to consider ecological effects more broadly.

Hydrologic Regime

Annually-averaged estimates of DGWPE consumptive use vary by subbasin but total 0.9 cfs, 6.80 cfs, and 11.80 cfs for water use scenarios 4, 5A, and 6, respectively. Accounting for both DGWPE consumptive use impacts and projects, there is a considerable spatial gap evident, with the vast majority (>80%, >500 miles) of affected stream length showing a net negative streamflow impact under all three water use scenarios evaluated (scenario 4, 5A, and 6). Absolute magnitude of cumulative DGWPE consumptive impact within any single stream segment is relatively low for much of the affected stream length, with less than 0.3 cfs under water use scenario 4, increasing to maxima of 2 cfs and 3.6 cfs at the mouth of the Nooksack River under legally permissible water use scenarios 5A and 6. Accounting for offsets, net streamflow benefit is evident for the Nooksack River, South Fork, Bertrand Creek, and in portions of some independent tributary watersheds (Dakota, Terrell, California, Whatcom/Lake Whatcom, and other smaller watersheds). At the highest water use scenario 6, net streamflow deficit is greatest (>0.5 cfs) in Dakota, Tenmile, Squalicum, and California Creeks, and the North Fork and Sumas River. Relative net streamflow impact under relatively normal July streamflow conditions (i.e. impact relative to 50th percentile exceedance flow for July) is less than 10% for most of the locations for which hydrologic modeling is available. However, significant net streamflow deficits are evident in the Silver, Dakota, Tenmile/Deer, lower Squalicum Creek, and Wiser Lake Creeks and Sumas River, especially at higher water use scenarios. During more extreme July low streamflows (i.e. when flows are at or below 95th percentile exceedance flows), 4.5%, 17%, and 28% of locations (nodes) show a greater than 10% net streamflow deficit under water use scenarios 4, 5A, and 6.

Since it is based on annually-averaged estimates of new DGWPE well consumptive use, the spatial analysis likely underestimates impacts during irrigation season (April to September; NRCS 1992), especially during peak irrigation. To the extent that action offsets have been quantified, the vast majority of offsets are associated with projects that are in conceptual status and thus lower in implementation certainty. If fully implemented and effective, projects across WRIA 1 offset consumptive use impacts through the year for scenario 4, spatial gaps notwithstanding, but not for the water use scenario 5A (3000 gallons per day annual average) with no constraint on daily maximum withdrawal). Quantified offsets, associated largely with conceptual projects, in Lower Nooksack and South Fork aggregated subbasins far exceed DGWPE consumptive use. Seasonal gaps are evident for Coastal West subbasin under water use scenario 4, and for Coastal North, Coastal West, Middle Fork, and Lake Whatcom under higher water use scenarios. No offsets have been quantified for the Coastal South, North Fork and Sumas subbasins.

Given that many of the projects are in conceptual status, the timing of the onset of offsets have not been well-characterized and benefits may not accrue during the planning period. This may hold most true for projects involving restoration of hydrologic processes (e.g. Middle Fork Porter Creek Alluvial Fan project; Stewart Mountain/Sf Nooksack Conservation Sale; Wetland Restoration, Enhancement, and/or Creation on Ecology-approved NEP parcels; Skookum Creek Restoration), even though such restoration may provide the most sustainable streamflow benefits into perpetuity. Lifespan of benefits is also a concern: although consumptive use impacts will presumably last, many of the identified projects will require ongoing maintenance and operations funding for offsets to persist into perpetuity.

Other Ecological Effects

Although the magnitude of cumulative streamflow impacts is relatively small through much of WRIA 1, it is significant in some stream systems, and even minor impacts will exacerbate degraded water quality conditions, especially high stream temperatures and low dissolved oxygen, that exist through much of the Nooksack Basin. A number of streams throughout WRIA 1 have been listed as impaired for low dissolved oxygen and high stream temperature on Washington State’s 303(d) list (Figure 10), many of which will be impacted by DGWPE consumptive use.

Although most projects are designed to offset DGWPE consumptive use impacts to streamflow, several projects will have other ecological benefits (Bucknell et al. 2018), albeit more localized to the project area. Table 9 summarizes other (non-hydrologic) ecological benefits of projects. Except for the PDR program, all would benefit areas considered high priority for Nooksack chinook recovery.

Salmonid Impacts

As described in the *WRIA 1 Salmonid Recovery Plan* (WRIA 1 SRB 2005), stream flow exerts a strong influence over salmonid habitat by regulating wetted surface area and thus the amount of available habitat, as well as by controlling the spatial distribution of depths and velocities. In addition to generally reducing habitat availability, low streamflows also affect salmonids as follows: (1) impeded upstream migration for prespawn migrants, especially in tributaries; (2) reduced availability of habitat for spawners, which require sufficient depth and velocities in areas with suitable spawning substrate;

Table 3. Summary of Other (Non-Hydrologic) Ecological Effects of Projects.

	Habitat Conditions				Ecosystem Processes			
Project	Physical Habitat Structure	Water Quality	Sediment Dynamics	Riparian	Floodplain-Channel Interactions	Habitat Connectivity	Organic Matter	Nutrient Supply
Middle Fork Porter Creek Alluvial Fan Project	X	X	X		X	X		
Wetland Restoration, Enhancement, and/or Creation on Ecology-Approved NEP Parcels		X		X				
Skookum Creek Restoration	X	X	X	X	X		X	X
Stewart Mountain/SF Nooksack Conservation Sale		X		X	X		X	X
North Fork Maple Reach Restoration Phase 1	X		X	X	X		X	X
Purchase of Development Rights Program			X	X	X		X	X

redd dewatering, since incubating embryos require sufficient intragravel flow to maintain adequate temperature and dissolved oxygen and to eliminate waste; (4) dewatering and/or reduced connectivity of secondary channels and complex edge habitat, affecting fry; (5) decreased survival of rearing juveniles due to increased vulnerability to terrestrial predators in shallow depths; and (6) degraded water quality, including increased temperatures and concentration of contaminants and reduced dissolved oxygen.

Salmonid species distribution by aggregated subbasin is shown in Table 3. Negative impacts of DGWPE consumptive use to ESA-listed salmonid species is expected to be greatest for steelhead, which are broadly distributed throughout much of the WRIA 1 lowlands, and especially the Nooksack River Winter Run, Drayton Harbor Tributaries Winter Run, and Samish River/Bellingham Bay Tributaries Winter Run demographically independent populations. Fall chinook and foraging and overwintering bull trout will also likely be negatively impacted. Where spatial and temporal gaps exist, life stages present during low-flow conditions, especially juvenile rearing but also upstream migration for summer-migrating species (Chinook, Sockeye, and Pink salmon; summer steelhead; bull trout), are the most vulnerable (Table 4).

Net Ecological Benefit

In conclusion, there is low certainty that the cumulative impacts of both the projected DGWPE consumptive use over the next 20 years and the streamflow and other ecological benefits associated with selected actions will result in a net ecological benefit in perpetuity**. Conversely, there is reasonable certainty that the cumulative impacts will rather result in a net ecological deficit,** to instream resources, including salmonids, in WRIA 1 due to the considerable spatial gap between estimated annualized consumptive use impacts and project offsets (as currently quantified) and other ecological benefits, the significant magnitude of net streamflow deficit at selected locations, the temporal gap in project offsets during peak irrigation (including during drought periods) in areas benefitting from offsets, uncertainty in magnitude and spatial distribution of future DGWPE consumptive use impacts, and uncertainty about project implementation, effectiveness, and magnitude, seasonal timing, and onset of streamflow offsets . Measures that would increase certainty of net ecological benefit include:

- Fully mitigating (in-kind, in time, in place) DGWPE consumptive use impacts in all affected streams (e.g. through onsite mitigation by each well owner or other means) year-round, including during drought periods.
- Increasing the number, magnitude, and/or location of project offsets to provide a factor of safety to buffer against uncertainty in DGWPE consumptive use impacts and project offsets.
- Implementing policies and programs that:
    - Avoid or minimize impact (e.g. reducing withdrawal limits; water conservation)
    - Reduce uncertainty in consumptive use impacts (e.g. metering; stream monitoring)
    - Reduce uncertainty in project implementation and effectiveness (e.g. ensure sufficient funding available; implement strong monitoring and adaptive management program).

Table 4. Salmonid species presence by aggregated subbasin.

		Coastal North	Coastal South	Coastal West	Lake Whatcom	Lower Nooksack	Middle Fork	North Fork	South Fork	Sumas
Nooksack Early Chinook	NF/MF Nooksack Early Chinook					X	X	X		
	SF Nooksack Early Chinook					X			X	
Puget Sound Steelhead	Drayton Harbor Tributaries Winter Run	X								
	Nooksack River Winter Run					X	X	X	X	
	South Fork Nooksack River Summer Run					X			X	
	Samish River, Bellingham Bay Tributaries		X							
Bull Trout	Nooksack Core Area					X	X	X	X	
	Chilliwack Core Area									X
Fall chinook salmon		X	X	X		X	X	X	X	X
Coho salmon		X	X	X		X	X	X	X	X
Chum salmon		X	X	X		X	X	X	X	X
Pink salmon		X	X	X		X	X	X	X	X
Sockeye salmon			X	X		X	X	X	X	X
Coastal cutthroat trout		X	X	X	X	X	X	X	X	X
Kokanee					X					

Table 5. Salmon life stage periodicity relative to seasonal variation in DGWPE consumptive use impacts (color indicates relative magnitude of monthly consumptive use).

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Spring Chinook Salmon	River Entry		X	X	X	X	X	X	X				
	Upstream Migration / Holding		X	X	X	X	X	X	X	X	X		
	Spawning							X	X	X	X		
	Intragravel Development	X	X	X				X	X	X	X	X	X
	Age-0 rearing[a]	X	X	X	X	X	X	X	X	X	X	X	X
	Age-0 outmigration[a]	X	X	X	X	X	X	X	X	X	X	X	
	Age-1+ rearing[b]	X	X	X	X	X	X	X	X	X	X	X	X
	Age-1+ outmigration[b]	X	X	X	X	X	X	X	X	?	?	?	?
Fall Chinook Salmon	River Entry						?	X	X	X	X	?	
	Upstream Migration / Holding						?	X	X	X	X	X	?
	Spawning									X	X	X	?
	Intragravel Development	X	X	X	X					X	X	X	X
	Fry <~55mm	X	X	X	X	X	X						
	Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Outmigration		X	X	X	X	X	X	X	X	X	X	
Coho Salmon	River Entry	X	?					X	X	X	X	X	X
	Upstream Migration / Holding	X	X					X	X	X	X	X	X
	Spawning	X	?								X	X	X
	Intragravel Development	X	X	X	X	X					X	X	X
	Fry <~55mm		X	X	X	X	X						
	Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Outmigration			X	X	X	X	X					
Chum Salmon	River Entry	X							X	X	X	X	X
	Upstream Migration / Holding	X	X						X	X	X	X	X
	Spawning	X	X								X	X	X
	Intragravel Development	X	X	X	X						X	X	X
	Fry		X	X	X	X	X	X					
	Juvenile Rearing (not applicable)												
	Outmigration		X	X	X	X	X	X					
Pink Salmon	River Entry						?	X	X	X			
	Upstream Migration / Holding						?	X	X	X	X		
	Spawning								X	X	X		
	Intragravel Development	X	X	X	X	X			X	X	X	X	X
	Fry	X	X	X	X	X	X						X
	Juvenile Rearing (not applicable)												
	Outmigration	X	X	X	X	X	X						
Sockeye salmon	River Entry				X	X	X	X	X	X	X		
	Upstream Migration / Holding				X	X	X	X	X	X	X	X	
	Spawning								X	X	X	X	
	Intragravel Development	X	X	X	X				X	X	X	X	X
	Fry and Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Outmigration			X	X	X	X	X					

Notes: (a) Age-0 refers to fish that outmigrate as subyearlings.

(b) Age-1+ refers to fish that outmigrate as yearlings or older.

Legend:

X	Months in which the species lifestage occurs in WRIA 1.
?	Months in which there is a question whether the species lifestage occurs in WRIA 1.

Table 6. Life stage periodicity for other salmonids relative to seasonal variation in DGWPE consumptive use (color indicates relative magnitude of monthly consumptive use).

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Summer Steelhead	Upstream Migration				X	X	X	X	X	X	X		
	Holding	X	X	X	X	X	X	X	X	X	X	X	X
	Spawning		X	X	X								
	Adult Outmigration		X	X	X	X							
	Intragravel Development		X	X	X	X	X						
	Fry <~55mm	X			X	X	X	X	X	X	X	X	X
	Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Juvenile Outmigration		X	X	X	X	X	X	X				
Winter Steelhead	Upstream Migration	X	X	X	X	X	X				X	X	X
	Holding	X	X	X	X	X	X	X			X	X	X
	Spawning	X	X	X	X	X	X	X					X
	Adult Outmigration	X	X	X	X	X	X	X					X
	Intragravel Development	X	X	X	X	X	X	X	X				X
	Fry <~55mm	X		X	X	X	X	X	X	X	X	X	X
	Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Juvenile Outmigration		X	X	X	X	X	X	X				
Coastal Cutthroat (anad.)	Upstream Migration	X	X	X	X	X	X	X	X	X	X	X	X
	Holding	X	X	X	X	X	X	X	X	X	X	X	X
	Spawning	X	X	X	X	X	X	X					
	Adult Outmigration	X	X	X	X	X	X						
	Intragravel Development	X	X	X	X	X	X	X	X	X			
	Fry <~55mm	X	X	X	X	X	X	X	X	X	X	X	X
	Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Juvenile Outmigration		X	X	X	X	X	X	X				
Bull Trout/Dolly Varden (anad.)	Upstream Migration					X	X	X	X	X	X	X	
	Subadult Upstream Migration								X	X	X	X	
	Subadult Overwinter Holding	X	X	X	X	X			X	X	X	X	X
	Holding	X	X	X	X	X	X	X	X	X	X	X	X
	Spawning								X	X	X	X	X
	Adult Outmigration	X	X	X	X	X	X	X					
	Intragravel Development	X	X	X	X				X	X	X	X	X
	Fry <~55mm		X	X	X	X	X	X	X				
	Juvenile Rearing	X	X	X	X	X	X	X	X	X	X	X	X
	Juvenile Outmigration			X	X	X	X	X	?				

Analysis Limitations and Uncertainty

Time and resource constraints strongly limited the depth and breadth of this ecological assessment. RCW 90.94 established a very tight timeframe (February 1, 2019) for adoption of the WRIA 1 Watershed Plan update, leaving less than 10 months to conduct the technical analyses and develop the preliminary draft of the WRIA 1 Watershed Plan update. Ecology's *Net Ecological Benefit* guidance (Ecology 2018), published in June 2018, provided guidance but not specific methods for evaluating net ecological effects, so new methods based on best professional judgement were developed. As time allows, this assessment will be updated and refined.

Sources of uncertainty in the ecological assessment include:

- Uncertainty in magnitude, spatial distribution, and timing of consumptive use associated with new DGWPE wells
- Uncertainty in magnitude, spatial distribution, and timing of offsets from actions
- Uncertainty in the implementation and effectiveness of actions
- Assumptions underlying analysis methods

Input Data

Population growth rate, proportion of growth outside of urban areas, and water source (i.e. whether new development connects to an existing water association or water district) will all affect the number of new DGWPE wells through 2038. Estimates of consumptive use are a function of the number of connections and household water use, which in turn is based on irrigation needs, area irrigated, and other factors. The climate is warmer since the period upon which crop irrigation requirements are based (1951-1980; NRCS 1992) and is predicted to continue to warm, which will further increase water used for irrigation. The growth scenario used in this analysis is a reasonable estimate of the spatial distribution of growth across WRIA 1 and perhaps at the scale of aggregated subbasins, but there is greater uncertainty at the parcel level, as the number of buildable parcels outside of UGAs far exceed the projected rural growth over the next 20 years.

The project list has been evolving through the process, and not all of the projects are characterized in the RH2 Task 2 memo (Bucknell et al. 2018). Level of detail available varies by project, and information about project benefits is especially limited for conceptual projects. Several projects lack quantification of offsets, including the Managed Aquifer Recharge Feasibility Study, the Purchase of Development Rights program, the WRIA 1-wide conservation program, and the North Fork Maple Reach Restoration Phase 1 project. Excluding these from quantitative analyses may underestimate their associated streamflow benefits. However, there is also high uncertainty around (and possibly overestimate of) the magnitude of offset for the two projects with the largest offsets – Skookum Creek Restoration and Stewart Mountain/SF Conservation Sale. There is also uncertainty in project locations – offset was attributed to downstream stream segments based on geospatial (point) data provided by RH2, but the analysis could be refined later with more detailed location information, such as that available in the RH2 Task 2 memo. Finally, there is a high degree of uncertainty that offsets will be realized, especially for conceptual projects, due to uncertain feasibility, low certainty of implementation success, and low certainty of effectiveness.

Analysis Methods

Analysis methods also introduced uncertainty in the location and magnitude of impact to streamflow. Since there were no geospatial data available that would align with the selected option (option 4) for the number of new DGWPE connections over the next twenty years, total consumptive use within a subbasin was distributed to each parcel in the growth scenario proportional to the number of projected new households associated with the parcel. As such, consumptive use was attributed to some parcels that fall within (and may ultimately upon development be connected to) existing water service and water association boundaries. Consumptive use was also attributed to parcel centroids, whereas actual location of consumptive use will depend on where in the parcel the well is drilled.

Other potentially significant sources of uncertainty are the assumptions underlying the spatial analysis. The assumption that groundwater flow paths match surface topography is generally supported, although there are notable discrepancies, including in the northeast corner of Coastal North subbasin, northeast corner of Lower Nookasck, and the Coastal West subbasin (Dunn and Neff 2018). However, assuming that 100% of consumptive use from DGWPE wells results in flow deficit to closest stream segment and that the timing of deficit is immediate and synchronous with deficits elsewhere likely overestimates the impact of consumptive use on streamflow. However, the spatial analysis is based on estimates of annually-averaged consumptive use and likely underestimates consumptive use during peak irrigation season, except for water use scenario 6, which assumes withdrawal of 5000 gallons per day throughout the year.

As with RH2's estimates of total consumptive use, estimating monthly consumptive use for scenarios 5A and 6 requires assumptions about consumptive use and timing of "excess water use" (i.e. that required to achieve established daily or average annual maxima). This assessment is consistent with RH2's method regarding consumptive rates for "excess" water. It is generally assumed valid that the timing of excess water use parallels the combined indoor domestic and outdoor water use. Finally, estimates of increase in DGWPE well consumptive use over time assume a constant rate of population growth. While that assumption may generally be valid at the broader WRIA 1 scale, certainty decreases at finer spatial scales (i.e. at the subbasin level) due to uneven spatial distribution of rural growth from one year to the next.

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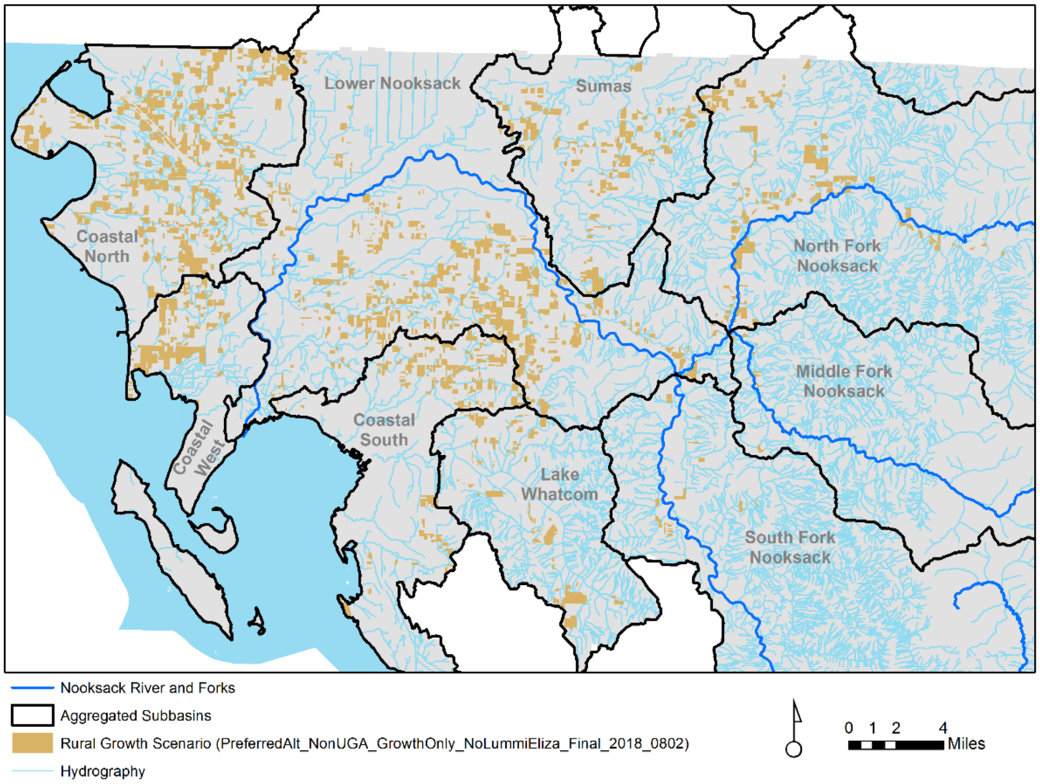


Figure 1. Rural growth scenario used in analysis (Source: Whatcom County Planning & Development).

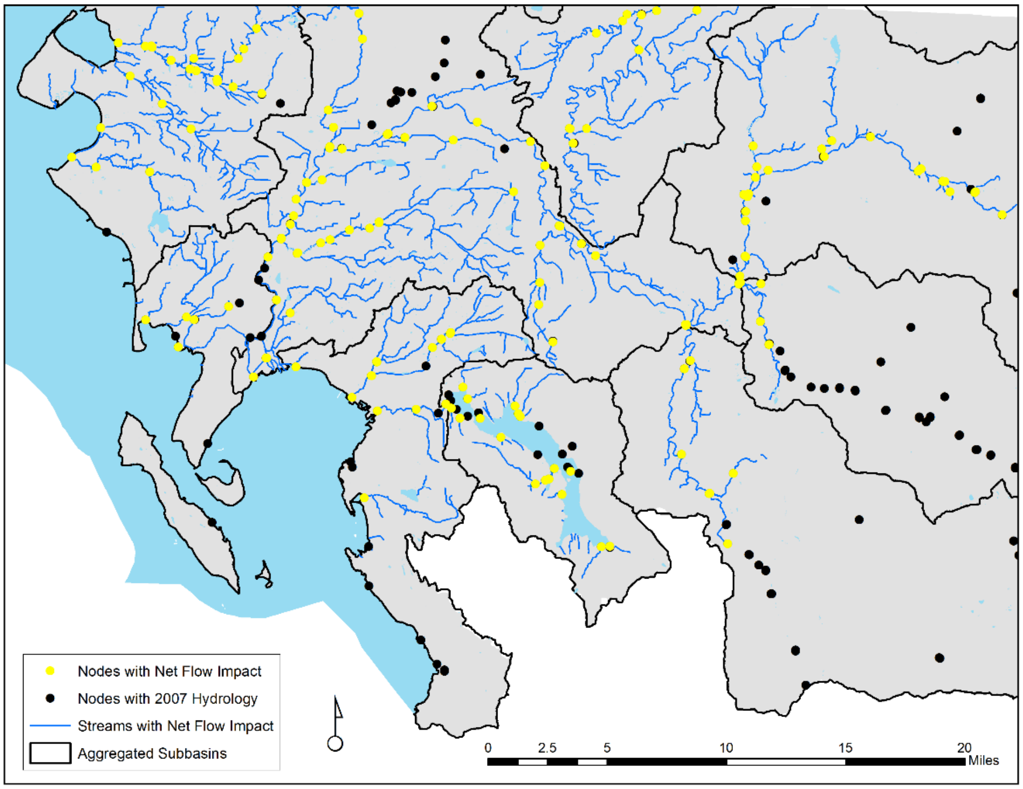


Figure 2. Nodes and streams with net flow impact (positive or negative) from DGWPE well consumptive use and/or selected actions.

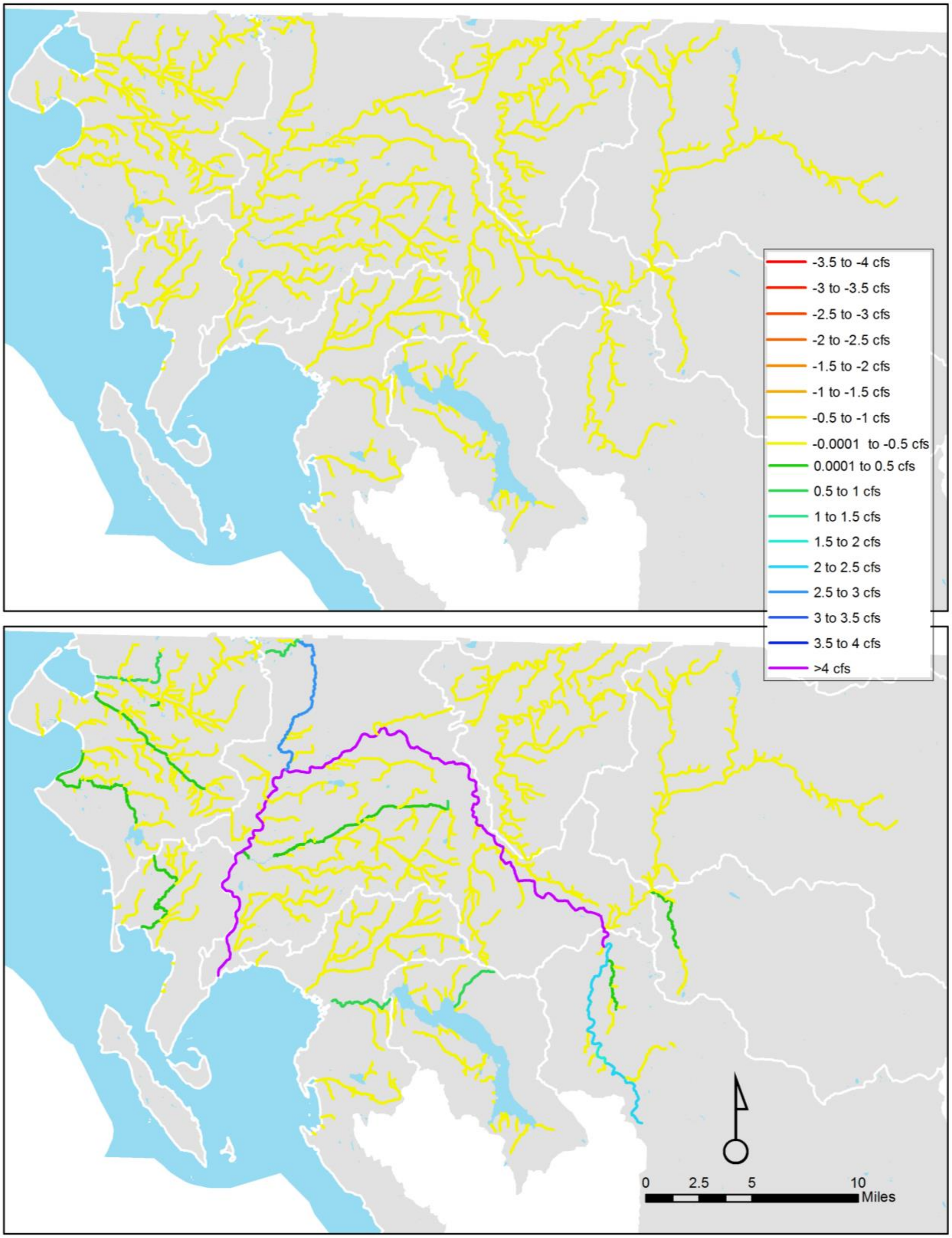


Figure 3. Cumulative streamflow impact (annually-averaged) from DGWPE well consumptive use (upper) and net streamflow impact with offset actions added (lower) under water use scenario 4 (option 4). In the lower panel, note that warmer colors (yellow to red) indicate net streamflow deficit and cooler colors (green to purple) indicate net streamflow benefit.

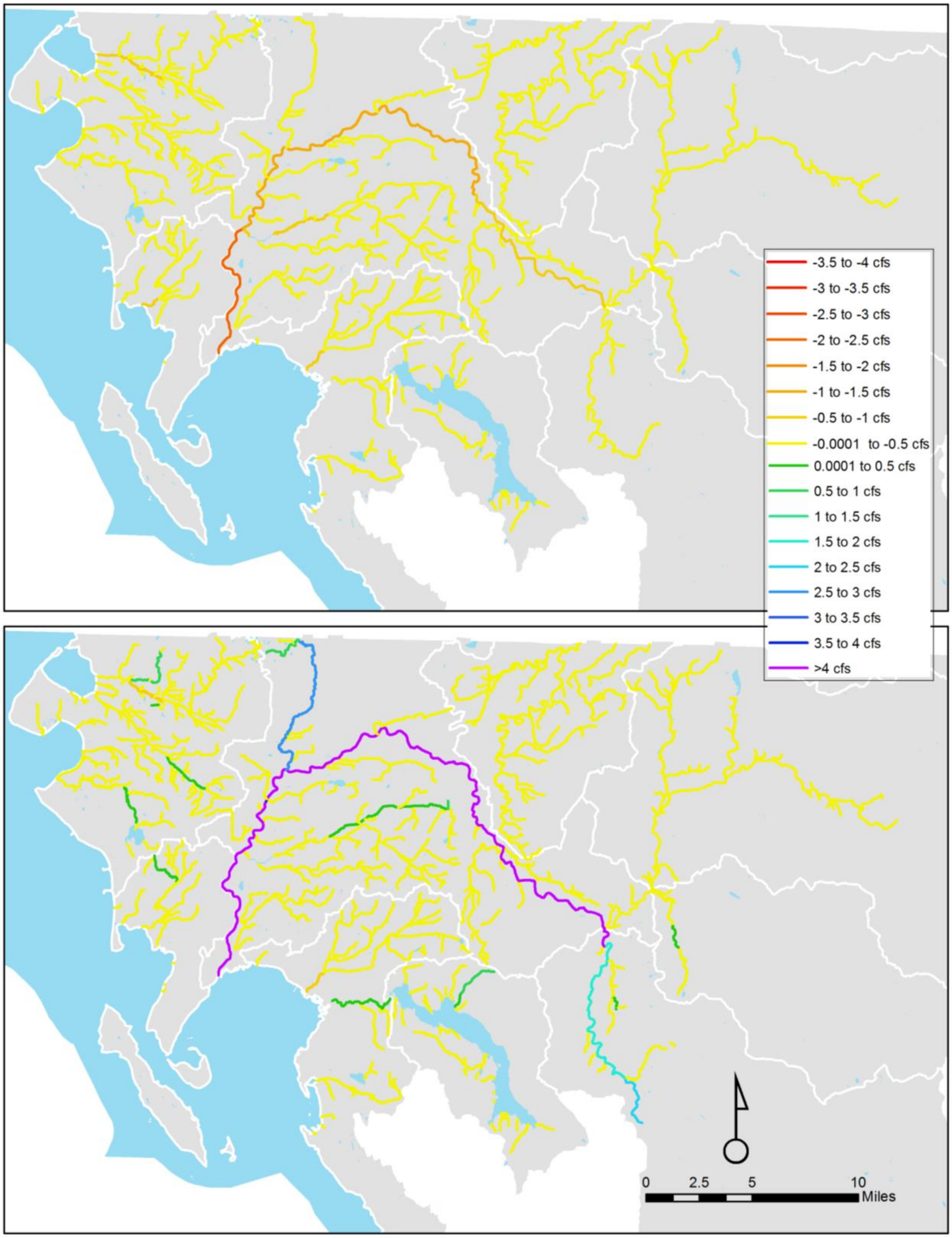


Figure 4. Cumulative streamflow impact (annually-averaged) from DGWPE well consumptive use (upper) and net streamflow impact with offset actions added (lower) under water use scenario 5A (option 4). In the lower panel, note that warmer colors (yellow to red) indicate net streamflow deficit and cooler colors (green to purple) indicate net streamflow benefit.

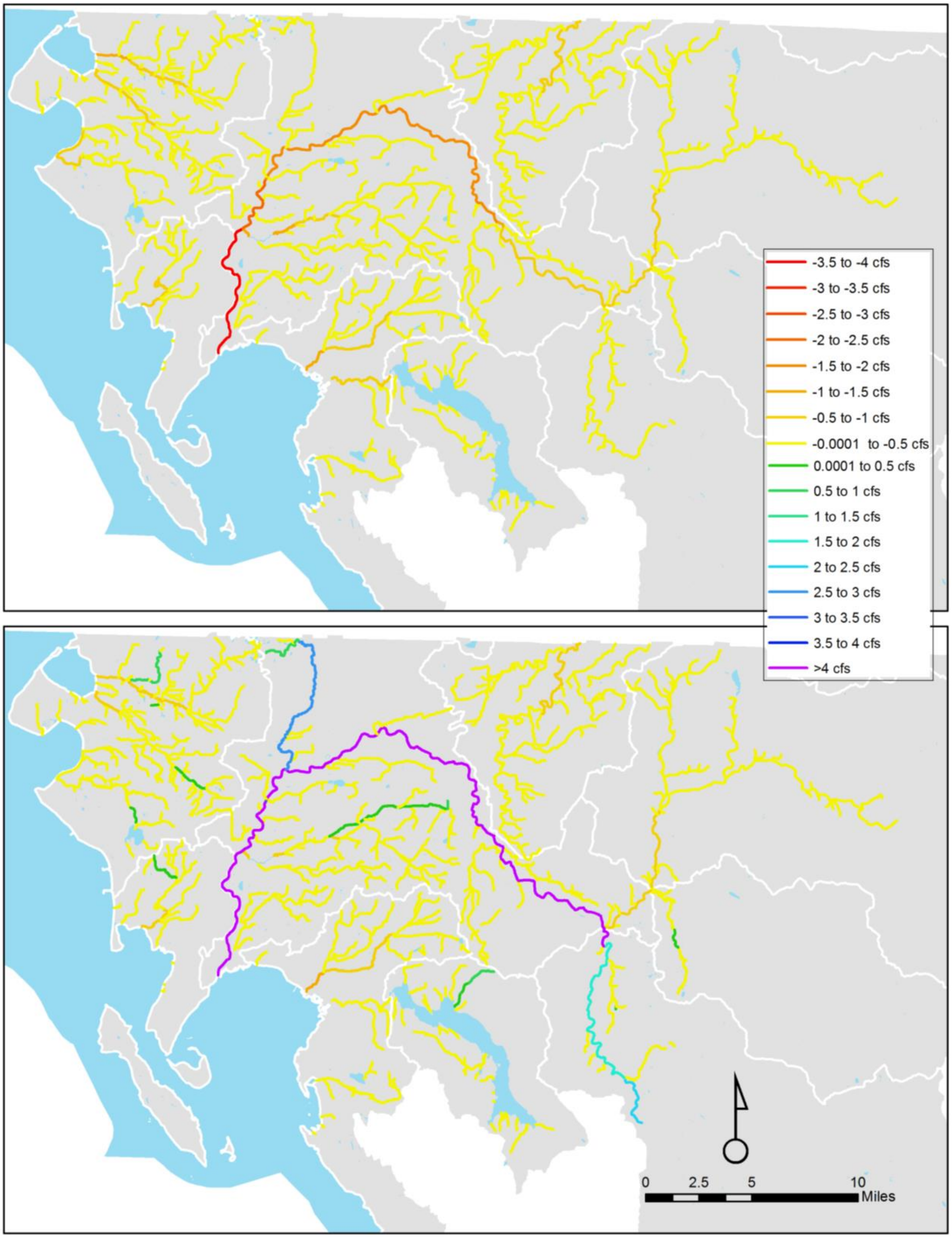
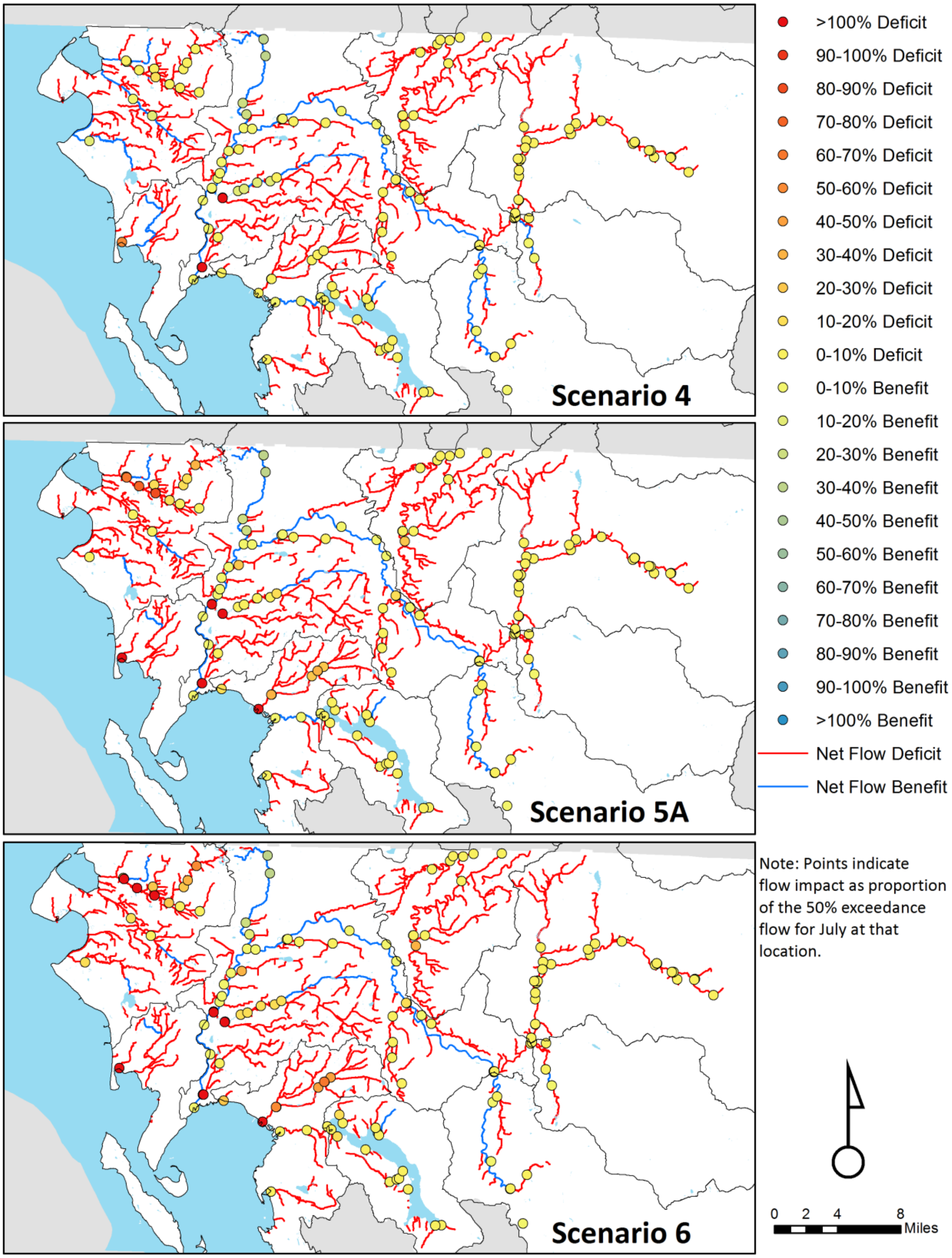
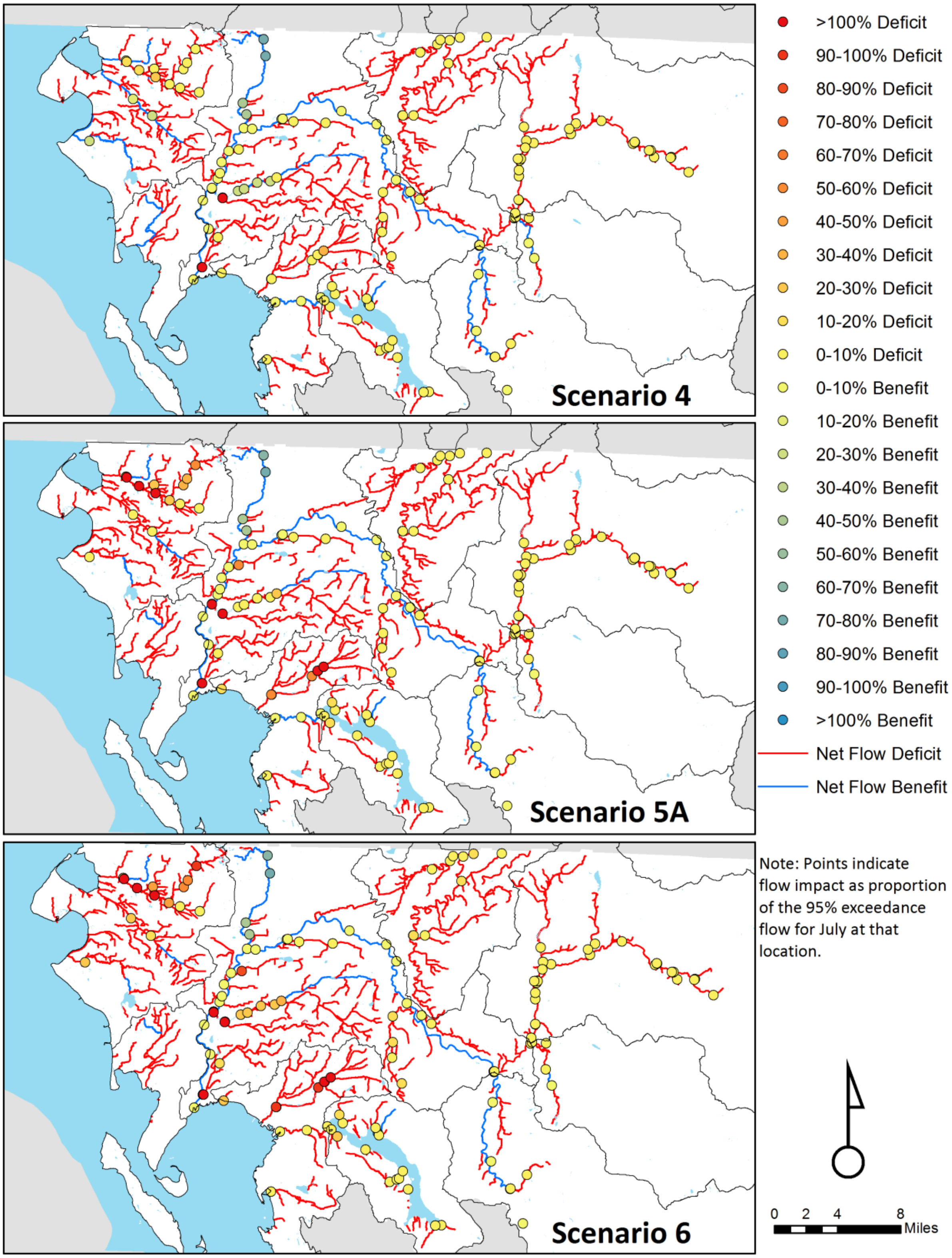


Figure 5. Cumulative streamflow impact (annually-averaged) from DGWPE well consumptive use (upper) and net streamflow impact with offset actions added (lower) under water use scenario 6 (option 4). In the lower panel, note that warmer colors (yellow to red) indicate net streamflow deficit and cooler colors (green to purple) indicate net streamflow benefit.



Note: Points indicate flow impact as proportion of the 50% exceedance flow for July at that location.

Figure 6. Cumulative streamflow impact from DGWPE well consumptive use and offset actions as a percentage of the 50th percentile July exceedance flow (relatively normal July streamflow).



Note: Points indicate flow impact as proportion of the 95% exceedance flow for July at that location.

Figure 7. Cumulative streamflow impact from DGWPE well consumptive use and offset actions as a percentage of the 95th percentile July exceedance flow (less common July low flow).

Figure 8. Frequency histograms for relative net streamflow impact (deficit or benefit). Upper panel: net streamflow impact as proportion of 50th percentile exceedance flow for July (representative of relatively normal July streamflows). Lower panel: net streamflow impact as proportion of 95th percentile exceedance flow for July (representative of less common extreme low flow).

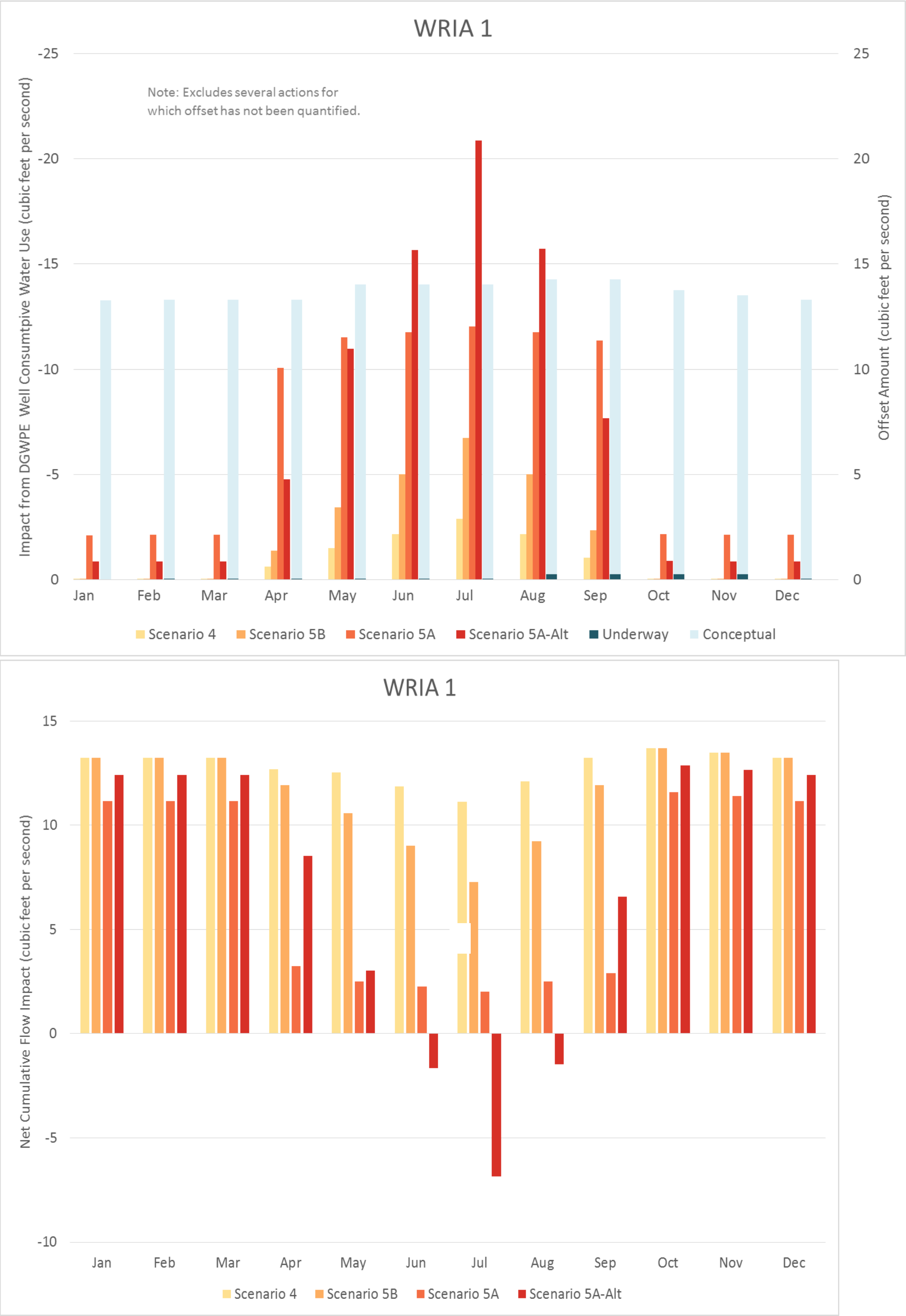


Figure 9. Seasonal variation in streamflow impact from DGWPE well consumptive water use and offset actions across WRIA 1 (upper panel) and net cumulative streamflow impact (lower panel) across WRIA 1.

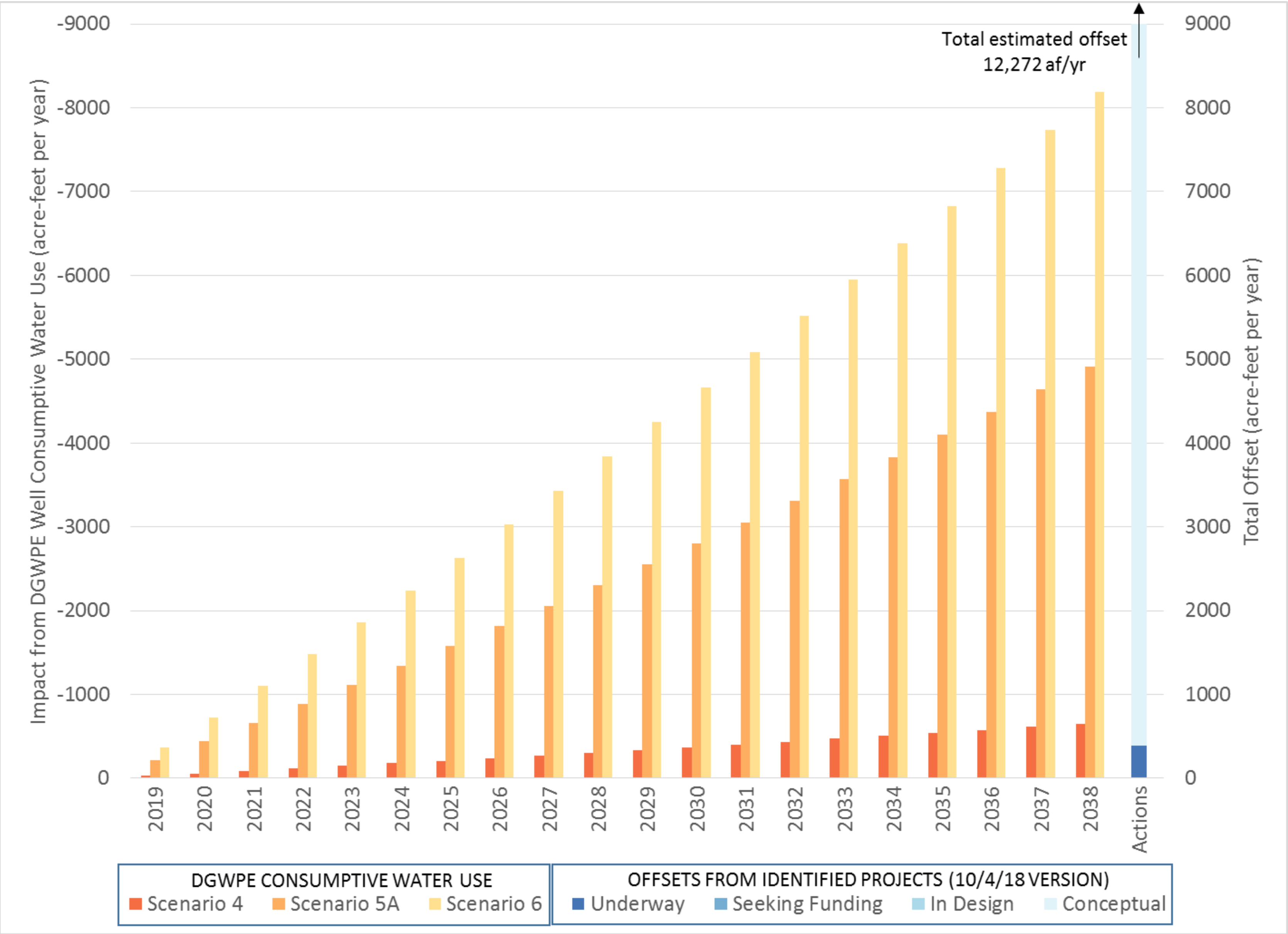


Figure 10. Anticipated increase in new DGWPE well consumptive water use over time relative to project offsets.

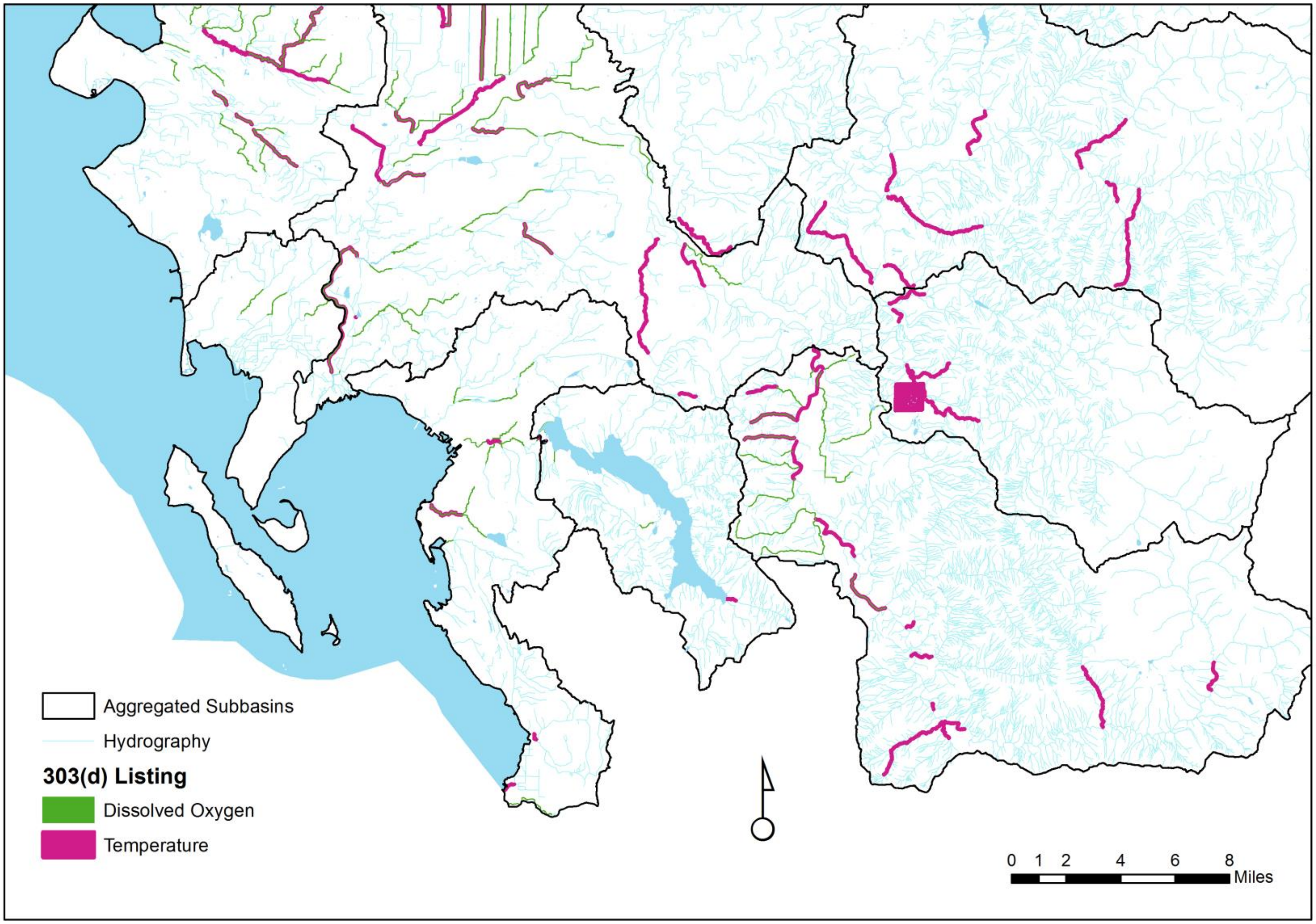
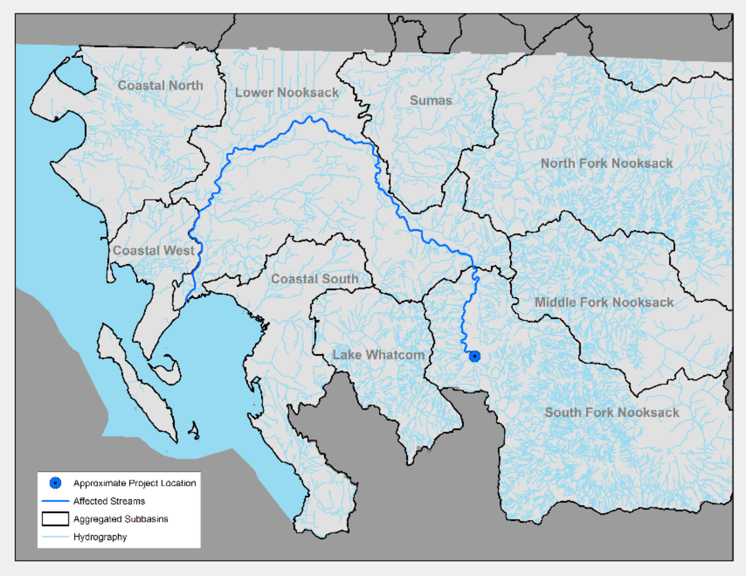


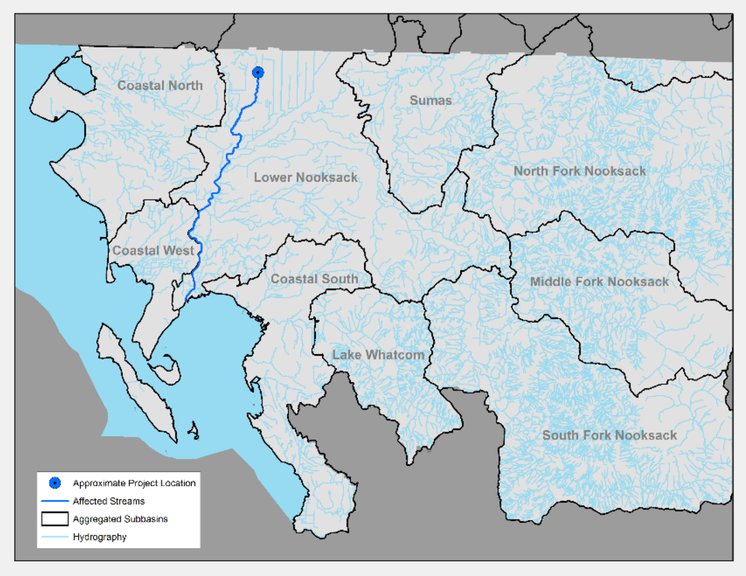
Figure 11. Stream segments on the 303(d) list for high stream temperature and low dissolved oxygen (Source: WA Department of Ecology).

Appendix A: Assignment of Project Offsets to Streams

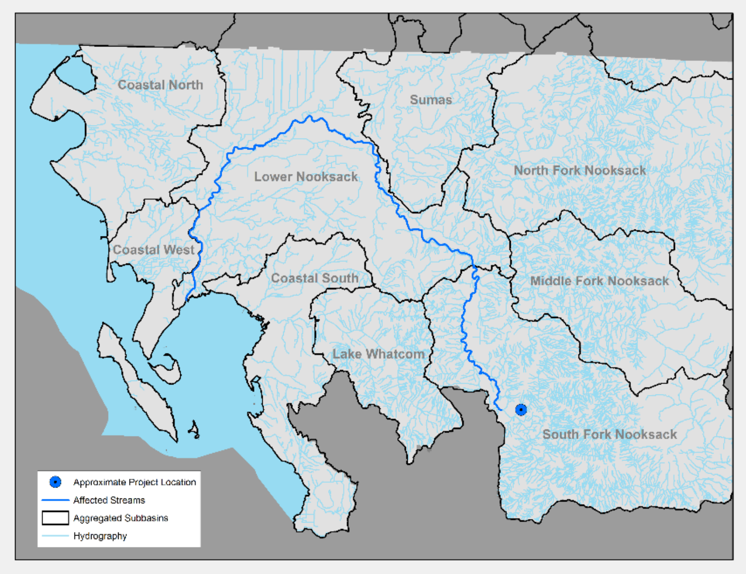
#1 Dairy Waste Processing/Treatment



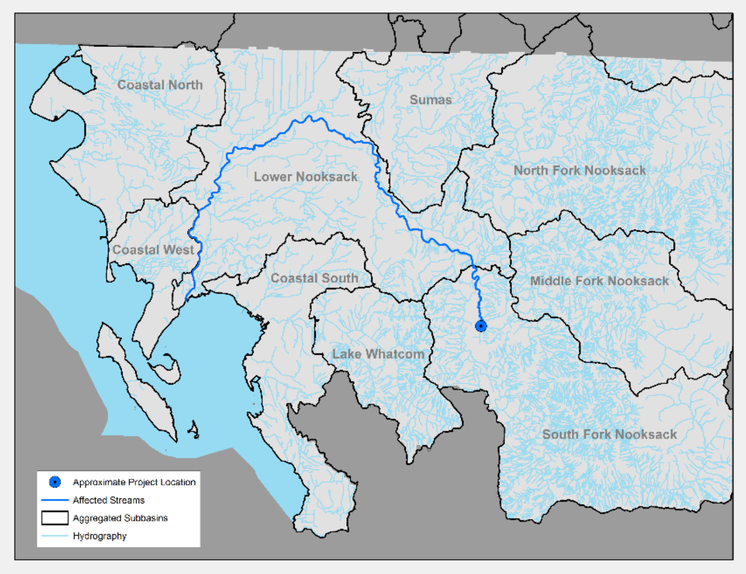
#2 Bertrand WID Ground Water Augmentation of Tributaries



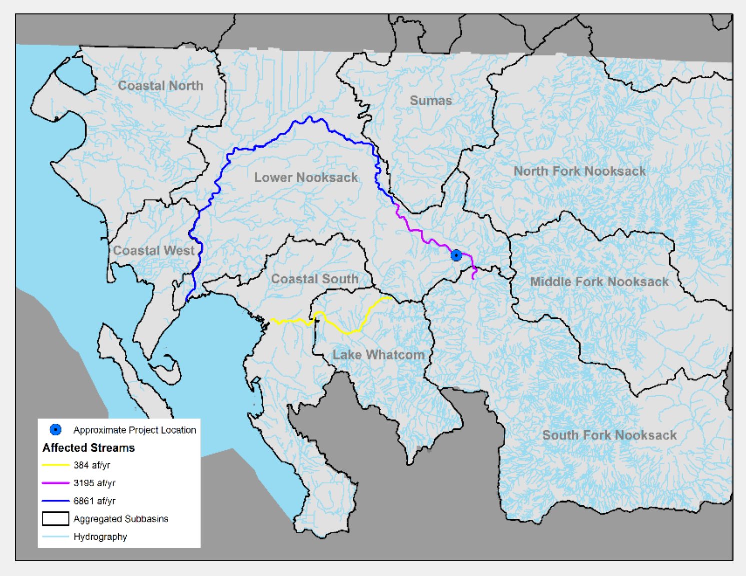
#19 Skookum Creek Restoration



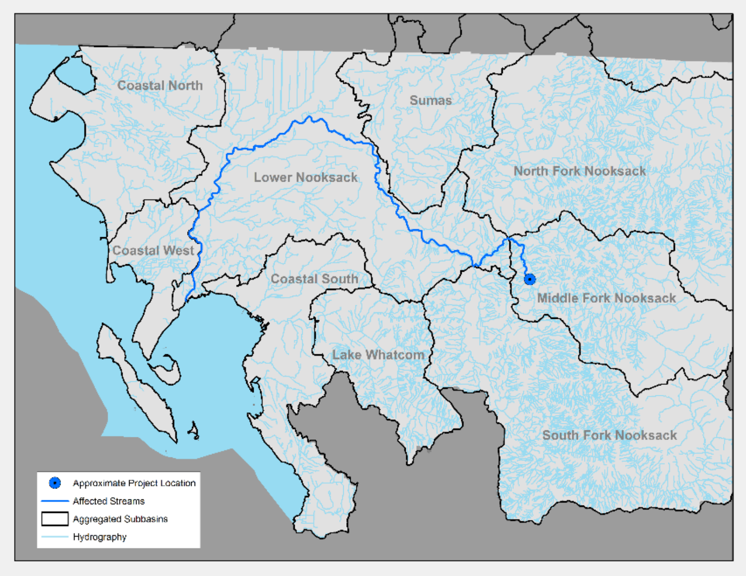
#19NG NEP Wetland Restoration/Enhancement Creation



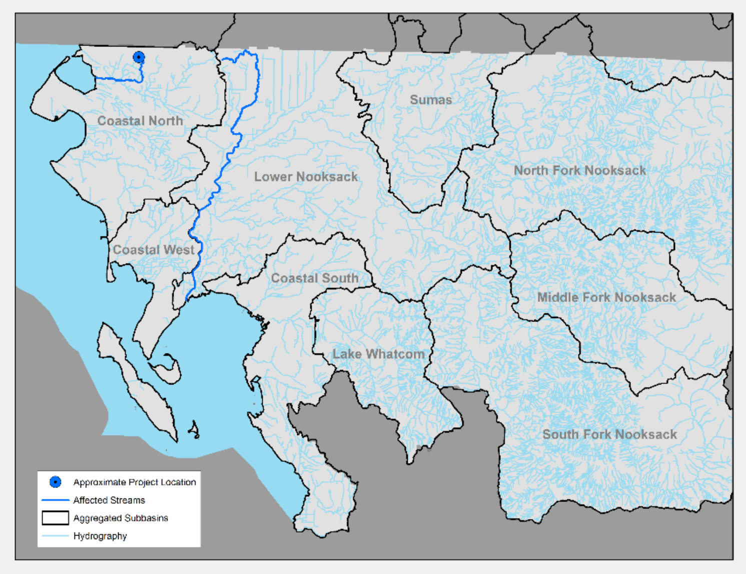
#21 Stewart Mountain/SF Nooksack Conservation Sale



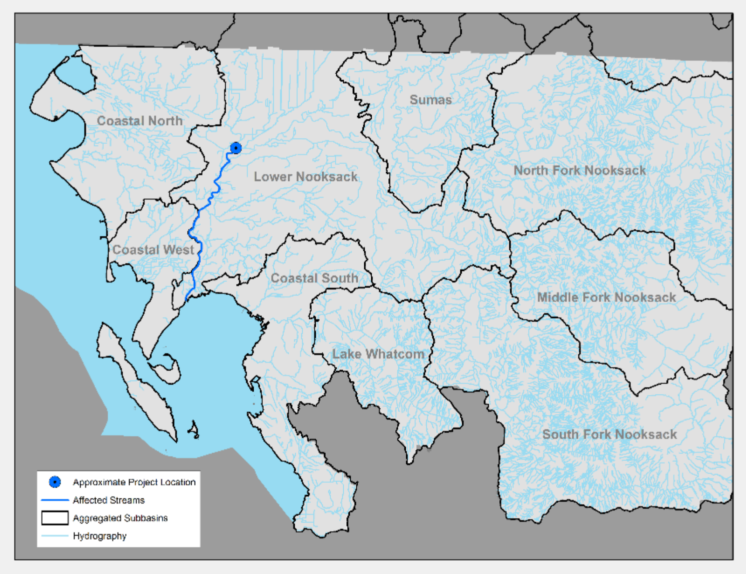
#23 Middle Fork Porter Creek Alluvial Fan Project



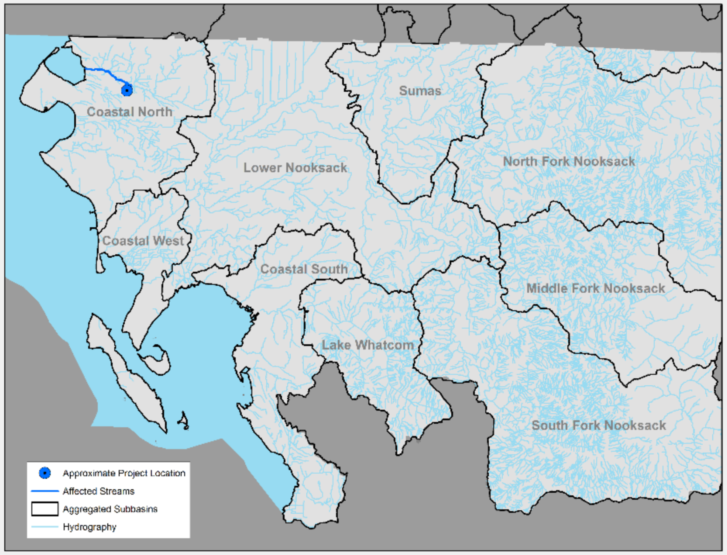
#24 Birch Bay Water & Sewer District Deep Wells



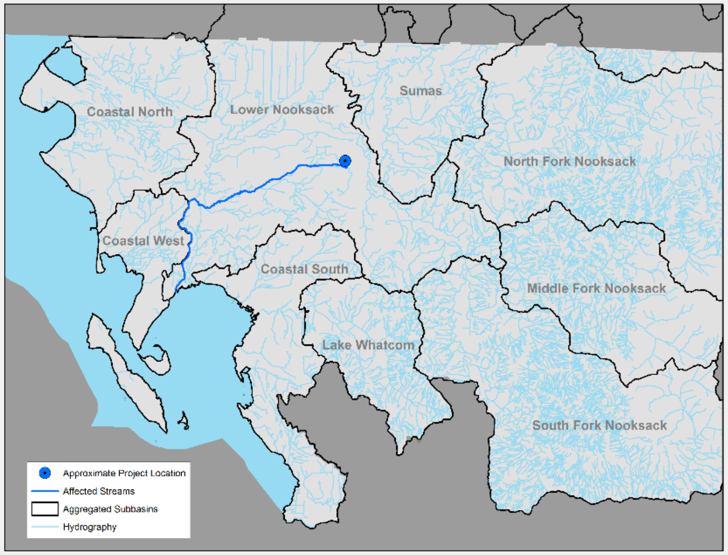
#26 Lower Nooksack-Convert Surface Use to Groundwater Use



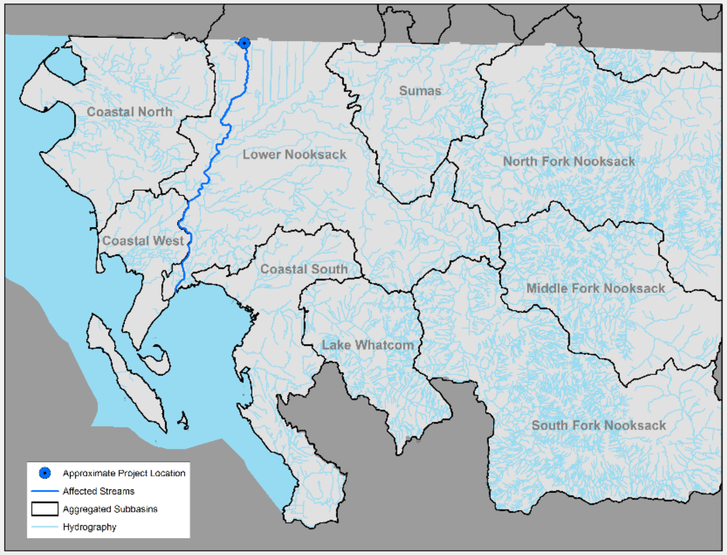
#27 Coastal North-Convert Surface Use to Groundwater Use



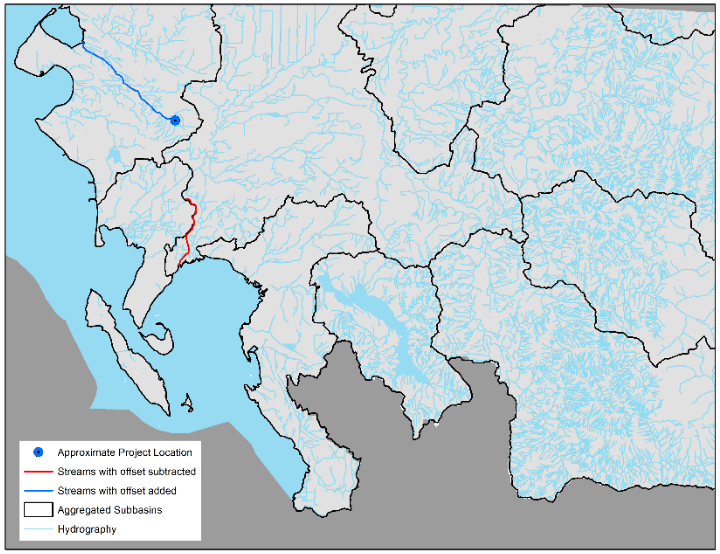
#28 Storage Projects including Gravel Pits



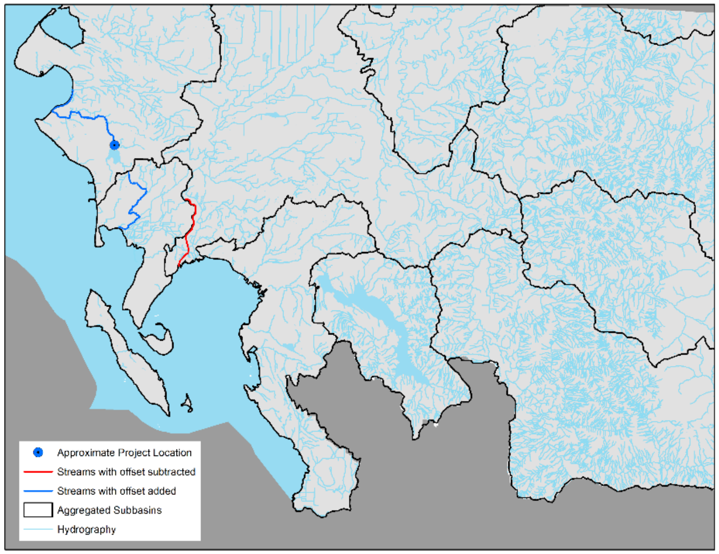
#43 PUD #1: Pipeline from Mainstem to Tributaries



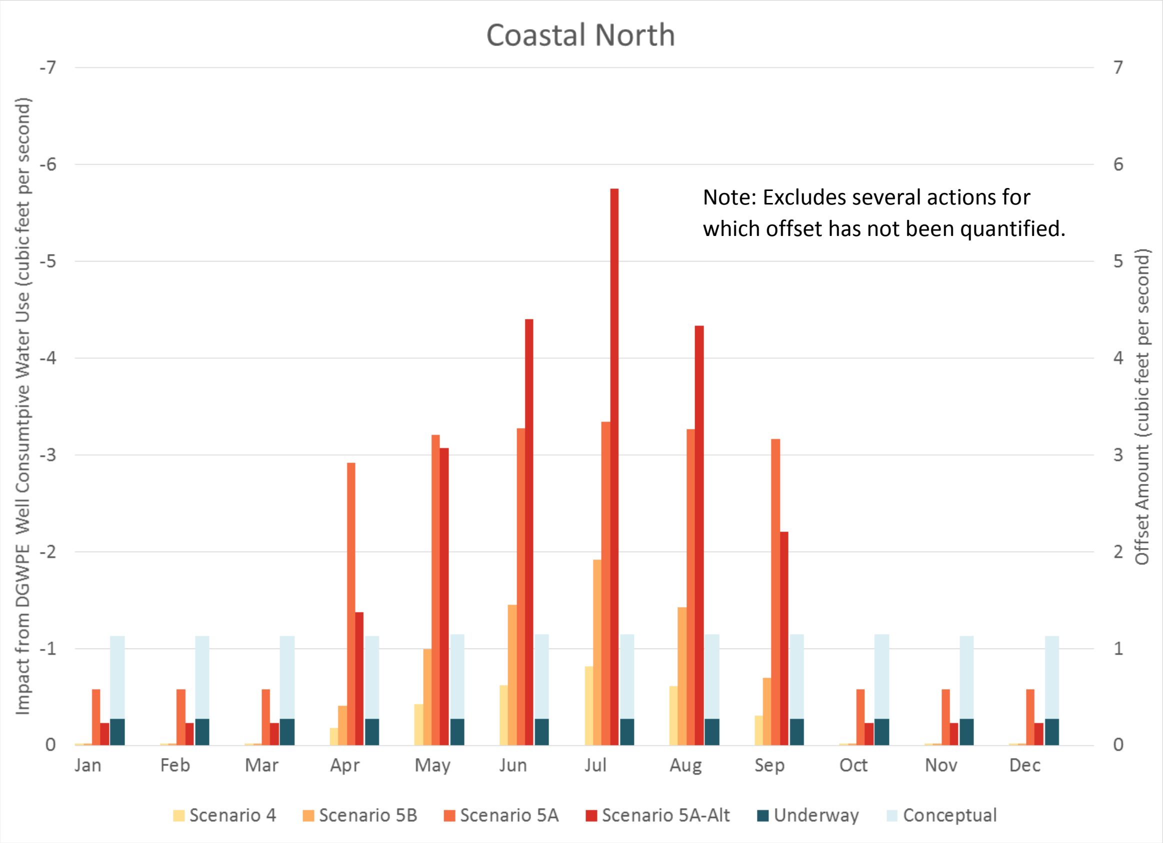
#44 PUD #1: Vista Road Project



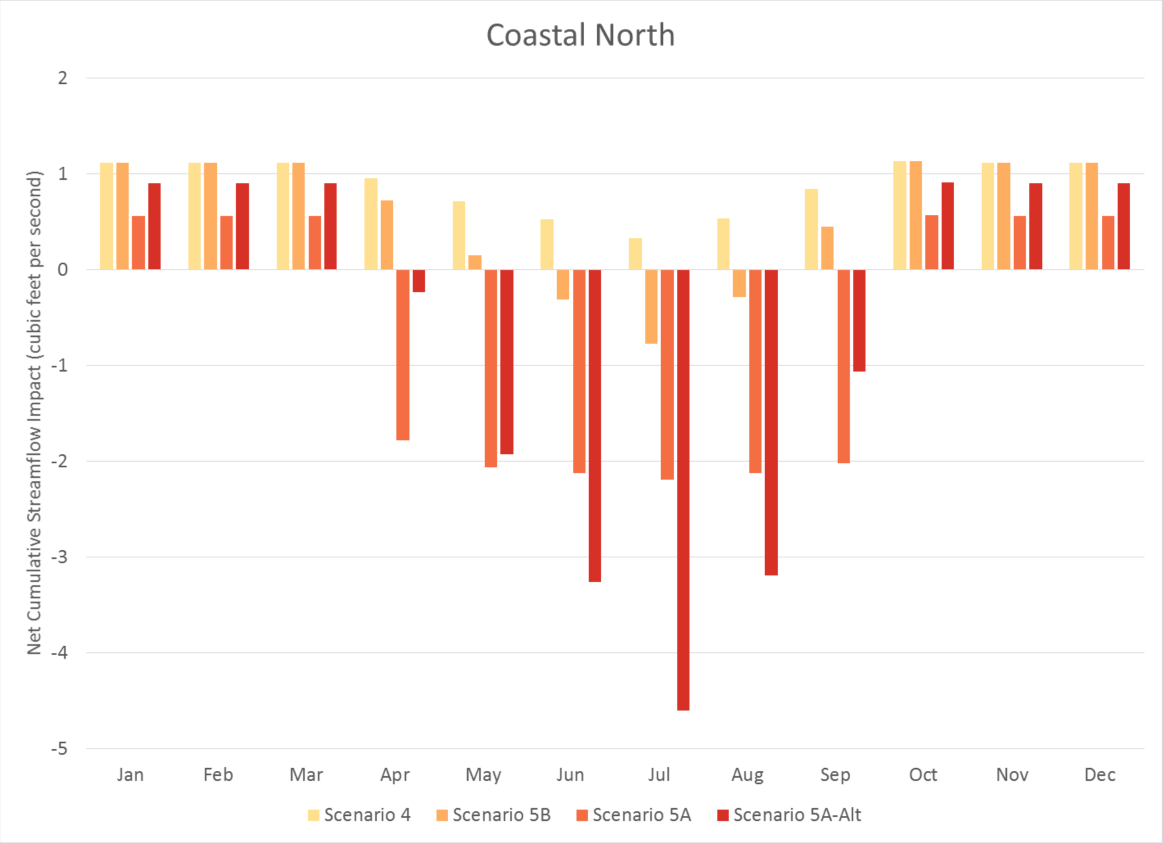
#45 PUD #1: Lake Terrell

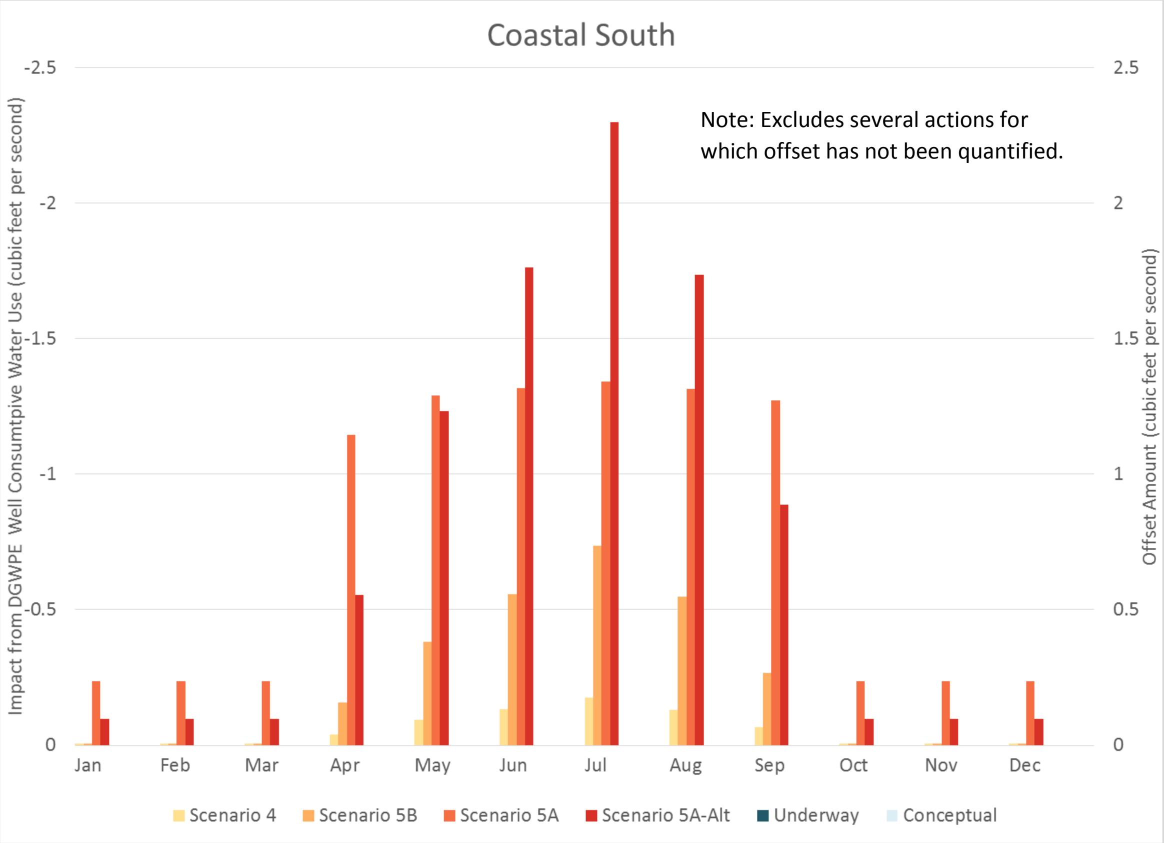


Appendix B: Seasonal Variation in Streamflow Impact by Aggregated Subbasin

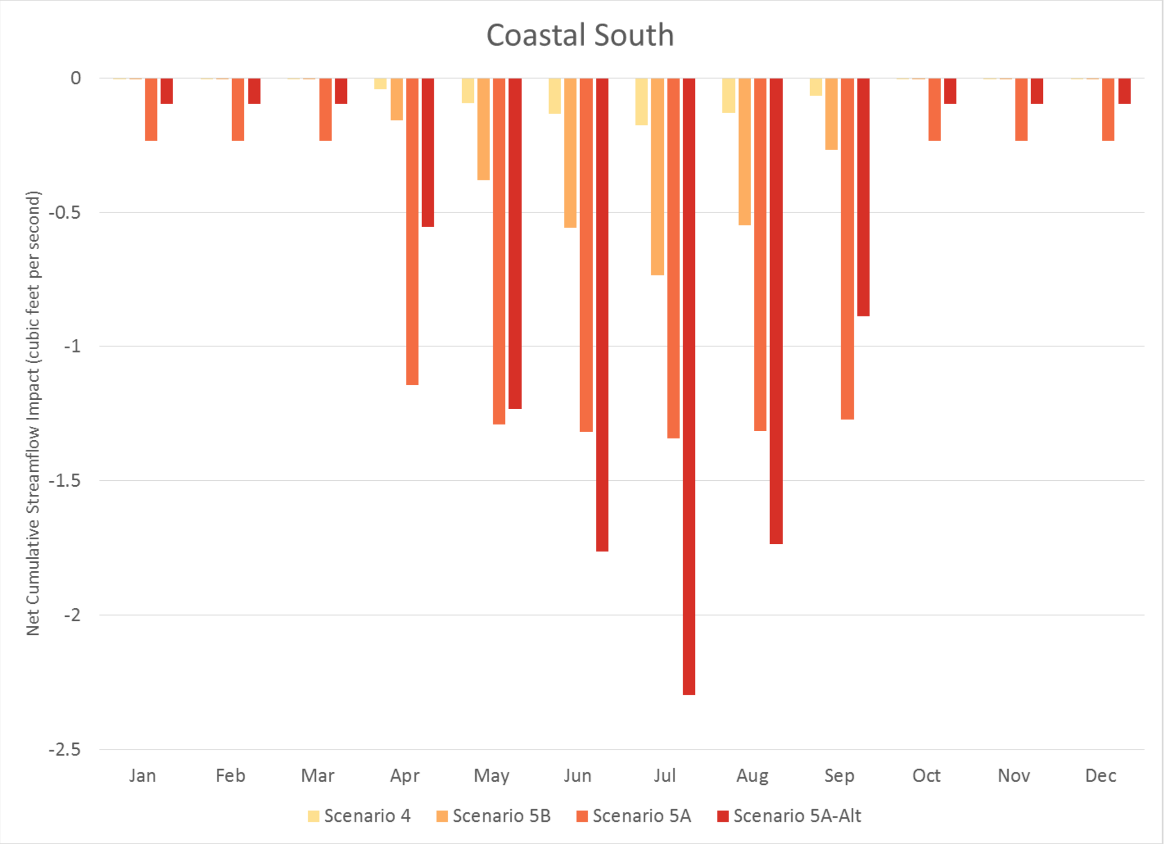


Note: Excludes several actions for which offset has not been quantified.

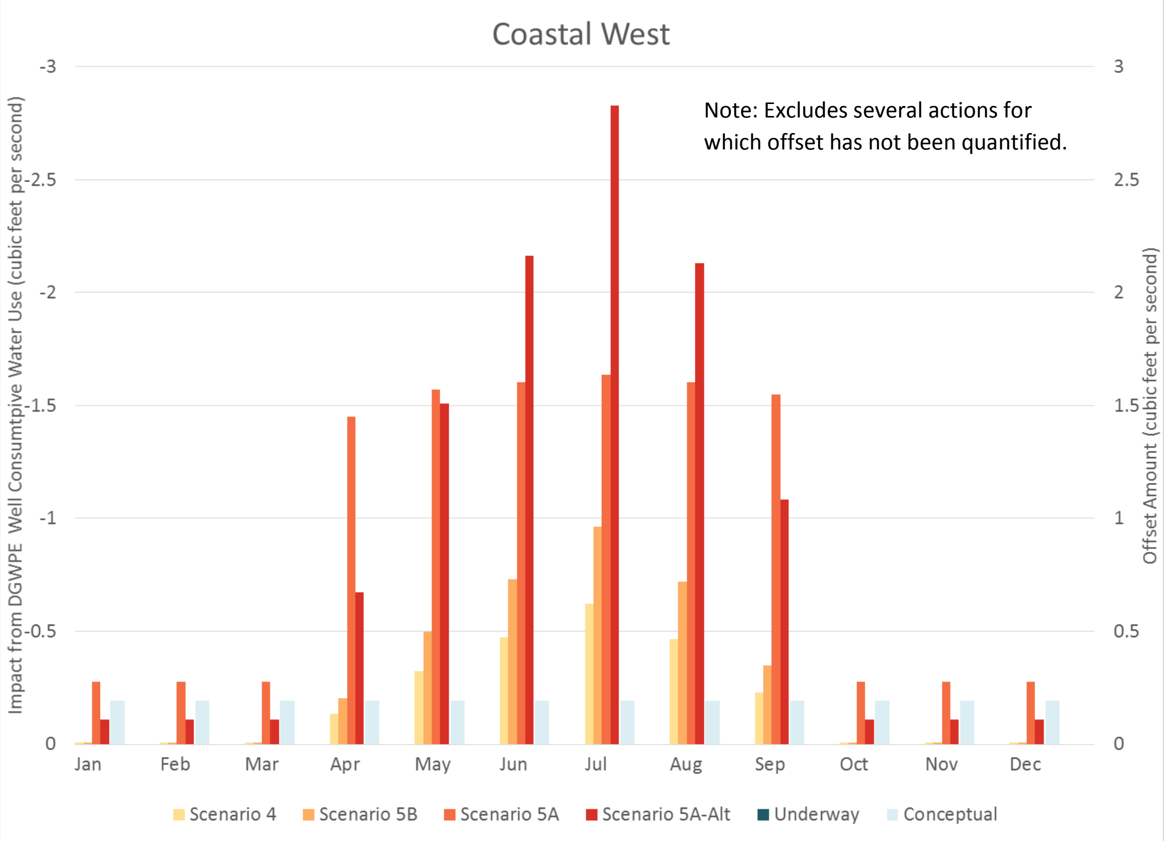


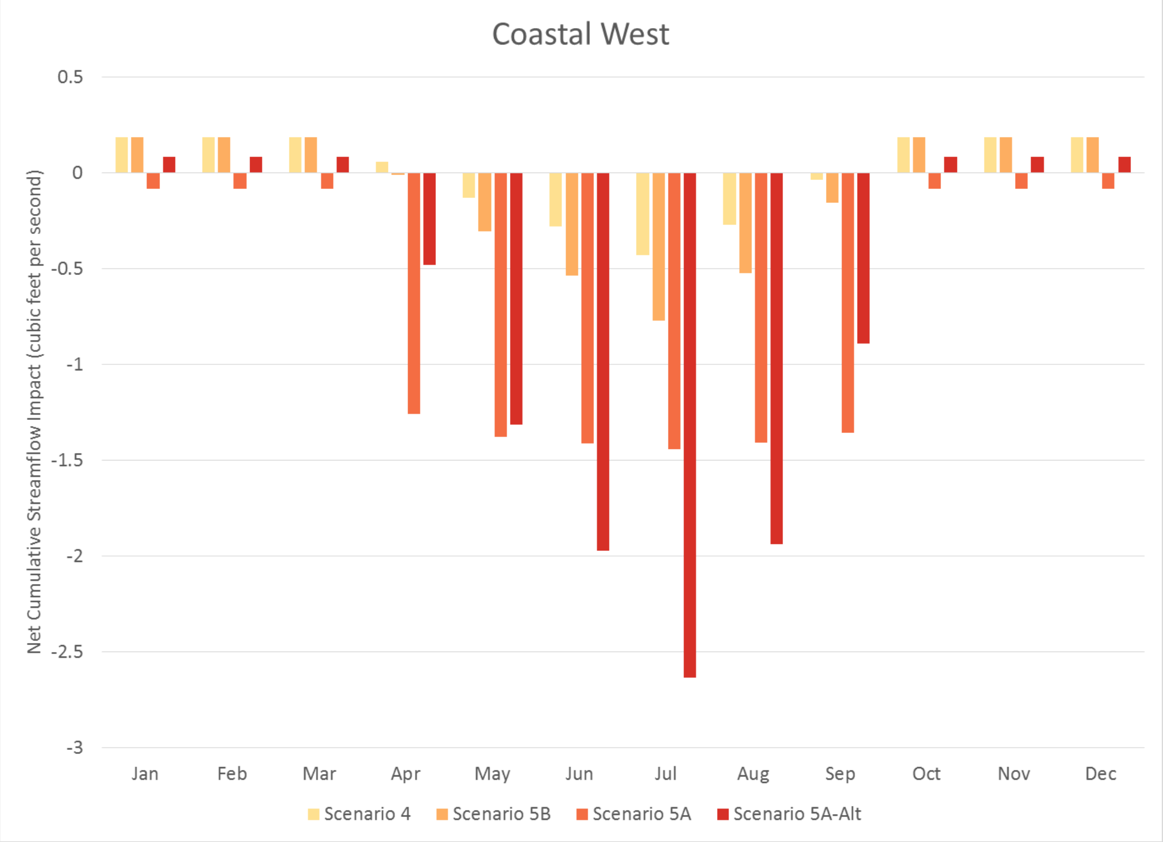


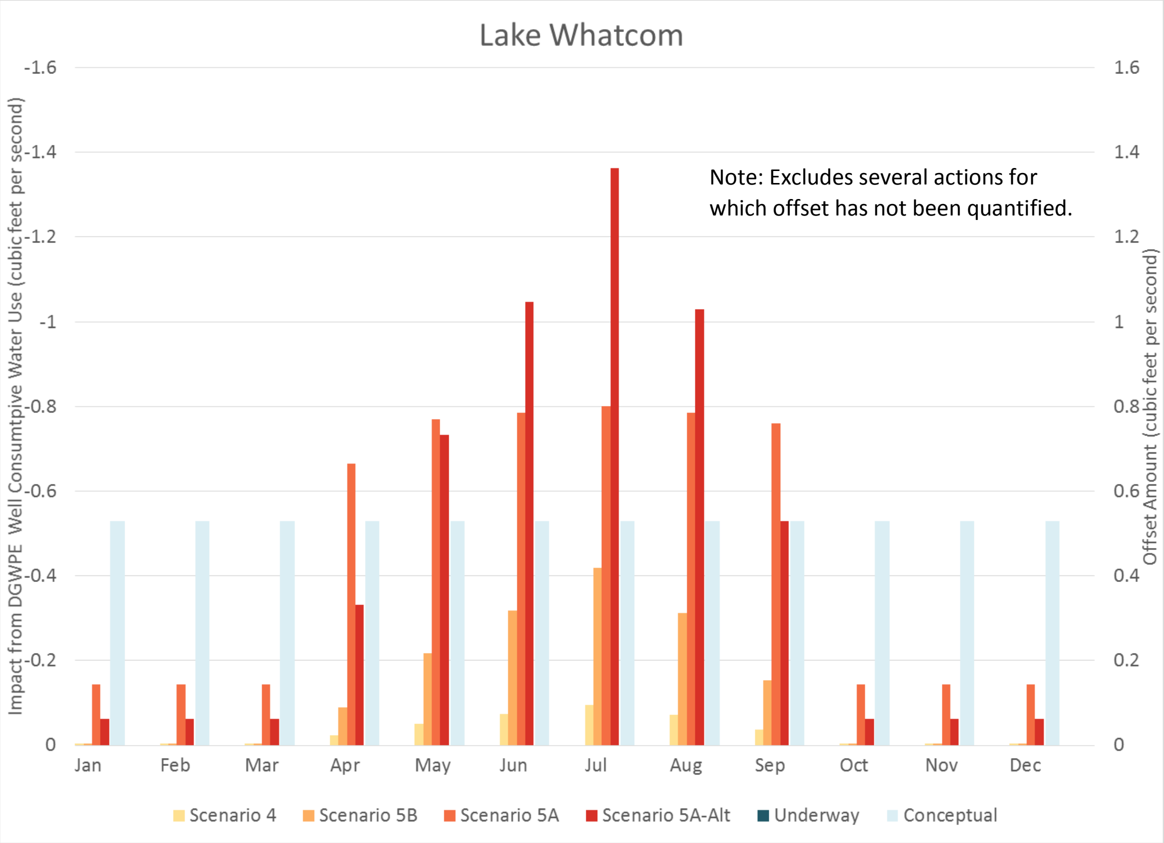
Coastal South
Note: Excludes several actions for which offset has not been quantified.
Impact from DGWPE Well Consumtpive Water Use (cubic feet per second)
Offset Amount (cubic feet per second)
-2.5
-2
-1.5
-1
-0.5
0
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt
Underway
Conceptual

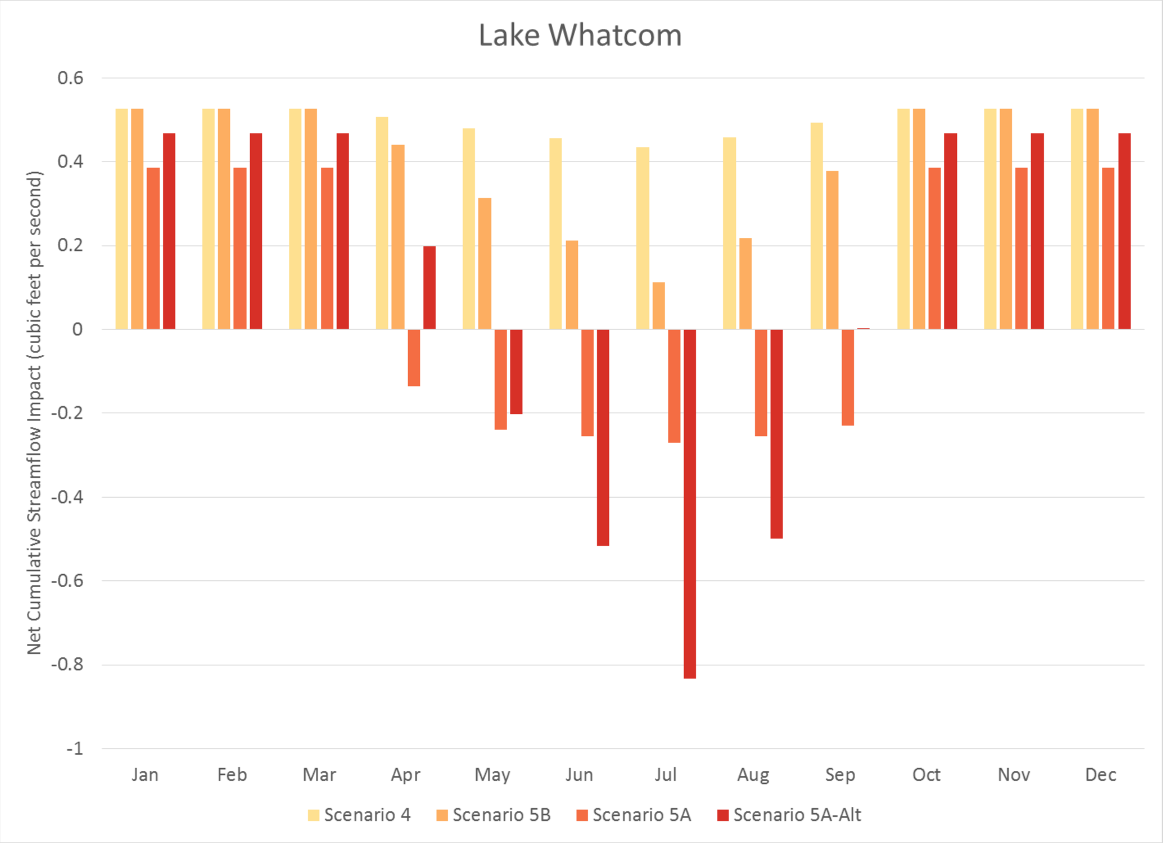


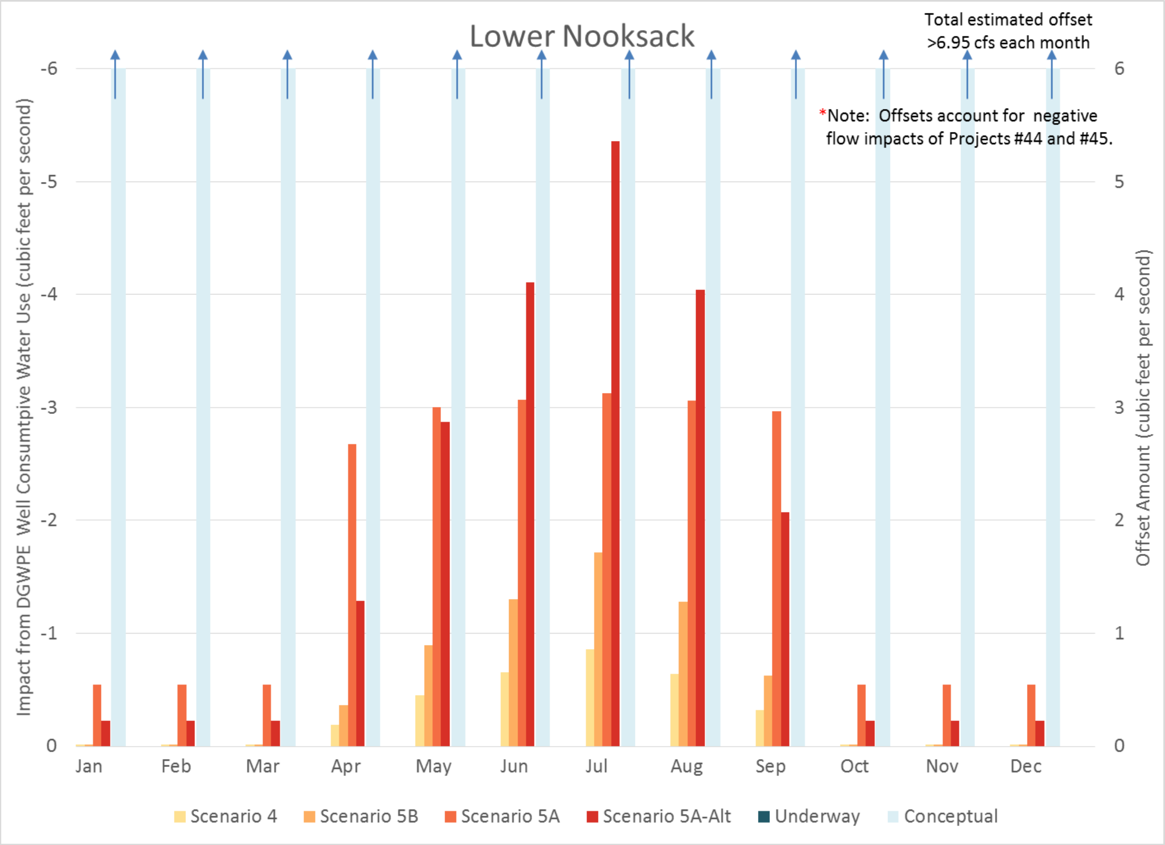
Coastal South
Net Cumulative Streamflow Impact (cubic feet per second)
0
-0.5
-1
-1.5
-2
-2.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt


Coastal West
Note: Excludes several actions for which offset has not been quantified.
Impact from DGWPE Well Consumtpive Water Use (cubic feet per second)
Offset Amount (cubic feet per second)
-3
-2.5
-2
-1.5
-1
-0.5
0
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt
Underway
Conceptual


Coastal West
Net Cumulative Streamflow Impact (cubic feet per second)
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt


Lake Whatcom
Impact from DGWPE Well Consumtpive Water Use (cubic feet per second)
-1.6
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
Offset Amount (cubic feet per second)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Note: Excludes several actions for which offset has not been quantified.
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt
Underway
Conceptual

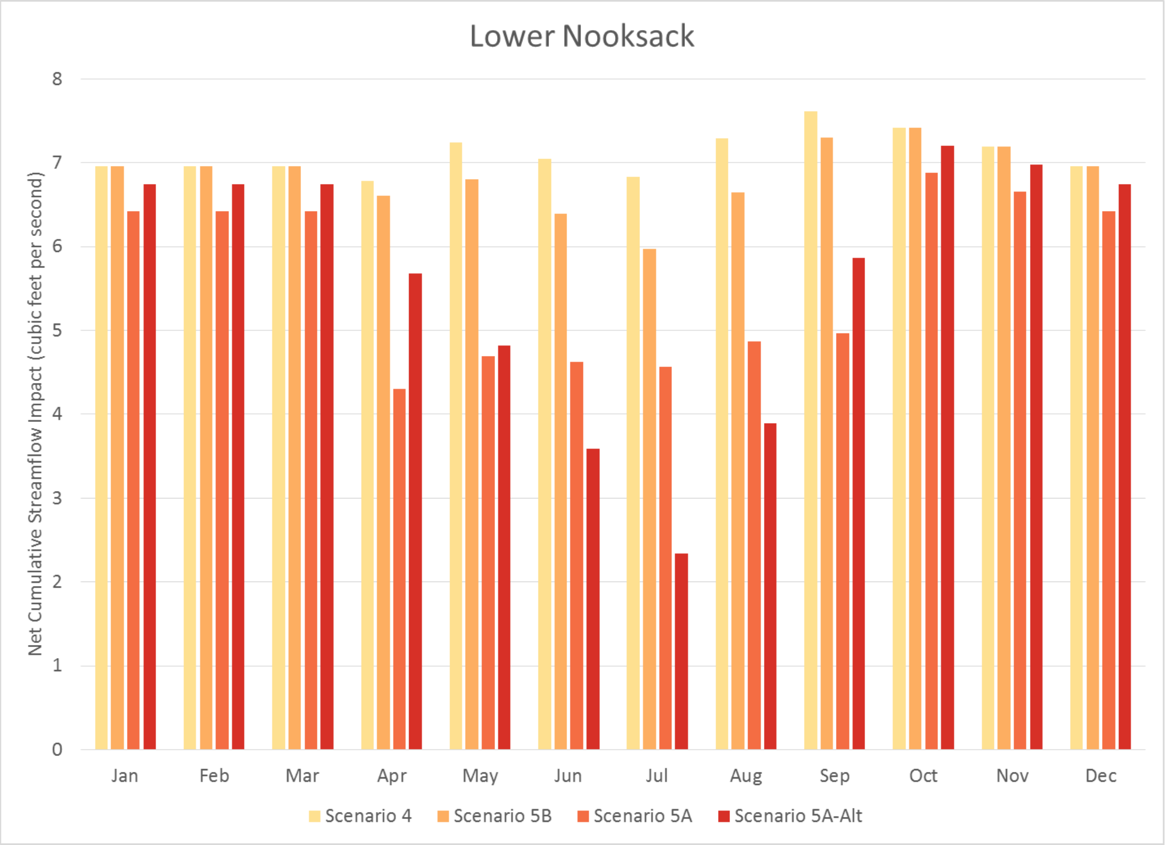

Lake Whatcom
Net Cumulative Streamflow Impact (cubic feet per second)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt



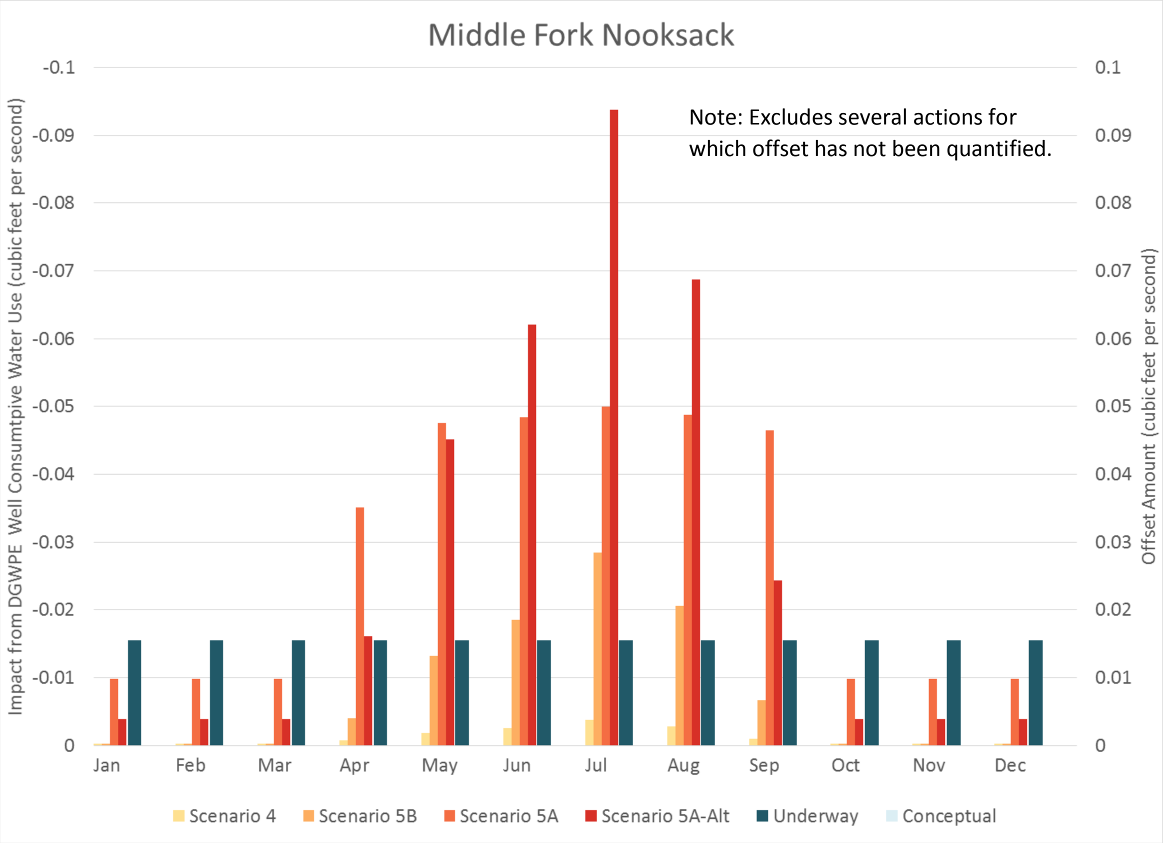
Lower Nooksack

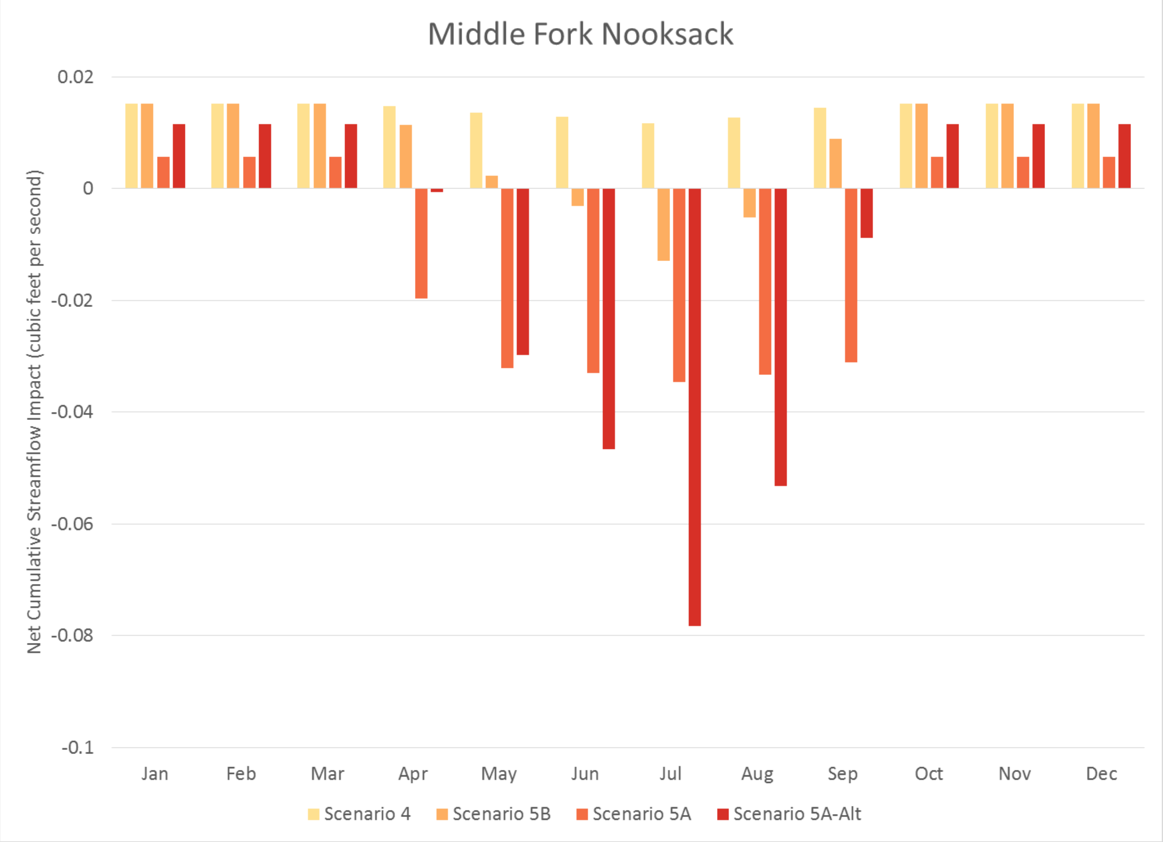
Total estimated offset >6.95 cfs each month

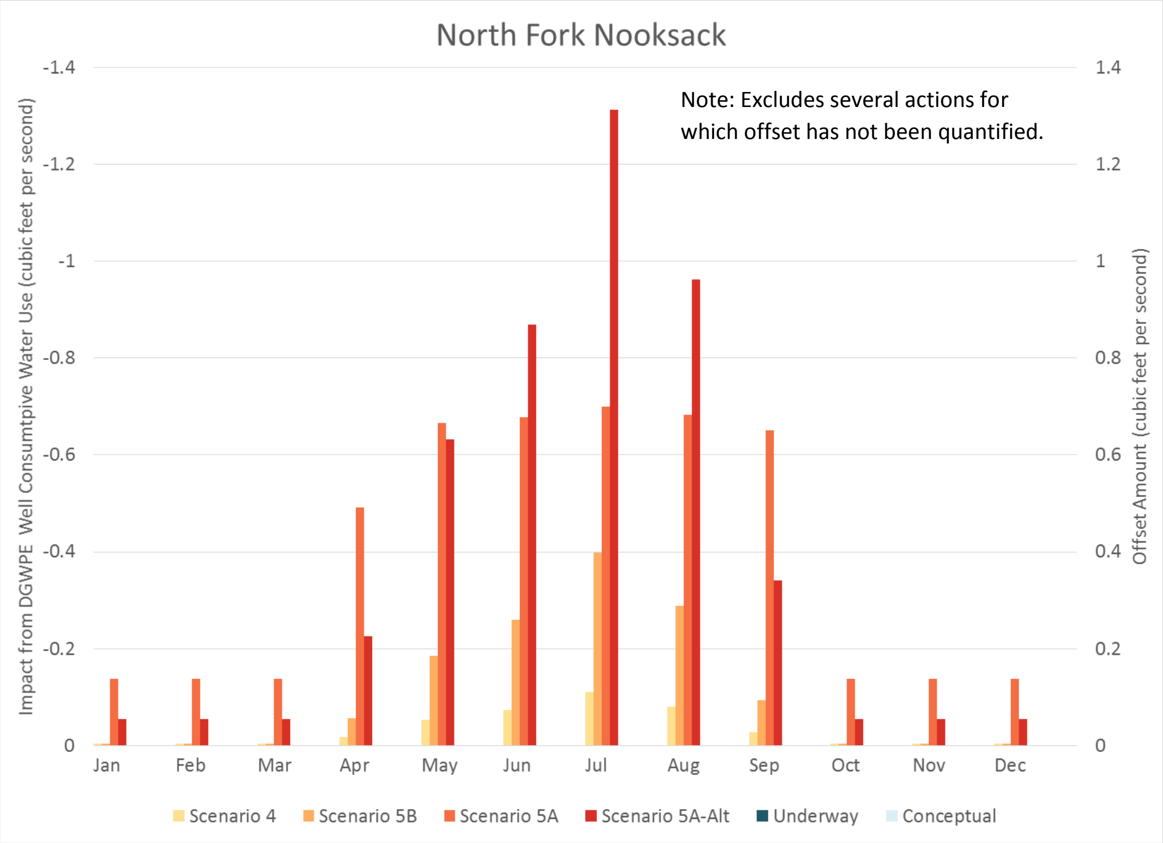
*Note: Offsets account for negative flow impacts of Projects #44 and #45.

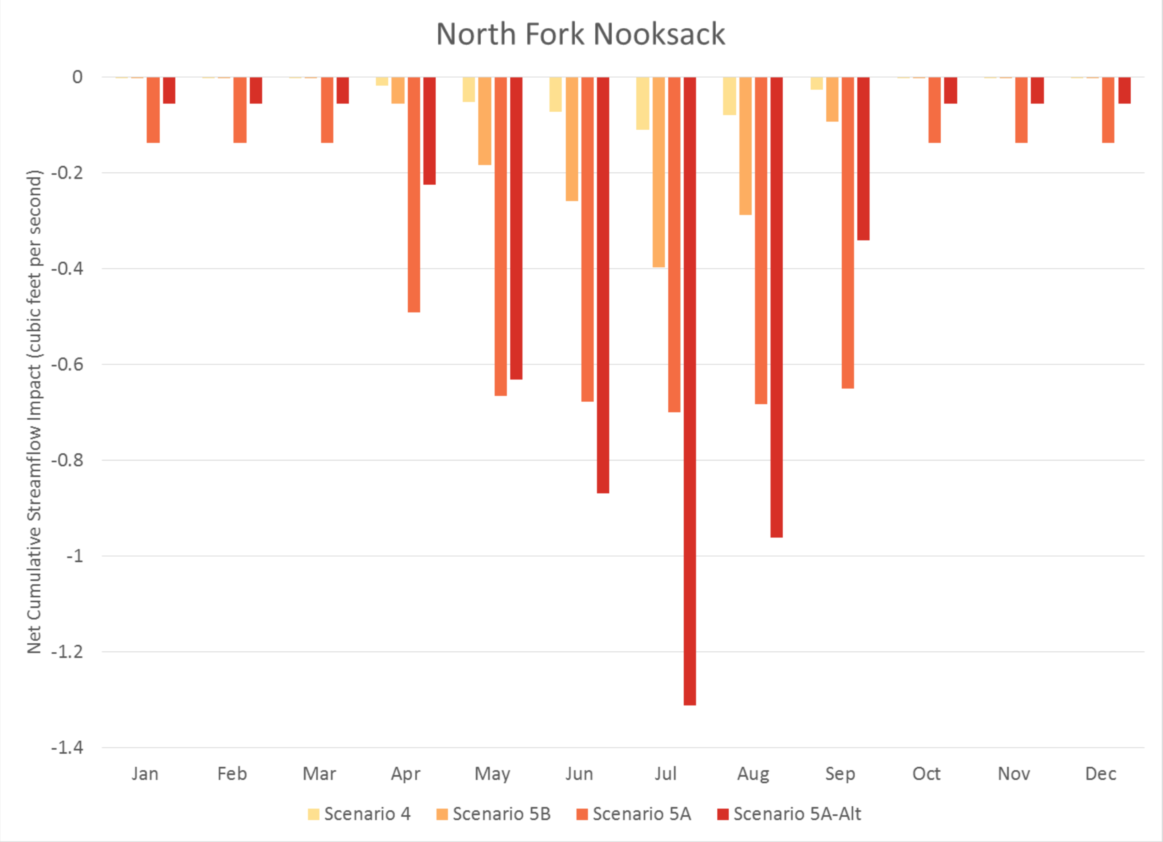


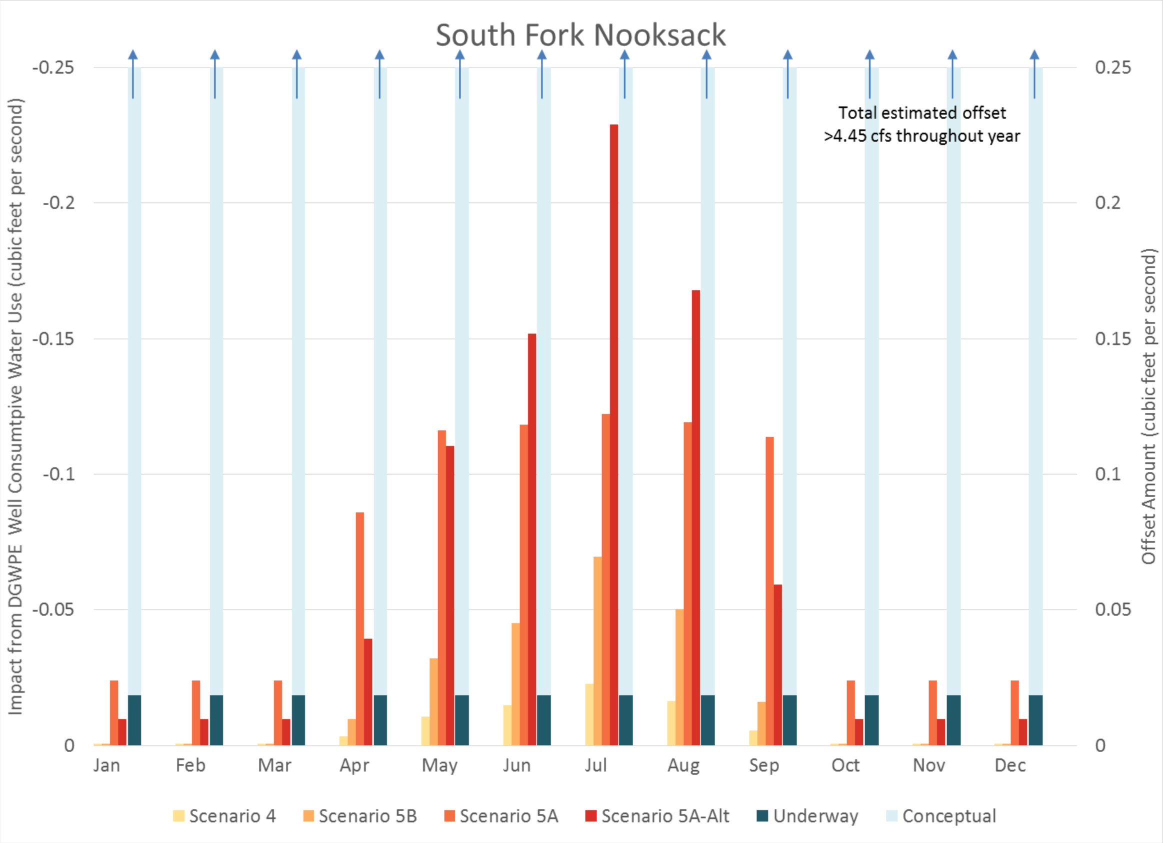
Lower Nooksack

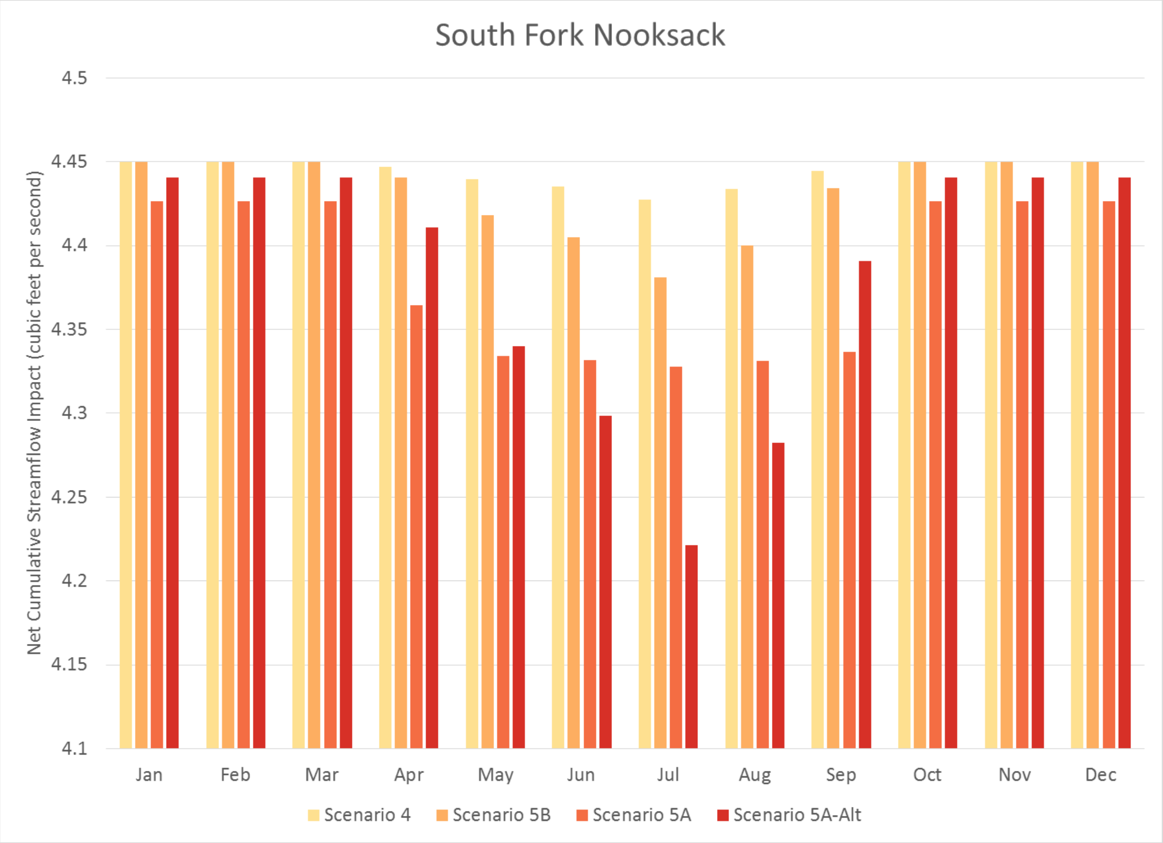

Middle Fork Nooksack
Note: Excludes several actions for which offset has not been quantified.
Impact from DGWPE Well Consumtpive Water Use (cubic feet per second)
Offset Amount (cubic feet per second)
-0.1
-0.09
-0.08
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt
Underway
Conceptual

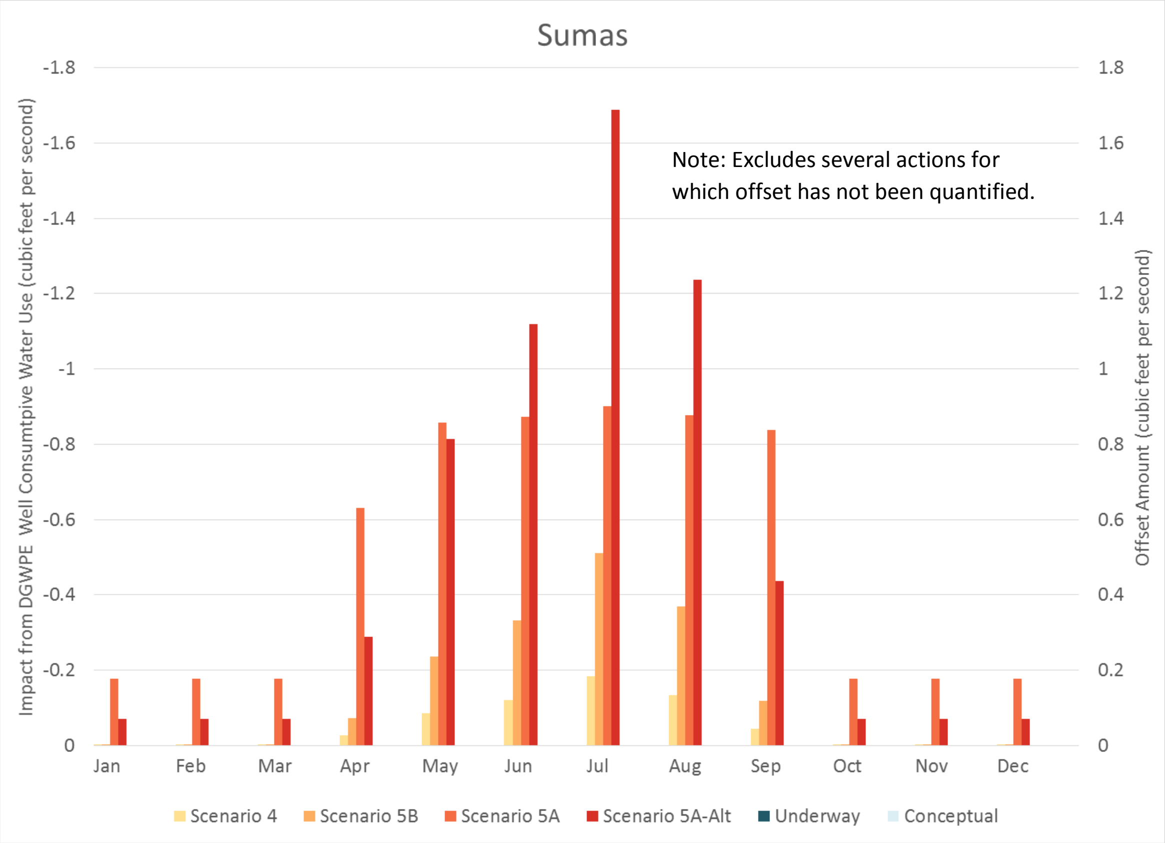

Middle Fork Nooksack
Net Cumulative Streamflow Impact (cubic feet per second)
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt


North Fork Nooksack
Note: Excludes several actions for which offset has not been quantified.
Impact from DGWPE Well Consumtpive Water Use (cubic feet per second)
Offset Amount (cubic feet per second)
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt
Underway
Conceptual

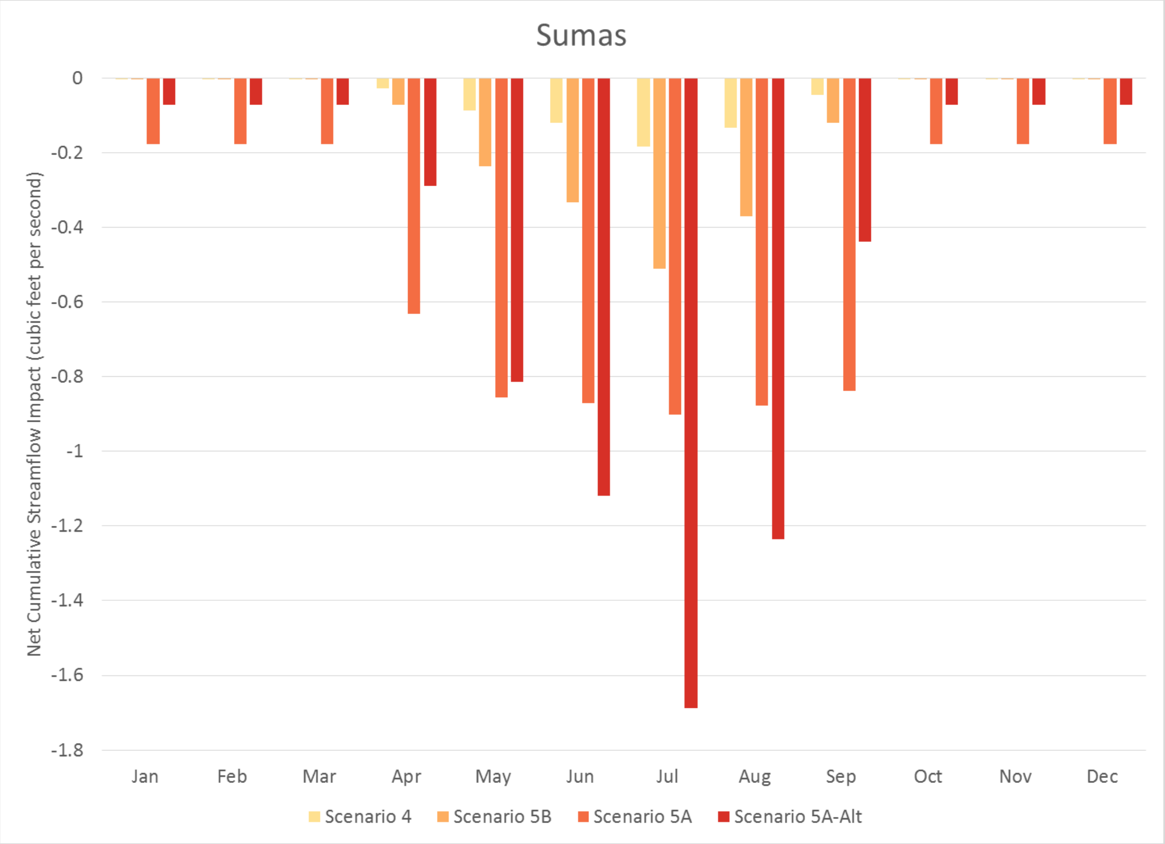

North Fork Nooksack
Net Cumulative Streamflow Impact (cubic feet per second)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt


South Fork Nooksack
Impact from DGWPE Well Consumtpive Water Use (cubic feet per second)
Offset Amount (cubic feet per second)
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.25
0.2
0.15
0.1
0.05
0
Total estimated offset
>4.45 cfs throughout year
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt
Underway
Conceptual

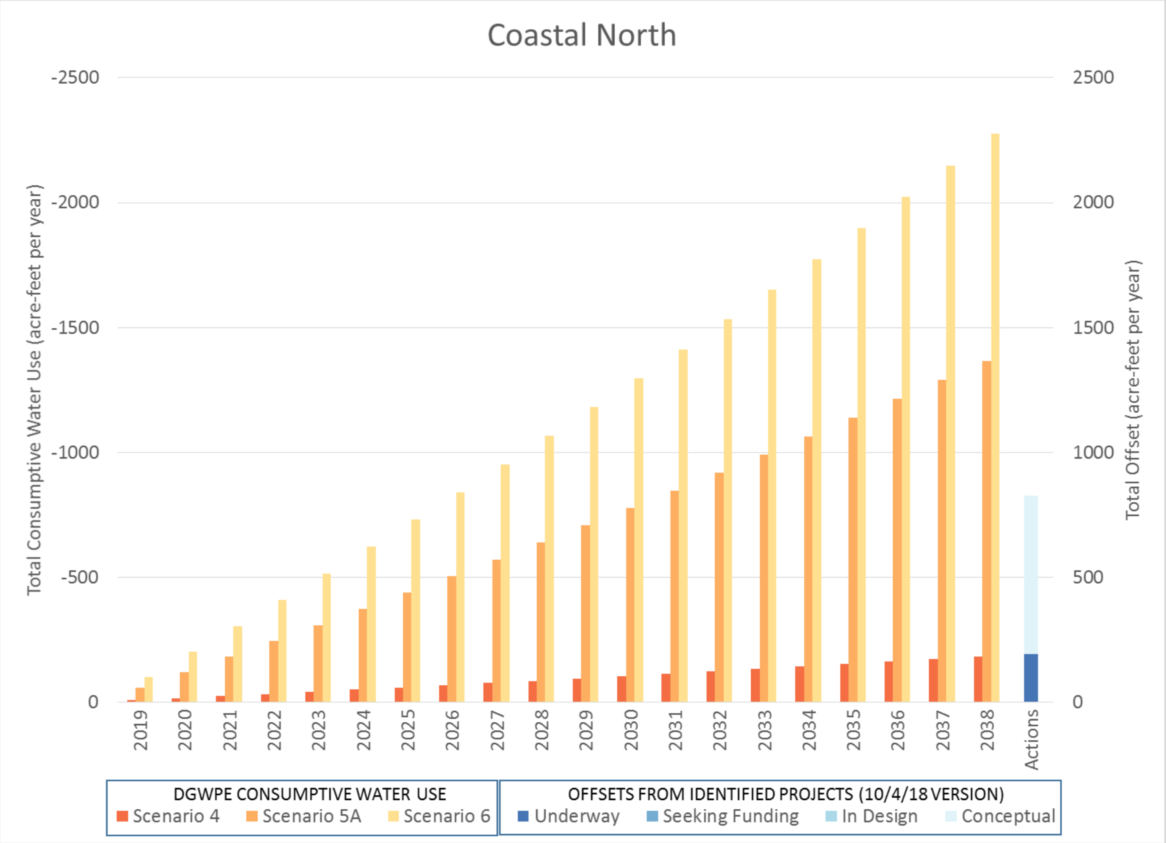

South Fork Nooksack
Net Cumulative Streamflow Impact (cubic feet per second)
4.5
4.45
4.4
4.35
4.3
4.25
4.2
4.15
4.1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Scenario 4
Scenario 5B
Scenario 5A
Scenario 5A-Alt

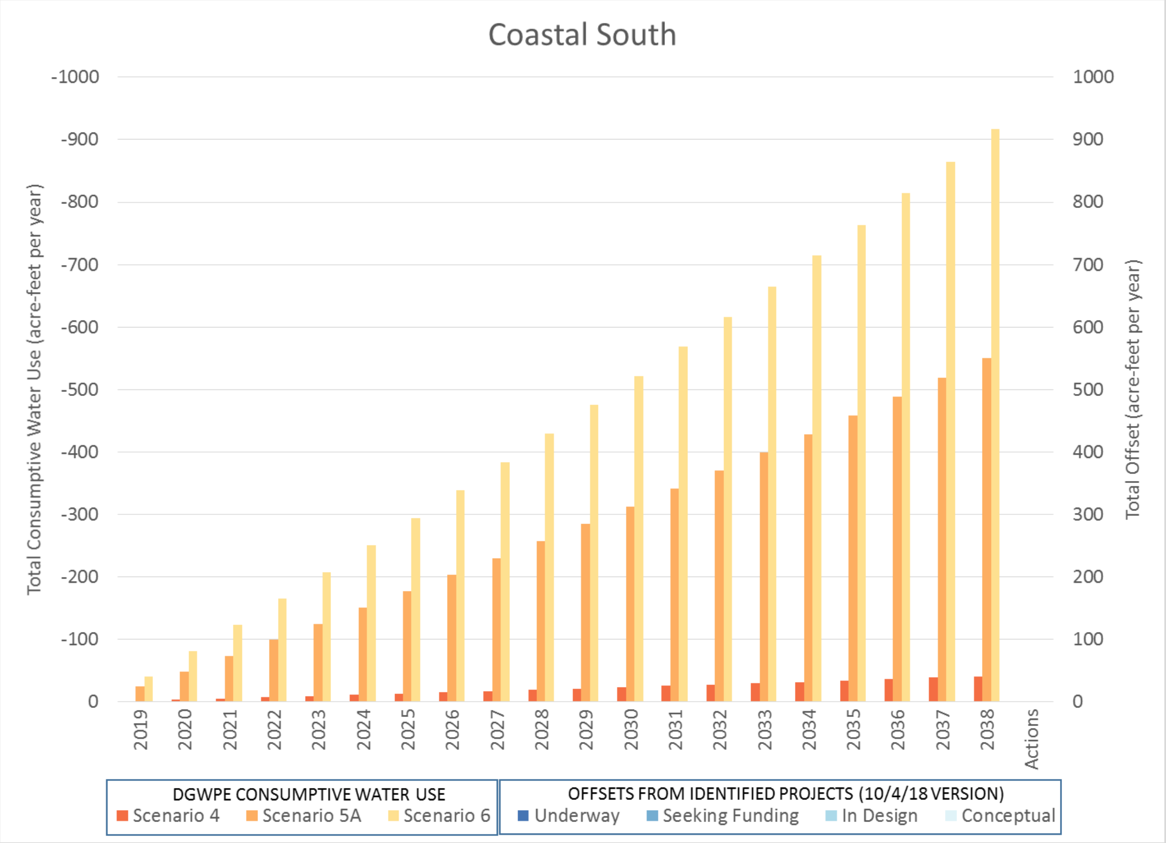

Sumas

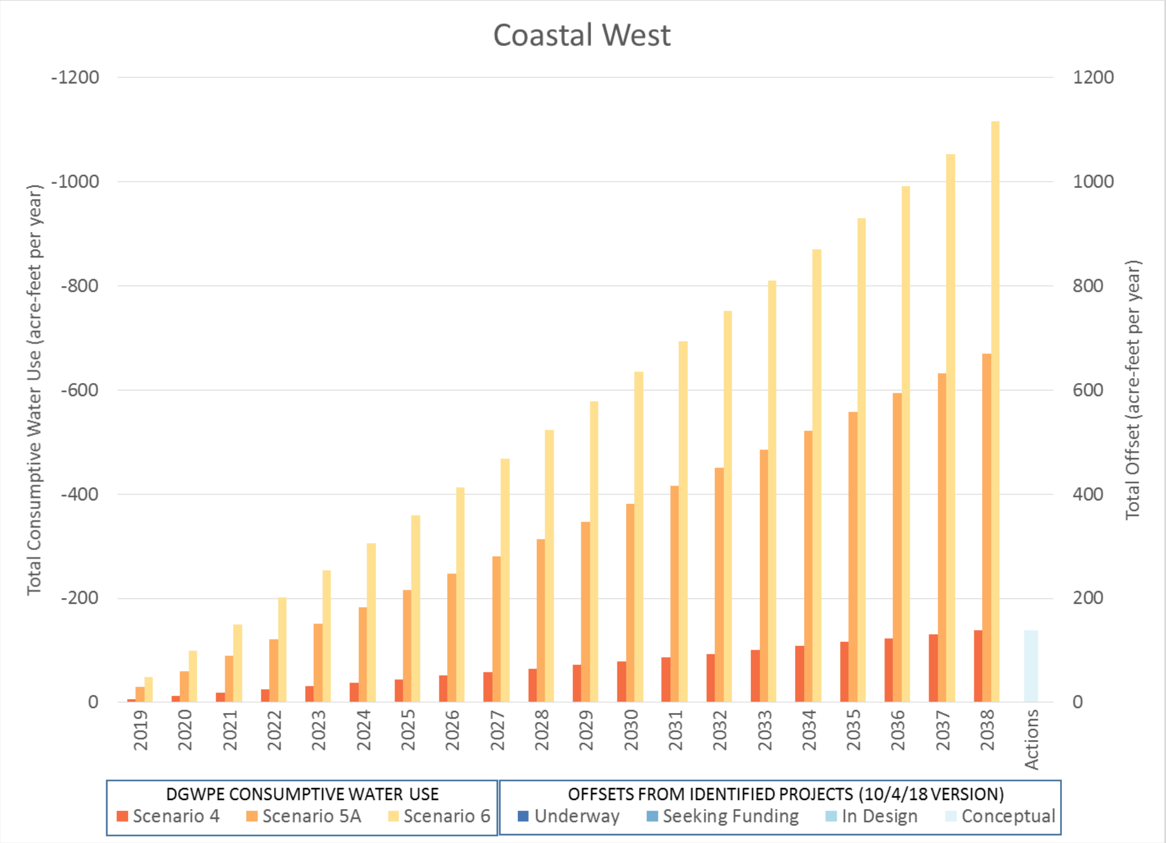
Note: Excludes several actions for which offset has not been quantified.

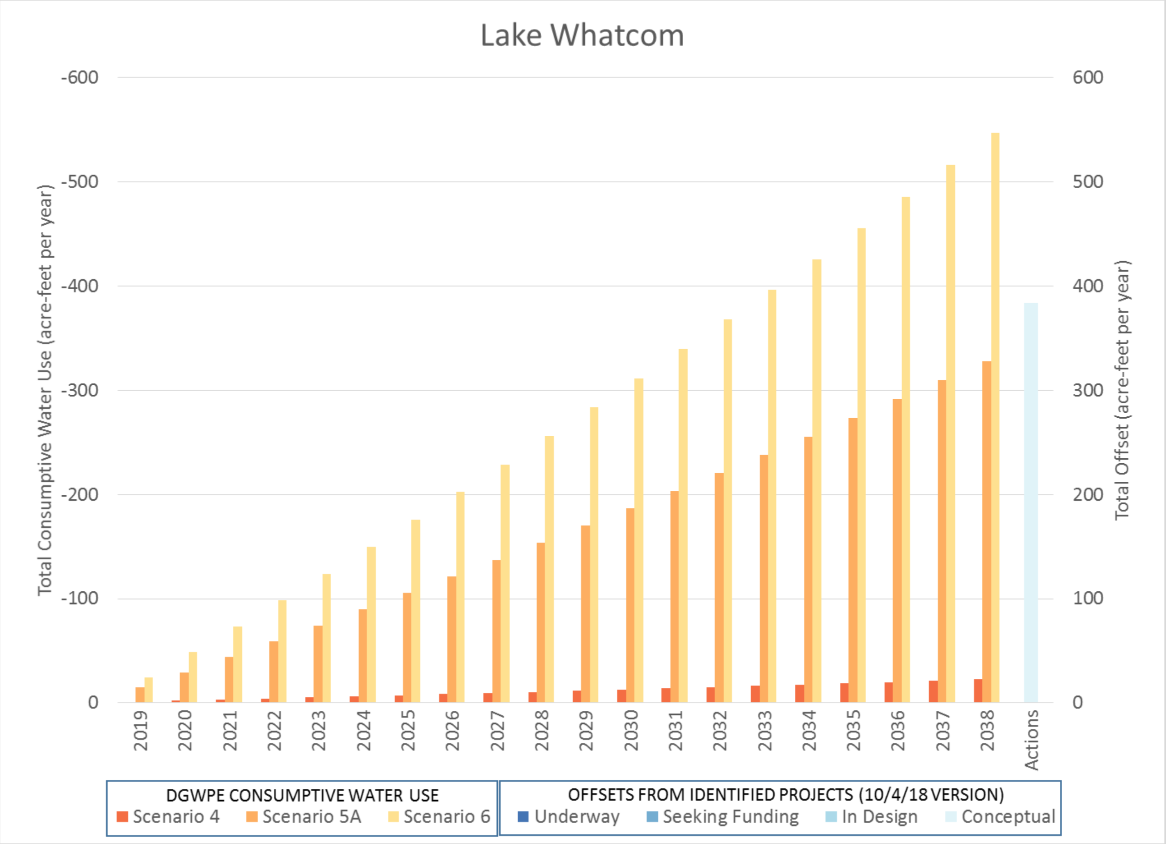

Sumas

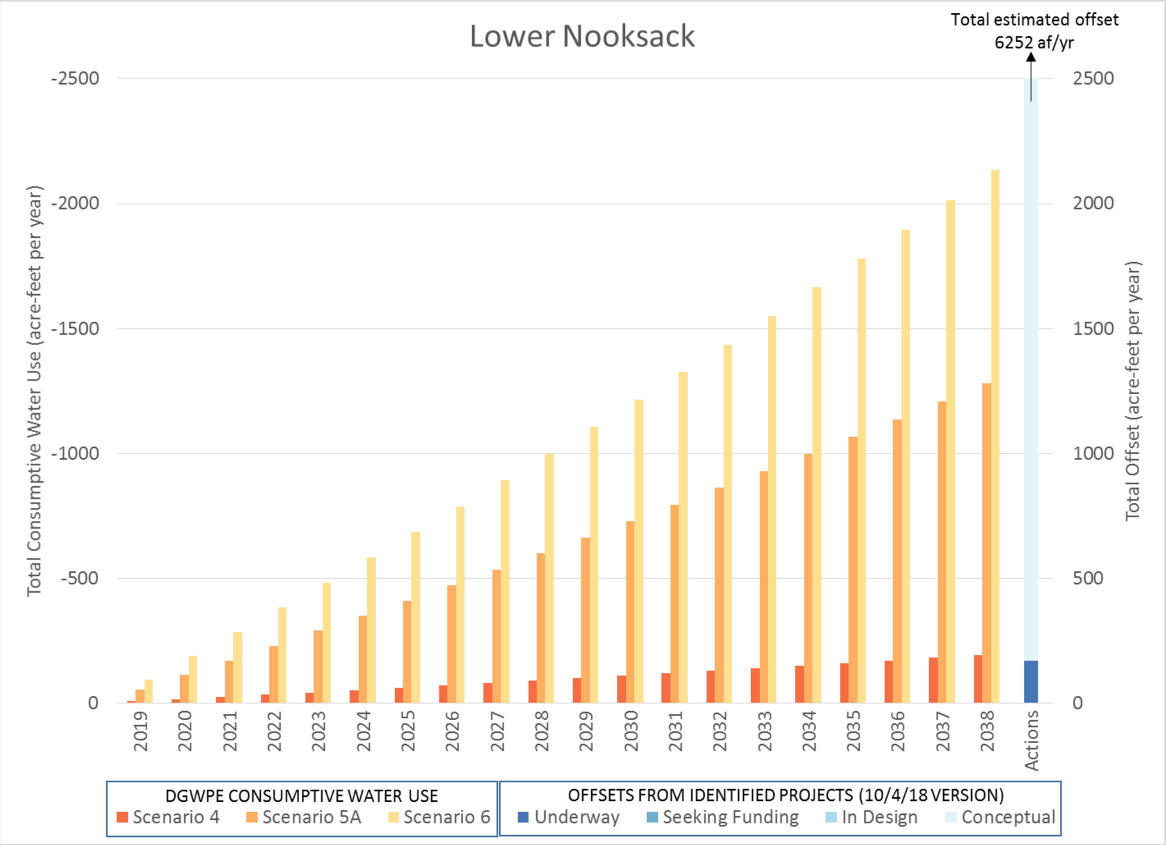
Appendix C: New DGWPE well consumptive water Use over time relative to project offsets over time by Aggregated Subbasin

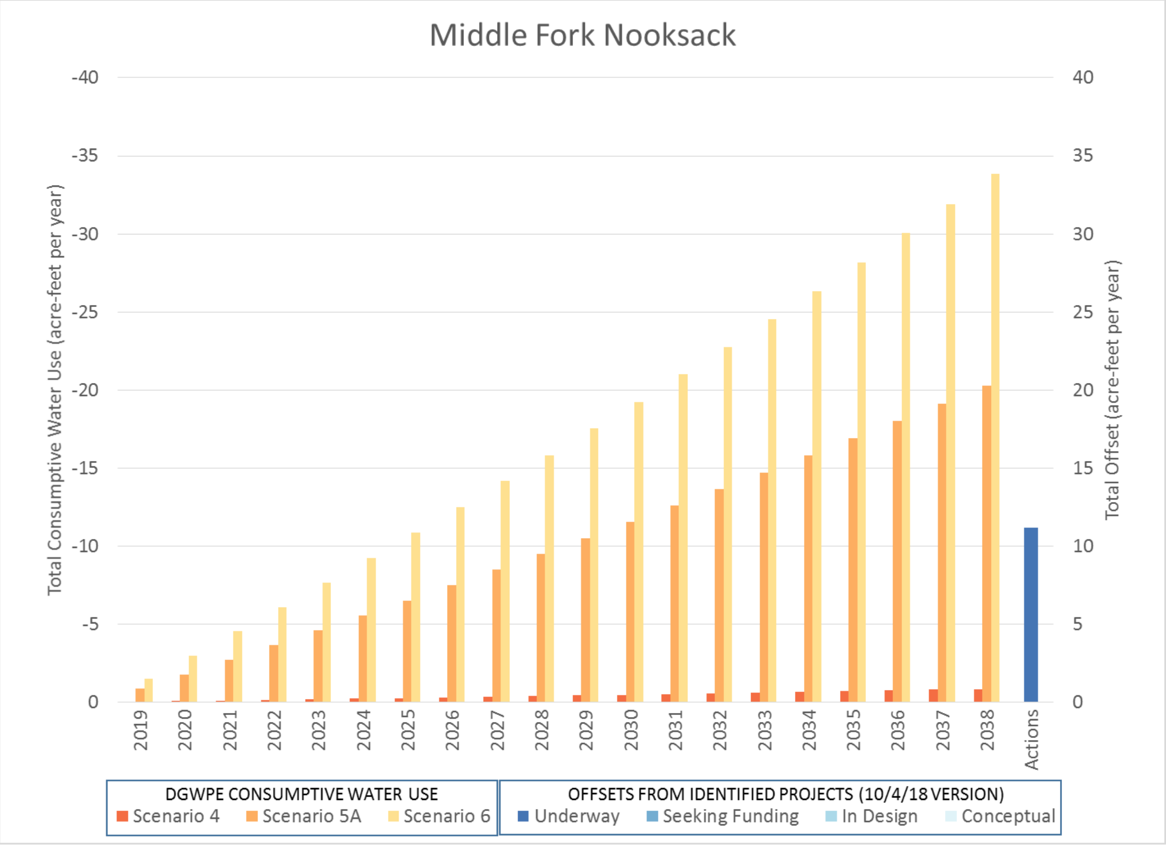

Coastal North
-2500
-2000
-1500
-1000
-500
0
2500
2000
1500
1000
500
0
Total Consumptive Water Use (acre-feet per year)
Total Offset (acre-feet per year)
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual

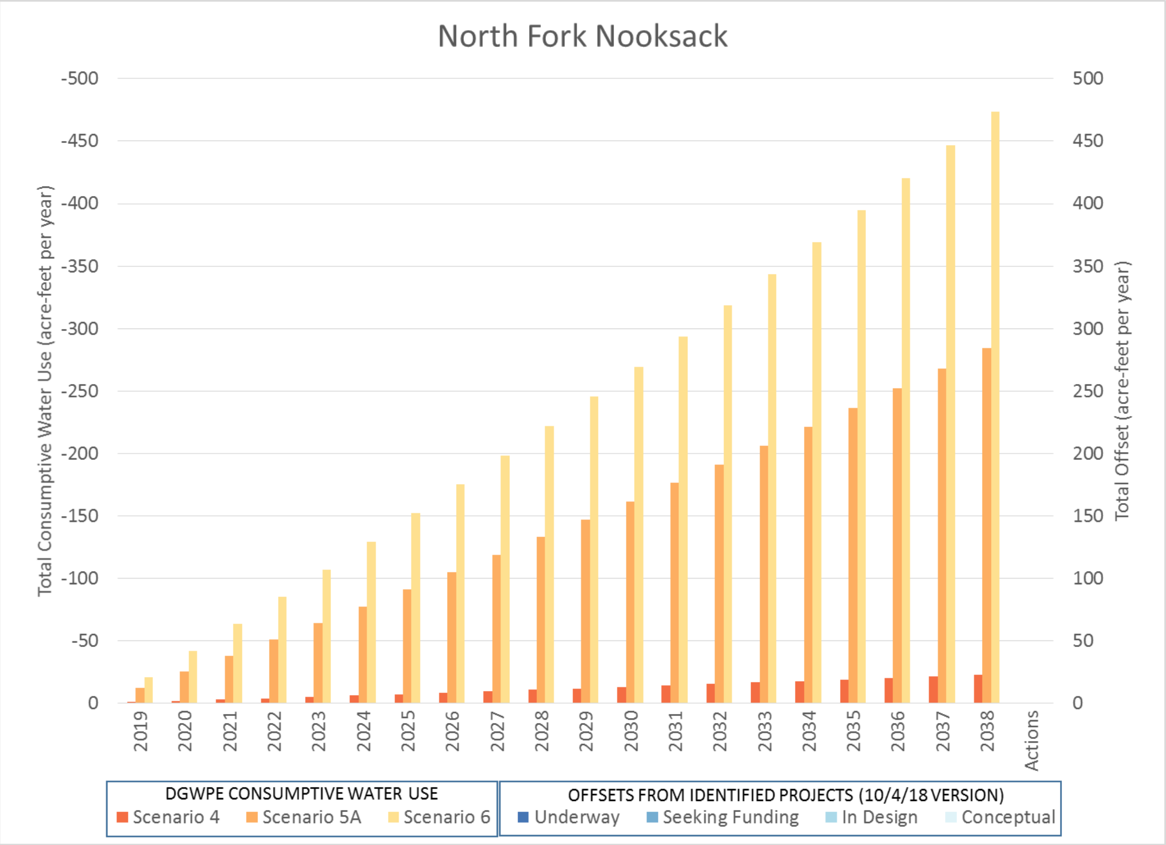

Coastal South
-1000
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
1000
900
800
700
600
500
400
300
200
100
0
Total Consumptive Water Use (acre-feet per year)
Total Offset (acre-feet per year)
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual

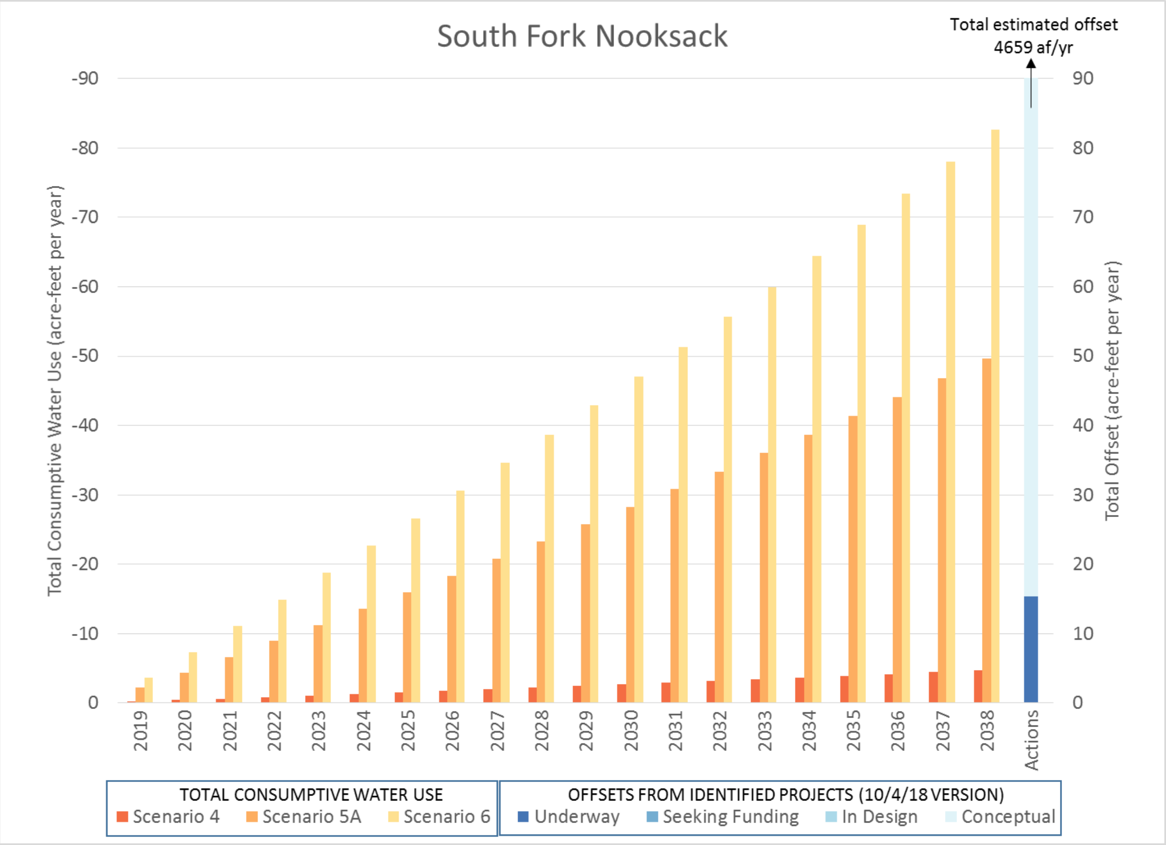

Coastal West
Total Consumptive Water Use (acre-feet per year)
Total Offset (acre-feet per year)
-1200
-1000
-800
-600
-400
-200
0
1200
1000
800
600
400
200
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual

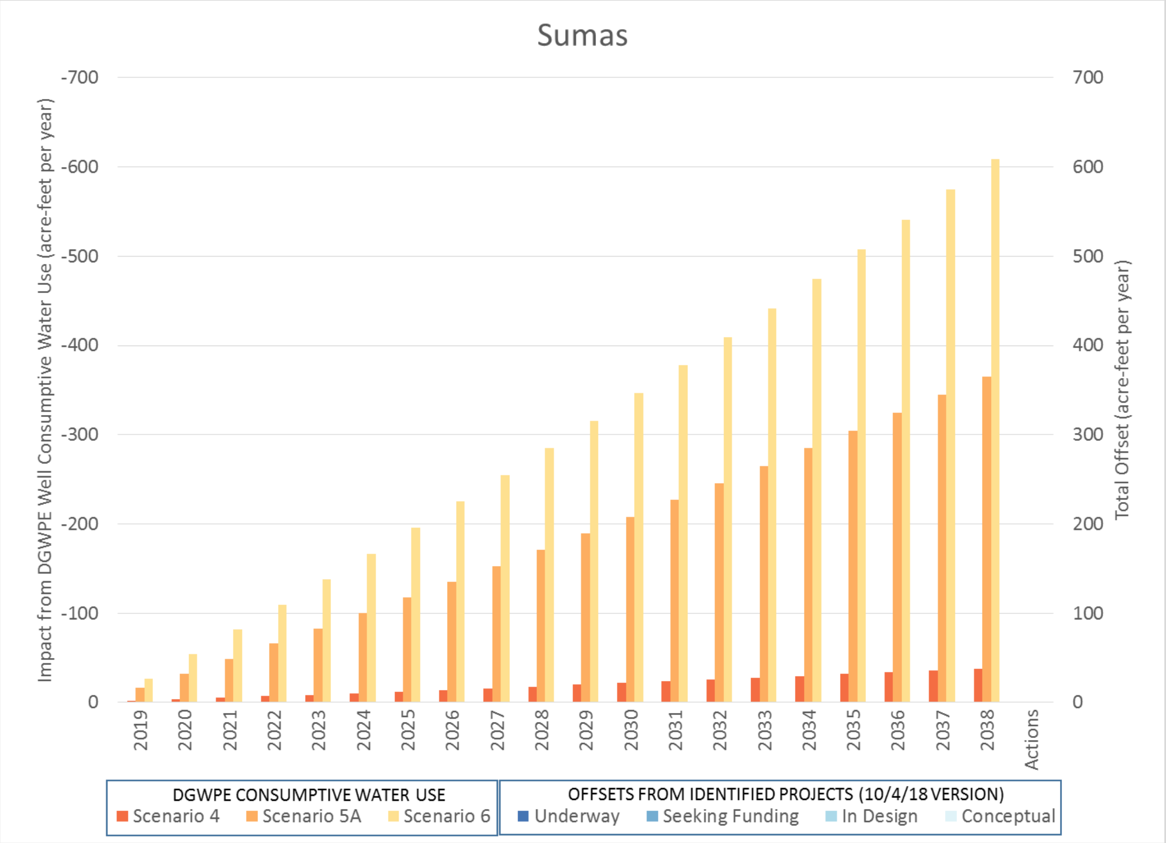

Lake Whatcom
Total Consumptive Water Use (acre-feet per year)
Total Offset (acre-feet per year)
-600
-500
-400
-300
-200
-100
0
600
500
400
300
200
100
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual


Lower Nooksack
Total estimated offset 6252 af/yr
Total Consumptive Water Use (acre-feet per year)
-2500
-2000
-1500
-1000
-500
0
Total Offset (acre-feet per year)
2500
2000
1500
1000
500
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual


Middle Fork Nooksack
Total Consumptive Water Use (acre-feet per year)
-40
-35
-30
-25
-20
-15
-10
-5
0
Total Offset (acre-feet per year)
40
35
30
25
20
15
10
5
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual


North Fork Nooksack
Total Consumptive Water Use (acre-feet per year)
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
Total Offset (acre-feet per year)
500
450
400
350
300
250
200
150
100
50
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual


South Fork Nooksack
Total estimated offset
4659 af/yr
Total Consumptive Water Use (acre-feet per year)
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
Total Offset (acre-feet per year)
90
80
70
60
50
40
30
20
10
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
TOTAL CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual


Sumas
-700
-600
-500
-400
-300
-200
-100
0
Impact from DGWPE Well Consumptive Water Use (acre-feet per year)
700
600
500
400
300
200
100
0
Total Offset (acre-feet per year)
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
Actions
DGWPE CONSUMPTIVE WATER USE
Scenario 4
Scenario 5A
Scenario 6
OFFSETS FROM IDENTIFIED PROJECTS (10/4/18 VERSION)
Underway
Seeking Funding
In Design
Conceptual