Exhibit B (Part 1) to
New York Attorney General's
Comments dated March 30, 2018

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF NEW YORK
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STATE OF NEW YORK,

Plaintiff,

v.

UNITED STATES ARMY CORPS OF ENGINEERS; *et al.*,

Defendants.
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DECLARATION OF DR. CHARLES SILVER

CV-11-2599
(Garaufis, J.)
(Pollak, M.J.)

ECF Case

DR. CHARLES SILVER states as follows:

1. I am the Watershed Inspector General Scientist in the Environmental Protection Bureau of the New York State Attorney General's Office. I submit this declaration in opposition to defendants' motions for dismissal and/or summary judgment and in support of plaintiff State of New York's cross-motion for summary judgment.

2. In this action, New York asserts that defendant federal agencies are violating the National Environmental Policy Act of 1969, 42 U.S.C. § 4321 et seq. ("NEPA"), by refusing to prepare an environmental impact statement to study and develop measures to prevent potential adverse environmental impacts from proposed federal regulations that would authorize natural gas development, including horizontal drilling and high volume hydraulic fracturing, within the Delaware River Basin (the "Basin").

3. The purpose of this declaration is to show the substantial risk of injury to New York's waters, wildlife, and related interests resulting from defendants' failure to perform environmental review pursuant to NEPA.

I. Professional Qualifications

4. I have been employed as the Watershed Inspector General Scientist in the Attorney General's Environmental Protection Bureau since June 2000. My duties and responsibilities include scientific analysis of the impacts of water pollution on surface waters and groundwater within the New York City Watershed and elsewhere within New York and the Nation.

5. I received a Ph.D. in Soil Pollution/Soil Ecology in 1985 from the State University of New York College of Environmental Science and Forestry, and a B.A. in Zoology from Ohio Wesleyan University in 1975, and have been employed as an environmental scientist in both the private and public sectors for 28 years. I have edited, authored, and/or commented on many environmental impact statements ("EISs") prepared pursuant to NEPA and New York law concerning the fate and transport of pollutants, and impacts of pollution on water quality, endangered species and other organisms. In my current position, I have frequently evaluated and commented on EISs concerning potential water pollution impacts of major development projects in the New York City Watershed, including natural gas development employing horizontal drilling and high volume hydraulic fracturing ("HVHF"). My past government work includes employment as an aquatic biologist with Defendant United States Environmental Protection Agency ("EPA") in its Region II laboratory, assessing whether industrial pollutant discharges were toxic to fish and crustaceans.

II. The Governmental Consensus that Natural Gas Development Employing HVHF Has the Potential to Cause Significant Adverse Environmental Impacts

6. The Basin is an area comprising approximately 13,539 square miles, draining parts of Pennsylvania, New Jersey, New York, and Delaware into the Delaware River, and supplies drinking water to 15 million people. The Basin includes the Delaware portion of the

New York City Watershed, which provides most of the unfiltered drinking water consumed by 9 million New Yorkers each day, and the pristine Upper Delaware River, a federally designated "Scenic and Recreational River" administered by Defendant National Park Service ("NPS").

7. The Marcellus shale and potentially other rock formations within the Basin contain natural gas. Natural gas development in the Basin is expected to employ HVHF, a technique that liberates the natural gas by pumping millions of gallons of water, sand, and chemicals (some of which are toxic) under high pressure deep underground. This technique releases natural gas by creating multiple fractures within the Marcellus shale formation. Defendant Delaware River Basin Commission ("DRBC" or "the Commission") and Defendant NPS have stated that they expect thousands of natural gas wells to be developed using this technology within the Basin.

8. There is broad consensus, shared by Defendant federal agencies, Plaintiff New York, and other federal and local government agencies that natural gas development employing HVHF has the potential to cause significant adverse environmental impacts and that an environmental impact analysis should be performed to assess those impacts and mitigate them.

9. That consensus can be summarized as follows:

a. Defendant Collier, as Executive Director of Defendant DRBC issued a finding on May 19, 2009 that "as a result of water withdrawals, wastewater disposal and other activities, natural gas extraction projects in these [gas bearing] formations may individually or cumulatively affect the water quality of Special Protection Waters [including the Delaware portion of the New York City Watershed and the Upper Delaware River and its drainage basin]

by altering their physical, biological, chemical or hydrological characteristics."[1] Based on that finding, DRBC has imposed a moratorium on natural gas development within the Basin pending its promulgation of regulations that would authorize such development.

b. In June 2010, DRBC stated that the "collective effects of the thousands of wells and supporting facilities that are projected in the basin pose potentially significant adverse effects on the surface water and groundwater of the basin."[2] DRBC stated that these potential impacts result from three major areas of concern: (1) "reducing the flow in streams and/or aquifers used to supply the significant amounts of fresh water needed in the gas mining process," (2) "drilling operations may potentially add, discharge or cause the release of pollutants into the groundwater or surface water," and (3) "recovered 'frac water' must be treated and disposed of properly."[3]

c. Defendants United States Fish and Wildlife Service ("FWS") and NPS, services within Defendant Department of Interior, have concluded that "[l]arge-scale changes in land use and increased water withdrawals, like those associated with natural gas development (including the construction of exploratory wells) will likely affect the Services' trust resources

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[1] *See* DRBC "Determination of the Executive Director Concerning Natural Gas Extraction Activities in Shale Formations within the Drainage Area of Special Protection Waters," dated May 19, 2009, available at: http://www.nj.gov/drbc/library/documents/EDD5-19-09.pdf, attached as Exhibit A.

[2] *See* "Statement by the Delaware River Basin Committee (DRBC) on the Upper Delaware River Being Named by American Rivers to its 'America's Most Endangered Rivers' List," dated June 2, 2010, available at: http://www.nj.gov/drbc/library/documents/DRBCstatement_EndangeredRivers_6-2-2010.pdf, attached as Exhibit B.

[3] *See* DRBC, "Natural Gas Drilling Index Page," available at: http://www.state.nj.us/drbc/programs/natural/, attached as Exhibit C.

and should be reviewed for both individual and cumulative environmental effects."[4] Those trust resources include over two hundred migratory birds and various endangered and threatened species under the jurisdiction of FWS, and the "Upper Delaware Scenic and Recreational River," administered by NPS. The representative of Defendant Army Corps of Engineers on the DRBC, who in turn represents various other federal agencies in matters before the Commission, previously stated that the federal government's "position is to continue fully supporting the need for a cumulative impact study."[5]

d. Defendant United States Environmental Protection Agency ("EPA") has frequently acknowledged the potential significant adverse impacts of natural gas development employing HVHF, and is engaged in a study it expects to complete in 2014 of potential impacts on drinking water resources from HVHF activities including: large volume water withdrawals; surface spills on or near well pads of hydraulic fracturing fluids, flowback, and produced water; and inadequate treatment of hydraulic fracturing wastewaters.[6] Given the potential for adverse impacts to water, EPA has expressed "serious reservations about whether gas drilling in the New York City watershed [including its Delaware portion within the Basin] is consistent with the vision of long-term maintenance of a high quality unfiltered water supply."[7] EPA has also

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[4] *See* Letter from Marvin E. Moriarty and Dennis Reidenbach to Carol Collier, dated June 25, 2010, attached as Exhibit D.

[5] *See* Letter from Duke DeLuca to Congressman Maurice Hinchey, dated September 14, 2010, attached as Exhibit E.

[6] *See* EPA Office of Research and Development, "Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources," at xi (November 2011), available at: http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hf_study_plan_110211_final_508.pdf, p. xi attached as Exhibit F.

[7] *See* Letter from John Filippelli, Chief of EPA's Strategic Planning and Multi-Media Programs Branch, to New York State Department of Environmental Conservation, dated December 30, 2009, attached as Exhibit G.

recently concluded in a draft report that natural gas development employing HVHF was likely responsible for shallow and deep groundwater contamination in Pavillion, Wyoming, where elevated concentrations of methane, benzene, toluene, ethylbenzene, xylene, diesel, and various chemicals used in hydraulic fracturing were found.[8]

e. The federal government's Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board ("SEAB") has also acknowledged potential adverse environmental impacts of natural gas development employing HVHF, including "four major areas of concern: (1) Possible pollution of drinking water from methane and chemicals used in fracturing fluids; (2) Air pollution; (3) Community disruption during shale gas production; and (4) Cumulative adverse impacts that intensive shale production can have on communities and ecosystems."[9] SEAB has concluded "that if action is not taken to reduce the environmental impact accompanying the very considerable expansion of shale gas production expected across the country - perhaps as many as 100,000 wells over the next several decades - there is a real risk of serious environmental consequences."[10]

f. The New York State Department of Environmental Conservation ("the New York DEC" or "the Department") has determined that HVHF "raises new, potentially

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[8] *See* EPA Office of Research and Development, "Investigation of Ground Water Contamination Near Pavillion, Wyoming," at xi-xiii (December 2011), available at: http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf, pp. xi - xiii attached as Exhibit H.

[9] *See* United States Department of Energy, "The SEAB Shale Gas Production Subcommittee Ninety-Day Report - August 11, 2011," available at: http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf, pp. 1 and 8 attached as Exhibit I.

[10] *See* United States Department of Energy, "The SEAB Shale Gas Production Subcommittee Second Ninety Day Report - November 18, 2011," at Exec. Summary, p. 10, available at: http://www.shalegas.energy.gov/resources/111811_final_report.pdf, p. 10 attached as Exhibit J.

significant adverse impacts" to the environment not previously subject to environmental review by the Department.[11] Compared to previous natural gas development activities in New York, with HVHF, well pads "are larger and the industrial activity taking place on the pads is more intense. Also hydraulic fracturing requires chemical additives, some of which may pose hazards when highly concentrated."[12] New York DEC has concluded that "[a]ll phases of natural gas well development. . . have the potential to cause water resource impacts during rain and snow melt events if stormwater is not properly managed[,]"[13] and that "spills or releases in connection with high-volume hydraulic fracturing could have significant adverse impacts on water resources."[14] New York DEC recommended that HVHF be prohibited in the New York City Watershed based on the risk that "significant high volume hydraulic fracturing activities in [the New York City Watershed] could result in a degradation of drinking water supplies from accidents, surface spills, etc. Moreover, such large scale industrial activity in these areas, even without spills, could imperil EPA's Filtration Avoidance Determinations and result in [the City] incurring substantial costs to filter [its] drinking water supply."[15] Pursuant to those determinations, New York City has been able to avoid expenditures exceeding $10 billion associated with construction of a filtration plant for drinking water supplies.

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[11] *See* New York State DEC, Revised Draft Supplemental Generic Environmental Impact Statement, ("DSGEIS"), dated September 7, 2011, at Exec. Summary p. 1, available at http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf, Exec. Summary, p.1 attached as Exhibit K.

[12] *See id.*

[13] *See id.*at Exec. Summary, p. 10.

[14] *See id.*

[15] *See id.* at Exec. Summary, p. 20.

g. The New York City Department of Environmental Protection ("NYCDEP"), which supplies the drinking water obtained from the City's Watershed, has stated in comments to DRBC concerning its proposed regulations to authorize natural gas development: (1) "Clearly this type of industrial activity has the potential to have a significant impact on the Delaware River and its tributaries, and the City continues to believe that it is premature for the Delaware River Basin Commission (DRBC) to adopt these regulations;"[16] and (2) "Prior to issuing any regulations, DRBC should conduct a rigorous analysis of the potential cumulative impacts natural gas development could have on water quantity and water quality in the Delaware Basin."[17] NYCDEP has also concluded, based on third-party scientific studies, that natural gas development would "pose an unacceptable threat to the unfiltered, fresh water supply of nine million New Yorkers, and cannot safely be permitted within the New York City watershed."[18]

h. The City of Philadelphia Water Department ("PWD") provides drinking to almost two million consumers in the Philadelphia region. In light of potential adverse impacts to the Delaware River, a source of much of its water, PWD has concluded that "a study of the long-term implications of natural gas drilling for Philadelphia's drinking water supply is needed. At a minimum, this study should include an evaluation of the cumulative impact on surface waters of

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[16] *See* Testimony of Paul V. Rush, P.E., Deputy Commissioner, NYCDEP, at DRBC Hearing, February 22, 2011, available at: http://www.state.nj.us/drbc/library/documents/NGC/Agencies/NYCDEP022211.pdf, attached as Exhibit L.

[17] *See* Letter of Paul V. Rush, P.E. to DRBC, dated April 7, 2011, available at: http://www.state.nj.us/drbc/library/documents/NGC/Agencies/NYCDEP040711.pdf, attached as Exhibit M.

[18] *See* Letter from Steven W. Lawitts to New York State DEC, dated December 22, 2009, available at: http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/12_22_2009_impact_statement_letter.pdf, attached as Exhibit N.

improperly cased wells and on-site spills and accidents involving toxic substances. Additionally the study should evaluate transportation pathways in the Delaware River Basin of hydraulic fracturing fluids and wastewater and determine the risk of spills and accidents in proximity to drinking water supplies."[19]

10. I agree with the broad consensus of federal, state, and local agencies that natural gas development employing HVHF poses potential significant adverse environmental impacts and that an environmental impact statement should be prepared to study and address those impacts before federal regulations authorizing such development in the Basin are finalized. For the reasons discussed below, if defendants do not comply with NEPA and do not prepare an environmental impact statement, New York's waters, wildlife, and related interests will be at significant risk of injury from natural gas development in nearby areas in Pennsylvania.

III. Generation of Potential Harmful Water Pollutants from Natural Gas Development Employing HVHF

11. Unlike traditional methods of natural gas development, HVHF requires large volumes of water obtained from rivers, streams, lakes, or groundwater within the Basin, from recycled HVHF fluids, or by importing water from outside the Basin. Various chemicals or "fracking additives" are mixed in with the water to facilitate hydraulic fracturing, including chemicals which can pose risks to health and the environment, such as benzene, toluene, ethylbenzene, and xylene (referred to as BTEX); microbiocides; glycols; glycol ethers; and petroleum products.[20]

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[19] *See* Letter from Howard Neukrug, P.E., Commissioner, City of Philadelphia Water Department to DRBC, dated March 3, 2010, available at: http://www.phila.gov/water/pdfs/DRBC_Letter.pdf, attached as Exhibit O.

[20] *See* DSGEIS, pp. 5-46 through 5-66, attached as Exhibit K.

12. The U.S. House Committee on Energy and Commerce recently asked the 14 leading oil and gas companies to disclose the types and volumes of hydraulic fracturing additives they used in their fluids between 2005 and 2009. In their responses, the companies identified 29 chemicals in these fluids that are considered toxic because they are known or possible human carcinogens; regulated under the Safe Drinking Water Act for their risks to human health; or listed as hazardous air pollutants under the Clean Air Act. Five of the 29 chemicals were classified in all three categories. In addition, some of the 29 chemicals (e.g. naphthalene and xylene) have the propensity to bioaccumulate in fish and other aquatic organisms. The 29 toxic chemicals are constituents of 652 products used as fracking additives, which means that one quarter of these products contain toxic constituents. The 14 companies used 780 million gallons of hydraulic fracturing additives between 2005 and 2009.[21]

13. Natural gas is contained within Marcellus shale, which is typically more than 4,000 feet below ground. During HVHF, as much as 10 million gallons of water containing sand and fracking additives (collectively referred to as "fracking fluids") are injected into each well under high pressure causing numerous fractures to develop along the well bore. The sand keeps the newly fractured shale from compressing or closing up and allows the liberated natural gas to flow to the well, where it can be extracted.

14. In addition to natural gas, naturally occurring brine is present in the Marcellus shale. Brine can contain toxic metals and radioactive substances.[22] EPA has found that brine

[21] U.S. House of Representatives Committee on Energy and Commerce Minority Staff April 2011 "Chemicals Used in Hydraulic Fracturing," available at: http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf, 30 pp.

[22] Congressional Research Service, Memorandum to House Committee on Natural Resources: Marcellus Shale Gas Development: Royalty Rates, Surface Owner Protection, and Water Issues (October 14, 2008) at CRS-13 and CRS-14.

"can be very damaging to the environment and public health if it is discharged to surface water or the land surface."[23] Prior to HVHF, brine remains deep underground where it is generally unable to migrate into and contaminate fresh groundwater or surface waters above. However, brine mixes with the fracking fluids once they are injected into the Marcellus shale formation.

15. Some 15 to 20% of fracking fluids flow back up through the well and are collected at the ground surface. These returning fluids are referred to as "flowback," and most surface within ten days after HVHF. Flowback contains barium, calcium, iron, magnesium, and sulfur from the shale formation as well as brine that may contain radioactive elements. The production phase follows the hydrofracking/well completion phase. During the natural gas production phase, brine continues to flow up through the well. The brine coming up to the surface during this phase is referred to as "production brine." Like flowback, production brine must be stored and subsequently treated, reused, and/or disposed.

16. Both flowback and production brine contain high concentrations of total dissolved solids ("TDS"). TDS is a general term for particles suspended in a liquid which can easily flow through a small filter. The TDS associated with natural gas development includes minerals, metals, and various soluble salts. TDS in production brine and flowback can reach concentrations as high as 200,000 milligrams per liter (mg/L) or 200,000 parts per million.[24]

17. The high levels of TDS found in flowback and production brine, if discharged into freshwater streams, rivers or lakes in the Basin, would likely present a severe threat to water

[23] USEPA, Underground Injection Control Program. Oil and Gas Injection Wells: Class II, available at: http://water.epa.gov/type/groundwater/uic/class2/index.cfm.

[24] *See* Source: Ohio Environmental Protection Agency, "Drilling for Natural Gas in Marcellus and Utica Shales: Environmental Regulatory Basics," follow link to "The Basics," available at: http://www.epa.ohio.gov/shale.aspx

quality and the survival of aquatic organisms, including fish.[25] TDS in flowback and production brine includes elevated levels of salts, such as sodium chloride. Due to the toxic impact of chlorides on freshwater organisms, EPA assembled and evaluated lethal and sublethal toxicity data for a wide variety of freshwater plants and animals, including snails, clams, crustaceans, insects and five species of fish. EPA developed acute (one hour) and chronic (four day) water quality criteria for chlorides in fresh water. The acute water quality criteria for sodium chloride is 860 mg/L and the chronic water quality criteria is 230 mg/L. This means that exposure of aquatic organisms to water having chloride concentrations exceeding these criteria would harm or kill some of these organisms.[26]

18. Because of the large number of wells expected to be developed within the Basin, billions of gallons of flowback and production brine would have to be treated, reused, and/or disposed of within the Basin, or these wastewaters would have to be exported for treatment or disposal elsewhere. I am not aware of any facilities currently within the Basin capable of treating these wastewaters. Existing sewage treatment plants within the Basin are generally not suitable for treating these wastewaters because the high concentrations of total dissolved solids in production brine and flowback (and the biocides and other toxic additives found in flowback) may interfere with their ability to treat sanitary sewage.[27] In addition, disposal by underground injection within the Basin, at this time, is unlikely. Accordingly, to treat and dispose of HVHF

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[25] *See id.*

[26] USEPA Ambient Water Quality Criteria for Chloride-1988 (a.k.a. Ambient Aquatic Life Water Quality Criteria for Chloride) EPA 440/5-88-001 39, dated February 1988, available at: http://water.epa.gov/scitech/swguidance/standards/criteria/upload/chloride1988.pdf, pp. 46.

[27] Congressional Research Service, Memorandum to House Committee on Natural Resources: Marcellus Shale Gas Development: Royalty Rates, Surface Owner Protection, and Water Issues (October 14, 2008) at CRS-15.

wastewaters within the Basin would require construction of new treatment facilities; otherwise these wastewaters must be exported.

19. The scale of anticipated natural gas development in the Basin means that some spills, leaks, blowouts, well operation failures, and other incidents would likely result in pollutant discharges of natural gas, fracking fluids, flowback, production brine, and/or other chemicals related to natural gas development unless adequate protective measures are put in place. Spills and leaks can occur from above-ground tanks, impoundments and containers, compressor engines, trucks, and from defects in well design or construction (including problems in well cementing and casing) and other failures.

20. Leaking or spilled substances can contaminate surface waters directly or indirectly when they are carried by stormwater runoff or otherwise flow overland into streams and rivers within the Basin. Groundwater generally flows toward and discharges to surface water. Groundwater can become contaminated from leaks, spills, and discharges at the well pad and from defects below the ground in well casings and cementing. Local geologic features below the land surface, such as faults, fractured bedrock, coarse gravel, or other permeable materials can serve as conduits for the rapid migration of contaminated groundwater to surface waters.

IV. Pollution Problems From Natural Gas Development in Pennsylvania

21. Currently natural gas development in Pennsylvania is proceeding on a large scale outside the Basin. However, protective measures have not been followed or have been inadequate and significant pollution discharges to surface waters and groundwater have occurred. From January 1, 2008 through August 20, 2010, natural gas development in Pennsylvania outside of the Basin resulted in issuance by the Pennsylvania Department of Environmental

Protection of 1,614 violations to drilling operators (not including traffic citations or written warnings), of which 1,056 were judged as having "the most potential for direct impact on the environment."[28]

22. A few examples illustrate the significant pollution problems that have been occurring in Pennsylvania.

23. In October 2008, levels of TDS exceeded federal and state drinking water standards in Pennsylvania's Monongahela River for 70 miles, affecting eleven public water suppliers. According to PADEP Secretary John Hanger, much of the TDS was from natural gas development well drilling wastewaters that were discharged from sewerage treatment plants along the river. To address this, the PADEP directed all applicable sewage treatment plants located along the Monongshela River to reduce their intake of drilling wastewaters by up to 95%.[29] In addition to TDS, bromide concentrations in the Monongahela River were also recorded at elevated levels, which would potentially subject people drinking the water to increased health risks from disinfection.[30]

24. Polluted stormwater from natural gas development activities occurring in McKean County, Pennsylvania, has repeatedly flowed across the border into Yeager Brook within New York's Allegany State Park from August 2010 through January 17, 2012. The pollution

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[28] Pennsylvania Land Trust Association Report, "Marcellus Shale Drillers in Pennsylvania Amass 1614 Violations since 2008," dated October 1, 2010, available at: http://conserveland.org/violationsrpt.

[29] Don Hopey, "DEP Seeks Cause of River Pollution," *Pittsburgh Post-Gazette*, dated October 22, 2008, available at: http://www.post-gazette.com/pg/08296/922096-100.stm.

[30] Paul Handke, Water Program Specialist, Pennsylvania Department of Environmental Protection, "Trihalomethane Speciation and the Relationship to Elevated Total Dissolved Solid Concentrations Affecting Drinking Water Quality at Systems Utilizing the Monongahela River as a Primary Source During the Third and Fourth Quarters of 2008," pp. 27.

discharges, apparently caused by improper drilling operations and ineffective stormwater pollution prevention measures, caused New York's Yeager Brook to turn variously milky white, yellowish brown, and grey in color in violation of State water quality standards. The drilling company responsible for the pollution, U.S. Energy Development Corporation, has entered into two administrative consent orders with New York DEC without disputing the underlying facts.[31]

25. On April 19, 2011, Chesapeake Energy Corporation, a national leader in natural gas development, experienced a failure at a natural gas well in Bradford County, Pennsylvania, located outside of the Basin, during the hydraulic fracturing process. As a result of the failure, thousands of gallons of water containing fracking chemicals were discharged into a nearby creek, and seven families were evacuated from the area.[32] [33]

26. In the week prior to September 25, 2009, three spills occurred at the Heitsman well, located outside of the Basin, during Cabot Oil and Gas Corporation's hydrofracking operations in Dimock Township, Susquehanna County, Pennsylvania. According to a Consent Order and Settlement Agreement with Cabot, the Pennsylvania Department of Environmental Protection ("PADEP") determined that the drinking water at nineteen nearby homes was adversely affected by the drilling activities and required Cabot Oil and Gas Corporation to provide water to the residents. At least once every two weeks, the adversely affected water

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[31] *See* New York DEC Orders on Consent, (File No. 10-46; R9-20100913-39 December 20, 2010), and (File No. 11-01; R9-20110111-1 August 24, 2011). *See also* New York DEC Administrative Complaint, *In re U.S. Energy Development Corp.*, (File No. 11-57, R9-20111104-150 January 24, 2012).

[32] Marshall, C.J., *The Daily Review*, "Spill at well drilling site causes evacuation," dated April 21, 2011, available at: 2011 WLNR 7782375.

[33] Notice of Violation to Chesapeake Energy from the Pennsylvania DEP, published April 23, 2011, available at: http://thedailyreview.com/news/notice-of-violation-to-chesapeake-energy-from-the-pennsylvania-dep-1.1136743.

supplies for the affected houses were to be sampled and analyzed for dissolved methane, dissolved ethane, and dissolved propane.[34]

IV. The Role of Environmental Impact Statements in Preventing Adverse Environmental Impacts Associated with Natural Gas Development in New York

27. I have substantial experience in editing, drafting, and commenting on environmental impact statements as part of the environmental review process under NEPA and under New York's state law analogue to that statute, the State Environmental Quality Review Act (New York Environmental Conservation Law, Article 8) ("SEQRA"). The environmental review process under these laws requires government decision makers to identify, analyze, and document potential adverse environmental impacts, and consider alternatives or mitigation measures that would prevent or lessen such impacts. While there are no guarantees that these laws will achieve those results, it is my experience that they typically do reduce environmental impacts.

28. In fact, the environmental review New York DEC is engaged in concerning natural gas development in the State, including development in New York's portion of the Basin, will likely reduce such impacts. The Department has prepared two detailed draft environmental impact statements based on its review of thousands of public comments, the input of Department staff, and reports from expert consultants. As a result of that process, New York DEC has proposed (but has not yet finalized) a wide array of protective measures. For example, in its Revised Supplemental Draft Generic Environmental Impact Statement, dated September 7, 2011 ("Revised Draft EIS"), the Department analyzed potential adverse impacts to the New York City Watershed and the Skaneateles Lake Watershed (which provide unfiltered drinking water to residents of New York City and Syracuse, respectively), "primary aquifers" (major municipal

[34] PADEP Consent Order and Settlement Agreement, dated December 15, 2010.

drinking water systems relying on groundwater), and State lands. Based on that analysis, the Department has proposed prohibiting natural gas development altogether within these areas and in buffer areas surrounding those watersheds and primary aquifers.

29. Within the Basin, the proposed prohibitions against HVHF, if finalized by New York DEC, would apply to the Delaware portion of the New York City Watershed, which include the Cannonsville, Neversink, Pepacton, and Rondout Reservoirs and their drainage areas, and to State lands along the Upper Delaware River. These state lands are intended to facilitate the public's recreational use of the River and to protect State forests, fish and wildlife. As described in greater detail in the Declaration of William Rudge, those lands include fishing and boating access sites, the Mongaup Valley Wildlife Management and Bird Conservation areas, forest preserve lands, and a scenic highway.

30. The EIS process has also resulted in proposals by New York DEC to prevent water pollution in areas of New York in which it proposes to authorize natural gas development employing HVHF. In its Revised Draft EIS, the Department analyzed potential adverse impacts to surface waters and groundwater from stormwater runoff, spills, and releases associated with such development. New York DEC found that "all phases of natural gas well development, from initial land clearing for access roads, equipment staging areas and well pads, to drilling and fracturing operations, and production and final reclamation, have the potential to cause water resource impacts during rain and snow melt events if stormwater is not properly managed."[35] The Department also found that, in the course of natural gas development "[s]pilled, leaked or

[35] *See* DSGEIS, p. 6-14, attached as Exhibit K.

released fluids could flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers."[36]

31. To address such impacts, New York DEC has proposed regulations that would require drilling companies to: (1) evaluate the use of alternative fracking additives that exhibit reduced aquatic toxicity and pose less risk to water resources and the environment, and use less toxic additives if feasible;[37] (2) create and implement separate comprehensive stormwater pollution prevention plans for specific phases of natural gas development to minimize or eliminate introduction of pollutants into stormwater;[38] and (3) impose requirements for well pad operations to prevent conditions that have resulted in water pollution in Pennsylvania.[39]

32. These comprehensive measures, not required in Pennsylvania or proposed by DRBC, would likely prevent pollution or, in the case of measures to reduce the use of toxic hydraulic fracturing additives, lessen the harm from pollution. New York DEC's proposed stormwater pollution measures would include detailed spill prevention and good housekeeping measures to prevent pollution from occurring. According to EPA: "Spill response, good housekeeping, and material management are critical elements of the HVHF SWPPP (stormwater pollution prevention plan)."[40] In addition, the proposed stormwater pollution measures would

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[36] *See id.*, pp. 6-15 through 6-17.

[37] *See id.*, p. 8-30.

[38] NYSDEC Draft SPDES General Permit for Stormwater Discharges from High-Volume Hydraulic Fracturing GP-0-XX-00X, available at: http://www.dec.ny.gov/docs/water_pdf/hvhfgp.pdf, pp. 16 to 21 & 29 to 40.

[39] *See* DSGEIS, pp. 1-12 and 7-52, Exhibit K.

[40] USEPA Region 2 Comments on the NYSDEC's SPDES General Permit for Stormwater Discharges from High Volume Hydraulic Fracturing (HVHF) December 22, 2011, available at: http://www.epa.gov/region2/newsevents/pdf/HVHF%20NYSDEC%20Permit%20Enclosure.pdf, p. 4.

require periodic sampling and laboratory analysis of stormwater to detect potential contaminants. This would help identify pollution problems and correct them before discharges to water courses occur.[41]

33. New York is also proposing in its Revised Draft EIS that drillers generally be required to install three casings at each HVHF well, in contrast to Pennsylvania which generally requires two.[42] The installation of three casings is designed to ensure there is no subsurface leakage of potential contaminants into fresh groundwater supplies. In general, when three casings are installed, the surface casing extends from the ground surface to below the base of the freshwater aquifer, the intermediate casing extends from the ground surface to below areas that may have shallow gas bearing zones, and the production casing extends from the ground surface to the furthest extent of the horizontal component of the well.

34. Problems in Pennsylvania have occurred when the intermediate casing was not installed and only two casings were used. For example, the PADEP entered into a consent order and agreement with Chesapeake Appalachia, LLC (Chesapeake) on May 16, 2011, concerning seven discrete areas in five townships in Bradford County affecting 18 residences. The PADEP issued Chesapeake a notice of violation (NOV) for the failure to prevent the migration of natural gas into fresh groundwater at all seven areas. In addition, six of the seven areas received NOVs for the unpermitted discharge of polluting substances. Two of the seven areas also received NOVs for defective well casing and cementing. As a result, all gas wells drilled after May 16,

[41] *See* fn. 35, *infra*, p. 41-77.

[42] *See* fn. 34, *infra*; *see* 25 PA Code Chapter 78. Oil and Gas Wells Sections 78.81 to 78.87, available at: http://www.pacode.com/secure/data/025/chapter78/chap78toc.html.

2011 by, or on behalf of, Chesapeake in the areas identified in the consent order are required to install three casings, unless they notify the PADEP of alternate practices.[43]

V. Environmental Review Under NEPA Is Needed to Prevent Harm to New York's Waters, Wildlife, Lands and Scenic Vistas From Natural Gas Development in the Basin in Pennsylvania

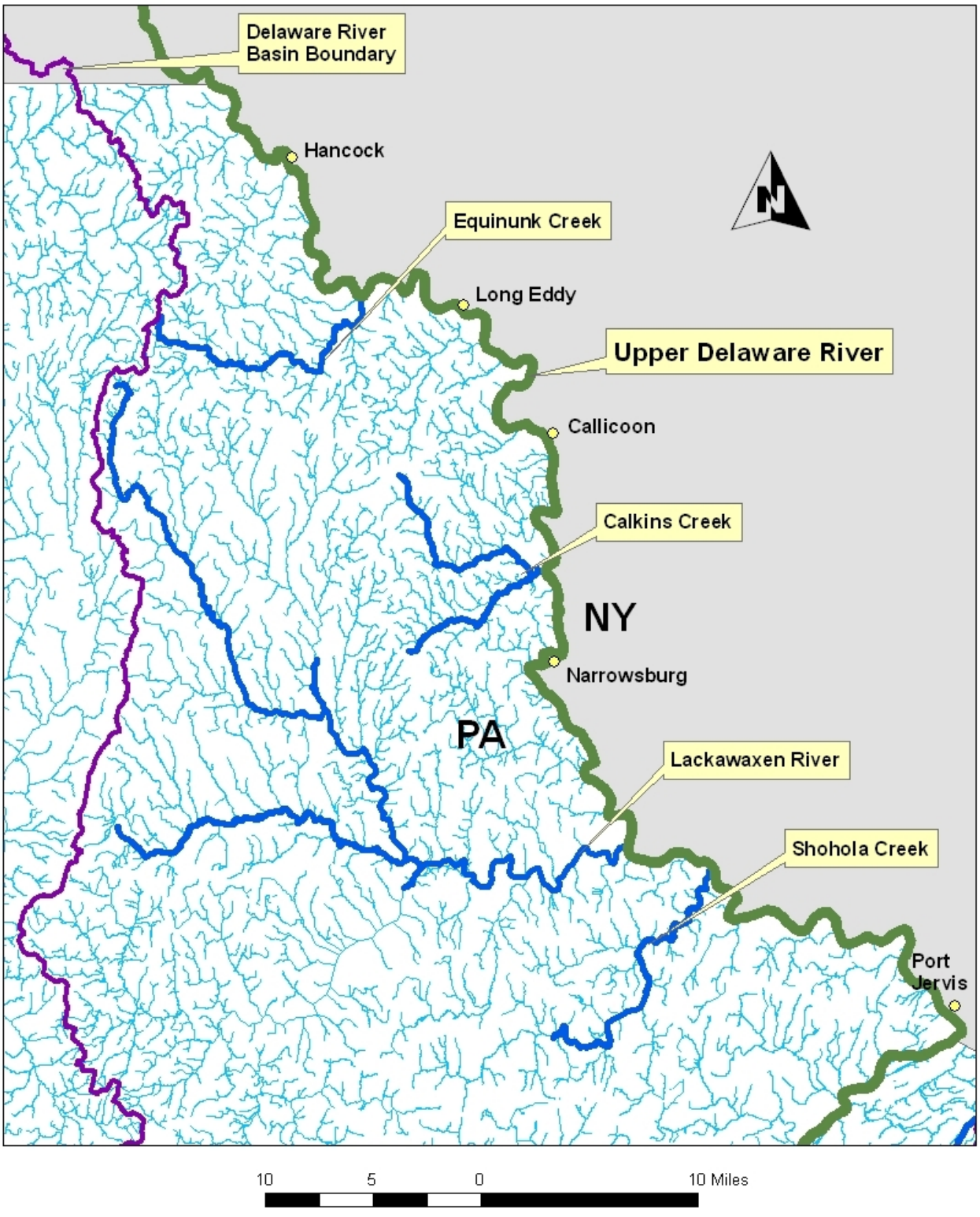
35. The preventive measures that the New York DEC has proposed (but not yet finalized), would apply only to natural gas development employing HVHF in New York, and would not apply to areas of the Basin within Pennsylvania that drain into New York waters, such as in Wayne and Pike Counties.

36. Surface waters in those Pennsylvania counties flow from many smaller waterbodies into Equinunk Creek, Calkins Creek, Lackawaxen River, and Shohala Creek, which in turn drain to the Upper Delaware River, the eastern half of which lies within New York as depicted in Figure 1 below. Accordingly, unless adequate protective measures are taken in Pennsylvania, discharges of pollutants that occur in these watersheds would likely be transported downstream into the New York portion of the Upper Delaware River. The continuing flow of stormwater pollution into New York waters from natural gas development sites outside the Basin in McKean County, Pennsylvania, illustrates this problem.

37. Unlike SEQRA which applies in New York, Pennsylvania does not have a state environmental review law analogous to NEPA. Pennsylvania regulations of natural gas development, promulgated without benefit of such environmental review, include less stringent measures to prevent pollution discharges. As discussed above, Pennsylvania does not require drilling companies to use alternatives to toxic fracking additives, or to implement strict and comprehensive stormwater pollution prevention measures or more stringent well pad operation

[43] PADEP Consent Order and Settlement Agreement, dated May 16, 2011.

Figure 1



Pennsylvania Tributaries to the Upper Delaware River

measures. Moreover, Pennsylvania does not prohibit natural gas development within its state lands and parks. This means that large tracts of Pennsylvania state lands on the banks of the Upper Delaware River, including State Game Lands and the Delaware State Forest, would be subject to natural gas development employing HVHF within the Basin.

38. DRBC has published successive sets of draft regulations that would authorize natural gas development in the Basin. But these proposed regulations do not include the protective measures described above or similar measures to prevent pollution impacts to surface waters and groundwater. Instead, pursuant to DRBC's draft regulations, Pennsylvania's stormwater and well pad operation regulations would apply to drilling in the portion of the Basin within that state and DRBC's general stormwater controls (not tailored to natural gas development) would also apply.[44]

39. If environmental review pursuant to NEPA is not performed by DRBC and other federal agencies, New York's half of the Upper Delaware River will be at risk from pollution emanating from natural gas development in nearby areas of Pennsylvania. As past experience in Pennsylvania outside the Basin suggests, some of that polluted water will likely flow downstream into New York's portion of the Upper Delaware River.

40. Pollution of the Upper Delaware River with fracking fluids, flowback, and production brine would likely harm water quality in that river and adversely impact the fish and wildlife that depend on clean water. As discussed above, fracking fluids, flowback and production brine contain a variety of toxic chemicals which, if discharged into a water bodydraining into the Upper Delaware River, would risk significant adverse impacts to the River and life within it.

[44] *See* Delaware River Basin Commission Natural Gas Development Regulations, dated

41. For example, production brine at a gas development site in Tioga County, Pennsylvania, was tested in 2010 and found to have a chloride concentration of 151,000 mg/L or 175 times the acute water quality criteria and 656 times the chronic criteria established by EPA to prevent the harm or death of aquatic organisms.[45] A spill of this magnitude into a water body draining into the Upper Delaware River would present a very serious risk of harm to aquatic organisms found there.

42. The federally endangered dwarf wedge mussel and other freshwater mussels found in the Upper Delaware River would be especially at risk from natural gas development in the Basin, as Defendant FWS found in testimony it previously submitted to DRBC.[46] Of the twelve species of mussels residing in the Upper Delaware River, nine are endangered, threatened, or imperiled. In 1990, FWS identified water pollution as a major cause for the endangerment of the dwarf wedge mussel.[47] According to FWS, freshwater mussels filter large volumes of water to respire and to feed. As a result, the mussels are susceptible to the impacts of water pollution because they rapidly assimilate and digest dissolved toxins, such as metals and biocides. In addition, because of their relative immobility, mussels are extremely vulnerable to spills of toxic chemicals. Unlike fish, which may be able to swim out of harm's way, mussels

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November 8, 2011, §§ 7.1(i) p. 5, §§ 7.4(d)(1)(viii) p. 53 and §§ 7.4(e)(4)(viii) p. 69-70.

[45] Form 26 R Chemical Analysis of Residual Waste Annual Report by Generator Submitted to the PADEP by AMEC Geomatrix, Inc. on behalf of Ultra Resources, Inc. on March 11, 2010.

[46] Anderson, R.M. (U.S. Fish & Wildlife Service) and D.A. Kreeger (Partnership for the Delaware Estuary). 2010. Testimony to the Delaware River Basin Commission available at: http://www.delawareriverkeeper.org/resources/Reports/DRBC_Expert_Reports_Gas.pdf, attached as Exhibit P.

[47] 55 Federal Register 9,447-01, Rules and Regulations, Department of the Interior, Fish and Wildlife Service, 50 C.F.R. Part 17, RIN 1018-AB31, *Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Dwarf Wedge Mussel,* dated March 14, 1990.

can respond by closing their shells, if they can detect the toxin, which has limited effectiveness in protecting them. According to Defendant NPS, freshwater mussels, including the dwarf wedge mussel, make up the greatest animal biomass in the Delaware River. See Rudge Declaration, par. 11. Because of the important role played by mussels in removing suspended particles from the water by filter feeding, harm to these organisms would adversely effect the Upper Delaware River's water quality because the important benefit they provide in filtering water will be lost.[48]

43. Fish populations would also be put at risk by spills of toxic chemicals and brine into the aquatic environment from well sites in Pennsylvania, as illustrated by the high chlorides found in flowback and production brine which frequently exceed EPA's water quality criteria.

44. Moreover, because fish serve as a primary component of the bald eagle diet in the Delaware River Basin, adverse impacts to fish populations would also pose risks to these threatened birds because it could deplete their food resources. The eagles could also suffer from ingesting contaminated fish or those that have been bioaccumulating toxic chemicals. In addition to consuming live fish, bald eagles scavenge dead fish, which could include fish killed by toxic chemicals. Ingesting contaminated fish by bald eagles could lead to breeding and/or behavioral modifications, illness, and potentially to death.

45. As discussed in greater detail in the Declaration of William Rudge, the Upper Delaware River is noted for its unique scenic beauty. Natural gas development within the Basin could cause significant adverse visual impacts along the River. As found by New York DEC in its Revised EIS, gas development employing HVHF would involve use of drilling rigs up to 170

[48] Anderson, R.M. (U.S. Fish & Wildlife Service) and D.A. Kreeger (Partnership for the Delaware Estuary). 2010. Testimony to the Delaware River Basin Commission.

feet in height along with ancillary equipment that could cause visual impairments.[49] The Department has proposed a variety of measures to reduce such adverse impacts.[50] In contrast to New York, DRBC has not proposed any measures to mitigate visual impacts associated with natural gas development in the Basin.

46. Unless DRBC and the other federal agencies perform environmental review pursuant to NEPA, adverse visual impacts may occur in New York as a result of natural gas development on the Pennsylvania side of the River. Areas adjacent to the River in Pennsylvania are observable from New York, as I can attest based on a tour I recently took along the New York side of the Upper Delaware River.

47. While DRBC proposes generally prohibiting drilling within a narrow corridor adjacent to the banks of the "Upper Delaware Scenic and Recreational River" administered by Defendant NPS, that prohibition would not prevent drilling that could impair views in New York. Under DRBC's proposed regulations, applicants for drilling permits would have the opportunity to seek variances from DRBC allowing them to develop natural gas within that corridor, and DRBC would not prevent drilling at all in other areas adjacent to the River outside of the corridor administered by NPS. In addition, it is possible to see very substantial distances inside of Pennsylvania beyond that corridor from areas in New York along the River.

48. Adverse water pollution, impacts to New York fish and wildlife, and visual impacts resulting from natural gas development in Pennsylvania, risk harm to New York's land holdings along the Upper Delaware, including boat launches, the Scenic Byway, and wildlife management areas. As owner of these lands, the State has chosen to make them available to its

[49] *See* DSGEIS, pp. 6-263 to 6-264.

[50] *See id.*, pp. 7-121 through 7-128.

residents for their recreational use and enjoyment. Unless adequate protective measures are in place, pollution and visual impairments from natural gas development in Pennsylvania would risk a reduction in the use and enjoyment of these lands by boaters, anglers, hikers, and bird watchers.

VI. Conclusion

49. Defendants' compliance with NEPA cannot guarantee that harms to New York's waters, wildlife and State lands caused by natural gas development in Pennsylvania will be eliminated or lessened. However, based on my experience with environmental review under NEPA and SEQRA, and the ongoing environmental review process in New York, there is a substantial likelihood that NEPA compliance would achieve those results.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on February 13, 2012.

Charles Silver

Charles Silver

EXHIBIT A

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Delaware River Basin Commission
25 State Police Drive
PO Box 7360
West Trenton, New Jersey
08628-0360
Phone: (609) 883-9500 Fax: (609) 883-9522
Web Site: http://www.drbc.net

Carol R. Collier
Executive Director

Robert Tudor
Deputy Executive Director

DETERMINATION OF THE EXECUTIVE DIRECTOR CONCERNING NATURAL GAS EXTRACTION ACTIVITIES IN SHALE FORMATIONS WITHIN THE DRAINAGE AREA OF SPECIAL PROTECTION WATERS

Technological advances in horizontal drilling and hydraulic fracturing have led to an increase in the number of active and planned natural gas extraction projects in shale formations within the Delaware River Basin. Each of these projects typically involves the construction of a well pad and associated roadways at or about surface elevations, the drilling of a well bore to depths of as much as 6000 feet or more, the withdrawal and transport of surface or ground water, the injection of the water and chemical fracturing mixtures into the wells to release the trapped gas, the recovery and storage of recovered fracturing fluid, water and associated leached constituents extracted with the gas, the storage and potentially the reuse of the recovered wastewater and chemicals and the eventual disposal of the water and chemicals. Each of these activities if not properly performed may cause adverse environmental effects, including effects on water resources.

Section 3.8 of the Delaware River Basin Compact provides in part: "No project having a substantial effect on the water resources of the basin shall hereafter be undertaken by any person, corporation or governmental authority unless it shall have been first submitted to and approved by the Commission…." In section 2.3.5 of the Commission's *Rules of Practice and Procedure* ("RPP"), the Commission has defined those projects that may have a substantial effect on the water resources of the basin in part by establishing thresholds for the daily average gross water withdrawal during any 30 consecutive day period and by the daily average design capacity of domestic sewage treatment facilities. Some natural gas extraction projects may exceed these thresholds and therefore be subject to review pursuant to these provisions, while others may fall below the thresholds and therefore not be subject to review pursuant to these provisions. The RPP further require the sponsor of any project that involves any discharge of pollutants into surface or ground waters of the basin irrespective of quantity to obtain Commission approval. RPP section 2.3.5B.6. See also Commission Water Code section 3.40

In recognition of the importance of protecting high quality waters that are subject to the Commission's antidegradation regulations, the RPP also give the Executive Director the authority in her discretion to require a project sponsor to obtain Commission approval notwithstanding the fact that the thresholds in the RPP have not been exceeded. Section 2.3.5B.18 of the RPP includes as a reviewable project: "Any other project that the Executive Director may specially direct by notice to the project sponsor or land owner as having a potential substantial water quality impact on waters classified as Special Protection Waters." Most of the shale formations that may be subject to the new horizontal drilling and hydraulic fracturing techniques are located within the drainage area to Special Protection Waters. The Executive Director has considered and has now determined that as a result of water withdrawals,

wastewater disposal and other activities, natural gas extraction projects in these shale formations may individually or cumulatively affect the water quality of Special Protection Waters by altering their physical, biological, chemical or hydrological characteristics.

The Executive Director therefore specially directs by this notice to natural gas extraction project sponsors that they may not commence any natural gas extraction project located in shale formations within the drainage area of Special Protection Waters without first applying for and obtaining Commission approval. For this purpose a project encompasses the drilling pad upon which a well intended for eventual production is located, all appurtenant facilities and activities related thereto and all locations of water withdrawals used or to be used to supply water to the project. Wells intended solely for exploratory purposes are not covered by this Determination. Commencing a project encompasses performing any of the activities associated with the project, including the activities identified in the first paragraph above. The Commission recognizes that each natural gas extraction project will also be subject to the review of the environmental agency of the state or Commonwealth in which the project is located and in some cases, subject to federal agency review. The Commission intends to coordinate with and where feasible to utilize the review process and approvals of the applicable state or federal agency to minimize duplication of effort and redundant requirements imposed on project sponsors.

A copy of this Declaration will be posted on the Commission's website, and additional copies will be mailed directly to those project sponsors and potential project sponsors that the Commission has identified. The Commission intends to promulgate regulations pertaining to the subject matter of this Declaration after public notice and a full opportunity for public comment.

Any person adversely affected by this Determination may request a hearing by submitting a request in writing to the Commission Secretary within thirty (30) days of the date of this Determination in accordance with the RPP.

Carol R. Collier

Carol R. Collier, Executive Director
Dated: May 19, 2009

EXHIBIT B

Statement by the Delaware River Basin Commission (DRBC) on the Upper Delaware River Being Named by American Rivers to its "America's Most Endangered Rivers" List
June 2, 2010

Being named to a "most endangered list" can lead uninformed people to draw incorrect conclusions that the quality of the Upper Delaware River is deteriorating. This is far from the truth and the five members of the Delaware River Basin Commission (DRBC) – Pennsylvania, New York, New Jersey, Delaware, and the federal government – intend on keeping it that way.

The DRBC recognizes the importance of natural gas development to the region and the nation, and is not opposed to the appropriate development of this natural resource. But we must make sure that any natural gas development is done smartly so we do not harm the incredible water resources of the Delaware River Basin (DRB) and the over 15 million people it serves.

Over three-quarters of the non-tidal Delaware River has been added to the National Wild and Scenic Rivers System. To support that federal action, DRBC has designated the entire 197-mile non-tidal Delaware River as Special Protection Waters (SPW) precisely because the water quality is better than the standards that protect the designated uses of the waterway. This designation provides these waters with protection under the DRBC's anti-degradation regulations and coincides with the location of shale deposits in the DRB.

The collective effects of the thousands of wells and supporting facilities that are projected in the basin pose potentially significant adverse effects on the surface water and groundwater of the basin. Direct water resource concerns include 1) the potentially large amount of water consumed in the shale fracking process; 2) potential on-site spills and impacts to groundwater and nearby streams; and 3) storage, transport, treatment, and disposal of the "flow-back and production waters."

There are also impacts to the land which can affect water resources. The headwaters region where gas drilling activities would be located is the most sensitive and vulnerable area of any watershed. Over 80 percent of the DRB headwaters area is covered with forests that are critical to the protection and maintenance of water resources. One big concern is the effect of forest fragmentation on our waters.

Both Pennsylvania and New York regulate gas well drilling activities in their respective states. The DRBC, which has separate legal authority over both water quality and water quantity-related issues throughout the basin, has also asserted its review over gas well drilling projects. The DRBC's role, which complements state requirements, reflects the significance and importance of a basin that supplies water to over 15 million people. To date, the DRBC has not approved any natural gas well drilling within the basin or natural gas-related water withdrawal.

On May 5, 2010, the DRBC commissioners agreed that no natural gas well pad applications for shales would be considered by the agency until specific regulations are adopted. DRBC staff were already in the process of drafting the regulations, and the commissioners determined that it

(over)

was logical for the development of new regulations to move forward in advance of any individual project decisions relating to natural gas well pads. The rulemaking process followed by the commission includes public notice and a full opportunity for public comment before the commissioners adopt the regulations.

Due to the May 2010 decision by the commissioners to postpone DRBC consideration of well pad applications until the new regulations are adopted, there has been a lot of recent interest about exploratory wells. Policy options now under consideration include: 1) possibly supplementing the May 2009 executive director determination to also cover wells intended solely for exploratory purposes; and 2) addressing both production and exploratory wells in the new regulations now under development.

The DRBC looks forward to working with the entire basin community to ensure that proper environmental controls are provided to safeguard the outstanding water resources of the Delaware River Basin both now and in the future.

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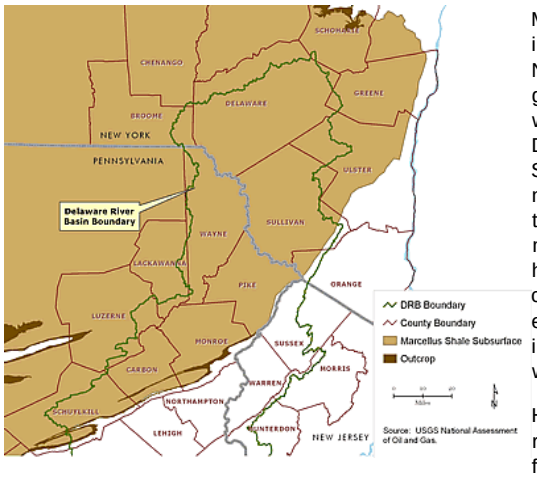
EXHIBIT C

Natural Gas Drilling Index Page

Background



Much of the new drilling interest taking place in northeastern Pennsylvania and southern New York is targeted at reaching the natural gas found in the Marcellus Shale formation, which underlies about 36 percent of the Delaware River Basin. Because the Marcellus Shale is considered a tight geologic formation, natural gas deposits were not previously thought to be practically and economically mineable using traditional techniques. New horizontal drilling and extraction methods, coupled with higher energy costs, have given energy companies reason to take a new interest in mining the natural gas deposits within the Marcellus Shale.

However, these new extraction methods require large amounts of fresh water to fracture the formation to release the natural gas. A significant amount of water used in the extraction process is recovered, but this "frac water" includes natural gas and chemicals added to facilitate the extraction process, as well as brine and other contaminants released from the formation.

Why Is The DRBC Involved?

The DRBC is a federal-interstate compact government agency that was formed by concurrent legislation enacted in 1961 by the United States and the four basin states (Pennsylvania, New York, New Jersey, and Delaware). Its five members include the basin state governors and the Division Engineer, North Atlantic Division, U.S. Army Corps of Engineers, who serves as the federal representative. The commission has legal authority over both water quality and water quantity-related issues throughout the basin.

In connection with natural gas drilling, the commission has identified three major areas of concern:

1. Gas drilling projects in the Marcellus Shale or other formations may have a substantial effect on the water resources of the basin by reducing the flow in streams and/or aquifers used to supply the significant amounts of fresh water needed in the natural gas mining process.
2. On-site drilling operations may potentially add, discharge or cause the release of pollutants into the ground water or surface water.
3. The recovered "frac water" must be treated and disposed of properly.

Note: The commission does not get involved in the private negotiations taking place between natural gas drilling companies and private property owners. However, property owners are advised to seek appropriate technical and legal representation to ensure that they obtain adequate protection of their property.

Status of DRBC Adoption of Regulations

The commissioners at their May 5, 2010 meeting unanimously directed staff to develop draft regulations in the shales for notice and comment rulemaking and postponed the DRBC's consideration of well pad dockets until regulations are adopted. The special meeting scheduled for Nov. 21, 2011 to consider adoption of draft natural gas development regulations was postponed to allow additional time for review by the five DRBC members. There are still some unresolved issues that the commissioners are working through and no new date has yet been announced for a vote on the draft regulations. Further information regarding the rulemaking will be posted on DRBC's web site as soon as it becomes available.

Natural Gas Drilling Index Page

Natural Gas Archives

Draft Natural Gas Regulations (info. on 12/9/10 draft and 11/8/11 revised draft)

Comments on Dec. 2010 Draft Regulations

Map: DRBC SPW, SPW Drainage Area, and Marcellus Shale Formation (pdf 1.1 MB)

Related Links

Sign Up to Receive Email Notice of Important DRBC Natural Gas Updates

DRBC Authorities, Regulations, and Guidance

DRBC Project Review/Permitting

New York State Dept. of Environmental Conservation

Pennsylvania Department of Environmental Protection

U.S. Environmental Protection Agency

P.O. Box 7360, West Trenton, NJ 08628-0360

Thanks to NJ for hosting the DRBC website

Last Modified: 02/01/2012

EXHIBIT D

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 Westgate Center Drive
Hadley, MA 01035-9589

In Reply Refer To:
FWS/Region 5/ES

JUN 25 2010

Carol Collier, Executive Director
Delaware River Basin Commission
P.O. Box 7360
West Trenton, New Jersey 08628-0360

Dear Ms. Collier:

The National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS) (jointly the Services) strongly support the Delaware River Basin Commission's (Commission) June 14, 2010, Supplemental Determination of the Executive Director expanding the requirement for Commission approval to new natural gas "exploratory" well projects and gas wells drilled through shale formations, in the area draining to the Special Protection Waters (SPW) in the Delaware River Basin. However, the Services believe that those "exploratory" wells already approved by the Pennsylvania Department of Environmental Protection (PADEP) should also be subject to Commission review under the new regulations now being drafted by your staff.

Consideration of all Natural Gas Projects

With the exception of activities related to hydraulic fracturing (for increasing production), the environmental effects of natural gas well construction, either as a "production" well or as an "exploratory" well, or into shale or non-shale formations, is virtually identical. Each drilling project involves construction of a well pad and associated roadways, the drilling of a well bore, the withdrawal and transport of surface or groundwater, and the recovery and handling of flow-back water and drilling fluids. As stated in your May 19, 2009, Executive Director's Determination, "Each of these activities, if not performed properly, may cause adverse environmental effects, including effects on water resources."

Additionally, it appears to be industry standard to convert exploratory or test wells to full production wells if suitable gas deposits are encountered. Based on our discussions with PADEP staff working on Marcellus permitting in southwestern Pennsylvania, we concluded that exploratory wells fall into two general categories. A small number of wells (e.g., one to two per county) are drilled during the initial phase of expansion into a new area and are truly exploratory wells intended to optimize drilling practices for the new area. The second and larger category of "exploratory" wells includes wells drilled during subsequent expansion into an area. Only a very

small percentage of these wells are abandoned without being converted to a production well. In fact, Pennsylvania regulations do not distinguish between exploratory and production wells for State-issued permits. The high rate of exploratory-to-production well conversion, the environmental effects common to both, and the cumulative effects are of concern to the Services.

Trust Resources

The high quality waters and habitats of the upper Delaware Basin support a variety of natural resources that are managed in trust by the Services for the benefit of the American people. Large-scale changes in land use and increased water withdrawals, like those associated with natural gas development (including the construction of exploratory wells) will likely affect the Services' trust resources and should be reviewed for both individual and cumulative environmental effects.

The natural resources of concern include the NPS Upper Delaware Scenic and Recreational River, the Delaware Water Gap National Recreation Area, the Middle Delaware National Scenic River, and the Lower Delaware Wild & Scenic River. The legislation establishing these units cited the need to protect the "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values ...and to fulfill other vital national conservation purposes."

USFWS trust resources in the Delaware Basin include federally listed species, migratory birds, several inter-jurisdictional fishes, and an approved National Wildlife Refuge. The species are protected under the Endangered Species Act (16 U.S.C. 1531 et. seq.) include the federally listed dwarf wedgemussel (*Alasmidonta heterodon*), Indiana bat (*Myotis sodalis*), bog turtle (*Glyptemys muhlenbergii*), and Northeastern bulrush (*Scirpus ancistrochaetus*).

The USFWS administers migratory birds under the Migratory Bird Treaty Act (16 U.S.C. 703 et seq.) and the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d). Approximately 200 species of migratory birds have been identified within the upper Delaware Basin, including an increasing population of bald eagles (*Haliaeetus leucocephalus*) and the largest congregation of wintering bald eagles in the northeast. Additionally, the Delaware River corridor and the corridor along the Kittatinny Ridge within the watershed are designated as Audubon Important Bird Areas. Many species of migratory birds for which USFWS has responsibility breed in or migrate through the high-quality riparian corridors of the Basin.

Managed fish species inhabiting the Delaware River and its tributaries include, but are not limited to, the federally endangered shortnose sturgeon (*Acipenser brevirostrum*), the American shad (*Alosa sapidissima*), Eastern brook trout (*Salvelinus fontinalis*), and American eel (*Anguilla rostrata*). These and other migratory fish species in the Delaware River and its tributaries are important to the aquatic environment and to the economies of many Pennsylvania, New York, and New Jersey communities.

The USFWS has also recently approved the creation of the Cherry Valley National Wildlife Refuge in eastern Pennsylvania. Cherry Creek, in the bottom of the valley, ultimately flows into the Delaware River. The established boundary for this new refuge encompasses 20,466 acres in Monroe and Northampton counties, and when completed will protect an area that stretches west from the Delaware Water Gap National Recreation Area and encompasses a stretch of the Appalachian Trail and the slopes of Kittatinny Ridge.

Summary

Natural gas development has the potential to significantly degrade the natural habitats and water quality in the Delaware River Basin, therefore we fully support the Commission's review of all natural gas well projects in the areas draining to SPW. Furthermore, we strongly support the Commission's promulgation of new regulations for assessing the individual and cumulative effects of natural gas development and believe that through thoughtful siting of gas well pads and infrastructure and the use of Best Management Practices, degradation of the high quality natural resources in the Basin can be minimized. We look forward to working with you in the future on this issue. Please contact Paul Phifer, Assistant Regional Director for Ecological Services, at 413-253-8304, if you have any questions.

Sincerely,

Marvin E. Moriarty
Acting Northeast Regional Director, USFWS

Dennis R. Reidenbach
Dennis Reidenbach
Northeast Regional Director, NPS

EXHIBIT E

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers, North Atlantic Division
Bldg 302, General Lee Avenue
Brooklyn, NY 11252

September 14th, 2010

Office of Rep. Hinchey
2431 Rayburn H.O.B.
Washington, DC 20515
Phone: (202) 225-6335
Fax: (202) 226-0774

Dear Congressman Hinchey:

Thank you very much for your letter and concern regarding the Delaware River Basin Commission's role and tasks regarding Marcellus Shale Gas Drilling in the basin.

The commissioners and staff of the DRBC all appreciate your efforts, with your colleagues in Congress, to secure the required funding to enable the joint U.S. Geological Survey-DRBC cumulative impact study on water withdrawals for gas drilling within the Basin, and we look forward to final approval and appropriation of these resources for Fiscal Year 2011.

The process to execute this study and its results would greatly enhance the ability of the Commission to make informed decisions over the long life cycle of gas energy development in the region. However, there are many steps left in the legislative process; and even if things progress promptly, it could be several years before the final results of the study are known.

The federal family of agencies that I represent on the commission are collectively charged with a requirement to support the economic needs of the region and our nation's need to secure energy reserves while protecting the environment. The citizens of the Basin are counting on the Commission to make smart choices that allow for environmental protection to proceed together with economic development. This balancing was an underlying reason for the creation of the Commission. The DRBC has therefore attempted to avoid undue delays to the exploratory well program and is continuing to approve water withdrawal requests from drilling companies while withholding approvals for production wells so far.

The results of test wells within the basin could better inform the scope and scale of the needed cumulative impacts study and frame the parameters of it with fewer assumptions and more facts. This is of great benefit to the Commission in its responsibilities and to the basin. Natural gas is not uniformly distributed throughout the Marcellus and Utica Shales nor is it uniformly distributed around the Delaware Basin. For these reasons among others, the DRBC is moving forward very deliberately and carefully with draft regulations that are designed to facilitate natural gas development while protecting the water resources of the basin.

The Commission has stated that it will not approve production wells until the regulations are refined and are in place. I will do my part to stand by that commitment because I believe the economic development and resource protection goals can both be achieved if the entire Basin community works together cooperatively. If draft regulations proceed as expected, there will be several public hearings as well as a written comment period sometime later in the calendar year. The Commission values public participation from all stakeholders and invites their comments, as the final regulations will be the benchmark for future decisions on proposed projects.

As you may know, Lt. Col. Philip M. Secrist, the U.S. Army Corps of Engineers Philadelphia District Engineer and alternate Federal Commissioner, will represent the federal government at the Commission public meeting on Sept. 15, 2011. He is aware of your concerns, the position of the federal agencies, and of my thoughts summarized here, on how to best represent our federal partners within the Commission.

I would welcome a chance to talk with you and/or your staff regarding the Federal programs and oversight activities related to natural gas energy development in the Marcellus Shale and the Delaware Basin and how we are representing these agencies in the activities of the Commission. You or your staff may contact me r my administrative assistant anytime at 347-370-4500 to set up a meeting or telephone conversation.

Sincerely,

Duke DeLuca
Brigadier General, U.S. Army
Division Engineer/DRBC Federal Commissioner

EXHIBIT F

EPA/600/R-11/122/November 2011/www.epa.gov/research

United States
Environmental Protection
Agency

Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

United States Environmental Protection Agency
Office of Research and Development

EPA/600/R-11/122
November 2011

United States
Environmental Protection
Agency

Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

Office of Research and Development

US Environmental Protection Agency

Washington, D.C.

November 2011

surface or ground water and ends with discharge into surface waters or injection into deep wells. Specifically, the water lifecycle for hydraulic fracturing consists of water acquisition, chemical mixing, well injection, flowback and produced water (collectively referred to as "hydraulic fracturing wastewater"), and wastewater treatment and waste disposal.

The EPA study is designed to provide decision-makers and the public with answers to the five fundamental questions associated with the hydraulic fracturing water lifecycle:

- Water Acquisition: What are the potential impacts of large volume water withdrawals from ground and surface waters on drinking water resources?
- Chemical Mixing: What are the possible impacts of surface spills on or near well pads of hydraulic fracturing fluids on drinking water resources?
- Well Injection: What are the possible impacts of the injection and fracturing process on drinking water resources?
- Flowback and Produced Water: What are the possible impacts of surface spills on or near well pads of flowback and produced water on drinking water resources?
- Wastewater Treatment and Waste Disposal: What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?

Answering these questions will involve the efforts of scientists and engineers with a broad range of expertise, including petroleum engineering, fate and transport modeling, ground water hydrology, and toxicology. The study will be conducted by multidisciplinary teams of EPA researchers, in collaboration with outside experts from the public and private sector. The Agency will use existing data from hydraulic fracturing service companies and oil and gas operators, federal and state agencies, and other sources. To supplement this information, EPA will conduct case studies in the field and generalized scenario evaluations using computer modeling. Where applicable, laboratory studies will be conducted to provide a better understanding of hydraulic fracturing fluid and shale rock interactions, the treatability of hydraulic fracturing wastewaters, and the toxicological characteristics of high-priority constituents of concern in hydraulic fracturing fluids and wastewater. EPA has also included a screening analysis of whether hydraulic fracturing activities may be disproportionately occurring in communities with environmental justice concerns.

Existing data will be used answer research questions associated with all stages of the water lifecycle, from water acquisition to wastewater treatment and waste disposal. EPA has requested information from hydraulic fracturing service companies and oil and gas well operators on the sources of water used in hydraulic fracturing fluids, the composition of these fluids, well construction practices, and wastewater treatment practices. EPA will use these data, as well as other publically available data, to help assess the potential impacts of hydraulic fracturing on drinking water resources.

Retrospective case studies will focus on investigating reported instances of drinking water resource contamination in areas where hydraulic fracturing has already occurred. EPA will conduct retrospective case studies at five sites across the US. The sites will be illustrative of the types of problems that have been reported to EPA during stakeholder meetings held in 2010 and 2011. A determination will be made

EXHIBIT G

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 2
290 BROADWAY
NEW YORK, NY 10007-1866

DEC 30 2009

dSGEIS Comments
Bureau of Oil & Gas Regulation
NYSDEC Division of Mineral Resources
625 Broadway, Third Floor
Albany, NY 12233-6500

Dear Sir or Madam:

The U.S. Environmental Protection Agency (EPA) has reviewed the September 2009 draft Supplemental Generic Environmental Impact Statement (dSGEIS) that was prepared by the New York State Department of Environmental Conservation (NYSDEC) Division of Mineral Resources on the Oil, Gas and Solution Mining Regulatory Program Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs. The purpose of the dSGEIS is to satisfy the requirements of the State Environmental Quality Review Act (SEQRA) for NYSDEC to review and process permit applications for the horizontal drilling and hydraulic fracturing (hydrofracturing) of natural gas bearing shales, including the Marcellus Shale. This letter responds to NYSDEC's requests for comments on the dSGEIS and presents EPA's major concerns. Technical comments on the dSGEIS are enclosed.

EPA believes that the analysis and discussion of cumulative and indirect impacts in the dSGEIS need to be significantly expanded. Even with its generic format, the dSGEIS should discuss the impacts that may result from past, present, and reasonably foreseeable future projects as well as those impacts associated with gas drilling and hydrofracturing that may occur later in time or at a distance from the immediate project site. For example, as the New York State Public Service Commission (PSC) has the regulatory authority over the construction and operation of the natural gas gathering pipes, the dSGEIS does not include an evaluation of the environmental impacts of the separate yet interrelated actions of siting and constructing gathering lines. EPA also notes that the dSGEIS does not analyze the impacts from new drilling service industries that would undoubtedly result. To ensure a full analysis of cumulative and indirect impacts, we recommend that the PSC become a cooperating agency and that the PSC-related issues be fully integrated in the finalization of this document, and that all potential environmental impacts for the actions of drilling, hydrofracturing, collecting and transporting natural gas from the Marcellus Shale be assessed. Such collaboration may also provide the opportunity to coordinate actions in order to minimize the amount of flaring of gas between the time of opening a well and the construction of gathering lines.

In addition, a greater emphasis needs to be placed on the potential health impacts that may be associated with gas drilling and hydrofracturing. EPA suggests that the New York State Department of Health (DOH) join NYSDEC as a co-lead on the SEQRA document. Not only does DOH have expertise to offer on health impacts, but it was delegated primary enforcement responsibility (primacy) of the Safe Drinking Water Act

by EPA. This is of direct interest to EPA as we are responsible for overseeing DOH's implementation and enforcement of the drinking water program.

While EPA understands that this dSGEIS is the SEQRA documentation to specifically evaluate hydraulic fracturing, it supplements a 1992 SEQRA document. EPA is concerned that over the past 17 years since the 1992 GEIS was written, the "existing" environment and conditions in New York State have changed sufficiently that using the information from that report as a baseline for the dSGEIS will not take into account the cumulative impacts from habitat fragmentation, population increase, and climate change that may have occurred during that time.

EPA is particularly concerned about the potential risks associated with gas drilling activities in the New York City watershed and the reservoirs that collect drinking water for nine million people. As a signatory to the 1997 New York City Watershed Memorandum of Agreement (MOA), EPA strongly supports its major tenets, one of which is that watershed protection and community vitality can be achieved concurrently. Nevertheless, the potential for gas drilling in the watershed poses new challenges that were unanticipated at the point at which the MOA signatories agreed on a common approach to protect drinking water. Despite the mitigation measures already proposed by NYSDEC in the dSGEIS, EPA has serious reservations about whether gas drilling in the New York City watershed is consistent with the vision of long-term maintenance of a high quality unfiltered water supply. As NYSDEC is well aware, the watershed supplies drinking water to over nine million people and the avoidance of filtration saves New York taxpayers billions of dollars that would be needed to construct and operate a water filtration plant should the watershed be compromised.

EPA agrees with the sentiments expressed by Acting Commissioner Steven Lawitts of the New York City Department of Environmental Protection (NYCDEP) in his December 23, 2009 comment letter to NYSDEC: "Balancing environmental and public health concerns with the need for adequate energy resources and economic development is a complex and challenging issue – not only in New York but throughout the nation." Acting Commissioner Lawitts also states, "New York City's watershed is a unique resource and deserves special attention and consideration." To address this concern, EPA recommends a very cautious approach in all watershed areas so that NYSDEC can gain experience with, as well as ensure it has the resource capacity for regulating, high volume hydraulic fracturing activities.

Periodically, EPA reviews drinking water quality in the New York City watershed to ensure that drinking water meets all drinking water standards. If gas drilling, however, adversely impacts water quality in the watershed, the city of New York would likely be required to build a filtration treatment system at an expenditure of $10 billion in capital costs and $100 million in annual operating costs. Clearly, it is in all our interests to avoid this scenario.

Although EPA has not had the opportunity to fully review the information contained in NYCDEP's Final Impact Assessment Report, we expect NYSDEC to incorporate appropriate technical information into the SEQRA document. Furthermore, we repeat

our proposal of late 2008, that NYSDEC partner with EPA and the NYCDEP to develop an enhanced oversight approach for the New York City watershed that would allow for coordination of regulatory programs such as stormwater permitting, industrial pretreatment, and underground injection control as they relate to horizontal drilling and high volume hydraulic fracturing of the Marcellus Shale. While protecting the New York City watershed is important because of the millions of New Yorkers who rely on this drinking water supply, we also have concerns about water quality impacts throughout the state. Just because fewer people rely on upstate water sources does not imply that these supplies are not also worthy of protection. Therefore, we extend an offer to partner with NYSDEC on similar coordinated efforts state-wide.

Moreover, EPA strongly recommends that the SEQRA documentation reflect any and all direct consultation with each of the Indian Nations in New York State as the dSGEIS does not specifically discuss the impact on the nations. While EPA is aware that NYSDEC has already taken steps in this regard, at the EPA annual Indian leaders meeting in November 2009, representatives of virtually every Indian Nation expressed serious opposition to hydrofracturing. Indian Nation concerns include the radioactivity of cuttings and flowback materials, the fate of toxic/carcinogenic chemicals used in hydrofracturing solutions, the impact on water quality and supply, climate impacts and long-term sustainability.

In addition, to the extent allowed by law, EPA encourages NYSDEC to release information regarding the composition of the hydrofracturing solutions that are expected to be used.

In conclusion, EPA believes that NYSDEC has prepared an informative dSGEIS on hydrologic fracturing of the Marcellus Shale. However, we have concerns regarding potential impacts to human health and the environment that we believe warrant further scientific and regulatory analysis. Of particular concern to EPA are issues involving water supply, water quality, wastewater treatment operations, local and regional air quality, management of naturally occurring radioactive materials disturbed during drilling, cumulative environmental impacts, and the New York City watershed. EPA recommends that these concerns be addressed and essential environmental protection measures established prior to the completion of the SEQRA process.

Thank you for the opportunity to comment on the dSGEIS. EPA's technical comments on the document are enclosed. If you have any questions, please call Lingard Knutson of my staff at (212) 637-3747.

Sincerely,

John Filippelli, Chief
Strategic Planning and Multi-Media Programs Branch

Enclosure

EXHIBIT H

EPA 600/R-00/000 | December 2011 | www.epa.gov/ord

EPA
United States
Environmental Protection
Agency

DRAFT

Investigation of Ground Water Contamination near Pavillion, Wyoming

Office of Research and Development
National Risk Management Research Laboratory, Ada, Oklahoma 74820

DRAFT

Investigation of Ground Water Contamination near Pavillion, Wyoming

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Extended Abstract

In response to complaints by domestic well owners regarding objectionable taste and odor problems in well water, the U.S. Environmental Protection Agency initiated a ground water investigation near the town of Pavillion, Wyoming under authority of the Comprehensive Environmental Response, Compensation, and Liability Act. The Wind River Formation is the principal source of domestic, municipal, and stock (ranch, agricultural) water in the area of Pavillion and meets the Agency's definition of an Underground Source of Drinking Water. Domestic wells in the area of investigation overlie the Pavillion gas field which consists of 169 production wells which extract gas from the lower Wind River Formation and underlying Fort Union Formation. Hydraulic fracturing in gas production wells occurred as shallow as 372 meters below ground surface with associated surface casing as shallow as 110 meters below ground surface. Domestic and stock wells in the area are screened as deep as 244 meters below ground surface. With the exception of two production wells, surface casing of gas production wells do not extend below the maximum depth of domestic wells in the area of investigation. At least 33 surface pits previously used for the storage/disposal of drilling wastes and produced and flowback waters are present in the area. The objective of the Agency's investigation was to determine the presence, not extent, of ground water contamination in the formation and if possible to differentiate shallow source terms (pits, septic systems, agricultural and domestic practices) from deeper source terms (gas production wells).

The Agency conducted four sampling events (Phase I - IV) beginning in March 2009 and ending in April, 2011. Ground water samples were collected from domestic wells and two municipal wells in the town of Pavillion in Phase I. Detection of methane and dissolved hydrocarbons in several domestic wells prompted collection of a second round of samples in January, 2010 (Phase II). During this phase, EPA collected additional ground water samples from domestic and stock wells and ground water samples from 3 shallow monitoring wells and soil samples near the perimeter of three known pit locations. Detection of elevated levels of methane and diesel range organics (DRO) in deep domestic wells prompted the Agency to install 2 deep monitoring wells screened at 233 - 239 meters (MW01) and 293 - 299 meters (MW02) below ground surface, respectively, in June 2010 to better evaluate to deeper sources of contamination. The expense of drilling deep wells while utilizing blowout prevention was the primary limiting factor in the number of monitoring wells installed. In September 2010 (Phase III), EPA collected gas samples from well casing from MW01 and MW02. In October 2010, EPA collected ground water samples from MW01 and MW02 in addition to a number of domestic wells. In April 2011 (Phase IV), EPA resampled the 2 deep monitoring wells to compare previous findings and to expand the analyte list to include glycols, alcohols, and low molecular weight acids.

Detection of high concentrations of benzene, xylenes, gasoline range organics, diesel range organics, and total purgeable hydrocarbons in ground water samples from shallow monitoring wells near pits indicates that pits are a source of shallow ground water contamination in the area of investigation. When considered separately, pits represent potential source terms for localized ground water plumes of unknown extent. When considered as whole they represent potential broader contamination of shallow ground water. A number of stock and domestic wells in the area of investigation are fairly shallow (e.g., < 30 meters below ground surface) representing potential receptor pathways.

Determination of the sources of inorganic and organic geochemical anomalies in deeper ground water was considerably more complex than determination of sources in shallow media necessitating the use of mulitiple

lines of reasoning approach common to complex scientific investigations. pH values in MW01 and MW01 are highly alkaline (11.2-12.0) with up to 94% of the total alkalinity contributed by hydroxide suggesting addition of a strong base as the causative factor. Reaction path modeling indicates that sodium-sulfate composition of ground water typical of deeper portions of the Wind River Formation provides little resistance to elevation of pH with small addition of potassium hydroxide. Potassium hydroxide was used in a crosslinker and in a solvent at this site.

The inorganic geochemistry of ground water from the deep monitoring wells is distinctive from that in the domestic wells and expected composition in the Wind River formation. Potassium concentration in MW02 (43.6 milligrams per liter) and MW01 (54.9 milligrams per liter) is between 14.5 and 18.3 times values in domestic wells and expected values in the formation. Chloride concentration in monitoring well MW02 (466 milligrams per liter) is 18 times the mean chloride concentration (25.6 milligrams per liter) observed in ground water from domestic wells and expected in the formation. Chloride enrichment in this well is significant because regional anion trends show decreasing chloride concentration with depth. In addition, the monitoring wells show low calcium, sodium, and sulfate concentrations compared to the general trend observed in domestic well waters. The formulation of fracture fluid provided for carbon dioxide foam hydraulic fracturing jobs typically consisted of 6% potassium chloride. Potassium metaborate was used in crosslinkers. Potassium hydroxide was used in a crosslinker and in a solvent. Ammonium chloride was used in crosslinker.

A number of synthetic organic compounds were detected in MW01 and MW02. Isopropanol was detected in MW01 and MW02 at 212 and 581 micrograms per liter, respectively. Diethylene glycol was detected in MW01 and MW02 at 226 and 1570 micrograms per liter, respectively. Triethylene glycol was detected in MW01 and MW02 at 46 and 310 micrograms per liter, respectively. Another synthetic compound, *tert*-butyl alcohol, was detected in MW02 at a concentration of 4470 micrograms per liter. Isopropanol was used in a biocide, in a surfactant, in breakers, and in foaming agents. Diethylene glycol was used in a foaming agent and in a solvent. Triethylene glycol was used in a solvent. *Tert*-butyl alcohol is a known breakdown product of methyl *tert*-butyl ether (a fuel additive) and *tert*-butyl hydroperoxide (a gel breaker used in hydraulic fracturing). Material Safety Data Sheets do not indicate that fuel or tert-butyl hydroperoxide were used in the Pavillion gas field. However, Material Safety Data Sheets do not contain proprietary information and the chemical ingredients of many additives. The source of *tert*-butyl alcohol remains unresolved. However, *tert*-butyl alcohol is not expected to occur naturally in ground water.

Benzene, toluene, ethylbenzene, and xylenes (BTEX) were detected in MW02 at concentrations of 246, 617, 67, and 750 micrograms per liter, respectively. Trimethylbenzenes were detected in MW02 at 105 micrograms per liter. Gasoline range organics were detected in MW01 and MW02 at 592 and 3710 micrograms per liter. Diesel range organics were detected in MW01 and MW02 at 924 and 4050 micrograms per liter, respectively. Aromatic solvent (typically BTEX mixture) was used in a breaker. Diesel oil (mixture of saturated and aromatic hydrocarbons including naphthalenes and alkylbenzenes) was used in a guar polymer slurry/liquid gel concentrate and in a solvent. Petroleum raffinates (mixture of paraffinic, cycloparaffinic, olefinic, and aromatic hydrocarbons) were used in a breaker. Heavy aromatic petroleum naphtha (mixture of paraffinic, cycloparaffinic and aromatic hydrocarbons) was used in surfactants and in a solvent. Toluene and xylene were used in flow enhancers and a breaker.

Detections of organic chemicals were more numerous and exhibited higher concentrations in the deeper of the two monitoring wells. Natural breakdown products of organic contaminants like BTEX and glycols include

acetate and benzoic acid. These breakdown products are more enriched in the shallower of the two monitoring wells, suggesting upward/lateral migration with natural degradation and accumulation of daughter products. Hydraulic gradients are currently undefined in the area of investigation. However, there are flowing conditions in a number of deep stock wells suggesting that upward gradients exist in the area of investigation.

Alternative explanations were carefully considered to explain individual sets of data. However, when considered together with other lines of evidence, the data indicates likely impact to ground water that can be explained by hydraulic fracturing. A review of well completion reports and cement bond/variable density logs in the area around MW01 and MW02 indicates instances of sporadic bonding outside production casing directly above intervals of hydraulic fracturing. Also, there is little lateral and vertical continuity of hydraulically fractured tight sandstones and no lithologic barrier (laterally continuous shale units) to stop upward vertical migration of aqueous constituents of hydraulic fracturing in the event of excursion from fractures. In the event of excursion from sandstone units, vertical migration of fluids could also occur via nearby wellbores. For instance, at one production well, the cement bond/variable density log indicates no cement until 671 m below ground surface. Hydraulic fracturing occurred above this depth at nearby production wells.

A similar lines of reasoning approach was utilized to evaluate the presence of gas in monitoring and domestic wells. A comparison of gas composition and stable carbon isotope values indicate that gas in production and monitoring wells is of similar thermogenic origin and has undergone little or no degradation. A similar evaluation in domestic wells suggests the presence of gas of thermogenic origin undergoing biodegradation. This observation is consistent with a pattern of dispersion and degradation with upward migration observed for organic compounds.

Elevated levels of dissolved methane in domestic wells generally increase in those wells in proximity to gas production wells. Near surface concentrations of methane appear highest in the area encompassing MW01. Ground water is saturated with methane at MW01 which is screened at a depth (239 meters below ground surface) typical of deeper domestic wells in the area. A blowout occurred during drilling of a domestic well at a depth of only 159 meters below ground surface close to MW01. A mud-gas log conducted in 1980 (prior to intensive gas production well installation) located only 300 m from the location of the blowout does not indicate a gas show (distinctive peaks on a gas chromatograph) within 300 meters of the surface. Again, with the exception of two production wells, surface casing of gas production wells do not extend below the maximum depth of domestic wells in the area of investigation. A number of production wells in the vicinity of MW01 have sporadic bonding or no cement over large vertical instances. Again, alternate explanations of data have been considered. Although some natural migration of gas would be expected above a gas field such as Pavillion, data suggest that enhanced migration of gas has occurred within ground water at depths used for domestic water supply and to domestic wells. Further investigation would be needed to determine the extent of gas migration and the fate and transport processes influencing migration to domestic wells.

EXHIBIT I

The SEAB Shale Gas Production Subcommittee
Ninety-Day Report – August 11, 2011

Executive Summary

The Shale Gas Subcommittee of the Secretary of Energy Advisory Board is charged with identifying measures that can be taken to reduce the environmental impact and improve the safety of shale gas production.

Natural gas is a cornerstone of the U.S. economy, providing a quarter of the country's total energy. Owing to breakthroughs in technology, production from shale formations has gone from a negligible amount just a few years ago to being almost 30 percent of total U.S. natural gas production. This has brought lower prices, domestic jobs, and the prospect of enhanced national security due to the potential of substantial production growth. But the growth has also brought questions about whether both current and future production can be done in an environmentally sound fashion that meets the needs of public trust.

This 90-day report presents recommendations that if implemented will reduce the environmental impacts from shale gas production. The Subcommittee stresses the importance of a process of continuous improvement in the various aspects of shale gas production that relies on best practices and is tied to measurement and disclosure. While many companies are following such a process, much-broader and more extensive adoption is warranted. The approach benefits all parties in shale gas production: regulators will have more complete and accurate information; industry will achieve more efficient operations; and the public will see continuous, measurable improvement in shale gas activities.

A list of the Subcommittee's findings and recommendations follows.

- Improve public information about shale gas operations: Create a portal for access to a wide range of public information on shale gas development, to include current data available from state and federal regulatory agencies. The portal should be open to the public for use to study and analyze shale gas operations and results.

The rapid expansion of production is rooted in change in applications of technology and field practice. It had long been recognized that substantial supplies of natural gas were embedded in shale rock. But it was only in 2002 and 2003 that the combination of two technologies working together – hydraulic fracturing and horizontal drilling – made shale gas commercial.

These factors have brought new regions into the supply mix. Parts of the country, such as regions of the Appalachian mountain states where the Marcellus Shale is located, which have not experienced significant oil and gas development for decades, are now undergoing significant development pressure. Pennsylvania, for example, which produced only one percent of total dry gas production in 2009, is one of the most active new areas of development. Even states with a history of oil and gas development, such as Wyoming and Colorado, have experienced significant development pressures in new areas of the state where unconventional gas is now technically and economically accessible due to changes in drilling and development technologies.

The urgency of addressing environmental consequences

As with all energy use, shale gas must be produced in a manner that prevents, minimizes and mitigates environmental damage and the risk of accidents and protects public health and safety. Public concern and debate about the production of shale gas has grown as shale gas output has expanded.

The Subcommittee identifies four major areas of concern: (1) Possible pollution of drinking water from methane and chemicals used in fracturing fluids; (2) Air pollution; (3) Community disruption during shale gas production; and (4) Cumulative adverse impacts that intensive shale production can have on communities and ecosystems.

There are serious environmental impacts underlying these concerns and these adverse environmental impacts need to be prevented, reduced and, where possible, eliminated as soon as possible. Absent effective control, public opposition will grow, thus putting continued production at risk. Moreover, with anticipated increase in U.S. hydraulically fractured wells, if effective environmental action is not taken today, the potential environmental consequences will grow to a point that the country will be faced a more

EXHIBIT J

Secretary of Energy Advisory Board

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Shale Gas Production Subcommittee Second Ninety Day Report

November 18, 2011

U.S. DEPARTMENT OF ENERGY

production over the coming years disciplined attention must be devoted to reducing the environmental impact that accompanies this development, and (2) a prudent balance between development and environmental protection is best struck by establishing a strong foundation of regulation and enforcement, and adopting a policy and practice that measures, discloses, and continuously improves shale gas operations.

The Subcommittee believes that if action is not taken to reduce the environmental impact accompanying the very considerable expansion of shale gas production expected across the country – perhaps as many as 100,000 wells over the next several decades – there is a real risk of serious environmental consequences causing a loss of public confidence that could delay or stop this activity. Thus, the Subcommittee has an interest in assessing and reporting on, the progress that is being made on implementing its recommendations or some sensible variations of these recommendations.

The Subcommittee has the impression that its initial report stimulated interest in taking action to reduce the environmental impact of shale gas production by the administration, state governments, industry, and public interest groups. However, the progress to date is less than the Subcommittee hoped and it is not clear how to catalyze action at a time when everyone's attention is focused on economic issues, the press of daily business, and an upcoming election. The Subcommittee cautions that whether its approach is followed or not, some concerted and sustained action is needed to avoid excessive environmental impacts of shale gas production and the consequent risk of public opposition to its continuation and expansion.

EXHIBIT K

New York State Department of Environmental Conservation

Revised Draft

Supplemental Generic Environmental Impact Statement

On The Oil, Gas and Solution Mining

Regulatory Program

Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs

Lead Agency:

NYSDEC, 625 Broadway, Albany, NY 12233

Lead Agency Contact:

Eugene Leff
NYSDEC, 625 Broadway, 14th Floor
Albany, NY 12233
(518) 402-8044

Action Location: **Statewide**

Comments Due By: **December 12, 2011**

Prepared By:

NYSDEC, with Assistance from Alpha Environmental, Inc., Ecology and Environment Engineering, P.C., ICF International, URS Corp, NTC Consultants and Sammons/Dutton LLC.

Date of Completion of dSGEIS: **September 30, 2009**

Date of Completion of Revised dSGEIS: **September 7, 2011**

REVISED DRAFT

Supplemental Generic Environmental Impact Statement

On The Oil, Gas and Solution Mining Regulatory Program

Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs

Prepared By:

NYSDEC DIVISION OF WATER

NYSDEC DIVISION OF AIR RESOURCES

NYSDEC DIVISION OF LANDS AND FORESTS

NYSDEC DIVISION OF FISH, WILDLIFE & MARINE RESOURCES

Coordinated and Edited By:

NYSDEC DIVISION OF MINERAL RESOURCES

Assisted By:

Ecology and Environment Engineering, P.C.

NEW YORK STATE ENERGY RESEARCH & DEVELOPMENT AUTHORITY*

NEW YORK STATE DEPARTMENT OF HEALTH
Bureau of Water Supply Protection
Bureau of Toxic Substance Assessment
Bureau of Environmental Radiation Protection

NYSDEC OFFICE OF CLIMATE CHANGE
NYSDEC DIVISION OF MATERIALS MANAGEMENT
NYSDEC DIVISION OF ENVIRONMENTAL PERMITS
NYSDEC DIVISION OF ENVIRONMENTAL REMEDIATION

* NYSERDA research assistance for September 2009 draft SGEIS contracted to Alpha Environmental Inc., ICF International, URS Corporation and NTC Consultants. NYSERDA research assistance for 2011 revised draft contracted to Alpha Geological Services, Inc., URS Corporation, NTC Consultants and Sammons/Dutton LLC.

EXECUTIVE SUMMARY

High-volume hydraulic fracturing is a well stimulation technique that has greatly increased the ability to extract natural gas from very tight rock. High-volume hydraulic fracturing, which is often used in conjunction with horizontal drilling and multi-well pad development, is an approach to extracting natural gas in New York that raises new, potentially significant, adverse impacts not studied in 1992 in the Department of Environmental Conservation's (Department or DEC) previous Generic Environmental Impact Statement (1992 GEIS) on the Oil, Gas and Solution Mining Regulatory Program.[1] Increased production of domestic natural gas resources from deep underground shale deposits in other parts of the country has dramatically altered future energy supply projections and has the promise of lowering costs for users and purchasers of this energy commodity.

High-volume hydraulic fracturing is distinct from other types of well completion that have been allowed in the State under the 1992 GEIS and Department permits due to the much larger volumes of water and additives used to conduct hydraulic fracturing operations. The use of high-volume hydraulic fracturing with horizontal well drilling technology provides for a number of wells to be drilled from a single well pad (multi-pad wells). Although horizontal drilling results in fewer well pads than traditional vertical well drilling, the pads are larger and the industrial activity taking place on the pads is more intense. Also, hydraulic fracturing requires chemical additives, some of which may pose hazards when highly concentrated. The extra water associated with such drilling may also result in significant adverse impacts relating to water supplies, wastewater treatment and disposal and truck traffic. Horizontal wells also generate greater volumes of drilling waste (cuttings). The industry projections of the level of drilling, as

[1] The Generic Environmental Impact Statement (1992 GEIS) on the Oil, Gas and Solution Mining Regulatory Program is posted on the Department's website at http://www.dec.ny.gov/energy/45912.html. The 1992 GEIS includes an analysis of impacts from vertical gas drilling as well as hydraulic fracturing. Since 1992 the Department has used the 1992 GEIS as the basis of its State Environmental Quality Review Act (SEQRA) review for permit applications for gas drilling in New York State.

were temporally proximate and from the same water resource, could potentially be significant. The mitigation measures to ensure that such impacts are prevented are described in Chapter 7, summarized below.

Chapter 6 also describes the potential impacts on water resources from stormwater flow associated with the construction and operation of high-volume hydraulic fracturing well pads. All phases of natural gas well development, from initial land clearing for access roads, equipment staging areas and well pads, to drilling and fracturing operations, production and final reclamation, have the potential to cause water resource impacts during rain and snow melt events if stormwater is not properly managed. Proposed mitigation measures to prevent significant adverse impacts from stormwater runoff are described in Chapter 7.

The dSGEIS concludes that spills or releases in connection with high-volume hydraulic fracturing could have significant adverse impacts on water resources. The dSGEIS identifies a significant number of contaminants contained in fracturing additives, or otherwise associated with high-volume hydraulic fracturing operations. Spills or releases can occur as a result of tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, or improper operations. Spilled, leaked or released fluids could flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers. Proposed mitigation measures to prevent significant adverse impacts from spills and releases are described in Chapter 7.

Chapter 6 also assesses the potential significant adverse impacts on groundwater resources from well drilling and construction associated with high-volume hydraulic fracturing. Those potential impacts include impacts from turbidity, fluids pumped into or flowing from rock formations penetrated by the well, and contamination from natural gas present in the rock formations penetrated by the well. The dSGEIS concludes that these potential impacts are not unique to horizontal wells or high-volume hydraulic fracturing and are described and fully assessed in the 1992 GEIS. Nevertheless, because of the concentrated nature of the activity on multi-well pads and the larger fluid volumes and pressures associated with high-volume hydraulic fracturing, enhanced procedures and mitigation measures are proposed and described in Chapter 7.

No High-Volume Hydraulic Fracturing Operations in the New York City and Syracuse Watersheds

In April 2010 the Department concluded that due to the unique issues presented by high-volume hydraulic fracturing operations within the drinking watersheds for the City of New York and Syracuse, the SGEIS would not apply to activities in those watersheds. Those areas present unique issues that primarily stem from the fact that they are unfiltered water supplies that depend on strict land use and development controls to ensure that water quality is protected.

The revised analysis of high-volume hydraulic fracturing operations in the revised dSGEIS concludes that the proposed high-volume hydraulic fracturing activity is not consistent with the preservation of these watersheds as an unfiltered drinking water supply. Even with all of the criteria and conditions identified in this dSGEIS, a risk remains that significant high-volume hydraulic fracturing activities in these areas could result in a degradation of drinking water supplies from accidents, surface spills, etc. Moreover, such large scale industrial activity in these areas, even without spills, could imperil EPA's Filtration Avoidance Determinations and result in the affected municipalities incurring substantial costs to filter their drinking water supply. Accordingly, this dSGEIS supports a finding that site disturbance relating to high-volume hydraulic fracturing operations not be permitted in the Syracuse and New York City watersheds or in a protective 4,000 foot buffer area around those watersheds.

No High-Volume Hydraulic Fracturing Operations on Primary Aquifers

Although not subject to Filtration Avoidance Determinations, 18 other aquifers in the State of New York have been identified by the New York State Department of Health as highly productive aquifers presently utilized as sources of water supply by major municipal water supply systems and are designated as "primary aquifers." Because these aquifers are the primary source of drinking water for many public drinking water supplies, the Department recommends in this dSGEIS that site disturbance relating to high-volume hydraulic fracturing operations should not be permitted there either or in a protective 500-foot buffer area around them. Horizontal extraction of gas resources underneath primary aquifers from well pads located outside this area would not significantly impact this valuable water resource.

- Requirement for fully cemented production casing or intermediate casing (if used), with the cement bond evaluated by use of a cement bond logging tool; and

- Required certification prior to hydraulic fracturing of the sufficiency of as-built wellbore construction.

1.7.7.2 Revised Draft SGEIS

Additional well construction enhancements for high-volume hydraulic fracturing that the Department proposes to require pursuant to permit condition and/or regulation are listed below:

- Specific American Petroleum Institute (API) standards, specifications and practices would be incorporated into permit conditions related to well construction. Among these would be requirements to adhere to specifications for centralizer type and for casing and cement quality;

- Fully cemented intermediate casing would be required unless supporting site-specific documentation to waive the requirement is presented. This directly addresses gas migration concerns by providing additional barriers (i.e., steel casing, cement) between aquifers and shallow gas-bearing zones;

- Additional measures to ensure cement strength and sufficiency would be incorporated into permit conditions, also directly addressing gas migration concerns. Compliance would continue to be tracked through site inspections and required well completion reports, and any other documentation the Department deems necessary for the operator to submit or make available for review; and

- Minimum compressive strength requirements.

    - Minimum waiting times during which no activity is allowed which might disturb the cement while it sets;

    - Enhanced requirements for use of centralizers which serve to ensure the uniformity and strength of the cement around the well casing; and

    - Required use of more advanced cement evaluation tools.

1.7.8 Flowback Water Handling On-Site

The Department proposes to require that operators storing flowback water on-site would be required to use watertight tanks located within secondary containment, and remove the fluid from the wellpad within specified time frames.

Product Name
Unicide 100 / EC6116A
Unifoam
Unigel 5F
UniHibA / SP-43X
UnihibG / S-11
Unislik ST 50 / Stim Lube
Vicon NF
WG-11
WG-17
WG-18
WG-35
WG-36
WLC-6
XL-1
XL-8
XLW-32
Xylene

Table 5.5 - Fracturing Additive Products – Partial Composition Disclosure to the Department (Updated July 2011)

Product Name
20 Degree Baume Muriatic Acid
AcTivator / 78-ACTW
AMB-100
B869 / Corrosion Inhibitor B869 / Corrosion Inhibitor A262
B885 / ClearFRAC LT B885 / ClearFRAC LT J551A
B892 / EZEFLO B892 / EZEFLO F110 Surfactant
CL-22UC
CL-28M
Clay Master 5C
Corrosion Inhibitor A261
FAW- 5
FDP-S798-05
FDP-S819-05
FE ACID
FR-48
FRW-16
FRW-18
Fracsal FR-143
Fracsal III
Fracsal NE-137
Fracsal Ultra
Fracsal Ultra-FM1
Fracsal Ultra-FM2
Fracsal Ultra-FM3
Fracsal Waterbase
Fracsal Waterbase-M1
FRW-25M
GA 8713
GBW-15L
GW-3LDF
HVG-1, Fast Hydrating Guar Slurry
ICA 400
ICP-1000
Inflo-102
Inhibisal Ultra CS-135
Inhibisal Ultra SI-141
J134L / Enzyme Breaker J134L
KCLS-2, KCL Substitute

Product Name
L065 / Scale Inhibitor L065
LP-65
Magnacide 575 Microbiocide
MSA ACID
Multifunctional Surfactant F105
Nitrogen, Refrigerated Liquid
Product 239
PS 550
S-150
SandWedge WF
SilkWater FR-A
Super TSC / Super Scale Control TSC
Super Sol 10/20/30
Ultra Breake-C
Ultra Breake-CG
Ultra Breake-M
Ultra-Breake-MG
Unislick 30 / Cyanaflo 105L
WC-5584
WCS 5177 Corrosion Scale Inhibitor
WCW219 Combination Inhibitor
WF-12B Foamer
WF-12B Salt Inhibitor Stix
WF-12B SI Foamer/Salt Inhibitor
WF12BH Foamer
WRR-5
WFR-C
XLBHT-1
XLBHT-2

Information in sections 5.4.1-3 below was compiled primarily by URS Corporation,[46] under contract to NYSERDA.

5.4.1 Properties of Fracturing Fluids

Additives are used in hydraulic fracturing operations to elicit certain properties and characteristics that would aide and enhance the operation. The desired properties and characteristics include:

- Non-reactive;
- Non-flammable;
- Minimal residuals;
- Minimal potential for scale or corrosion;
- Low entrained solids;
- Neutral pH (pH 6.5 – 7.5) for maximum polymer hydration;
- Limited formation damage;
- Appropriately modify properties of water to carry proppant deep into the shale;
- Economical to modify fluid properties; and
- Minimal environmental effects.

5.4.2 Classes of Additives

Table 5.6 lists the types, purposes and examples of additives that have been proposed to date for use in hydraulic fracturing of gas wells in New York State.

[46] URS, 2011, p. 2-1 & 2009, p. 2-1.

Table 5.6 - Types and Purposes of Additives Proposed for Use in New York State (Updated July 2011)

Additive Type	Description of Purpose	Examples of Chemicals[47]
Proppant	"Props" open fractures and allows gas / fluids to flow more freely to the well bore.	Sand [Sintered bauxite; zirconium oxide; ceramic beads]
Acid	Removes cement and drilling mud from casing perforations prior to fracturing fluid injection, and provides accessible path to formation.	Hydrochloric acid (HCl, 3% to 28%) or muriatic acid
Breaker	Reduces the viscosity of the fluid in order to release proppant into fractures and enhance the recovery of the fracturing fluid.	Peroxydisulfates
Bactericide / Biocide / Antibacterial Agent	Inhibits growth of organisms that could produce gases (particularly hydrogen sulfide) that could contaminate methane gas. Also prevents the growth of bacteria which can reduce the ability of the fluid to carry proppant into the fractures.	Gluteraldehyde; 2,2-dibromo-3-nitrilopropionamide
Buffer / pH Adjusting Agent	Adjusts and controls the pH of the fluid in order to maximize the effectiveness of other additives such as crosslinkers	Sodium or potassium carbonate; acetic acid
Clay Stabilizer / Control /KCl	Prevents swelling and migration of formation clays which could block pore spaces thereby reducing permeability.	Salts (e.g., tetramethyl ammonium chloride Potassium chloride (KCl)
Corrosion Inhibitor (including Oxygen Scavengers)	Reduces rust formation on steel tubing, well casings, tools, and tanks (used only in fracturing fluids that contain acid).	Methanol; ammonium bisulfate for Oxygen Scavengers
Crosslinker	Increases fluid viscosity using phosphate esters combined with metals. The metals are referred to as crosslinking agents. The increased fracturing fluid viscosity allows the fluid to carry more proppant into the fractures.	Potassium hydroxide; borate salts
Friction Reducer	Allows fracture fluids to be injected at optimum rates and pressures by minimizing friction.	Sodium acrylate-acrylamide copolymer; polyacrylamide (PAM); petroleum distillates
Gelling Agent	Increases fracturing fluid viscosity, allowing the fluid to carry more proppant into the fractures.	Guar gum; petroleum distillates
Iron Control	Prevents the precipitation of metal oxides which could plug off the formation.	Citric acid;
Scale Inhibitor	Prevents the precipitation of carbonates and sulfates (calcium carbonate, calcium sulfate, barium sulfate) which could plug off the formation.	Ammonium chloride; ethylene glycol;
Solvent	Additive which is soluble in oil, water & acid-based treatment fluids which is used to control the wettability of contact surfaces or to prevent or break emulsions	Various aromatic hydrocarbons
Surfactant	Reduces fracturing fluid surface tension thereby aiding fluid recovery.	Methanol; isopropanol; ethoxylated alcohol

5.4.3 Composition of Fracturing Fluids

The composition of the fracturing fluid used may vary from one geologic basin or formation to another or from one area to another in order to meet the specific needs of each operation; but the

[47] Chemicals in brackets [ ] have not been proposed for use in the State of New York to date, but are known to be used in other states or shale formations.

range of additive types available for potential use remains the same. There are a number of different products for each additive type; however, only one product of each type is typically utilized in any given hydraulic fracturing job. The selection may be driven by the formation and potential interactions between additives. Additionally not all additive types will be utilized in every fracturing job.

Sample compositions, by weight, of fracturing fluid are provided in Figure 5.3, Figure 5.4 and Figure 5.5. The composition depicted in Figure 5.3 is based on data from the Fayetteville Shale[48] while those depicted in Figure 5.4 and Figure 5.5 are based on data from Marcellus Shale development in Pennsylvania. Based on this data, between approximately 84 and 90 percent of the fracturing fluid is water; between approximately 8 and 15 % is proppant (Photo 5.17); the remainder, typically less than 1 % consists of chemical additives listed above.

Photo 5.17 - Sand used as proppant in hydraulic fracturing operation in Bradford County, PA

[48] Similar to the Marcellus Shale, the Fayetteville Shale is a marine shale rich in unoxidized carbon (i.e. a black shale). The two shales are at similar depths, and vertical and horizontal wells have been drilled/fractured at both shales.

Barnett Shale is considered to be the first instance of extensive high-volume hydraulic fracturing technology use; the technology has since been applied in other areas such as the Fayetteville Shale and the Haynesville Shale. URS notes that data collected from applications to drill Marcellus Shale wells in New York indicate that the typical fracture fluid composition for operations in the Marcellus Shale is similar to the provided composition in the Fayetteville Shale. Even though no horizontal wells have been drilled in the Marcellus Shale in New York, applications filed to date as well as information provided by the industry[49] indicate that it is realistic to expect that the composition of fracture fluids used in the Marcellus Shale in New York would be similar to the fluids used in the Fayetteville Shale and the Marcellus Shale in Pennsylvania.

[49] ALL Consulting, 2010, p. 80.

Figure 5.3 - Sample Fracturing Fluid Composition (12 Additives), by Weight, from Fayetteville Shale[50]

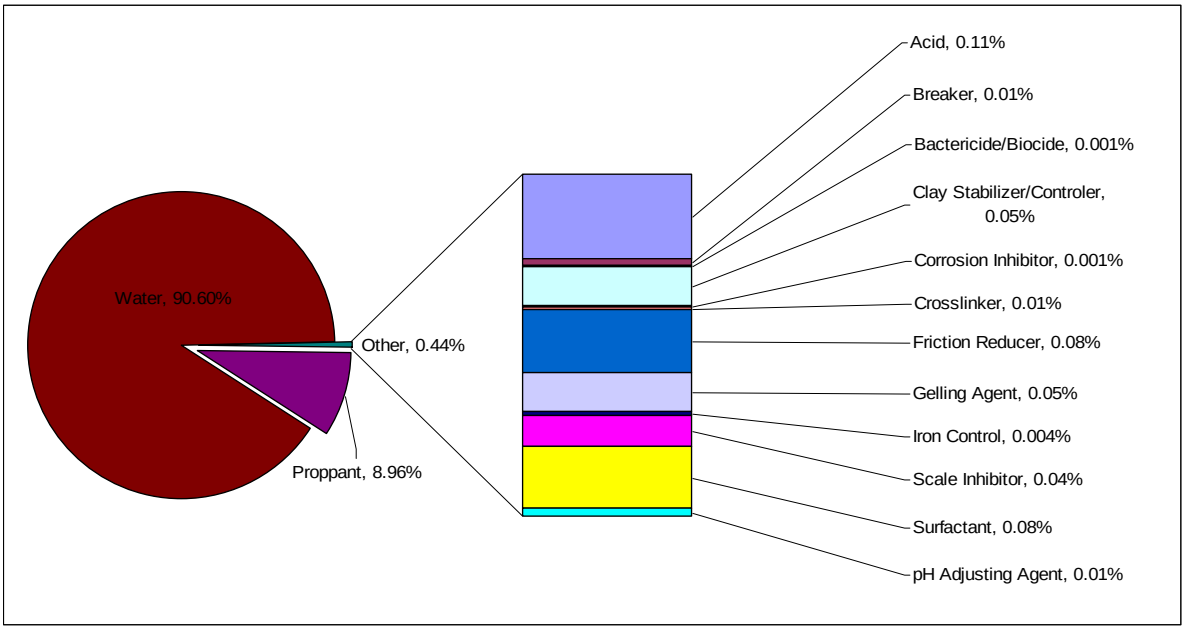
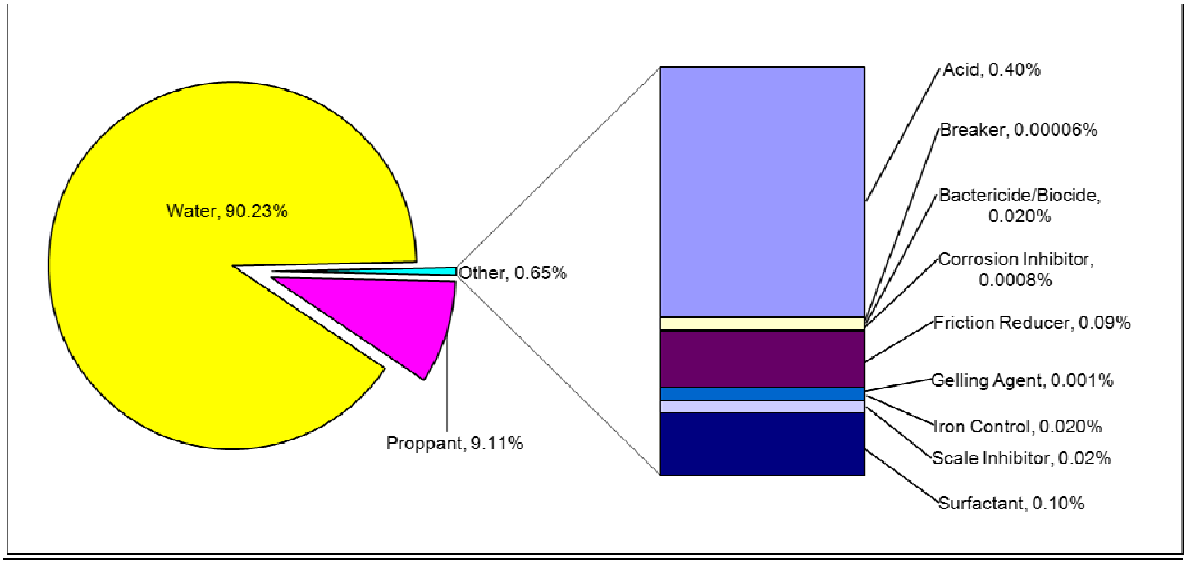


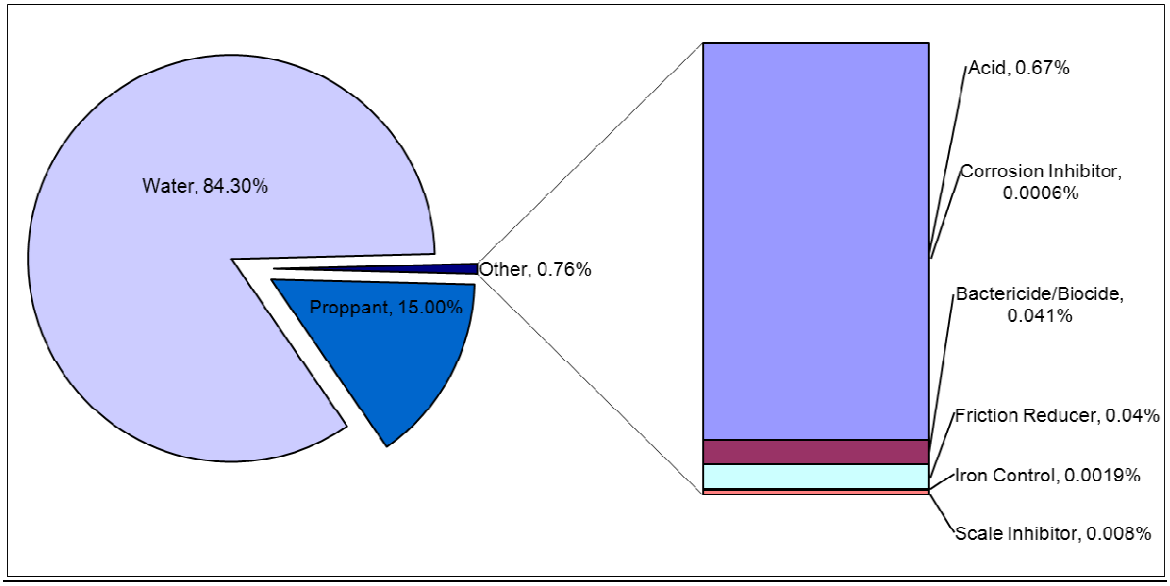
Figure 5.4 - Sample Fracturing Fluid Composition (9 Additives), by Weight, from Marcellus Shale[51] (New July 2011)



[50] URS, 2009, p. 2-4.

[51] URS, 2011, p. 2-4, adapted from ALL Consulting, 2010, p.81.

Figure 5.5 - Sample Fracturing Fluid Composition (6 Additives), by Weight, from Marcellus Shale[52] (New July 2011)



Each product within the 13 classes of additives may be made up of one or more chemical constituents. Table 5.7 is a list of chemical constituents and their CAS numbers, that have been extracted from product composition disclosures and MSDSs submitted to the Department for 235 products used or proposed for use in hydraulic fracturing operations in the Marcellus Shale in New York. It is important to note that several manufacturers/suppliers provide similar products (i.e., chemicals that would serve the same purpose) for any class of additive, and that not all types of additives are used in a single well.

Data provided to the Department to date indicates similar fracturing fluid compositions for vertically and horizontally drilled wells.

[52] URS, 2011, p.2-5, adapted from ALL Consulting, 2010, p. 81.

Table 5.7 - Chemical Constituents in Additives[53,54,55] (Updated July 2011)

CAS Number[56]	Chemical Constituent
106-24-1	(2E)-3,7-dimethylocta-2,6-dien-1-ol
67701-10-4	(C8-C18) and (C18) Unsaturated Alkylcarboxylic Acid Sodium Salt
2634-33-5	1,2 Benzisothiazolin-2-one / 1,2-benzisothiazolin-3-one
95-63-6	1,2,4 trimethylbenzene
93858-78-7	1,2,4-Butanetricarboxylicacid, 2-phosphono-, potassium salt
123-91-1	1,4 Dioxane
3452-07-1	1-eicosene
629-73-2	1-hexadecene
104-46-1	1-Methoxy-4-propenylbenzene
124-28-7	1-Octadecanamine, N, N-dimethyl- / N,N-Dimthyloctadecylamine
112-03-8	1-Octadecanaminium, N,N,N-Trimethyl-, Chloride /Trimethyloctadecylammonium chloride
112-88-9	1-octadecene
40623-73-2	1-Propanesulfonic acid
1120-36-1	1-tetradecene
95077-68-2	2- Propenoic acid, homopolymer sodium salt
98-55-5	2-(4-methyl-1-cyclohex-3-enyl)propan-2-ol
10222-01-2	2,2 Dibromo-3-nitrilopropionamide
27776-21-2	2,2'-azobis-{2-(imidazlin-2-yl)propane}-dihydrochloride
73003-80-2	2,2-Dobromomalonamide
15214-89-8	2-Acrylamido-2-methylpropanesulphonic acid sodium salt polymer
46830-22-2	2-acryloyloxyethyl(benzyl)dimethylammonium chloride
52-51-7	2-Bromo-2-nitro-1,3-propanediol
111-76-2	2-Butoxy ethanol / Ethylene glycol monobutyl ether / Butyl Cellusolve
1113-55-9	2-Dibromo-3-Nitriloprionamide /(2-Monobromo-3-nitriilopropionamide)
104-76-7	2-Ethyl Hexanol
67-63-0	2-Propanol / Isopropyl Alcohol / Isopropanol / Propan-2-ol
26062-79-3	2-Propen-1-aminium, N,N-dimethyl-N-2-propenyl-chloride, homopolymer
9003-03-6	2-propenoic acid, homopolymer, ammonium salt
25987-30-8	2-Propenoic acid, polymer with 2 p-propenamide, sodium salt / Copolymer of acrylamide and sodium acrylate
71050-62-9	2-Propenoic acid, polymer with sodium phosphinate (1:1)
66019-18-9	2-propenoic acid, telomer with sodium hydrogen sulfite

[53] Table 5.7, is a list of chemical constituents and their CAS numbers that have been extracted from product composition disclosures and MSDSs submitted to the Department. It was compiled by URS Corporation (2011) and was adapted by the Department to ensure that it accurately reflects the data submitted.

[54] These are the chemical constituents of all chemical additives proposed to be used in New York for hydraulic fracturing operations at shale wells. Only a few chemicals would be used in a single well; the list of chemical constituents used in an individual well would be correspondingly smaller.

[55] This list does not include chemicals that are exclusively used for drilling.

[56] Chemical Abstracts Service (CAS) is a division of the American Chemical Society. CAS assigns unique numerical identifiers to every chemical described in the literature. The intention is to make database searches more convenient, as chemicals often have many names. Almost all molecule databases today allow searching by CAS number.

CAS Number[56]	Chemical Constituent
107-19-7	2-Propyn-1-ol / Progargyl Alcohol
51229-78-8	3,5,7-Triaza-1-azoniatricyclo[3.3.1.13,7]decane, 1-(3-chloro-2-propenyl)-chloride,
106-22-9	3,7 - dimethyl-6-octen-1-ol
5392-40-5	3,7- dimethyl-2,6-octadienal
115-19-5	3-methyl-1-butyn-3-ol
104-55-2	3-phenyl-2-propenal
127-41-3	4-(2,6,6-trimethyl-1-cyclohex-2-enyl)-3-buten-2-one
121-33-5	4-hydroxy-3-methoxybenzaldehyde
127087-87-0	4-Nonylphenol Polyethylene Glycol Ether Branched / Nonylphenol ethoxylated / Oxyalkylated Phenol
64-19-7	Acetic acid
68442-62-6	Acetic acid, hydroxy-, reaction products with triethanolamine
108-24-7	Acetic Anhydride
67-64-1	Acetone
79-06-1	Acrylamide
38193-60-1	Acrylamide - sodium 2-acrylamido-2-methylpropane sulfonate copolymer
25085-02-3	Acrylamide - Sodium Acrylate Copolymer / Anionic Polyacrylamide / 2-Propanoic Acid
69418-26-4	Acrylamide polymer with N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy Ethanaminium chloride / Ethanaminium, N, N, N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, polymer with 2-propenamide (9Cl)
68891-29-2	Alcohols C8-10, ethoxylated, monoether with sulfuric acid, ammonium salt
68526-86-3	Alcohols, C11-14-iso, C13-rich
68551-12-2	Alcohols, C12-C16, Ethoxylated / Ethoxylated alcohol
64742-47-8	Aliphatic Hydrocarbon / Hydrotreated light distillate / Petroleum Distillates / Isoparaffinic Solvent / Paraffin Solvent / Napthenic Solvent
64743-02-8	Alkenes
68439-57-6	Alkyl (C14-C16) olefin sulfonate, sodium salt
9016-45-9	Alkylphenol ethoxylate surfactants
1327-41-9	Aluminum chloride
68155-07-7	Amides, C8-18 and C19-Unsatd., N,N-Bis(hydroxyethyl)
73138-27-9	Amines, C12-14-tert-alkyl, ethoxylated
71011-04-6	Amines, Ditallow alkyl, ethoxylated
68551-33-7	Amines, tallow alkyl, ethoxylated, acetates
1336-21-6	Ammonia
631-61-8	Ammonium acetate
68037-05-8	Ammonium Alcohol Ether Sulfate
7783-20-2	Ammonium bisulfate
10192-30-0	Ammonium Bisulphite
12125-02-9	Ammonium Chloride
7632-50-0	Ammonium citrate
37475-88-0	Ammonium Cumene Sulfonate
1341-49-7	Ammonium hydrogen-difluoride
6484-52-2	Ammonium nitrate
7727-54-0	Ammonium Persulfate / Diammonium peroxidisulphate

CAS Number[56]	Chemical Constituent
1762-95-4	Ammonium Thiocyanate
12174-11-7	Attapulgite Clay
121888-68-4	Bentonite, benzyl(hydrogenated tallow alkyl) dimethylammonium stearate complex / organophilic clay
71-43-2	Benzene
119345-04-9	Benzene, 1,1'-oxybis, tetratpropylene derivatives, sulfonated, sodium salts
74153-51-8	Benzenemethanaminium, N,N-dimethyl-N-[2-[(1-oxo-2-propenyl)oxy]ethyl]-, chloride, polymer with 2-propenamide
122-91-8	Benzenemethanol,4-methoxy-, 1-formate
1300-72-7	Benzenesulfonic acid, Dimethyl-, Sodium salt /Sodium xylene sulfonate
140-11-4	Benzyl acetate
76-22-2	Bicyclo (2.2.1) heptan-2-one, 1,7,7-trimethyl-
68153-72-0	Blown lard oil amine
68876-82-4	Blown rapeseed amine
1319-33-1	Borate Salt
10043-35-3	Boric acid
1303-86-2	Boric oxide / Boric Anhydride
71-36-3	Butan-1-ol
68002-97-1	C10 - C16 Ethoxylated Alcohol
68131-39-5	C12-15 Alcohol, Ethoxylated
1317-65-3	Calcium Carbonate
10043-52-4	Calcium chloride
1305-62-0	Calcium Hydroxide
1305-79-9	Calcium Peroxide
124-38-9	Carbon Dioxide
68130-15-4	Carboxymethylhydroxypropyl guar
9012-54-8	Cellulase / Hemicellulase Enzyme
9004-34-6	Cellulose
10049-04-4	Chlorine Dioxide
78-73-9	Choline Bicarbonate
67-48-1	Choline Chloride
91-64-5	Chromen-2-one
77-92-9	Citric Acid
94266-47-4	Citrus Terpenes
61789-40-0	Cocamidopropyl Betaine
68155-09-9	Cocamidopropylamine Oxide
68424-94-2	Coco-betaine
7758-98-7	Copper (II) Sulfate
14808-60-7	Crystalline Silica (Quartz)
7447-39-4	Cupric chloride dihydrate
1490-04-6	Cyclohexanol,5-methyl-2-(1-methylethyl)
8007-02-1	Cymbopogon citratus leaf oil
8000-29-1	Cymbopogon winterianus jowitt oil
1120-24-7	Decyldimethyl Amine
2605-79-0	Decyl-dimethyl Amine Oxide

CAS Number[56]	Chemical Constituent
3252-43-5	Dibromoacetonitrile
25340-17-4	Diethylbenzene
111-46-6	Diethylene Glycol
22042-96-2	Diethylenetriamine penta (methylenephonic acid) sodium salt
28757-00-8	Diisopropyl naphthalenesulfonic acid
68607-28-3	Dimethylcocoamine, bis(chloroethyl) ether, diquaternary ammonium salt
7398-69-8	Dimethyldiallylammonium chloride
25265-71-8	Dipropylene glycol
34590-94-8	Dipropylene Glycol Methyl Ether
139-33-3	Disodium Ethylene Diamine Tetra Acetate
64741-77-1	Distillates, petroleum, light hydrocracked
5989-27-5	D-Limonene
123-01-3	Dodecylbenzene
27176-87-0	Dodecylbenzene sulfonic acid
42504-46-1	Dodecylbenzenesulfonate isopropanolamine
50-70-4	D-Sorbitol / Sorbitol
37288-54-3	Endo-1,4-beta-mannanase, or Hemicellulase
149879-98-1	Erucic Amidopropyl Dimethyl Betaine
89-65-6	Erythorbic acid, anhydrous
54076-97-0	Ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, homopolymer
107-21-1	Ethane-1,2-diol / Ethylene Glycol
111-42-2	Ethanol, 2,2-iminobis-
26027-38-3	Ethoxylated 4-nonylphenol
9002-93-1	Ethoxylated 4-tert-octylphenol
68439-50-9	Ethoxylated alcohol
126950-60-5	Ethoxylated alcohol
67254-71-1	Ethoxylated alcohol (C10-12)
68951-67-7	Ethoxylated alcohol (C14-15)
68439-46-3	Ethoxylated alcohol (C9-11)
66455-15-0	Ethoxylated Alcohols
84133-50-6	Ethoxylated Alcohols (C12-14 Secondary)
68439-51-0	Ethoxylated Alcohols (C12-14)
78330-21-9	Ethoxylated branch alcohol
34398-01-1	Ethoxylated C11 alcohol
78330-21-8	Ethoxylated C11-14-iso, C13-rich alcohols
61791-12-6	Ethoxylated Castor Oil
61791-29-5	Ethoxylated fatty acid, coco
61791-08-0	Ethoxylated fatty acid, coco, reaction product with ethanolamine
68439-45-2	Ethoxylated hexanol
9036-19-5	Ethoxylated octylphenol
9005-67-8	Ethoxylated Sorbitan Monostearate
9005-70-3	Ethoxylated Sorbitan Trioleate
64-17-5	Ethyl alcohol / ethanol
100-41-4	Ethyl Benzene

CAS Number[56]	Chemical Constituent
93-89-0	Ethyl benzoate
97-64-3	Ethyl Lactate
9003-11-6	Ethylene Glycol-Propylene Glycol Copolymer (Oxirane, methyl-, polymer with oxirane)
75-21-8	Ethylene oxide
5877-42-9	Ethyloctynol
8000-48-4	Eucalyptus globulus leaf oil
61790-12-3	Fatty Acids
68604-35-3	Fatty acids, C 8-18 and C18-unsaturated compounds with diethanolamine
68188-40-9	Fatty acids, tall oil reaction products w/ acetophenone, formaldehyde & thiourea
9043-30-5	Fatty alcohol polyglycol ether surfactant
7705-08-0	Ferric chloride
7782-63-0	Ferrous sulfate, heptahydrate
50-00-0	Formaldehyde
29316-47-0	Formaldehyde polymer with 4,1,1-dimethylethyl phenolmethyl oxirane
153795-76-7	Formaldehyde, polymers with branched 4-nonylphenol, ethylene oxide and propylene oxide
75-12-7	Formamide
64-18-6	Formic acid
110-17-8	Fumaric acid
111-30-8	Glutaraldehyde
56-81-5	Glycerol / glycerine
9000-30-0	Guar Gum
64742-94-5	Heavy aromatic petroleum naphtha
9025-56-3	Hemicellulase
7647-01-0	Hydrochloric Acid / Hydrogen Chloride / muriatic acid
7722-84-1	Hydrogen Peroxide
64742-52-5	Hydrotreated heavy napthenic (petroleum) distillate
79-14-1	Hydroxy acetic acid
35249-89-9	Hydroxyacetic acid ammonium salt
9004-62-0	Hydroxyethyl cellulose
5470-11-1	Hydroxylamine hydrochloride
39421-75-5	Hydroxypropyl guar
35674-56-7	Isomeric Aromatic Ammonium Salt
64742-88-7	Isoparaffinic Petroleum Hydrocarbons, Synthetic
64-63-0	Isopropanol
98-82-8	Isopropylbenzene (cumene)
68909-80-8	Isoquinoline, reaction products with benzyl chloride and quinoline
8008-20-6	Kerosene
64742-81-0	Kerosine, hydrodesulfurized
63-42-3	Lactose
8022-15-9	Lavandula hybrida abrial herb oil
64742-95-6	Light aromatic solvent naphtha
1120-21-4	Light Paraffin Oil

CAS Number[56]	Chemical Constituent
546-93-0	Magnesium Carbonate
1309-48-4	Magnesium Oxide
1335-26-8	Magnesium Peroxide
14807-96-6	Magnesium Silicate Hydrate (Talc)
1184-78-7	methanamine, N,N-dimethyl-, N-oxide
67-56-1	Methanol
119-36-8	Methyl 2-hydroxybenzoate
68891-11-2	Methyloxirane polymer with oxirane, mono (nonylphenol) ether, branched
8052-41-3	Mineral spirits / Stoddard Solvent
64742-46-7	Mixture of severely hydrotreated and hydrocracked base oil
141-43-5	Monoethanolamine
44992-01-0	N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy Ethanaminium chloride
64742-48-9	Naphtha (petroleum), hydrotreated heavy
91-20-3	Naphthalene
38640-62-9	Naphthalene bis(1-methylethyl)
93-18-5	Naphthalene, 2-ethoxy-
68909-18-2	N-benzyl-alkyl-pyridinium chloride
68139-30-0	N-Cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine
68424-94-2	N-Cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine
7727-37-9	Nitrogen, Liquid form
68412-54-4	Nonylphenol Polyethoxylate
8000-27-9	Oils, cedarwood
121888-66-2	Organophilic Clays
628-63-7	Pentyl acetate
540-18-1	Pentyl butanoate
8009-03-8	Petrolatum
64742-65-0	Petroleum Base Oil
64741-68-0	Petroleum naphtha
101-84-8	Phenoxybenzene
70714-66-8	Phosphonic acid, [[(phosphonomethyl)imino]bis[2,1-ethanediylnitrilobis(methylene)]]tetrakis-, ammonium salt
8000-41-7	Pine Oil
8002-09-3	Pine Oils
60828-78-6	Poly(oxy-1,2-ethanediyl), a-[3,5-dimethyl-1-(2-methylpropyl)hexyl]-w-hydroxy-
25322-68-3	Poly(oxy-1,2-ethanediyl), a-hydro-w-hydroxy / Polyethylene Glycol
31726-34-8	Poly(oxy-1,2-ethanediyl), alpha-hexyl-omega-hydroxy
24938-91-8	Poly(oxy-1,2-ethanediyl), α-tridecyl-ω-hydroxy-
9004-32-4	Polyanionic Cellulose
51838-31-4	Polyepichlorohydrin, trimethylamine quaternized
56449-46-8	Polyethlene glycol oleate ester
9046-01-9	Polyethoxylated tridecyl ether phosphate
63428-86-4	Polyethylene glycol hexyl ether sulfate, ammonium salt
62649-23-4	Polymer with 2-propenoic acid and sodium 2-propenoate
9005-65-6	Polyoxyethylene Sorbitan Monooleate

CAS Number[56]	Chemical Constituent
61791-26-2	Polyoxylated fatty amine salt
65997-18-4	Polyphosphate
127-08-2	Potassium acetate
12712-38-8	Potassium borate
1332-77-0	Potassium borate
20786-60-1	Potassium Borate
584-08-7	Potassium carbonate
7447-40-7	Potassium chloride
590-29-4	Potassium formate
1310-58-3	Potassium Hydroxide
13709-94-9	Potassium metaborate
24634-61-5	Potassium Sorbate
112926-00-8	Precipitated silica / silica gel
57-55-6	Propane-1,2-diol, /Propylene glycol
107-98-2	Propylene glycol monomethyl ether
68953-58-2	Quaternary Ammonium Compounds
62763-89-7	Quinoline,2-methyl-, hydrochloride
62763-89-7	Quinoline,2-methyl-, hydrochloride
15619-48-4	Quinolinium, 1-(phenylmethl),chloride
8000-25-7	Rosmarinus officinalis l. leaf oil
7631-86-9	Silica, Dissolved
5324-84-5	Sodium 1-octanesulfonate
127-09-3	Sodium acetate
95371-16-7	Sodium Alpha-olefin Sulfonate
532-32-1	Sodium Benzoate
144-55-8	Sodium bicarbonate
7631-90-5	Sodium bisulfate
7647-15-6	Sodium Bromide
497-19-8	Sodium carbonate
7647-14-5	Sodium Chloride
7758-19-2	Sodium chlorite
3926-62-3	Sodium Chloroacetate
68-04-2	Sodium citrate
6381-77-7	Sodium erythorbate / isoascorbic acid, sodium salt
2836-32-0	Sodium Glycolate
1310-73-2	Sodium Hydroxide
7681-52-9	Sodium hypochlorite
7775-19-1	Sodium Metaborate .8H_2O
10486-00-7	Sodium perborate tetrahydrate
7775-27-1	Sodium persulphate
68608-26-4	Sodium petroleum sulfonate
9003-04-7	Sodium polyacrylate
7757-82-6	Sodium sulfate
1303-96-4	Sodium tetraborate decahydrate
7772-98-7	Sodium Thiosulfate

CAS Number[56]	Chemical Constituent
1338-43-8	Sorbitan Monooleate
57-50-1	Sucrose
5329-14-6	Sulfamic acid
68442-77-3	Surfactant: Modified Amine
112945-52-5	Syntthetic Amorphous / Pyrogenic Silica / Amorphous Silica
68155-20-4	Tall Oil Fatty Acid Diethanolamine
8052-48-0	Tallow fatty acids sodium salt
72480-70-7	Tar bases, quinoline derivs., benzyl chloride-quaternized
68647-72-3	Terpene and terpenoids
68956-56-9	Terpene hydrocarbon byproducts
533-74-4	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione (a.k.a. Dazomet)
55566-30-8	Tetrakis(hydroxymethyl)phosphonium sulfate (THPS)
75-57-0	Tetramethyl ammonium chloride
64-02-8	Tetrasodium Ethylenediaminetetraacetate
68-11-1	Thioglycolic acid
62-56-6	Thiourea
68527-49-1	Thiourea, polymer with formaldehyde and 1-phenylethanone
68917-35-1	Thuja plicata donn ex. D. don leaf oil
108-88-3	Toluene
81741-28-8	Tributyl tetradecyl phosphonium chloride
68299-02-5	Triethanolamine hydroxyacetate
68442-62-6	Triethanolamine hydroxyacetate
112-27-6	Triethylene Glycol
52624-57-4	Trimethylolpropane, Ethoxylated, Propoxylated
150-38-9	Trisodium Ethylenediaminetetraacetate
5064-31-3	Trisodium Nitrilotriacetate
7601-54-9	Trisodium ortho phosphate
57-13-6	Urea
25038-72-6	Vinylidene Chloride/Methylacrylate Copolymer
7732-18-5	Water
8042-47-5	White Mineral Oil
11138-66-2	Xanthan gum
1330-20-7	Xylene
13601-19-9	Yellow Sodium of Prussiate

Chemical Constituent
Aliphatic acids
Aliphatic alcohol glycol ether
Alkyl Aryl Polyethoxy Ethanol
Alkylaryl Sulfonate
Anionic copolymer
Aromatic hydrocarbons
Aromatic ketones
Citric acid base formula
Ethoxylated alcohol blend/mixture

Hydroxy acetic acid
Oxyalkylated alkylphenol
Petroleum distillate blend
Polyethoxylated alkanol
Polymeric Hydrocarbons
Quaternary amine
Quaternary ammonium compound
Salt of amine-carbonyl condensate
Salt of fatty acid/polyamine reaction product
Sugar
Surfactant blend
Triethanolamine

The chemical constituents listed in Table 5.7 are not linked to the product names listed in Table 5.4 and Table 5.5 because a significant number of product compositions have been properly justified as trade secrets within the coverage of disclosure exceptions of the Freedom of Information Law [Public Officers Law §87.2(d)] and the Department's implementing regulation, 6 NYCRR § 616.7. The Department however, considers MSDSs to be public information ineligible for exception from disclosure as trade secrets or confidential business information.

5.4.3.1 Chemical Categories and Health Information

The Department requested assistance from NYSDOH in identifying potential exposure pathways and constituents of concern associated with high-volume hydraulic fracturing for low-permeability gas reservoir development. The Department provided DOH with fracturing additive product constituents based on MSDSs and product-composition disclosures for hydraulic fracturing additive products that were provided by well-service companies and the chemical supply companies that manufacture the products.

Compound-specific toxicity data are very limited for many chemical additives to fracturing fluids, so chemicals potentially present in fracturing fluids were grouped together into categories according to their chemical structure (or function in the case of microbiocides) in Table 5.8, compiled by NYSDOH. As explained above, any given individual fracturing job will only involve a handful of chemicals and may not include every category of chemicals.

Table 5.8 - Categories based on chemical structure of potential fracturing fluid constituents.[57] (Updated July 2011)

Chemical	CAS Number
Amides	
Formamide	75-12-7
acrylamide	79-06-1
Amides, C8-18 and C19-Unsatd., N,N-Bis(hydroxyethyl)	68155-07-7
Amines	
urea	57-13-6
thiourea	62-56-6
Choline chloride	67-48-1
tetramethyl ammonium chloride	75-57-0
Choline Bicarbonate	78-73-9
Ethanol, 2,2-Iminobis-	111-42-2
1-Octadecanaminium, N,N,N, Trimethyl-, Chloride (aka Trimethyloctadecylammonium choride)	112-03-8
1-Octadecanamine, N,N-Dimethyl- (aka N,N-Dimethyloctadecylamine)	124-28-7
monoethanolamine	141-43-5
Decyldimethyl Amine	1120-24-7
methanamine, N,N-dimethyl-, N-oxide	1184-78-7
Decyl-dimethyl Amine Oxide	2605-79-0
dimethyldiallylammonium chloride	7398-69-8
polydimethyl dially ammonium chloride	26062-79-3
dodecylbenzenesulfonate isopropanolamine	42504-46-1
N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy ethanaminium chloride	44992-01-0
2-acryloyloxyethyl(benzyl)dimethylammonium chloride	46830-22-2
ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, homopolymer	54076-97-0
Cocamidopropyl Betaine	61789-40-0
Quaternary Ammonium Chloride	61789-71-7
polyoxylated fatty amine salt	61791-26-2
quinoline, 2-methyl, hydrochloride	62763-89-7
N-cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine	68139-30-0
tall oil fatty acid diethanolamine	68155-20-4
N-cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine	68424-94-2
amines, tallow alkyl, ethoxylated, acetates	68551-33-7
quaternary ammonium compounds, bis(hydrogenated tallow alkyl) dimethyl, salts with bentonite	68953-58-2

[57] The chemicals listed in this table are organized in order of ascending CAS Number by category.

Chemical	CAS Number
amines, ditallow alkyl, ethoxylated	71011-04-6
amines, C-12-14-tert-alkyl, ethoxylated	73138-27-9
benzenemethanaminium, N,N-dimethyl-N-[2-[(1-oxo-2-propenyl)oxy]ethyl]-, chloride, polymer with 2-propenamide	74153-51-8
Erucic Amidopropyl Dimethyl Betaine	149879-98-1
Petroleum Distillates	
light paraffin oil	1120-21-4
kerosene	8008-20-6
Petrolatum	8009-03-8
White Mineral Oil	8042-47-5
stoddard solvent	8052-41-3
Distillates, petroleum, light hydrocracked	64741-77-1
petroleum naphtha	64741-68-0
Mixture of severely hydrotreated and hydrocracked base oil	64742-46-7
Multiple names listed under same CAS#: LVP aliphatic hydrocarbon, hydrotreated light distillate, low odor paraffin solvent, paraffin solvent, paraffinic napthenic solvent, isoparaffinic solvent, distillates (petroleum) hydrotreated light, petroleum light distillate, aliphatic hydrocarbon, petroleum distillates, mixture of severely hydrotreated and hydrocracked base oil	64742-47-8
naphtha, hydrotreated heavy	64742-48-9
Multiple names listed under same CAS#: hydrotreated heavy napthenic distillate, Petroleum distillates	64742-52-5
petroleum base oil	64742-65-0
kerosine (petroleum, hydrodesulfurized)	64742-81-0
kerosine (petroleum, hydrodesulfurized)	64742-88-7
Multiple names listed under same CAS#: heavy aromatic petroleum naphtha, light aromatic solvent naphtha	64742-94-5
light aromatic solvent naphtha	64742-95-6
alkenes, C> 10 α-	64743-02-8
Aromatic Hydrocarbons	
benzene	71-43-2
naphthalene	91-20-3
naphthalene, 2-ethoxy	93-18-5

Chemical	CAS Number
1,2,4-trimethylbenzene	95-63-6
cumene	98-82-8
ethyl benzene	100-41-4
toluene	108-88-3
dodecylbenzene	123-01-3
xylene	1330-20-7
diethylbenzene	25340-17-4
naphthalene bis(1-methylethyl)	38640-62-9
Alcohols & Aldehydes	
formaldehyde	50-00-0
sorbitol (or) D-sorbitol	50-70-4
Glycerol	56-81-5
propylene glycol	57-55-6
ethanol	64-17-5
isopropyl alcohol	67-63-0
methanol	67-56-1
isopropyl alcohol	67-63-0
butanol	71-36-3
2-(4-methyl-1-cyclohex-3-enyl)propan-2-ol	98-55-5
3-phenylprop-2-enal	104-55-2
2-ethyl-1-hexanol	104-76-7
3,7 - dimethyloct-6-en-1-ol	106-22-9
(2E)-3,7-dimethylocta-2,6-dien-1-ol	106-24-1
propargyl alcohol	107-19-7
ethylene glycol	107-21-1
Diethylene Glycol	111-46-6
3-methyl-1-butyn-3-ol	115-19-5
4-hydroxy-3-methyoxybenzaldehyde	121-33-5
5-methyl-2-propan-2-ylcyclohexan-1-ol	1490-04-6
3,7-dimethylocta-2,6-dienal	5392-40-5
Ethyloctynol	5877-42-9
Glycol Ethers, Ethoxylated Alcohols & Other Ethers	
phenoxybenzene	101-84-8
1-methyoxy-4-prop-1-enylbenzene	104-46-1
propylene glycol monomethyl ether	107-98-2
ethylene glycol monobutyl ether	111-76-2

6.1.2 Stormwater Runoff

Stormwater, whether as a result of rainfall or snowmelt, is a valuable resource. It is the source of water for lakes and streams, as well as aquifers. However, stormwater runoff, particularly when it interacts with the human environment, is a pathway for contaminants to be conveyed from the land surface to streams and lakes and groundwater. This is especially true for stormwater runoff from asphalt, concrete, gravel/dirt roads, other impervious surfaces, outdoor industrial activity, and earthen construction sites, where any material collected on the ground is washed into a nearby surface water body. Stormwater runoff may also contribute to heightened peak flows and flooding.

On an undisturbed landscape, precipitation is held by vegetation and pervious soil, allowing it to slowly filter into the ground. This benefits water resources by using natural filtering properties, replenishing groundwater aquifers and feeding lakes and streams through base flow during dry periods. On a disturbed or developed landscape, it is common for the ground surface to be compacted or otherwise made less pervious and for runoff to be shunted away quickly with greater force and significantly higher volumes. Such hydrological modifications result in less groundwater recharge and more rapid runoff to streams, which may cause increased stream erosion and result in water quality degradation, habitat loss and flooding.

All phases of natural gas well development, from initial land clearing for access roads, equipment staging areas and well pads, to drilling and fracturing operations, production and final reclamation, have the potential to cause water resource impacts during rain and snow melt events if stormwater is not properly managed.

Excess sediment can fill or bury the rock cobble of streams that serve as spawning habitat for fish and the macro-invertebrate insects that serve as their food source. Stormwater runoff and heightened sediment loads carry excess levels of nutrient phosphorus and nitrogen that is a major cause of algae bloom, low dissolved oxygen and other water-quality impairments.

Initial land clearing exposes soil to erosion and more rapid runoff. Construction equipment is a potential source of contamination from such things as hydraulic, fuel and lubricating fluids. Equipment and any materials that are spilled, including additive chemicals and fuel, are exposed

Values and Groundwater Effluent Limitations.[9,10] In NYS, the state drinking water standards (10 NYCRR 5) apply to all public water supplies and set maximum contaminant levels (MCLs) for essentially all organic chemicals in public drinking water. See Table 6.1.

6.1.3.3 Flowback Water and Production Brine

Gelling agents, surfactants and chlorides are identified in the 1992 GEIS as the flowback water components of greatest environmental concern.[11] Other flowback components can include other dissolved solids, metals, biocides, lubricants, organics and radionuclides. Opportunities for spills, leaks, and operational errors during the flowback water recovery stage are the same as they are during the prior stages with additional potential releases from:

- hoses or pipes used to convey flowback water to tanks or a tanker truck for transportation to a treatment or disposal site; and
- tank leakage.

In general, *flowback water* is water and associated chemical constituents returning from the borehole during or proximate in time to hydraulic fracturing activities. *Production brine*, on the other hand, is fluid that returns from the borehole after completion of drilling operations while natural gas production is underway. The chemical characteristics and volumes of flowback water and production brine are expected to differ in significant respects.

Flowback water composition based on a limited number of out-of-state samples from Marcellus wells is presented in Table 5.9. A comparison of detected flowback parameters, except radionuclides, to regulated parameters is presented in Table 6.1.[12]

Table 5.10 lists parameters found in the flowback analyses, except radionuclides, that are regulated in New York. The number of samples that were analyzed for the particular parameter is shown in Column 3, and the number of samples in which parameters were detected is shown in Column 4. The minimum, median and maximum concentrations detected are indicated in

[9] URS, 2009, p. 4-18, et seq.

[10] http://www.dec.ny.gov/regulations/2652.html.

[11] NYSDEC, 1992, GEIS, p. 9-37.

[12] URS, 2009, p. 4-18, et seq.

6.8.5 Environmental Justice

As described in previous sections, there is potential for some localized negative impacts to occur as a result of allowing high-volume hydraulic fracturing. Therefore, implementation of such projects could have localized negative impacts on environmental justice populations if the projects are sited in identified environmental justice areas. However, specific project site locations have not been selected at this time.

Currently, natural gas well permit applications are exempt from requirements in NYSDEC Commissioner Policy 29, Environmental Justice and Permitting (CP-29); therefore, additional environmental justice screening would not be required for individual well permit applications. However, some of the auxiliary permits/approvals that would be needed prior to well construction may require environmental justice screening.

When necessary, project applicants would determine whether the proposed project area is urban or rural and would perform a geographic information system (GIS)-based analysis at the census tract or block group level to identify potential environmental justice areas. If a potential environmental justice area is identified by the preliminary screening, additional community outreach activities would be required.

6.9 Visual Impacts[135]

The visual impacts associated with vertical drilling in the Marcellus and Utica Shales would be similar to those discussed in the 1992 GEIS (NYSDEC 1992). Horizontal drilling and high-volume hydraulic fracturing are, in general, similar to those discussed in the 1992 GEIS (NYSDEC 1992), although changes that have occurred in the industry over the last 19 years may affect visual impacts. These visual impacts would typically result from the introduction of new landscape features into the existing settings surrounding well pad locations that are inconsistent with (i.e., different from) existing landscape features in material, form, and function. The introduction of these new landscape features would result in changes to visual resources or visually sensitive areas and would be perceived as negative or detrimental by regulating agencies and/or the viewing public.

[135] Section 6.9, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011, and was adapted by the Department.

The visual impacts of horizontal drilling and high-volume hydraulic fracturing would result from four general on-site processes associated with the development of viable well locations: construction, well development (drilling and fracturing), operation or production, and post-production reclamation. The greatest visual impacts would be associated with the construction of well pads and associated facilities, which would create new long-term features within surrounding landscapes, and well drilling and completion activities at viable well locations, which would be temporary and short-term in nature. Additional off-site activities could also result in visual impacts, including the presence of increased workforce personnel and vehicular traffic, and the use of existing or development of new off-site staging areas or contractor/storage yards.

The visual impacts of horizontal drilling and hydraulic fracturing would vary depending on topographic conditions, vegetation characteristics, the time of year, the time of day, and the distance of one or more well sites from visual resources, visually sensitive areas, or other visual receptors.

6.9.1 Changes since Publication of the 1992 GEIS that Affect the Assessment of Visual Impacts

A number of changes to equipment and drilling procedures since the 1992 GEIS have the potential to result in visual impacts over a larger surrounding area and/or visual impacts over a longer period of time. These changes can generally be separated into three categories: changes in equipment and drilling techniques; changes in the size of well pads; and changes in the nature and duration of drilling and hydraulic-fracturing activities.

6.9.1.1 Equipment and Drilling Techniques

The 1992 GEIS stated that drill rigs ranged in height from 30 feet for a small cable tool rig to 100 feet or greater for a large rotary rig. By comparison, the rigs currently used by the industry for horizontal drilling can be 140 feet or greater in height and have more supporting equipment. While a substantial amount of on-site equipment, including stationary tanks, compressors, and trucks, would be periodically present at each site during specific times of well development (drilling and fracturing), the amount of necessary on-site equipment during these times is similar to that addressed in the 1992 GEIS.

Intermediate Casing

Intermediate casing is run in a well after the surface casing but before production hole is drilled. Fully cemented intermediate casing can be necessary in some wells to prevent possible pressurization of the surface casing seat, and to effectively seal the hole below the surface casing to prevent communication between separate hydrocarbon-bearing strata and between hydrocarbon and water-bearing strata. The primary uses of intermediate casing are to 1) provide a means of controlling formation pressures and fluids below the surface casing, 2) seal off problematic zones prior to drilling the production hole and 3) ensure a casing seat of sufficient fracture strength for well control purposes. The intermediate casing's design and setting depth is typically based on various factors including anticipated or encountered geologic characteristics, wellbore conditions and the anticipated formation pressure at total depth of the well. Factors can also include the setting depth of the surface casing, occurrence of shallow gas or flows in the open hole, mud weights used to drill below intermediate casing, and well-control and safety considerations.

Current casing and cementing practices attached as conditions to all oil and gas well drilling permits state that intermediate casing string(s) and cementing requirements will be reviewed and approved by the Department on an individual well basis. The Department proposes to require, via permit condition and/or regulation, that for high-volume hydraulic fracturing the installation of intermediate casing in all wells covered under the SGEIS would be required. However, the Department may grant an exception to the intermediate casing requirement when technically justified. A request to waive the intermediate casing requirement would need to be made in writing with supporting documentation showing that environmental protection and public safety would not be compromised by omission of the intermediate string. An example of circumstances that may warrant consideration of the omission of the intermediate string and granting of the waiver could include: 1) deep set surface casing, 2) relatively shallow total depth of well and 3) absence of fluid and gas in the section between the surface casing and target interval. Such intermediate casing waiver request may also be supported by the inclusion of information on the subsurface and geologic conditions from offsetting wells, if available.

would impose specific construction windows within well construction permits in order to ensure that drilling activity and its cumulative adverse socioeconomic effects are not unduly concentrated in a specific geographic area.

Another way to mitigate the potential adverse impacts associated with in-migration to the region would be to actively encourage the hiring of local labor. Because natural gas exploration, drilling, and production activities typically require specialized skills, a jobs training program or apprentice program should be developed through the SUNY system (e.g., community colleges and agricultural and technical colleges) to increase the number of local residents with the requisite job skills for the natural gas industry, thereby reducing the number of workers that would need to be hired from outside the region. Such a program would also have the benefit of reducing unemployment in these regions. A jobs training program would not eliminate the need for in-migration of skilled labor, but the program could partially offset the in-migration of workers and thus partially offset the potential housing impact from such in-migration.

7.9 Visual Mitigation Measures[95]

As noted, in most cases high-volume hydraulic fracturing operations would not result in significant adverse impacts on visual resources. The most significant visual impacts would result from construction of the well pad and well, and those impacts would be of short duration. Nevertheless, this section describes generic measures to address temporary adverse impacts of well site construction, development, production, and reclamation on visual resources. These measures could be undertaken in cases where well construction takes place near visually sensitive areas identified within the area underlain by the Marcellus and Utica Shales in New York State. Measures to mitigate impacts on visual resources would be generally similar, regardless of the type of visual resource or its location, and despite the need for compliance with rules, regulations, and permits promulgated by other federal, state, and/or local (town, county or regional) agencies.

The development of measures to reduce impacts on visual resources or visually sensitive areas would follow the procedures identified in NYSDEC DEP-00-2, "Assessing and Mitigating

[95] Section 7.9, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011 and was adapted by the Department.

Visual Impacts" (NYSDEC 2000). These measures can generally be divided into: design and siting measures that could be incorporated during the construction, development, and production phases; maintenance measures that could be incorporated into the development and production phases; and decommissioning measures that could be incorporated into the reclamation phase. Offsetting mitigation, as opposed to avoidance and direct mitigation measures, would typically be used only as a last resort for the resolution of significant impacts on visual resources or visually sensitive areas, as determined by Department staff. These measures are discussed in greater detail in the following subsections.

Generally, mitigation measures would be developed in consultation between Department staff and well operators and would be site-specific, or project-specific where multiple sites are a part of the project design. Depending on the location of the well pad and the resource potentially impacted, it may also be necessary to consult with additional state and federal regulatory agencies to develop measures to mitigate visual impacts on specific types of visual resources or visually sensitive areas, including but not limited to the New York State Historic Preservation Officer for NRHP-listed or -eligible historic properties; consultation with the National Park Service for National Historic Landmarks (NHLs) and National Natural Landmarks (NNLs); consultation with the U.S. Fish and Wildlife Service for National Wildlife Management Areas; consultation with the NYSDOT for state-designated Scenic Byways, etc.; and consultation with local (town, county, or regional) agencies for locally designated visual resources or visually sensitive areas that were identified on the EAF.

7.9.1 Design and Siting Measures

Design and siting measures, as described in NYSDEC DEP-00-2, would typically consist of screening, relocation, camouflage or disguise, maintaining low facility profiles, downsizing the scale of a project, using alternative technologies, using non-reflective materials, and controlling off-site migration of lighting (NYSDEC 2000). These various design and siting techniques are summarized below.

- **Screening**. Screening uses natural or man-made objects to conceal other objects from view; these objects may be constructed of any material that is opaque.

- **Relocation**. Relocation consists of moving facilities or equipment within a site to take advantage of the mitigating effects of topography and/or vegetation.

- **Camouflage or disguise**. Camouflage or disguise consists of using forms, colors, materials, and patterns to minimize or mitigate visual impacts.

- **Low profiles**. The use of low profiles consists of reducing the height of on-site objects to minimize their visibility from surrounding viewsheds.

- **Downsizing**. Downsizing consists of reducing the number, areas, or density of objects on a site to minimize their visibility from surrounding viewsheds.

- **Alternative technologies**. The use of alternative technologies consists of substituting one technology for another to reduce impacts.

- **Non-reflective materials**. The use of non-reflective, materials consists of using materials that do not shine or reflect light into surrounding viewsheds.

- **Lighting**. Lighting should be the minimum necessary for safe working conditions and for public safety, and should be sited to minimize off-site light migration, glare, and 'sky glow' light pollution.

Design and siting measures are the simplest and most effective methods for avoiding, minimizing, or mitigating direct and indirect impacts on visual resources or visually sensitive areas. For example, the state has determined that surface drilling would be prohibited on state-owned land, including reforestation areas and wildlife management areas, which would include many of the types of visual resources or visually sensitive areas discussed in Section 2.4. Implementing this siting measure would result in the exclusion from surface drilling of many resources and areas that may be designated or used, in part or in whole, for their scenic qualities, thereby decreasing the potential for direct visual impacts of surface drilling on such resources or areas. The implementation of design and siting measures would also minimize indirect impacts on visual resources or visually-sensitive areas that are outside of, but in close proximity to, areas where drilling is proposed.

Additional use of design and siting measures to avoid, reduce, or mitigate visual impacts would typically be implemented during the construction, development, and production phases of a well site. These measures could be used individually or in combination as determined appropriate and feasible by Department staff and well operators.

For example, the use of multi-well pads for horizontal drilling and hydraulic fracturing is a design and siting measure that incorporates both relocation and downsizing techniques by installing more than one well in one location. The benefit of the multi-well pad is that it decreases the overall number of pads in the surrounding landscapes, which would result in the decreased potential for impacts on visual resources or visually sensitive areas during the construction, development, production, and reclamation phases.

The use of horizontal drilling and high-volume hydraulic fracturing is a design and siting measure that incorporates the use of alternative technology to extract natural gas from the prospective Marcellus and Utica Shale region. The benefit of horizontal drilling and high-volume hydraulic fracturing is that it provides flexibility in pad location, such that well pads can be sited to avoid or minimize the potential for temporary, short-term, and long-term impacts on visual resources or visually sensitive areas during the construction, development, production, and reclamation phases (NTC 2011). Such considerations should be reflected in Department consideration of well pad applications.

The potential benefit of using camouflage or disguise as a design measure to minimize impacts on visual resources or visually sensitive areas is shown in Photo 7.1 below. This photo shows fracturing activities on a well site, a phase when well sites are almost entirely filled with on-site equipment, which represents new landscape features and results in an area that appears visually prominent in views from nearby vantage points. Although the fracturing phase of development is considered temporary and periodic (as described in Section 6.11), it would be possible to minimize visual impacts during fracturing activities that might occur in the spring, summer, or fall by requiring on-site water storage tanks (the red tanks in Photo 7.1) to be a green color to mimic surrounding conditions. This would reduce the prominence of the tanks in the surrounding landscape during seasons when visual resources or visually sensitive areas are typically visible to the greatest numbers of the viewing public.

Photo 7.1 - View of a well site during the fracturing phase of development, with maximum presence of on-site equipment. (New August 2011)

The 2010 visual impact assessment (Upadhyay and Bu 2010) evaluated the effectiveness of implementing certain design and siting techniques as measures to mitigate visual impacts. Using aerial photograph interpretation, the authors suggested that reducing the size of the well pad (downsizing) after drilling (the development phase) was complete could result in reduced site-specific visual impacts from surrounding vantage points and that reducing the density of multiple well pads in an area could result in reduced visual impacts within a larger area or region (e.g., within a county). Their study further suggested that the following design and siting measures would avoid or minimize visual impacts from surrounding vantage points: relocating well sites to avoid ridgelines or other areas where aboveground equipment and facilities breaks the skyline; and minimizing off-site light migration by using night lighting only when necessary and using the minimum amount of nighttime lighting necessary, directing lighting downward instead of horizontally, and using light fixtures that control light to minimize glare, light trespass (off-site light migration), and light pollution (sky glow) (Upadhyay and Bu 2010).

A tourism study (Rumbach 2011) prepared for the Southern Tier Central (STC) Regional Planning and Development Board suggests that visual impacts from horizontal drilling and hydraulic fracturing could be most effectively addressed during the siting and design phases by ensuring that well pads are designed and located in ways that minimize potential impacts on visual resources or visually sensitive areas to the extent practicable. The study also encourages the inclusion of visual impact mitigation conditions, developed in accordance with NYSDEC DEP-00-2, in permits when visual resources may be impacted. The study also recommends the development of a best practices manual for Department staff and the industry, which would provide information on what is expected by the Department in terms of well siting and visual mitigation, and the identification of instances where visual mitigation may be necessary. Additional recommendations included encouraging local agencies (towns, counties, and regions) to identify areas of high visual sensitivity, which may require additional visual mitigation, and to develop a feedback mechanism in the project review process to confirm the success of measures to avoid, minimize, or mitigate visual impacts, based on the analysis of results for prior projects (Rumbach 2011).

7.9.2 Maintenance Activities

The maintenance activities described in NYSDEC DEP-00-2 should be implemented to prevent project facilities from becoming "eyesores." Such measures would typically consist of appropriate mowing or other measures to control undesirable vegetation growth; erosion control measures to prevent migration of dust and/or water runoff from a site; measures to control the off-site migration of refuse; and measures to maintain facilities in good repair and as organized and clean as possible according to the type of project (NYSDEC 2000).

Maintenance activities to avoid, reduce, or mitigate visual impacts would typically be implemented during the development and production phases for well sites. Facilities should be maintained in good repair and as organized and clean as possible.

Upadhyay and Bu's visual impact assessment evaluated the effectiveness of site restoration to minimize visual impacts on surrounding landscapes. Their definition of site restoration as a mitigation measure, defined as restoring drilling pads to their original condition after drilling and hydraulic fracturing activities (i.e., the development phase) are completed, is similar in concept

to the NYSDEC DEP-00-2 definition of maintenance activities as a mitigation measure. Their conclusion was that site restoration following drilling and hydraulic fracturing activities was an effective way to reduce adverse visual impacts of producing well sites within the existing landscape. With appropriate site restoration, well sites in the production phase, when activity is minimal and there are only a few relatively unobtrusive aboveground structures on site, are not prominent features within the surrounding landscape (Upadhyay and Bu 2010).

7.9.3 Decommissioning

The decommissioning activities described in NYSDEC DEP-00-2 should be implemented when the useful life of the project facilities is over; these activities would typically occur during the reclamation phase for well sites.[96] Such activities would typically consist of, at a minimum, the removal of aboveground structures at well sites. Additional decommissioning activities that may also be required include: the total removal of all facility components at a well site (aboveground and underground) and restoration of a well site to an acceptable condition, usually with attendant vegetation and possibly including recontouring to reestablish the original topographic contours; the partial removal of facility components, such as the removal or other elimination of structures or features that produce visual impacts (such as the restoration of water impoundment sites to original conditions); and the implementation of actions to maintain an abandoned facility and site in acceptable condition to prevent the well site from developing into an eyesore, or prevent site and structural deterioration (NYSDEC 2000).

The tourism study prepared for the STC (Rumbach 2011) discusses additional measures that could be implemented during the reclamation phase to mitigate visual impacts. These measures, which would be applied to all well pads, include the application of specific procedures identified in the 1992 GEIS for topsoil conservation and redistribution in agricultural districts. These procedures include stripping off and stockpiling topsoil during construction; protecting stockpiled topsoil from erosion and contamination; cutting well casings to a safe buffer depth of 4 feet below the ground surface; preparing areas before topsoil redistribution if compaction has

[96] Although substantial equipment and activity would be present at well sites during the construction and development phases, such equipment and activities are temporary. Once construction and well development is completed, some activities would cease and some equipment would be removed, and these are not considered to be decommissioning activities.

occurred on-site; and redistributing the topsoil over the disturbed area of the former well pads during reclamation (Rumbach 2011).

7.9.4 Offsetting Mitigation

The offsetting mitigation described in NYSDEC DEP-00-2 should be implemented when the impacts of well sites on visual resources or visually sensitive areas are significant and when such impacts cannot be avoided by locating the well pad in an alternate location. Per guidance in NYSDEC DEP-00-2, offsetting mitigation would consist of the correction of an existing aesthetic problem identified within the viewshed of a proposed well project. Thus, a decline in the landscape quality that would result from development of a proposed well site could, at least partially, be 'offset' by the correction. An example of offsetting mitigation might be the removal of an existing abandoned structure that is in disrepair (i.e., an 'eyesore') to offset impacts from the development of a well site within visual proximity to the same sensitive visual resource (NYSDEC 2000). Offsetting mitigation should be employed only when significant improvements in visually sensitive locations can be expected at a reasonable cost (NYSDEC 2000).

7.10 Noise Mitigation Measures[97]

Noise is best mitigated by increasing distance between the source and the receiver; the greater the distance the lower the noise impact. The second level of noise mitigation is direction. Directing noise-generating equipment away from receptors greatly reduces associated impacts. Timing also plays a key role in mitigating noise impacts. Scheduling the more significant noise-generating operations during daylight hours provides for tolerance that may not be achievable during the evening hours.

7.10.1 Pad Siting Equipment, Layout and Operation

Many of the potential negative impacts of gas development depend on the location chosen for the well pad and the techniques used in constructing the access road and well site. Before a drilling permit can be issued, Department staff must ensure that the proposed location of the well and access road complies with the Department's spacing regulations and siting restrictions. To assist

[97] Section 7.10, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011 and was adapted by the Department.

sets forth a water well testing protocol using indicators that are independent of specific additive chemistry.

For every well permit application the Department would require, as part of the EAF Addendum, identification of additive products, by product name and purpose/type, and proposed percent by weight of water, proppants and each additive. This would allow the Department to determine whether the proposed fracturing fluid is water-based and generally similar to the fluid represented by Figures 5.3, 5.4, and 5.5. Additionally, the anticipated volume of each additive product proposed for use would be required as part of the EAF Addendum. Beyond providing information about the quantity of each additive product to be utilized, this requirement informs the Department of the approximate quantity of each additive product that would be on-site for each high-volume hydraulic fracturing operation.

The Department would also require the submittal of an MSDS for every additive product proposed for use, unless the MSDS for a particular product is already on file as a result of the disclosure provided during the preparation process of this SGEIS (as discussed in Chapter 5) or during the application process for a previous well permit. Submittal of product MSDSs would provide the Department with the identities, properties and effects of the hazardous chemical constituents within each additive proposed for use.

Finally, the Department proposes to require that the application materials (i) document the applicant's evaluation of available alternatives for the proposed additive products that are efficacious but which exhibit reduced aquatic toxicity and pose less risk to water resources and the environment and (ii) contain a statement that the applicant will utilize such alternatives, unless it demonstrates to DMN's satisfaction that they are not equally effective or feasible. The evaluation criteria should include (1) impact to the environment caused by the additive product if it remains in the environment, (2) the toxicity and mobility of the available alternatives, (3) persistence in the environment, (4) effectiveness of the available alternative to achieve desired results in the engineered fluid system and (5) feasibility of implementing the alternative.

In addition to the above requirements for well permit applications, the Department would continue its practice of requiring hydraulic fracturing information, including identification of

EXHIBIT L

Testimony of Paul V. Rush, P.E.
Deputy Commissioner, Bureau of Water Supply
New York City Department of Environmental Protection
at a Hearing of the Delaware River Basin Commission
Draft Natural Gas Development Regulations
Tuesday, February 22, 2011, 1 pm, Liberty, New York

Good afternoon, I am Paul Rush, Deputy Commissioner for the Bureau of Water Supply, at the New York City Department of Environmental Protection (DEP).

We commend the Delaware River Basin Commission (DRBC) for taking on the daunting task of updating the rules and procedures to address natural gas activities within the Delaware River Basin. Clearly this type of industrial activity has the potential to have a significant impact on the Delaware River and its tributaries and a strong regulatory framework is required. DRBC brings a much-needed regional perspective and consistency to this multi-jurisdictional issue. In particular, DRBC is in a unique position to address cumulative impacts of multiple water withdrawals and wastewater disposal sites. In the interest of time, I will confine my testimony to this issue; DEP will submit comprehensive comments by the March 16 deadline.

Any decisions about drilling for natural gas in the Marcellus Shale must be based on detailed scientific and technical reviews. DEP's own study determined that based on the best available science and the current state of technology, hydrofracking cannot safely be conducted in the New York City Watershed. Decisions about drilling within the shared Delaware River Basin should be made on the same strong analytical foundation. We continue to urge DRBC to conduct a rigorous analysis of the potential cumulative impacts natural gas development could have on water quantity and water quality in the Delaware Basin. Given what is at stake and the estimates of natural gas wells in the Delaware River Basin numbering in the tens of thousands, it would be prudent to complete such a comprehensive analysis prior to the promulgation of final regulations, so that it can inform the rules and restriciton on natural gas exploration in the basin.

A cumulative impact assessment for the Delaware Basin must also include a depletive use budget for the basin, as recommended in the 1982 Good Faith Agreement. Depletive water use has a direct bearing on the basin's future development, its water quality, water quantity, ecological health, salinity intrusion, and drought management. This information is also critical for managing the effects of climate change, and must consider secondary impacts to other stakeholders as well. I urge DRBC to conduct and complete a cumulative impact assessment before issuing its natural gas regulations.

Thank you for the opportunity to comment. As always, New York City looks forward to working with our partners in the management of this common, precious resource.

EXHIBIT M

NYC Environmental Protection

Caswell F. Holloway
Commissioner

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April 7, 2011

Paula Schmitt, Commission Secretary
Delaware River Basin Commission
25 State Police Drive
PO Box 7360
West Trenton, NJ 08628

Re: Delaware River Basin Commission's Draft Natural Gas Extraction Regulations

Dear Ms. Schmitt:

The City of New York is very concerned with the prospect of natural gas drilling in the New York City (City) water supply watershed, much of which feeds the headwaters of the Delaware River. The City water supply provides high quality drinking water to nearly half the population of the State of New York – over eight million people in the City and one million people in upstate counties. The City has invested more than $1.5 billion in watershed protection programs that support sustainable farming, environmentally sensitive economic development, and local economic opportunity. These investments protect water quality for the 15 million people who rely on the Delaware River watershed for clean drinking water. The Delaware River is a shared resource and changes in its watershed's environment affect us all.

Overall, the draft regulations are a step in the right direction toward protecting the Delaware River from the potential impacts of gas drilling. They seek to strike a balance between deferring to state jurisdictions while still ensuring sufficient protection to the Delaware River and downstream stakeholders. However, the City continues to believe that it is premature for the Delaware River Basin Commission (DRBC) to adopt these regulations. Prior to issuing any regulations, DRBC should conduct a rigorous analysis of the potential cumulative impacts natural gas development could have on water quantity and water quality in the Delaware Basin. Second, in addition, DRBC should wait until the U.S. Environmental Protection Agency (EPA) completes its ongoing study of hydraulic fracturing's potential impacts on water quality. Only once those two critical analyses are complete can it be determined whether DRBC's proposed regulations will sufficiently protect the Delaware River.

The Department of Environmental Protection's (DEP) own study determined that, based on the best available science and the current state of technology, hydrofracking cannot safely be conducted in the New York City Watershed. Decisions about drilling within the shared Delaware River Basin should be made on the same strong scientific foundation. Given what is at stake and the estimates of natural gas wells in the Delaware River Basin numbering in the

tens of thousands, we urge DRBC to wait for the completion of both a DRBC and EPA studies to inform the natural gas regulations.

Cumulative Impact Assessment

A cumulative impact assessment for the Delaware Basin is essential to developing a full understanding of the impacts of natural gas drilling. Such an assessment must include a depletive use budget for the basin as recommended in Section V, Depletive Water Use Budget, Recommendation 13, of the 1982 Good Faith Agreement. Depletive water use has a direct bearing on the basin's future development, its water quality, water quantity, ecological health, salinity intrusion, and drought management. This information is also critical for managing the effects of climate change.

Performing a cumulative impact assessment before adopting regulations is particularly important because the regulations do not provide for such an assessment to be prepared in connection with individual approvals. The City is particularly concerned about the cumulative impacts of consumptive uses in the basin. As Section 7.4(b)(2) of the draft regulations states, "*... the water uses associated with natural gas development are almost entirely consumptive in nature.*" The draft regulations would nonetheless allow Approval by Rule (ABR) to exploit previously approved water sources for supply of natural gas development. This is not consistent with the principles embodied in the regulations as a whole because it implies that consumptive use of water for natural gas development is similar to, and will have the same impacts as, whatever use had previously been approved. Particularly if a previously approved water source is not consumptive, allowing it to be utilized for natural gas development, which is consumptive, would represent a significant change from the original approval warranting thorough review. While we have concerns about ABR provisions, however, the City greatly appreciates DRBC's recognition that the ABR process should not be allowed within the City watershed.

Additionally, Section 7.4(e)(1)(i) of the draft regulations states that "*A new water source located within the physical boundaries of an approved NGDP [Natural Gas Development Plan] may be approved for uses within the NGDP by means of an ABR.*" A new withdrawal for natural gas development will have the same substantial effect, as indicated in the Preliminary Determination in section 7.4(b), regardless of whether it is within the boundaries of an approved natural gas development plan, and thus should only be approved by docket as other new water sources for natural gas development.

In order to address potential cumulative impacts associated with consumptive withdrawals, DRBC should develop river flow conditions under which withdrawals or wastewater discharges would be temporarily halted. For example, DRBC should mandate, as a condition of approval, that gas drilling companies take water only during times when the City is not required to make releases as directed by the Delaware River Master to meet the Montague flow objective. Consumptive withdrawals with low by-pass requirements will adversely impact downstream conditions, especially during periods of low flow, requiring increased compensating releases by the City to meet the Montague flow objective. A similar mandate can be placed on the Trenton flow objective in order to prevent natural gas withdrawals or wastewater discharges from adversely impacting existing uses in the lower Delaware Basin. Wastewater treatment

plants discharging high salinity wastewaters from natural gas development should also be curtailed when the salt front nears the Philadelphia intake at Torresdale. A comprehensive basin-wide analysis would provide the data necessary to set appropriate restrictions on natural gas withdrawals and adequately protective pass-by flows.

EPA Drinking Water Study

Given that the Delaware River Basin is a critical source of drinking water for some 15 million people, and given the many open questions concerning the impact of hydrofracking on drinking water, we urge DRBC to wait to issue regulations until the EPA study is complete, and DRBC can evaluate whether EPA's findings dictate additional restrictions that should be imposed within such an important drinking water source. The City's own risk assessment identified substantial risks to water quality and water supply infrastructure associated with natural gas production in our watershed and in the vicinity of our water supply infrastructure. Accordingly, DRBC, as a steward of drinking water for such a substantial population, should approach this issue cautiously, and should wait to make decisions until it has the benefit of better information.

Other Concerns

Stormwater Controls. The required Natural Gas Development Plans will be valuable planning tools and will allow for more comprehensive reviews of natural gas development in the basin. We respectfully request, however, that the Non-point Source Pollution Control Plans (NPSPCP) be required to be submitted to the City in addition to New York State if the project is within the City watershed. The City has watershed rules and regulations governing stormwater that are based on New York State's regulatory program but which, in some situations, are more stringent. For the same reasons that the City has determined that rigorous stormwater controls are necessary to protect water quality, DRBC should add post-construction requirements covering items such as continuing maintenance of access roads or structural integrity of the well casing.

Reporting on Subsurface Conditions. Unusual subsurface conditions, if not properly mitigated, could result in migration of contaminants or gases away from the well bore. We recommend that conditions be added to the draft regulations requiring natural gas operators to submit a written report to the Commission in the event that any unexpected subsurface condition is encountered during drilling (e.g. blowout, borehole kick, lost circulation material, shallow methane or brine, etc.). The report should describe the event encountered and remedial action taken.

Spill Control Plans. The draft regulations do not mention the need for a spill control plan for natural gas development sites. Given the potential for spills and accidental releases from natural gas development utilizing hydraulic fracturing, DRBC regulations should require that a comprehensive spill control plan be submitted to the Commission for review as a condition of project approval. The spill control plan should be reviewed and updated annually to ensure it contains the most recent contact information for officials and first responders.

Setbacks from Water Supply Infrastructure. The setbacks provided for surface water intake (500 ft) and water supply reservoir (500 ft) are not sufficiently protective of water resources even given the prohibition of siting a well pad in the 100-year floodplain. The City urges DRBC to

reconsider these distances and also to specify how the setback will be measured. Horizontal drilling adds a new complication to traditional regulatory setbacks. If the setback is measured from the well pad, then horizontal drilling may occur directly *beneath* the intake or reservoir. Instead we recommend that the setback be measured from the end of the nearest horizontal drill leg to the resource in question.

Invasive Species. The draft regulation indicates that an invasive species control plan is only required if determined by the Commission. Given the fact that natural gas development will be distributed throughout the Delaware Basin and surrounding regions, and that trucks and equipment will be moved frequently, it is recommended that invasive species control plans be required for all natural gas development projects.

Duration of Approvals. Given the rapid pace of natural gas development in this region and the constantly evolving technology, the duration of withdrawal approvals for natural gas extraction purposes must be reevaluated. Approvals lasting ten years may not give DRBC or other stakeholders an adequate opportunity to evaluate potential impacts in the context of current environmental conditions, recent technological advances or improved scientific understanding. The City therefore recommends that no withdrawal approval, whether through an original docket or through ABR, allow withdrawals for natural gas extraction purposes for longer than five years.

We commend DRBC for taking on the critical task of developing natural gas regulations and balancing a wide range of stakeholder needs. If you have any questions or comments, or if we can be of any further assistance in this matter, please feel free to contact me directly at (845) 340-7800, or prush@dep.nyc.gov.

Sincerely,

Paul V. Rush, P.E.
Deputy Commissioner

c: James Tierney, Assistant Commissioner, NYS DEC

EXHIBIT N

New York City Department of
Environmental Protection
www.nyc.gov/dep

59-17 Junction Boulevard
Flushing, NY 11373

Steven W. Lawitts
Acting Commissioner

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December 22, 2009

Attn: dSGEIS Comments
Bureau of Oil & Gas Regulation
NYSDEC, Division of Mineral Resources
625 Broadway, Third Floor
Albany, NY 12233-6500

Re: Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program (dated 9/30/2009)

To Whom It May Concern:

The City of New York (City) submits the following comments on the New York State Department of Environmental Conservation's (DEC) September 30, 2009 Draft Supplemental Generic Environmental Impact Statement (dSGEIS) on the Oil, Gas and Solution Mining Regulatory Program – Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs.[1]

Overview

The City appreciates the opportunity to comment on DEC's plan to permit the development of natural gas in the Marcellus Shale formation, and the potential economic opportunity that this represents for the State. As promising as that opportunity may be, however, the City has concluded that based on the latest science and available technology, as well as the data and analysis presented in the State's dSGEIS, horizontal drilling and high-volume hydraulic fracturing (collectively, "hydro-fracking," or "gas drilling") pose an unacceptable threat to the unfiltered, fresh water supply of nine million New Yorkers, and cannot safely be permitted within the New York City watershed.

As the detailed comments that follow explain, the up to 6,000 wells required to extract natural gas based on current technology, seven million truck trips, one million tons of concentrated chemicals, and millions of gallons of wastewater that are necessities and by-products of current extraction methods, pose a substantial threat to the water supply. Further, the activity is inconsistent with the principles of watershed protection and pollution prevention that are incorporated into its Filtration Avoidance Determination (FAD) under the federal Surface Water Treatment Rule.

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[1] These comments are informed by and incorporate the findings of the attached Final Impact Assessment Report (Report) and the attached Rapid Impact Assessment Report, both of which were undertaken by the City with the assistance of Hazen and Sawyer/Leggette, Brashears and Graham.

Hydro-fracking requires a high-degree of invasive industrial activity, with potential geologic and public health impacts that are not well understood. Given these realities, permitting gas drilling in the watershed would upset the balance between watershed protection and economic activities that the City, DEC, and our upstate partners have worked so hard to establish over the past 15 years.

When lands already owned or controlled by the City and State are taken into account, only six percent of potentially exploitable Marcellus shale is within the New York City watershed. Prohibiting gas drilling of six percent of the available reserves is a more than reasonable price to pay to safeguard the State's greatest natural resource—unfiltered drinking water for nine million state residents.

Background of the City's Filtration Avoidance Determination

The City's position is grounded in data and analysis. But some context is crucial to understanding what is at stake for nine million state residents who rely on the City's water supply. The federal Environmental Protection Agency (EPA) granted the City's first FAD in 1993 and, subsequently, five additional FADs. In 1997, New York City signed a Memorandum of Agreement (MOA) with EPA, various State agencies, 70 watershed municipalities and many environmental organizations to establish a land acquisition program, updated rules, and a set of partnership programs for the watershed's protection. Since that time, the City has since spent or committed approximately $1.5 billion, funded almost exclusively by rate paying customers, on the development and implementation of the watershed protection plan for the Catskills/Delaware watershed (the Cat-Del System).

A key component of these ongoing efforts is the City's Land Acquisition Program. Since its creation, the Land Acquisition Program has protected more than 103,000 acres in the Cat-Del watersheds. When combined with lands protected by the State and other entities, these acquisitions have raised the level of permanently protected land in the Cat-Del System from 24 percent in 1997, to 34 percent today.[2] Together with City-funded acquisitions by the Watershed Agricultural Council (WAC), the program has acquired or is under contract for lands with a value of $354 million.[3]

The New York City Department of Environmental Protection (DEP) also pays taxes on its upstate holdings, including system infrastructure and vacant land. For the current fiscal year, the City's total upstate tax bill is approximately $120 million (that includes properties east of Hudson). And other watershed protection efforts—like septic repairs, stormwater retrofits and stream restorations—result in quality-of-life improvements for watershed residents. Finally, DEP has made significant improvements in allowing recreational uses of City property in the watershed, which have been well received by local communities. The success of these protection efforts has been recognized by both the EPA and the State. A 2006 EPA report, evaluating the

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[2] DEP, Long-Term Land Acquisition Plan 2012 to 2022 (September 30, 2009).

[3] Other key efforts as part of its watershed protection efforts include: upgrading plans that account for more than 98% of the wastewater flow in the Cat-Del System, at a cost of $355 million; spending $147 million since 1993 on the Watershed Agricultural Program (WAP), which aims to reduce pollutants leaving the farm through the implementation of best management practices; and a $60 million economic development fund for the West-of-Hudson watershed to support the economic vitality of the region.

City's performance, concluded that the City had "successfully satisfied the obligations specified in the 2002 FAD."[4]

DEC is a vital partner in these efforts. Through its Office of the New York City Watershed Program, the agency provides regulatory oversight and technical expertise, and administers State funding for watershed projects.[5] Praising the most recent FAD in 2007, DEC recognized that its extension strengthens protections for surrounding lands and reservoirs, and demonstrates a "tremendous fiduciary responsibility to the taxpayers."[6] That is because continuing to safeguard the watershed at its source will ensure the continued high quality of the water supply and save the minimum of $10 billion that would be required to build a filtration plant for Cat-Del water, and $100 million per year needed to operate it, if the FAD is ever discontinued or revoked.[7] That result is unacceptable because it is entirely unnecessary, and within the State's power to stop. The analysis that follows shows why hydro-fracking and horizontal drilling cannot safely be conducted in the watershed.

Analysis of the State's Gas-Drilling Proposal

The City's water supply provides high quality drinking water to nearly half the population of the State of New York – over eight million people in New York City and one million people in upstate counties. DEP is responsible for overseeing the operation, maintenance and management of the water supply, its infrastructure, and the protection of the 1,969 square mile watershed. The Marcellus shale underlies the entire West-of-Hudson portion of the New York City water supply, which typically supplies more than 90% of the City's drinking water. As noted above, the West-of-Hudson watershed supplies water of such high quality that the water does not require filtration.

Based on extensive analysis of the potential impacts of natural gas extraction, hydraulic fracturing threatens the water supply and the FAD in three principal ways:

1. Current extraction methods require a high degree of invasive industrialization that carries inherent short-term and cumulative environmental risks.

2. The chemicals currently used as part of the extraction process, and the significant volumes of wastewater produced can contaminate water supplies.

3. In their current anticipated form, the hydraulic fracturing process could damage water supply infrastructure located within and outside the New York City watershed.

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[4] EPA Region 2, Report on the City of New York's Progress in Implementing the Watershed Protection Program, and Complying with the Filtration Avoidance Determination (August 21, 2006), at 2, available at http://www.epa.gov/region02/water/nycshed/documents/epaeval_august2006.pdf.

[5] DEC's Role In The NYC Watershed, available at http://www.dec.ny.gov/lands/58529.html

[6] Press Release, State Health, Environmental Commissioners Applaud Agreement to Protect NYC Water Supply (July 30, 2007), available at http://www.dec.ny.gov/press/36767.html.

[7] The impacts of chemical contamination and other risks are, of course, environmental. However, the potential economic consequences of those environmental impacts are orders of magnitude greater than in other contexts.

These threats and other adverse impacts, including many known and emerging risks of hydraulic fracturing, are not adequately addressed (if at all) in the dSGEIS. Moreover, the dSGEIS does not fully analyze a range of reasonable alternatives to hydro-fracturing and horizontal drilling, and does not sufficiently mitigate known risks. The duty of the State is to take a hard look at the adverse environmental impacts of the action. A new SGEIS is required to adequately address the significant environmental impacts that would occur from the action, both at the local level and from a cumulative perspective. Site-specific environmental reviews to address the many discretionary elements of subsequent permit applications are also required.

We respectfully disagree with a fundamental assumption underlying many of the conclusions in the dSGEIS – that the combined technologies of horizontal drilling and high volume hydraulic fracturing are in large part similar to activities that have been conducted in New York State for decades. Rather, the extent and intensity of natural gas development that these new technologies make possible, together with the large volumes of water required, wastewater produced and associated industrial activities, raise serious concerns about a host of issues and potential impacts that was not previously anticipated or addressed in the 1992 Generic Environmental Impact Statement (GEIS) or in any existing regulatory program. Indeed, new information about spills from conventional gas wells in New York that have been unremediated calls into question the adequacy of the minimal requirements of the existing regulatory program to manage conventional pathways of harm and whether the scope of the dSGEIS has to be expanded to cover those issues.

If, notwithstanding the City's objections, DEC continues to pursue a plan to permit hydro-fracturing and/or horizontal drilling in the watershed, the current dSGEIS must be rescinded and these significant omissions and deficiencies must be addressed. The available knowledge of fractures in the watershed, seepages into DEP tunnels during construction, instances of contamination in other jurisdictions, and the sheer magnitude of truck trips, chemicals, and construction in the Watershed – much of it ignored in the dSGEIS – demonstrates that risks must be disclosed, analyzed, and mitigated on at least a site-specific basis for each well drilled.

The City's most serious concerns are summarized below:

Industrialization and the City's Filtration Avoidance Determination

The dSGEIS finds that "the possibility of high-volume hydraulic fracturing presents no realistic threat to the Filtration Avoidance Determination." This is simply not the case. The proposed action constitutes a significant and unacceptable threat to the FAD, and the integrity of the City's unfiltered water supply system.

The dSGEIS' erroneous finding is based, among other factors, on "New York City's control of a substantial amount of acreage surrounding the reservoirs through fee ownership or conservation easements ...." (dSGEIS, p. 7-63) In fact, DEP owns or has conservation easements on only 13% of watershed lands. Combined with the 21% of watershed lands protected by the State or other entities, a total of 34% of watershed land can be characterized as "protected" from natural gas drilling, though it should be noted that these areas are still subject to compulsory integration into a spacing unit under State law. According to our estimates, this would still allow 3,000 to 6,000 natural gas wells in the NYC watershed (see discussion under

Cumulative Impacts). The potential for this level of natural gas development under the terms and conditions presented in the dSGEIS can reasonably be anticipated to compromise the City's ability to comply with water quality regulations, and public confidence in our ability to adequately protect the water supply.

In the event that the FAD were revoked because of the impacts of natural gas exploration in the Catskill-Delaware watershed, the City would be required to construct a water filtration facility with a current estimated cost of $10 billion to build and $100 million per year to operate. This translates to a significant increase in the price of water and sewer service currently paid by NYC consumers. Additionally, the City expects that the current filtration plant design would be inadequate to remove the chemicals that are likely to be introduced into the watershed as a result of natural gas drilling activities. Additional technology such as advanced oxidation, granular activated carbon adsorption, and/or membrane filtration processes would likely be necessary. All of these advanced processes are significantly more expensive than those included in the current design. It is also important to note that it would take 10 years or more for the City to design and build a plant in the West-of-Hudson watershed capable of filtering the contaminants that would be introduced by hydraulic fracturing.

At a minimum, any regulatory framework for gas exploration, drilling, and development must protect against risks to public health and the environment. An appropriate regulatory framework would have to identify and address the remaining risks, such as the costs to build and operate the filtration plant in the event that drilling caused or contributed to the revocation of the City's Filtration Avoidance Determination. Failure to ensure that DEC's program to regulate and oversee natural gas production fully accounts for the potential costs of drilling in the City's watershed would impose a massive unfunded mandate on the City and its water rate payers, who are already bearing the cost of several billion-dollar projects that are driven by such mandates. In recognition of this growing problem, Governor Paterson recently stated in Executive Order 17 that "the fiscal impact of any legislative or regulatory proposal that imposes a mandate should be evaluated to the fullest extent possible to consider the cost to local governments." The significant potential costs of allowing drilling in the watershed cannot simply be passed on to New York City, and must not be ignored as this process moves forward. Yet the dSGEIS does not discuss or anticipate any regulatory, fiscal, or legal mechanism to make NYC whole should it suffer harm to its drinking water system or to the Filtration Avoidance Determination.

Cumulative Impacts of Gas Drilling in the Watershed

The City concurs with NYSDEC's premise that the "...level of impact on a regional basis will be determined by the amount of development and the rate at which it occurs." (dSGEIS, p. 6-143) (emphasis added) However, the dSGEIS does not adequately evaluate cumulative impacts, as SEQRA clearly requires. Specifically, the dSGEIS does not rigorously evaluate the cumulative impacts of horizontal drilling and high-volume hydraulic fracturing under a reasonable worst-case development scenario, nor does it evaluate the extent to which the proposed mitigation measures address those impacts.

The City's expert analysis shows that at the rates and densities of natural gas well development recorded in comparable formations, 3,000 to 6,000 wells could be drilled in the NYC watershed, with annual well completion rates on the order of 100 to 500 wells per year in peak years. Delivery of the equipment, chemicals and water needed for well development will

require many hundreds of truck trips per well, as will removal of equipment and hauling of flowback water. The proposed action will generate millions of truck trips, thousands of acres of site clearing and grading, millions of tons of fracking chemicals, and millions of tons of waste from produced water. Spills of hazardous materials will be inevitable, and can result in significant harm even if they are eventually remediated. As noted above, the track record of spill response and mitigation has been called into question, even without the substantially increased risks associated with the reasonably increased risks associated with the anticipated rate of drilling in the Marcellus shale.

Water Quality

Natural gas drilling has significant potential to adversely impact water quality through a variety of mechanisms, including but not limited to on-site spills, vehicle-related spills, and subsurface migration of contaminants. While we acknowledge that some safeguards are in place or proposed, we firmly believe that the risk to the water supply is significant and unacceptable, even with these safeguards.

Fracking Chemicals

The dSGEIS does not adequately analyze types and quantities of chemicals that will be used, stored and transported within the watershed; such chemicals are not well understood in any event. The oft-repeated statistic that fracking fluids comprise only 0.5 to 2 percent chemical additives is a better indication of the enormous water requirements involved in hydrofracturing than it is of the benign nature of the process. Even at 0.5 percent concentration, the additives in fracking fluid are an order of magnitude more concentrated than the dissolved pollutants in raw sewage. At 4 million gallons (mg) per job, a 1 percent concentration of chemical additives represents 160 tons of "chemistry" – much of it hazardous, unknown, and undisclosed.

The dSGEIS disclosure requirements are insufficiently protective of human health and the environment. First and foremost, disclosure is solely to DEC. The dSGEIS concludes that any chemical information disclosed in the permit submitted to DEC would be excluded from public disclosure under the trade secret exemption to the Freedom of Information Law. Without this information, the City, and other regulatory agencies, will be greatly hampered in the ability to conduct surveillance monitoring, protect inspection staff, safely and effectively respond to spills or other emergencies, and ultimately protect the public health of the water supply consumers. The City is ultimately faced with a scenario in which thousands of tons of unknown hazardous chemicals could be introduced into the watershed each year.

Second, the disclosure requirements to DEC are insufficient in that the proposed Environmental Assessment Form (EAF) Addendum requires that drillers would only be required to identify the additives to be used, but not necessarily their composition. This is a crucial distinction since many of the products contain undefined mixtures of chemicals; information about these mixtures would be necessary to effectively monitor these hazardous chemicals in the environment. For nearly one-quarter of the 197 products identified to DEC during the dSGEIS process, complete information on composition was not provided. Further, in addition to the 260 unique chemicals identified in the industry submission, there are "an additional 40 compounds which require further disclosure since many are mixtures." (dSGEIS, p. 5-34) The fact that DEC was unable to elicit complete chemical information from service companies during the environmental review process suggests the significant challenges associated with obtaining

adequate data on chemical composition as fracking proceeds in New York State. It would also be unrealistic to assume that these submitted data cover all the products and chemicals that will be used in the future, and it is currently unclear whether the dSGEIS establishes a requirement for ongoing disclosure of chemical composition data.

Surface Spills

The dSGEIS dismisses the potential for serious adverse impacts to water quality as a result of surface spills. This finding is based on an analysis that is technically flawed and relies on several assumptions which are not at all conservative, such as complete and instantaneous mixing of chemicals and dilution of chemicals with the entire volume of upstream reservoirs (the latter assumption is also physically impossible) and absorption to the soil of all fracking chemicals. When the gross errors in the analysis are corrected, the likelihood of Maximum Contaminant Level (MCL) violations is significantly greater than predicted. Additionally, MCLs are likely to become more stringent as information on the effect of contaminants on public health continues to improve, rendering an assessment based strictly on current MCL levels inadequate.

The analysis ignores a number of spill scenarios that could realistically occur, such as a truckload of raw fracking chemicals or a tanker of flowback/produced water entering a NYC reservoir or headwater stream. Given the enormous volume of chemicals and wastewater that would be transported into and generated within the NYC watershed over a multi-decade development period, such acute spill scenarios merit more serious consideration.

In addition to acute spills, it is reasonable to expect – and data from DEC's own mining program and other states provide evidence – that a chronic level of minor spills will occur. This is an inevitable outcome of a complex mechanized industrial activity occurring hundreds of times per year across the watershed. The dSGEIS does not acknowledge or analyze the impacts from such chronic spills. Moreover, even if mitigated, the cumulative impact of chronic spills will be to compromise public and regulatory confidence in the integrity of NYC's unfiltered water supply.

Subsurface Contaminant Migration

The dSGEIS does not meaningfully consider the possibility of subsurface migration of methane or other gases, fracking fluids, or formation water or brine. The analysis ignores critical data and gives inadequate consideration to the possibility of error and long-term consequences. It focuses on the short-term impacts of hydrofracturing operations without giving due consideration to long-term subsurface changes, and underestimates the likelihood of vertical migration of contaminants. The dSGEIS' conclusion that subsurface migration is not a serious concern appears to be based on the bulk properties of the rock separating the fracking zone from shallow aquifers and DEP tunnels (see dSGEIS App. 11). While the intervening rock layers could in principle provide substantial protection against migration, the pre-existing fractures, and the fractures that will be created through the gas production process, substantially increase hydraulic conductivity by several orders of magnitude as compared with the conductivity of unbroken rock.

An equally disturbing omission is observed in the selective presentation and use of available geologic data. The dSGEIS presents only mapped faults and fails to present or evaluate the significance of hundreds of other brittle structures (e.g., shear zones and linear features) that

indicate fracturing of the underlying bedrock and pathways for hydraulic contamination. The same data source reviewed in the dSGEIS indicates that extensive subsurface fracture systems and known "brittle" geological structures exist that commonly extend over a mile in length, and as far as seven miles in the vicinity of NYC infrastructure. These fracture systems have been demonstrated to transmit fluid and pressure, as evidenced by saline water and methane seeps encountered at grade and in shallow formations near NYC infrastructure during and since its construction.

The dSGEIS also discounts the risks from failure of well casings and grout designed to prevent vertical contamination between layers, despite the well-documented occurrence of such failure in conventional gas and oil wells in New York State and elsewhere.

Contrary to the findings in the dSGEIS, migration of fracking chemicals and/or poor quality formation water into overlying groundwater, watershed streams, reservoirs, and directly into tunnels is a reasonably foreseeable risk. This concern is further substantiated by similar events that have occurred in Pennsylvania over the past few years of drilling in the Marcellus shale and new information about contamination from conventional gas and oil wells in New York State. As the State has learned from its experience with MTBE and other pollutants, once groundwater is contaminated, chemicals are very hard if not impossible to remove.

Wastewater Disposal

The large volume and character of wastewater generated by hydraulic fracturing of horizontal wells is a direct result of the technology under evaluation in the dSGEIS, and raises issues and potential impacts, which are both quantitatively and qualitatively different from considerations addressed in the 1992 GEIS.

The dSGEIS does not provide a thorough evaluation of waste disposal issues, and instead describes existing permitting requirements. The absence of a thorough evaluation of waste disposal issues is a major deficiency in the dSGEIS analysis given the large volumes of concentrated waste streams generated by natural gas development. The elevated chlorides and total dissolved solids (TDS) concentrations (228,000 mg/l and 337,000 mg/l, respectively) documented in Section 5 of the dSGEIS clearly indicate the need for analysis of wastewater impacts.

Pennsylvania's recent experience is instructive. This past year, following water quality impacts in the Monongahela River that resulted from disposal of drilling wastes at municipal wastewater treatment plants, the Pennsylvania Department of Environmental Protection proposed effluent discharge limits of 500 mg/l for TDS. Gas industry technical papers indicate that there are no treatment plants currently in operation in Pennsylvania that can meet this standard. Furthermore, the only established technology that could meet this standard (evaporation/crystallization treatment) would generate 400 tons of salt waste for every 1 million gallons of treated waste.

The analysis of wastewater disposal issues is further deficient because of the absence of an analysis of cumulative impacts. Such an analysis would presumably address the insufficiency of regional waste disposal capacity, and the potential that this lack of capacity coupled with associated high disposal costs could lead to illegal dumping. Clearly, there is a need for a

thorough waste stream analysis in order to fully evaluate potential impacts of the proposed action.

Radioactivity

The City initially raised concerns over naturally occurring radioactive material (NORM) in comments on the draft scope for the SGEIS (letter to DEC dated December 12, 2008) stating: "Drilling associated with the Marcellus and other geologic formations deposited in anoxic environments (e.g., Utica shale) will produce cuttings and waste fluids that contain radiological contaminants (such as radon and uranium), low pH (acidic) water and dissolved metals (e.g., iron), and dissolved salts." We commend DEC for obtaining Marcellus-specific monitoring data as part of the dSGEIS, but these data raise serious issues for public health, particularly with disposal of both solid waste (i.e., drill cuttings and equipment) and wastewater (flowback and/or produced water). DEC acknowledges in the dSGEIS that more analysis is needed, including an analysis of local capacity to handle the associated waste stream (both solid waste and wastewater). Such an analysis must be completed before any activity that is likely to generate radioactive waste can move forward. Proposing additional testing and evaluation in the future is not sufficiently protective of public health and does not meet the standard for an environmental review of potential impacts, which requires that such impacts be studied and disclosed prior to any decision on the proposed action.

Finally, all of these water quality risks would be heightened if the network of pads, roads, pipelines and other infrastructure induces exploitation of the deeper gas bearing shale layers (the Utica, Oriskany, or Trenton/Black River formations) that underlie the NYC watershed. Yet the dSGEIS does not analyze the likelihood of that induced exploration or its overall cumulative effects.

Water Supply Reliability and Infrastructure Integrity

Cumulative Water Withdrawal Impacts

The dSGEIS analysis does not evaluate the impacts that natural gas water withdrawals may have on pre-existing consumptive uses, despite highlighting withdrawals as a potential impact from natural gas development. As such, the mitigation measures proposed are flawed in that pre-existing consumptive uses are not required to be included in the interim passby flow calculations. The interim passby flow analysis, which is based on an outdated methodology, also lacks specific monitoring and enforcement requirements that would ensure compliance. These withdrawals could have significant impacts on the City's mandated release targets and water supply flexibility, but these impacts are not adequately disclosed or discussed in the dSGEIS.

Additionally, it is not clear that DEC has sufficient regulatory authority to mitigate adverse environmental impacts of cumulative surface water, since it lacks authority over groundwater withdrawals that are not intended for public water supplies. The dSGEIS relies heavily on the protections established by the Susquehanna River Basin Commission (SRBC) and Delaware River Basin Commission (DRBC) in their respective basins, and sidesteps the fact that DEC lacks the authority to regulate withdrawals and effectively mitigate cumulative water withdrawal impacts in the rest of the state, including the Catskill portion of the West-of-Hudson NYC watershed.

Stream/Reservoir Buffers

The setbacks established in the dSGEIS do not prevent drilling in any sensitive areas but instead require a site-specific SEQRA analysis, with no defined mechanism for DEP (or public) review, for a well pad within 300 feet of a reservoir or 150 feet of a stream. These setbacks are wholly insufficient to protect NYC drinking water quality based on the surface and subsurface contamination risks identified previously. First, the setbacks must be measured from the closest point of the natural gas spacing unit (which encompasses the full horizontal extent of well bores) and not just the well pad. As proposed, horizontal wells could be drilling below main tributaries or even the reservoirs themselves. Second, the closest part of spacing units should be excluded within a 1,000-foot buffer of streams and a 2,000-foot buffer around reservoirs. These proposed buffer zones are consistent with the setback distances required for public water supply wells established in the original 1992 GEIS. Surface water supplies deserve equivalent protections.

Infrastructure Integrity / Tunnel Buffer

The dSGEIS ignores numerous subsurface features (discussed previously under Subsurface Contaminant Migration) that could enhance mobility of drilling fluids and formation materials. These same pathways could expose the City water tunnels to elevated external pressures that they are not designed to withstand.

The dSGEIS requires a site-specific SEQRA review for issuance of a permit to drill any well whose location is determined by DEP to be within 1,000 feet of subsurface water supply infrastructure. The 1,000-foot infrastructure setback was developed in connection with vertical geothermal wells and was based on concerns associated with drilling through a City water tunnel. The concerns raised by horizontal drilling and hydraulic fracturing are entirely different for several reasons:

- Horizontal well laterals can extend for over a mile from the actual well pad (the dSGEIS would currently allow fracking to occur underneath a City water tunnel).
- The hydraulic fracturing process is specifically designed to fracture rock, which inevitably intercepts and enhances existing hydraulic pathways, and chemicals from such operations have traveled 7,000 feet or more through natural and induced subsurface fissures.
- The unreinforced linings of the City water tunnels were designed to keep water in, not to withstand external pressures. Fracking raises the distinct possibility that the unreinforced tunnel linings will be exposed to pressures in excess of their design strength. This could occur during fracturing, or it could occur after fracturing, when newly expanded fractures expose tunnel linings to naturally occurring formation pressures.
- Hydraulic fracturing operations adjacent to the naturally occurring fracture systems that intersect City water tunnels will increase the risk of (a) contaminating drinking water with fracking chemicals and poor quality formation water; (b) methane accumulation around and within DEP subsurface infrastructure; and (c) tunnel liner structural failure.
- The impact of repeatedly fracturing and expanding strata of rock underlying thousands of square miles as thoroughly and extensively as economically feasible, and then depressurizing it through the removal of compressed gas, is not addressed. Potential impacts can reasonably be anticipated to include movement at faults and fractures,

alteration of subsurface flow pathways, and vertical migration of gas, liquid and previously contained pressure.

To protect water quality and water supply reliability/infrastructure integrity, natural gas spacing units should be excluded within a buffer zone of at least seven miles from NYC subsurface water supply infrastructure. This distance is based on the lateral extent of known fractures that intersect DEP tunnels.

Failure to Comply with SEQRA

On the merits, gas drilling as proposed cannot safely be done in the watershed. And the omissions and deficiencies described above clearly show that the dSGEIS does not meet the requirements of the Environmental Conservation Law. The City's concerns with the SEQRA process are summarized below.

Segmentation

The dSGEIS has segmented the review of the proposed action by excluding certain critical elements (e.g., waste disposal, cumulative impacts, induced growth, air quality impacts, pipeline construction, and ancillary infrastructure). SEQRA requires that impacts associated with a "whole action" be evaluated and provides tests for segmentation based on timeframe, goals, geography, common planning/ownership, and functional dependence. All of the excluded actions violate one or more of these tests.

Inadequate Analysis

A number of the analyses in the dSGEIS are inadequate or incomplete and therefore do not satisfy SEQRA's requirement to identify all areas of environmental concern, and provide a reasoned elaboration of NYSDEC's conclusions.

Cumulative Impacts – The dSGEIS does not contain a comprehensive cumulative impact analysis. By neglecting to evaluate a reasonable worst-case scenario of natural gas wells in the New York City watershed, the dSGEIS does not adequately evaluate the potential adverse environmental impact from the proposed action. By focusing only on the impacts of single well development the dSGEIS does not fully disclose the potential adverse environmental impacts that could result from the proposed action under the reasonable worst-case scenario.

Induced Growth – The dSGEIS does not evaluate the potential adverse impacts of induced growth due to natural gas development. Induced growth and the resulting development would increase traffic, impervious surface areas, stormwater flows, wastewater flows, and water usage, each of which have the potential to adversely impact the region, especially without careful advance planning and analysis.

Waste Stream – The dSGEIS does not adequately evaluate the waste stream resulting from natural gas development. Many issues remain unaddressed, such as the amount of wastewater generated, treatment and disposal requirements for the wastewater, and the regional capacity for disposal. Given the large quantities of wastewater involved and the potential radioactivity of the waste stream, this must be comprehensively addressed prior to any permitting.

Public Health – The dSGEIS does not sufficiently address public health concerns. A separate impact assessment on public health is warranted given the hazardous chemicals that are proposed for use, the potential radioactivity of the waste products, the rate and scale of the drilling and accompanying activities, and, last but not least, the fact that one of the newly impacted areas supplies high quality drinking water to nearly half the State's population.

Alternatives – The dSGEIS does not address alternatives to natural gas development. Alternatives to hydraulic fracturing and waste disposal are described but not assessed. The alternatives chapter considers only potential economic and energy interests and does not acknowledge the evolving history of contamination in other states, particularly Pennsylvania, where hydraulic fracturing and horizontal drilling have occurred. Given that the potential impact on the NYC water supply was one driving force behind doing a supplemental analysis, consideration of a partial or full prohibition within the watershed would be consistent with the Environmental Conservation Law. Such a prohibition seems to have been dismissed on the basis of economic and energy interests, without a proper consideration of the full array of potential environmental impacts and costs, and without a proper balancing of environmental protection concerns.

State Administrative Procedures Act

The mitigation section of the dSGEIS relies on DEC's commitment to write permits that will impose requirements of general applicability, or requirements that would apply to all drilling applications meeting certain conditions (such as high-volume hydraulic fracturing, multi-well pads, or proximity to natural features), as a basis for its conclusions concerning the lack of impacts from these activities. Such requirements are, however, rules and therefore require promulgation pursuant to the State Administrative Procedures Act. In the absence of binding rules adopted pursuant to SAPA, the dSGEIS' statements concerning DEC's intention to impose any permit conditions are not binding. Accordingly, such statements cannot and do not militate against potential adverse impacts.

Conclusion

Balancing environmental and public health concerns with the need for adequate energy resources and economic development is a complex and challenging issue – not only in New York but throughout the nation. New York City's watershed is a unique resource and deserves special attention and consideration. Even without the benefit of the complete review mandated by SEQRA, it is clear from the technical information in the dSGEIS, and the City's own analysis, that horizontal drilling and hydraulic fracturing – using current extraction methods and based on the latest science – presents an unacceptable risk to the City's water supply, and the FAD.

If a less invasive process, using fully disclosed and better understood agents, is developed to extract natural gas in the future, the City will gladly evaluate whether it is or can be compatible with the control we are required to maintain in the watershed. But the State's proposal to permit hydro-fracking and horizontal drilling does not meet that standard.

Given the serious omissions in the supplemental analysis and the grave consequences of the proposed action, the City strongly urges DEC to rescind the dSGEIS. If DEC chooses to continue the pursuit of a plan to permit gas drilling in the New York City watershed, the deficiencies with the dSGEIS must be addressed, and a revised draft released for public review and comment. We look forward to continuing to work with DEC and NYSDOH on this important issue. If you have any questions please do not hesitate to contact me.

Sincerely,

Steven W. Lawitts

c: The Honorable Pete Grannis, Commissioner, DEC
The Honorable Judith Enck, Regional Administrator, EPA Region 2
The Honorable Richard Daines, Commissioner, New York State Department of Health
Mr. Phil Bein, New York City Watershed Inspector General

EXHIBIT O

CITY OF PHILADELPHIA

WATER DEPARTMENT
ARAMARK Tower
1101 Market Street
Philadelphia, PA 19107-2994

HOWARD M. NEUKRUG,P.E.
Water Commissioner

March 3, 2011

Commission Secretary
Delaware River Basin Commission
P.O. Box 7360
West Trenton, NJ 08628

Re: Comments on DRBC Natural Gas Development Regulations

Dear Commission Secretary:

One of the Philadelphia Water Department's (PWD) core missions is the provision of safe, high quality drinking water to our nearly two million customers in the Philadelphia region. Philadelphia's drinking water sources are the Delaware and Schuylkill Rivers, and our pledge to our customers extends to the stewardship of our region's water resources. To this end, PWD has embraced a watershed protection approach that tracks and evaluates events and practices that may cause immediate or long term impacts on water quality. It is with an eye towards potential long term repercussions that PWD is closely following the discussions surrounding natural gas drilling.

We believe that the current regulatory framework, if enforced, is adequate to protect our water supply from *immediate* threats. Support from DRBC through its new regulatory framework is needed, however, to help monitor and protect us from *long term* impacts. In light of this goal, DRBC's new regulations should be framed around complementing and strengthening state regulations. One such example already in the draft regulations is the requirement to store wastewater from hydraulic fracturing in closed tanks prior to treatment or transportation of the wastewater. This requirement helps supplement state regulations in Pennsylvania and helps protect Philadelphia's drinking water supply from the potential cumulative impacts of repeated spills and leaks from storing wastewater in open air pits. The following recommendations reflect other improvements to DRBC's regulations that would address key concerns for drinking water suppliers. Also included are recommendations that supplement changes to the draft regulations and that are critical to understanding and

minimizing the potential impacts of natural gas development in the basin. Lastly, we request clarifications of the draft regulations to better understand their full impact.

RECOMMENDATIONS FOR DRBC'S DRAFT NATURAL GAS DEVELOPMENT REGULATIONS

1. **Increase Groundwater and Surface Water Monitoring Requirements**

   A. Increase the Number of Samples Required

   Prior to alteration of a well pad site, DRBC's regulations require one sample at a representative number of groundwater wells within 1,000 ft. For surface water, the regulations require one sample up gradient and one sample down gradient of the planned well pad site. Additionally, the draft DRBC regulations require annual monitoring at the same locations following well construction until the well is plugged. This sampling helps to supplement Pennsylvania regulations, which do not stipulate monitoring of this type. Yet the number of samples requested is not sufficient. Much more data is needed to effectively evaluate baseline conditions and to detect and track changes following drilling and hydraulic fracturing of a well. For groundwater, PWD recommends two samples prior to site alteration and one sample every three months thereafter. For surface water, PWD recommends sampling every two weeks beginning at least six months prior to site alteration. Sampling should occur on a fixed schedule and continue throughout the land clearing, drilling, hydraulic fracturing, and production phases of each well.

   B. Specify the Parameters to be Analyzed

   All samples – regardless of whether they are groundwater or surface water samples – should be analyzed for the parameters regulated under the Safe Drinking Water Act. Additionally, detection limits should be set to those established by EPA under the Safe Drinking Water Act.

   C. Install Continuous Monitoring Probes at Priority Surface Water Locations

   Natural gas companies operating in the Delaware River Basin should be required to fund continuous monitoring probes at priority locations selected by DRBC in collaboration with the Monitoring Advisory Committee. Parameters to be sampled for include, at a minimum, conductivity, pH and temperature. This continuous monitoring is critical for evaluating long-term data trends and detecting potential cumulative changes due to natural gas drilling in the basin. Monitoring units at these locations should be connected to the Delaware Valley Early Warning System, which is a secure notification and monitoring system designed to support downstream users and emergency responders in case of spills, accidents and other emergencies. This system already has much of the infrastructure necessary to accommodate multiple monitoring units. Additional monitoring locations could easily be incorporated.

2. **Do Not Allow Discharges of Treated Natural Gas Wastewater Upstream of Philadelphia's Intakes on the Schuylkill and Delaware Rivers**

The impacts of discharging treated wastewater from hydraulic fracturing on surface water and drinking water quality are unknown. Other states with similar shale formations use alternate methods of wastewater disposal, so data to evaluate the impact of discharging wastewater to surface waters are limited. Pre-treatment regulations in Pennsylvania established to address total dissolved solids do not directly deal with other parameters of concern found in natural gas wastewater, such as radionuclides. The ancillary effects of pre-treatment on these parameters, and ultimately on the quality of surface waters, have not been studied sufficiently. Additionally, no water quality criteria exist for many of the constituents found in natural gas wastewater, including certain metals. As a result, regulators are not able to develop permits that effectively protect water resources. Until more data and information are available, all discharges of treated natural gas wastewater upstream of the Philadelphia drinking water supply should be prohibited.

3. **Require Full Reforestation of Lands Cleared to Accommodate Drilling**
   Forests provide irreplaceable protection of drinking water supplies. Yet current regulations in Pennsylvania, while requiring site stabilization and vegetative restoration, do not require reclamation of a well pad site that was once forested back to its original state. PWD requests that DRBC's regulations be modified to supplement state law by requiring full restoration and reforestation of all lands that are impacted by gas drilling and related activities, including access roads, when drilling is complete. This is especially critical for the long-term viability of multi-use state owned forest lands where much of this drilling will occur.

4. **Expand Land Application Prohibitions**
   Page 59 of DRBC's draft regulations states that "wastewater, recovered flowback and or production water and brines from natural gas well pads may not be applied to any road or other surface within the Delaware River Basin." This prohibition should be expanded to include treated wastewater and solids produced from the treatment of brines from natural gas well pads.

OTHER RECOMMENDATIONS FOR ADDRESSING THE POTENTIAL IMPACTS OF NATURAL GAS DRILLING ON PHILADELPHIA'S DRINKING WATER SUPPLY

PWD recommends the following actions, in addition to the above changes to the draft regulations, that will help minimize the potential impacts of natural gas development in the basin. PWD encourages a commitment to these activities by DRBC and other regulating agencies before drilling occurs in the basin.

1. **Encourage Participation in the Delaware Valley Early Warning System**
   PWD requests that all entities dealing with hydraulic fracturing fluids or wastewater in the Delaware Basin – including haulers and treatment facilities – be encouraged to join the Delaware Valley Early Warning System to support advanced notification of downstream surface water users of spills and accidents.

2. **Support a Study that Evaluates the Long-Term Implications of Natural Gas Drilling on Drinking Water Supplies**
   A study of the long-term implications of natural gas drilling for Philadelphia's drinking water supply is needed. At a minimum, this study should include an evaluation of the cumulative impact on surface waters of improperly cased wells and on-site spills and accidents involving toxic substances. Additionally, the study should evaluate transportation pathways in the Delaware River Basin of hydraulic fracturing fluids and wastewater and determine the risk of spills and accidents in proximity to drinking water supplies. The study should also evaluate the potential impacts of disposing recovered wastewater from hydraulic fracturing upstream of PWD's intakes, should this activity be allowed.

3. **Participate in a Marcellus Shale Task Force**
   A task force committed to protecting Philadelphia's drinking water supply is needed. This task force should represent a diversity of stakeholders including, at a minimum, members of the gas industry, state agencies, DRBC, the environmental community and PWD. This task force would help direct the cumulative study described above, make recommendations for future regulatory changes, and help improve coordination among regulators and regulated entities for the benefit of drinking water supply protection.

4. **Commit to Future Regulatory Changes as Needed**
   DRBC should consider the recommendations from the cumulative impact study and Task Force and update its regulations accordingly. Permitting should cease if any contamination of drinking water supplies due to natural gas drilling or hydraulic fracturing is detected.

REQUESTED CLARIFICATIONS OF DRBC'S DRAFT REGULATIONS

PWD requests several clarifications of the draft regulations in order to improve our understanding of their full impact.

1. PWD has conducted an extensive analysis of both Pennsylvania's and DRBC's regulations for natural gas development. As a result of this analysis, we have identified significant overlap between the two sets of regulations in the areas of planning, permitting, reporting and bonding. In some cases, only minor differences exist within these areas of overlap. PWD recommends that guidance be developed to streamline both sets of regulations. This will help minimize confusion – and possible non-compliance – within the gas industry.

2. More explanation of DRBC's proposed Approval by Rule is needed. A chart demonstrating when an Approval by Rule is applicable would be helpful. An explanation of how, specifically, the Approval by Rule process works and its implications for public notification is also requested.

3. More information about DRBC's planned methods of inspections and enforcement at all stages of natural gas development is needed.

We look forward to continuing our longstanding partnership with the DRBC as we address the many challenges to water quality in the Delaware River Basin. Thank you for the opportunity to comment on the Draft Natural Gas Drilling regulations. Please do not hesitate to contact me with any questions.

Sincerely,

Howard Neukrug, P.E.
Commissioner

EXHIBIT P

Potential for Impairment of Freshwater Mussel Populations in DRBC Special Protection Waters as a Consequence of Natural Gas Exploratory Well Development

By

Robert M. Anderson, Fish & Wildlife Biologist, U.S. Fish & Wildlife Service
Expert in Freshwater Mussels and Mussel Habitat

and

Danielle A. Kreeger, Ph.D., Science Director,
Partnership for the Delaware Estuary
Expert in Aquatic Ecology and Functional Ecology

November 23, 2010

Our testimony addresses the question of whether natural gas exploratory wells have the potential for a substantial effect on the quality of waters classified by the Delaware River Basin Commission (DRBC or "Commission") as Special Protection Waters (SPW), for which the Commission has established a policy of "no measurable change except towards natural conditions . . . ." *DRBC Water Quality Regulations* § 3.10.3 A.2. We focus on the water quality value and susceptibility to impairment of freshwater mussel populations, which both depend upon and contribute to the exceptional water quality of the main stem upper and middle Delaware River. We also highlight characteristics of the dwarf wedgemussel, a federally listed endangered species found in portions of the main stem upper Delaware River and its tributaries underlain by the Marcellus shale. The dwarf wedgemussel is particularly susceptible to siltation, hydrologic changes, exposure to contaminants, and losses of population caused by invasive species, all of which are likely to accompany the development of natural gas in the region, including the construction of exploratory wells. We contend that in light of the potential for adverse effects on water quality and aquatic resources as a result of natural gas exploratory well development, regulation by the Delaware River Basin Commission is warranted. Such regulation may help to prevent impairment, ensure that any water resource impacts, should they occur, are measured, and require that those responsible for causing damage to water quality and aquatic resources have the means and legal obligation to perform restoration.

I. Freshwater Mussel Status and Trends in the Delaware Basin

Freshwater mussels include abundant species that are vital for ecosystem function. These are also the most imperiled of all animals and plants in the Delaware River Basin, as elsewhere in North America (Williams et al. 1993.) This otherwise highly successful and diverse group has specific life history characteristics that contribute to their apparent sensitivity and have resulted in substantial declines in range and abundance of some species. These characteristics include a dependence upon populations of an unrelated species of fish for successful reproduction, low annual recruitment balanced by a long reproductive life-span, relative immobility, and filtering of water to extract food.

II. Mussel Assemblages in the Delaware River System

Population Abundance and Biodiversity

As a result of being undammed and well managed, the upper mainstem Delaware River retains healthy numbers of several native species of freshwater mussels (Lellis 2001, Lellis 2002). Although there are numerous state and federal listed imperiled species in the basin (e.g. dwarf wedgemussels), the numerical health of the collective mussel assemblage is sizeable in the river itself, extending down even into the tidal areas of the Delaware River.

Approximately 60 species of bivalve mollusks live in headwater streams and lakes of the Delaware basin as well as in the non-tidal main stem and other large tributaries, freshwater tidal areas, and in the brackish and saline portions of the Estuary (Kreeger and Kraeuter 2010).

Approximately 12-14 species are native freshwater mussels (Unionidae, Table 1) based on historical accounts (e.g., Ortmann 1919.) Numerous species of special concern to PA and NJ are known to remain in portions of the basin (Table 1) including the Upper Delaware. Although the status terminology varies among states, nine of the twelve remaining native species are deemed imperiled by New York, New Jersey, Pennsylvania, and/or the Federal Government, or are deemed to be globally imperiled (Table 1.)

Scientific Name	**Common Name**	**Conservation Status**			
		NY Status	**NJ Status**	**PA Status**	**Global/ Federal Status**
Alasmidonta heterodon	Dwarf wedgemussel	Critically imperiled/ **Endangered**	Critically imperiled/ **Endangered**	Critically imperiled/ **Endangered**	Critically imperiled/ **Endangered**
Alasmidonta undulata	Triangle floater	Apparently secure	Imperiled/ **Threatened**	Vulnerable	Apparently secure
Alasmidonta varicosa	Brook floater	Critically imperiled/ **Threatened**	Critically imperiled/ **Endangered**	Imperiled	Vulnerable/ **Species of concern**
Anodonta implicata	Alewife floater	Critically imperiled	Secure	Not ranked	Secure
Elliptio complanata	Eastern Elliptio	Secure	Secure	Secure	Secure
Lampsilis cariosa	Yellow lampmussel	Vulnerable	Imperiled/ **Threatened**	Vulnerable	Vulnerable
Lampsilis radiata	Eastern lampmussel	Apparently secure	Imperiled/ **Threatened**	Critically imperiled	Secure
Leptodea ochracea	Tidewater mucket	Critically imperiled	Imperiled/ **Threatened**	Critically imperiled/ extirpated	Vulnerable
Ligumia nasuta	Eastern pondmussel	Vulnerable	Critically imperiled/ **Threatened**	Critically imperiled	Apparently secure
Maragatifera maragatifera	Eastern pearlshell	Imperiled	Not ranked Proposed	Critically imperiled/ **Endangered**	Apparently secure

			Endangered		
Pyganodon cataracta	Eastern floater	Apparently secure	Secure	Vulnerable	Secure
Strophitus undulatus	Creeper	Apparently secure	Vulnerable/ **Species of concern**	Apparently secure	Secure

Table 1. Conservation status of native freshwater mussel species of the Delaware River watershed. Bold text indicates legally protected species status by state. Natural Heritage status accessed on NatureServe (www.natureserve.org) on November 16, 2010.

Within the Delaware basin, colonies of dwarf wedgemussels, a federally listed endangered species, currently are found only in portions of the main stem upper Delaware River and in four tributaries – the Neversink River, within the drainage area of DRBC Special Protection Waters in New York State, and the Flat Brook/Little Flat Brook, Paulins Kill River and Pequest River in New Jersey. The distribution of dwarf wedgemussels was once much wider across the mid-Atlantic watersheds than it is today.

The natural mixed-species assemblage of mussels would have consisted of aggregated populations of numerous species, occupying different niches (benthic habitats) within the stream, and collectively filtering a tremendous amount of water. Today, only one of our native 12+ mussel species can be readily found (*Elliptio complanata*). Unfortunately, mussel abundance appears greatly reduced in virtually all tributary streams and rivers in the Delaware River Basin. (PDE 2008.)

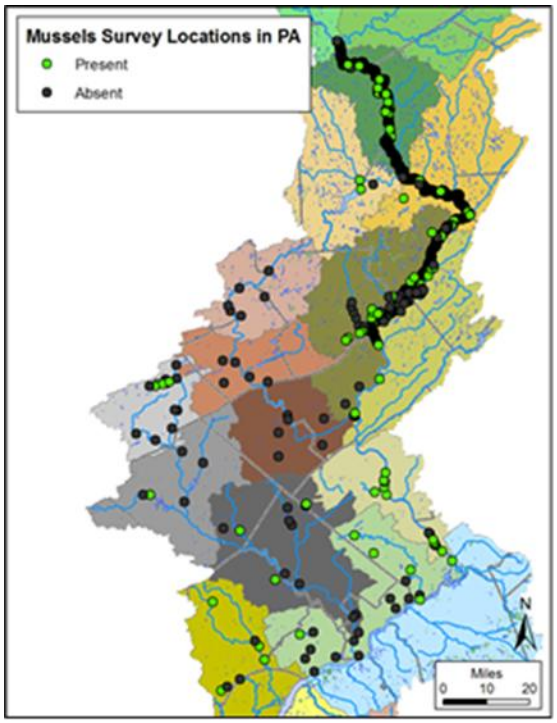

Figure 1. Presence and absence of freshwater mussels in Pennsylvania locations where they were historically reported as surveyed by various researchers since 1980.

Based on the limited current distribution of mussels of any species in tributary streams (<10% in southeast PA, limited surveys elsewhere, Fig. 1), and the patchiness and low mussel abundance (<1 m^2) within streams where they are found (often only in wooded reaches), the healthy assemblages that exist in the main stem and tributaries of the Upper Delaware are particularly valuable and require protection.

Preservation of Existing Colonies is Critical to Stemming Mussel Declines

A number of factors make it critically important that existing colonies be preserved to serve as broodstock for restoring populations to streams from which they have been lost.

Mussels likely become extirpated from streams because of either: 1) general impaired water or habitat quality, 2) specific incidents (i.e. spills) that cause acute mortality in a single event, 3) overharvesting/predation, or 4) loss of fish host species to support larval growth and distribution.

Once extirpated from a stream or reach, mussels are not able to recolonize easily, particularly if there is no longer broodstock nearby. In some tributaries, dams and other impediments to fish passage may block dispersal of juveniles (via fish hosts, see life history below) back into the stream (McMahon 1991). Most mussels have a long lifespan (30-100 years) and don't reproduce until at least 8 years old. Therefore, even if conditions permit redistribution via fish hosts, recolonization and recovery can take decades.

Remaining mussel beds in the Delaware River are vulnerable to spills and land-based development. Protection of the existing metapopulation includes ensuring that it does not become further fragmented, less able to disperse and exchange genes, and as a result, less resilient.

III. Importance of Freshwater Mussels

There are societal and ecological reasons for maintaining large populations of filter feeders in aquatic ecosystems. Where abundant, they help to maintain water quality, stabilize substrates, decrease erosion, and create beneficial habitat complexity. Some species are also commercially and historically important. Filter-feeders are effective at accumulating many classes of contaminants and so are useful in assessing water and sediment contamination in specific areas and for specific time periods. The health of individual bivalves and assemblages of bivalves can directly indicate the health of the aquatic ecosystem.

Ecosystem Function Values

Freshwater mussels, like most bivalves, are considered “ecosystem engineers” because they modify habitat complexity and improve water quality, often dominating the ecology of rivers and streams where they are still abundant. Similar to oyster and coral reefs, these animals form dense assemblages that create habitat conditions beneficial for other organisms. The habitat benefits are myriad, including physical, chemical, and biological modifications. They help to stabilize stream channels and decrease bed transport during high flow events (physical). The vertical structure of large-bodied mussels also furnishes stable microhabitats for benthic macroinvertebrates and fish (physical). Mussel shells protruding from the bottom increase turbulent mixing in the benthic boundary layer and provide refugia for other fauna.

Through their biodeposits (agglutinated mussel feces and pseudofeces), mussels enrich sediments (Vanni 2002, Howard and Cuffey 2005) with organic materials and biochemical compounds (chemical) providing for enhanced benthic algal production and greater food resources for other benthic fauna (biological).

Although mussel beds provide many ecosystem services such as streambed stabilization and enrichment of sediments for other animals and plants, they are most valued for their water

processing ability. Mussels improve water quality by removing suspended particulates through filter-feeding. Each adult mussel filters liters of water per day during the growing season, and the combined biofiltration by beds of mussels in healthy streams may exceed the system's downstream flushing volume. For instance, Dr. Kreeger estimated that a relic population of 500,000 mussels on the lower Brandywine River in Pennsylvania still filters more than 1 billion liters and removes 26 metric tons of dry total suspended solids (TSS) each summer season. This population is old, may not be reproducing, and represents a fraction of the system's carrying capacity for mussels. Approximately 4 billion *E. complanata* are estimated to reside in the Delaware River Basin today and they collectively filter about 10 billion liters of water per hour in the summer (Kreeger, unpublished).

Water quality and mussel abundance in the main stem and tributaries affect the ecosystem health of the Delaware Estuary. Kreeger and Kraeuter (2010) estimated that populations of all bivalve species in the Delaware Estuary watershed collectively filter more than 100 billion liters of water every hour during warmer seasons (10^8 m^3 hr^{-1}). If true, this represents about 2500 times the volume of freshwater entering the tidal estuary every hour (Kreeger and Kraeuter 2010.) Still, many streams contain no mussels at all, and others, such as the lower Brandywine, host older populations that may not be reproducing.

Biofiltration by mussels has direct implications for reduction of impacts of stormwater runoff and particulate nutrient control. Since much of the material filtered from the water column (e.g. particle bound nutrients, phytoplankton) is metabolized and then either used by the mussels or transformed into usable materials by other organisms, mussels facilitate nutrient control in streams and rivers.

Other important ecosystem functions include serving as prey for wildlife, biogeochemical cycling and remineralization, and in some areas facilitation of microbial denitrification. Freshwater mussels are eaten by many mammals and birds (van Tets 1994, Tyrrell and Hornbach 1998). Mussels therefore represent important links in aquatic food webs by feeding on microscopic matter at the base of the food chain and in turn being eaten by secondary consumers such as vertebrates.

In healthy rivers such as the main stem upper Delaware River where mussels are numerous, base-of–food-web conditions are richer and ecological turnover rates higher, compared to streams with few mussels.

In summary, healthy beds of mussels provide a multitude of structural and functional services including nutrient sequestration and cycling, substrate stabilization, suspended sediment removal, and the transfer of particulate matter from the water column and into easily assimilated foods for other aquatic species, including fish (Bauer and Wächtler 2001, Pusch et al. 2001, Kreeger 2004).

Bioindicator Value

Mussels are long-lived "sentinel bioindicators", meaning their abundance, biodiversity, and physiological health can tell us a great deal about overall environmental conditions (Kreeger et al. 2002; Martel et al. 2003, PDE 2008). Being relatively sessile, long-lived (up to 100 years), and sensitive to environmental conditions, freshwater mussels are excellent bioindicators of

long-term changes in watershed condition. Due to their limited mobility that prohibits their movement to escape suboptimal environmental conditions, mussel fitness and population vigor is therefore directly indicative of local conditions. In addition, they are indicators of long-term habitat stability because their riverbed habitat is dependent on channel hydraulics and sediment transport.

Internationally, suspension-feeding bivalves have long been considered to be among the best bioindicators of aquatic ecosystems (Dame 1996). For example, in 1976 the U.S. instituted the "Mussel Watch Monitoring Program" to examine the environmental impact of pollution in aquatic ecosystems. Although initially conceived as including bivalves in marine, estuarine and freshwater habitats, the concept was embraced primarily by scientists and resource managers in marine habitats, and the program thereafter focused on marine species such as oysters and blue mussels. The program has been extended to the United Kingdom, France, Canada, Australia, Japan, Taiwan, India, South Africa and the Soviet Republic. In 1986, the U.S. program evolved into the National Status and Trends Mussel Watch Project. Today, a diverse array of chemical and biological contaminants is uniformly analyzed in bivalve tissue from more than 280 coastal sites in the U.S. Mussel Watch.

A comparable, bivalve-based biological monitoring program for freshwater systems is technically feasible but not yet developed, although many studies are now using caged mussels to monitor water quality (e.g., Kreeger et al. 2002).

Due to their unparalleled ability to filter water and improve water quality, suspension-feeding bivalves such as mussels are also perceived as top restoration targets, because enhanced mussel populations will promote positive feedbacks for water and habitat quality, which then benefit mussels. Again, where we are fortunate to have healthy mussel colonies, it is essential that they be preserved.

IV. Potential for Impairment of Freshwater Mussels as a Result of Activities Associated with Development of Natural Gas Exploratory Wells

The greatest diversity and abundance of mussels are associated with clean-swept sand and gravel substrates, but as largely sessile organisms, the complex life history traits of mussels make it possible for populations to thrive in a highly dynamic environment where rapid changes in flow and water quality can occur at each rain event. These same adaptations, however, limit the ability of freshwater mussels to withstand, or recover from, lethal and chronic impacts to which these animals are sensitive, such as increased siltation, water quality alteration, hydrologic alteration, and introduced species. These factors are discussed in greater detail below.

Sedimentation

Mortality, injury and stress to mussels from siltation and other types of sedimentation caused by onshore construction (*i.e.,* staging areas and access road use) is more likely to occur near the source, but erosion and siltation in tributaries at distant locations in the watershed can cause damage when this material is flushed downstream. Silt in the form of increased turbidity and suspended sediment transport is detrimental to mussel health and habitat because it reduces the

depth of light penetration leading to alteration of primary productivity, decreases oxygen levels, increases water temperature, irritates or clogs mussel gills, and deposits silt on the substrate.

High turbidity may also interfere with sight lures, such as conglutinates, which attract host fish. Silt that settles from the water column can smother, bury and/or clog the gills of freshwater mussels unable to avoid these effects due to the extent of siltation or particular phase of the animals' annual life history (for example, gravid female mussels hold eggs and young within a specialized gill structure for weeks to months of a year).

Silt deposition also affects mussels by smothering the eggs or larvae of the fish host populations and by reducing food availability for either the fish or the mussels themselves. Siltation also may result in reduced dissolved oxygen and increased organic material at the substrate level (Ellis 1936, Harman 1974) even when it does not blanket the substrate due to quantity or local water velocity. Silt that settles between sand and gravel particles alters water flow, food and oxygen through the gravel. The interstitial space between sand and gravel is vital for spawning habitat and survival of young host fish and juvenile mussels. When this area becomes unsuitable for juvenile mussels, the population may be unable to reproduction even when the adults continue to survive. Finally, alteration of sediment grain size or excessive volumes of highly mobile soft sediments can increase the risk of scour and hinder the sediment-stabilization benefits of mussels

Excessive sedimentation reduces suitable bottom habitat for mussels, leading to reduced populations and reduced ecosystem services.

Excessive sedimentation can smother mussels, causing acute mortality, reduced populations and reduced ecosystem services.

Suspended Sediments

As filter feeders on microscopic food items, mussels are very susceptible to not only acute mortality due to smothering by silt but also high sediment loads in the water. High turbidity can directly hinder or prevent filter-feeding and respiration when mussels close their valves to avoid intake of silt. At sublethal levels, silt interferes with feeding and metabolism in general (Aldrige *et al*. 1987) because the mussels must divert more energy to sort silt particles from food, again resulting in starvation. Over time, this will reduce an animal's fitness through starvation and, at the population scale, decreases biofiltration services.

Finally, chemicals and compounds are often bound to, and mixed with, fine silts due to their high surface area-to -volume ratio and positive charge. While mussels have some ability to select particular particle sizes, they indiscriminately feed on vast numbers of these small particles, both organic and inorganic. Since particle capture is achieved on the soft tissue gills, which are also used for gas exchange (countercurrent), they have a high degree of exposure to any particle-associated chemicals. Furthermore, particle sorting is inefficient on the gills and labial palps prior to ingestion, so these animals unavoidably consume a variety of non-food particles. Although the chemical conditions in the digestive tract of the mussel can metabolize or mobilize some of the particle-associated contaminants, the high surface area-to -volume ratio of the very small particles exposes the animal to higher levels of toxic compounds than non-filter feeding species that consume larger prey.

In summary, filter feeding bivalves such as freshwater mussels are typically exposed to greater amounts of both waterborne dissolved contaminants and particle-associated contaminants than

other aquatic organisms. Although some classes of contaminants can be broken down through metabolism, most tend to be bioaccumulated within the tissues of the animals, leading to either acute mortality, chronic stress, or mediation into the food web as other animals prey on mussels. For these reasons, bivalves are regarded as sentinel bioindicators around the world; e.g. by International Mussel Watch.

Excessive suspended sediments can impair feeding processes of mussels, leading to acute or chronic stress, reduced fitness and populations, and reduced ecosystem services.

Excessive suspended sediments that include contaminants can be efficiently captured and often efficiently bioaccumulated by mussels, leading to acute or chronic stress, reduced fitness and populations, and reduced ecosystem services, as well as facilitating contaminant entry to aquatic food webs.

Brines, Contaminants, Water Quality

Freshwater mussels are very sensitive to water quality and most classes of contaminants. Contaminant exposure can be particle-mediated (discussed above) or direct via dissolved compounds or attributes associated with the water (discussed here.) Because freshwater mussels feed and respire by filtering large volumes of water across many thin tissue layers (e.g., mantel, gills) they are highly exposed to changes in water quality. Therefore, dissolved toxins (e.g. heavy metals, TDS, biocides) are rapidly taken up by direct absorption (Russell and Gobas 1989, Metcalfe Smith et al. 1996, Riedel et al. 1998) and indirectly via the food (Wikfors et al. 1994).

Mussels can temporarily (hours to days) avoid some contaminants or poor water quality (e.g. low dissolved oxygen) by closing their shells, if the contaminant is of a type and at a concentration that the animal can detect.

Suboptimal water quality (e.g. high conductivity) or the presence of waterborne (dissolved) contaminants might cause acute toxicity and mortality by exceeding mussel tolerance levels.

Suboptimal water quality or the presence of contaminants will impart chronic toxicity to mussels, leading to decreased productivity or reproductive output due to stress or bioaccumulation of contaminants in soft tissues.

Stressed mussels consume more oxygen, especially at higher temperatures, potentially contributing to low DO in some deeper areas.

Physiological impairment due to acute or chronic toxicity from chemical or high solute exposure will reduce population-level ecosystem services, especially biofiltration services.

Ecological Flows

As aquatic organisms, freshwater mussels can survive only brief exposure to the atmosphere, particularly when high temperatures rapidly desiccate exposed mussels or when low air temperatures quickly freeze exposed mussels. Very low water can buffer temperature changes to some extent but low water velocity also allows for greater solar exposure in the summer and increased temperature (and decreases in dissolved oxygen) resulting in stress and mortality.

Similarly, low water during colder periods can result in the formation of ice, which in shallow water can reach the substrate, killing any mussels that freeze.

Riverine mussel species depend upon flow for not only food and oxygen but also to maintain water quality and shape the physical habitat. For example, reduced flow increases the likelihood of silt deposition in areas that may typically have velocity that precludes deposition, and contaminants in the water are increasingly concentrated during low flow events.

Sustained low flows, which could result from unregulated withdrawals from headwater streams, can alter quality and quantity of food, causing stress and reproductive failure for mussels.

Low flows can interfere with mussel reproduction if fish hosts are unavailable for mussel larvae, depending on seasonality.

Any physiological impairment due to extreme low or high temperatures associated with low flows or reduced habitable bottom will reduce population-level ecosystem services, especially biofiltration services.

Invasive Species

Activities that result in transfer of water between watersheds have also resulted in the transfer of exotic or invasive species that can cause direct mortality of freshwater mussels through predation, toxicity, and disease or through competition for food or habitat. Resource management agencies have taken great pains in recent years to educate the public and institute practices to prevent the accidental spread of invasive species by anglers, boaters and other recreationists.

Once established in a waterway, zebra mussel populations can become extremely abundant, directly competing with native mussels for food and rapidly covering any exposed surface of a mussel shell. In some locations, populations of native freshwater mussels have been severely reduced, or eliminated, after zebra mussel colonization that altered substrate, flow, and food availability.

In the fall of 2009, Dunkard Creek, a tributary of the Monongahela River located along the border of southwestern Pennsylvania and West Virginia experienced a massive aquatic kill affecting native freshwater mussels, fish and salamanders in a 43-mile reach of the Creek. The kill was associated with a spike in conductivity that may have caused direct mortality of freshwater mussels, but which also contributed to the bloom of an invasive marine alga *Prymnesium parvum* or "golden alga", a species that proliferates in saline waters more typical of coastal Texas than the Appalachian Mountains of Pennsylvania. Golden algae produce a toxin fatal to other aquatic organisms. The species had never been observed in Pennsylvania waters before the Dunkard Creek aquatic kill but is known to thrive at the higher TDS concentrations that are often associated with mining and drilling activity. Its presence in state waters makes spread of the species to other surface waters of the state highly likely. Transfer of water between basins increases the risk that invasive species like golden algae and zebra mussel will also be inadvertently introduced to the Delaware Basin. Once established, invasive species are very difficult or impossible to remove.

Loss of Forest Cover

Some mussel species depend on leaf litter inputs for their nutrition. Forest loss or fragmentation, especially in areas near streams and rivers, has the potential to significantly impair food quality and quantity as well as degrade stream habitats for mussels by altering nutritional conditions as well as physical and chemical habitat conditions. In streams of southeast Pennsylvania, for example, the only remaining mussel beds are found within heavily forested areas of watersheds such as the Brandywine and Ridley Creeks – mussel abundance decreases dramatically in stream reaches above and below forested segments.

Loss or fragmentation of forests near streams and rivers can impair mussels by altering nutrition support and degrading habitats, thereby reducing mussel populations and ecosystem services.

V. Special Considerations – Dwarf Wedgemussels

The federal endangered dwarf wedgemussel (*Alasmidonta heterodon*) is sensitive to many of the same threats described above for other native species of freshwater mussels. Siltation, hydrologic changes, and contaminants are among the threats to the species survival cited at the time it was listed in 1990 (55 FR 9447 9451; U.S. Fish and Wildlife Service 1993).

Dwarf wedgemussels have characteristics that likely increase their susceptibility to these factors. First, the species is small compared to most other freshwater mussel species, (in the range of about an inch in length); therefore, relatively minor siltation events can deposit a smothering silt layer that reaches a depth that animals cannot push above.

Second, although they require flowing water and occur in a diversity of habitats from small streams to large rivers, dwarf wedgemussel are a thin shelled species that could be easily transported during a scour event. Like many freshwater mussels, dwarf wedgemussel populations tend to occur in areas protected from high-flow events, such as side channels of larger rivers and lower gradient streams. These low to medium velocity areas tend to have finer particle size substrates. Infiltration of relatively smaller amounts of silt between sands and smaller gravel particles can quickly hinder interstitial flow.

In the Delaware River this microhabitat preferred by dwarf wedgemussels tends to be away from the main channel, and therefore it is very susceptible to low flow exposure and associated changes in temperature. The seasonality of low flow and temperature rise may also be critical for dwarf wedgemussel reproduction and nutrition since freshwater mussels require specific food conditions for reproductive conditioning.

Dwarf wedgemussels are sensitive to all of the factors listed in Sections I-IV and potentially more susceptible than other mussel species to sedimentation, low flow, and temperature extremes.

VI. Management Implications for Natural Gas Development

It is our opinion that natural gas drilling activities, including the construction of natural gas exploratory wells, pose a substantial risk to mussel populations in the Special Protection Waters

of the Delaware River Basin but that this risk can be reduced through the mandatory use of protective management practices of the types set forth below:

A. Consistent use of avoidance and minimization measures across the supporting watershed in three states to reduce the risks that siltation, spills or other releases of contaminants, flow changes and the spread of invasive species could adversely affect mussel populations, including the federally listed dwarf wedgemussels that inhabit the upper Delaware River.

B. Implementation of stormwater management and erosion and sedimentation control practices to help minimize sources of sediment during and after construction of natural gas well pads, wells and impoundments.

C. Monitoring of water quality, flow conditions, and invasive species in potentially affected areas before, during and after project construction in order to identify where preventive measures may have failed, where they were effective, and where mitigation or restoration measures are warranted.

D. Monitoring of the diversity, fitness and abundance of freshwater mussel assemblages in potentially affected areas.

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