to report monitoring well data collected during the hydraulic fracturing operation. 6 NYCRR § 750-3.8(c) should be modified to require the HVHF SWPPP to include provisions to monitor, record and submit to the department the average and maximum injection pressure for each HVHF stage and the results from the monitoring of changes in water level, EC, and turbidity, during each HVHF stage at the dedicated groundwater monitoring wells. Records should be submitted to the department and made public on a GIS site.

6 NYCRR § 750-3.8(c)(2) Monitoring Requirements in HVHF SPDES Permits

Revised Proposed Regulation: Newly proposed section 6 NYCRR § 750-3.8(c)(2) requires the HVHF General Permit to include a Stormwater Pollution Plan that includes provisions to monitor and record the "volume of all recycled wastewater." However, the draft SPDES General Permit for Stormwater Discharges from HVHF is silent on the issue of recycled wastewater.

Recommendation: NYSDEC should amend the SPDES General Permit Part IX.A., "General SWPPP Requirements," to include provisions to monitor and record the volume of all recycled wastewater so that it is consistent with the requirements of this subsection.

6 NYCRR § 750-3.11(d) Setbacks from Principal Aquifers, Perennial or Intermittent Streams, Storm Drains, Lakes or Ponds within which HVHF Operations Cannot Be Authorized by a HVHF General Permit

Revised Proposed Regulation: 6 NYCRR § 750-3.11(d) prohibits HVHF GPs from authorizing HVHF operations sited within 500' from principal aquifers, and within 300' from wetlands and perennial or intermittent streams, storms drains, lakes, or ponds, and instead requires authorization under an individual SPDES permit.

Prior Comment and Response: Although NYSDEC accepted our 2012 Recommendations to increase setbacks around wetlands and around perennial or intermittent streams, storm drains, lakes, or ponds, NYSDEC did not adequately address our additional recommendation to further increase setbacks around principal aquifers, as well as streams, storm drains, lakes, and ponds. In Response 3785, NYSDEC provided its justification for preventing HVHF operations within 500' of principal aquifers from obtaining coverage under an HVHF SPDES GP, as opposed to prohibiting all HVHF operations within 500' of principal aquifers. NYSDEC stated that this distinction stems from the fact that principal aquifers do not serve major municipal water supply systems and therefore serve fewer individuals than primary aquifers. [Response 3785.] This Response, however, does not provide any scientific or technical justification for a 500'setback, which is inadequate to protect actual or potential public drinking water supplies. Principal aquifers are a productive water source and contamination from HVHF fluid or flowback could render them unusable. Furthermore, the differential protection the proposed regulations provide for primary and principal aquifers ignores the connections between surface and groundwater. Wells near principal aquifers should be subject to the same setback as wells near primary aquifers, since the only difference between a primary and principal aquifer is the number of people currently using the aquifer. All public and private drinking water sources should be subject to the same setback of at least 4,000'.

NYSDEC also ignored our 2012 Recommendation to increase setbacks around perennial or intermittent streams, storm drains, lakes, and ponds to 660'. [LBG Report at 7; Harvey Report at 136, Recommendation No. 68.] NYSDEC did not respond to our recommendation and provided no scientific or technical justification for reducing its previously proposed setback from 500' to 300'. In addition, this requirement conflicts with the 50' setback around "any public stream, river, or other body of water" provided for in current 6 NYCRR § 553.2. In response to comments on the resulting confusion about which setbacks would be applied to lakes, ponds, and perennial or intermittent streams and rivers, NYSDEC's Response 5895 states that duplication and consistency has been addressed, but there is no proposed revision to 6 NYCRR § 553.2. It is our recommendation that there should be consistent setback requirements applied to all drilling operations in the state.

Furthermore, NYSDEC did not adequately respond to our 2012 Recommendations requesting that NYSDEC require all setbacks to be measured from the edge of the well site, as defined in proposed 6 NYCRR §750-3.2(52), which includes the contiguous disturbed area and ancillary facilities around the well pad. [Harvey Report at 137, Recommendation No. 72.]

Our 2012 Recommendations also stated that NYSDEC should require all wells on the well site to be centered on the well pad and set back at least 100' from the pad edge to maximize setbacks from sensitive receptors. [Harvey Report at 137, Recommendation No. 72.] In Response 6136, NYSDEC did not explain why setbacks, which "are designed to provide an added level of protection from potential surface spills from a well pad," must therefore be "measured from the closest edge of the well pad instead of the drill site."

In addition, the current draft SPDES General Permit for Stormwater Discharges is inconsistent with NYSDEC's Revised Proposed Regulations. The current draft SPDES General Permit authorizes to HVHF operations over 100' from wetlands, even though 6 NYCRR § 750-3.11(d) requires an individual SPDES permit for such operations within 300' of wetlands. Similarly, the current draft SPDES General Permit authorizes HVHF operations over 150' from perennial or intermittent streams, even though 6 NYCRR § 750-3.11(d) requires an individual SPDES permit for such operations within 300' of these waterbodies. NYSDEC should revise the draft SPDES General Permit for Stormwater Discharges to reflect its final setback regulations.

Recommendation: NYSDEC should increase the buffer around principal aquifers to at least 4,000'. This setback should however be provided for in 6 NYCRR § 750-3.3(a)(5), not in 6 NYCRR § 750-3.11(d). In addition, NYSDEC should increase the buffer in which an individual SPDES permit is required around perennial or intermittent streams that are not tributary to a water supply, as well as storm drains, lakes, and ponds, to at least 660'. At a bare minimum, the buffer in which a SPDES permit is required should be restored to the 500'provided for in the 2011 proposed regulations. Moreover, it should revise 6 NYCRR §§ 750-3.11(d) and 553.2 to provide consistent requirements that are protective of water resources and that apply to all drilling operations in the state. NYSDEC should clarify that setbacks are measured from the edge of the well site. Wells should be centered on the well pad and should be set back at least 100'from the pad edge to improve protection of sensitive receptors. Finally, NYSDEC should revise the draft SPDES General Permit for Stormwater Discharges to reflect its final setback regulations.

6 NYCRR § 750-3.11(f)(1) Centralized Flowback Impoundments

Revised Proposed Regulation: 6 NYCRR § 750-3.11(f)(1) provides that construction and use of a centralized flowback impoundment are activities ineligible for coverage under an HVHF general permit and require authorization under an individual SPDES permit.

Prior Comment and Response: NYSDEC ignored our 2012 Recommendations commenting on the use of centralized flowback impoundments and requesting their prohibition. [Harvey Report at 103. Recommendation No. 46.] NYSDEC's response barely addresses the use of centralized flowback impoundments at all. Comments 4025, 4034, 5909, 6864, and 6964 all requested that NYSDEC prohibit the use of centralized flowback impoundments. NYSDEC's brief responses to these comments state only that before permitting, NYSDEC will perform a site-specific SEQRA review subject to public participation requirements and possible mitigation measures. [Response 5909.] Such a response ignores the hazards posed by centralized flowback impoundments, which are a significant source of air pollution, particularly hazardous air pollutants, as well as increased risk of spills and resulting contamination of surface waters. These hazards are so great, individually and cumulatively, that they should be fully considered by NYSDEC now instead of when individual HVHF operator applies an authorization for such use, on a site-by-site basis.

Centralized flowback impoundments have been used in Pennsylvania and other states and the impact on human health and the environment is reasonably foreseeable. The potential impacts of this practice are too significant to defer analysis until future site-specific review under SEQRA, as NYSDEC asserts in Response 5909. In addition, addressing impacts on a case-by-case basis forgoes uniform standards, prevents analysis of cumulative impacts, does not provide industry with consistency, and invites inconsistencies between regions and permit administrators.

Recommendation: NYSDEC should amend the NYCRR to prohibit the use of centralized impoundments, both at the well site and away from the well site. If NYSDEC declines to ban centralized flowback impoundments, NYSDEC should prepare a new draft RDSGEIS, or a draft supplement to the RDSGEIS, that includes a full analysis of the potentially significant adverse impacts of centralized flowback impoundments and make this draft available for public comment. Mitigation measures to address the potential significant impacts on human health and the environment identified must be included in both a final SGEIS and codified in final regulations.

6 NYCRR § 750-3.12(c) Requirements for Acceptance, Treatment, and Disposal of HVHF wastewater at POTWs

Revised Proposed Regulation: 6 NYCRR § 750-3.12(c) sets forth proposed requirements for acceptance of HVHF wastewater at publicly owned treatment works (POTWs).

We do not believe that HVHF wastewater should be permitted to be accepted, treated or disposed of at POTWs.[52]

Recommendation: 6 NYCRR § 750-3.12(c) should be removed and replaced with a prohibition on acceptance, treatment, or disposal of HVHF wastewater at POTWs.

[52] Our rationales for disallowing treatment of HVHF wastewater at POTWs are set forth in this report: Van Briesen, J. and Hammer, R. (2012), In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater (NRDC).

6 NYCRR § 750-3.12(c)(6) and § 750-3.12(e) Disposal of Radioactive Waste

Revised Proposed Regulation: 6 NYCRR §§ 750-3.12(c)(6) and (e) allow NORM to be disposed of at low level radioactive waste facilities, if transport and disposal complies with 6 NYCRR §§ 360, 364, 380, 381, and 750-2.8(e).

Prior Comment and Response: We agree that the residuals from wastewater treatment or recycling, which may contain NORM, should be subject to regulations for the disposal of radioactive wastes. However, all other radioactive waste in New York is subject to 6 NYCRR § 382 and § 383.

Recommendation: NYSDEC should require the disposal of residuals from wastewater treatment to be subject to 6 NYCRR § 382 and § 383.

6 NYCRR § 750-3.12(d) Effluent Limitations Guidelines

Revised Proposed Regulation: NYSDEC revised 6 NYCRR § 750-3.12(d), which now lists requirements for offsite acceptance, treatment, recycling, and disposal of HVHF wastewater at privately owned industrial wastewater treatment facilities.

We disapprove of the absence of effluent limitations guidelines (ELGs) in revised Part 750-3.12(d). All industrial wastewater treatment plants should at a minimum comply with all federal effluent limitations guidelines for centralized waste treatment point sources under 40 CFR Part 437. In Pennsylvania, EPA requires wastewater treatment plants to comply with Part 437. NYSDEC should conduct a further analysis and consider imposition of the ELGs set forth in 25 Pa. Code § 95.10(b)(3)(iii)-(vi).

Recommendation: : NYSDEC should amend Part 750-3.12(d) to require all privately owned industrial wastewater treatment facilities to comply with all federal Part 437 effluent limitations guidelines and, as determined appropriate, with the guidelines set forth in 25 Pa. Code § 95.10(b)(3)(iii)-(vi).

6 NYCRR § 750-3.12(d)(2)(iii) Treatability Analyses at Privately Owned Industrial Wastewater Treatment Facilities

Revised Proposed Regulation: NYSDEC revised 6 NYCRR § 750-3.12(d)(2)(iii) to require that treatability analyses at privately owned industrial wastewater treatment facilities include "a representative assay of the concentrations or chemicals constituents present, as well as other parameters that may be present in the HVHF wastewater."

We approve of this change from previously proposed subparagraphs 750-3.12(d)(2)(ii)(a) and (iii)(a)(2), which required treatability analyses to analyze only "HVHF chemicals" and "expected effluent concentrations of all HVHF specific parameters." A "representative assay" will include not only the chemicals used in HVHF processes but also the chemicals in the waste, including those mobilized by subsurface HVHF operations.

Recommendation: The results of the representative assay should be made publicly available on NYSDEC's website.

6 NYCRR § 750-3.12(f) Requirements for Deep Well Injection of HVHF Wastewater

Proposed Revised Regulation: NYSDEC has proposed a completely new subsection that sets forth the requirements for the state permitting of deep well injection of HVHF wastewater.

6 NYCRR § 750-3.12 (f) Requirements for deep well injection of HVHF wastewater:

(1) HVHF wastewater may be accepted only by a deep well injection facility that has a valid SPDES permit and is permitted by the department to accept HVHF wastewater.

(2) The owner or operator of the disposal well must obtain a permit, or a modification to an existing permit, under the EPA Underground Injection Control (UIC) program for disposal wells prior to applying for a SPDES permit, or a modification to an existing SPDES permit, in accordance with this subpart and subpart 750-1.

(3) The SPDES permit application for a new deep well injection facility or modification of an existing deep well injection facility SPDES permit to accept HVHF wastewater must include the following:

(i) each source of HVHF wastewater and the identity of each HVHF well owner or operator;

(ii) the total volume of HVHF wastewater from each source of HVHF wastewater, and the proposed rate of introduction into the disposal well;

(iii) for each identified source of HVHF wastewater, a representative assay of the concentrations of chemical constituents present, as well as other parameters that may be present in the HVHF wastewater;

(iv) geotechnical information regarding the ability of the disposal stratum to accept and retain the injected fluid, including an estimate of available capacity;

(v) a water quality analysis of the receiving stratum for chemical constituents present, as well as other parameters that may be present in the HVHF wastewater; and

(vi) injection well construction and operational control information showing that the well meets the applicable EPA UIC injection well standards as promulgated under 40 CFR Parts 144-148 and sections 1423 and 1425 of the Safe Drinking Water Act.

(4) The SPDES permit application for an existing deep well injection facility that has already been approved to accept HVHF wastewater, but wishes to accept another source of HVHF wastewater must include the items listed in paragraph 750-3.12 (f)(3).

(5) In addition to the requirements of the EPA UIC program, the department may propose appropriate monitoring, recording and reporting requirements and effluent limitations in the SPDES permit, including:

(i) effluent limitations, pursuant to Parts 701-706 of this Title for chemical constituents present, as well as other parameters that may be present in the HVHF wastewater;

(ii) the proposed well construction and operation program; and

> *(iii) installation of upgradient and downgradient monitoring wells and a monitoring program with periodic monitoring for chemical constituents present, as well as other parameters that may be present in the HVHF wastewater.*

Prior Comment and Response: No specific comments requested that NYSDEC establish a deep well injection program for HVHF.

The RDSGEIS listed deep well injection as a viable disposable option at p. 6-59, but other sections discuss the process only briefly and in regard to the potential for inducing earthquakes.[53] The brief discussion in RSDGEIS is insufficient and does not discuss the requirements or the ramifications of implementing regulations. At present, the NYSDEC lists only six deep injection wells for the disposal of brine associated with oil and gas production.[54] New York State apparently has little experience with deep well injection for the disposal of flowback fluids or production brine. Therefore, it is not appropriate for the State to issue special regulations without a detailed analysis in an SGEIS.

Recommendation: NYSDEC should withdraw all of the 6 NYCRR § 750-3.12(f) regulations until they are analyzed in a new draft SGEIS, or a new draft supplement to the RDSGEIS. That SGEIS should, among other things, examine the geology in the areas expected to be targeted and discuss whether it is appropriate. To be appropriate, a receiving formation would have to have sufficient storage capability and be sufficiently permeable to accept the injection. The formation also would have to have a sufficient capstone, which should not be the Marcellus formation because fracturing that formation will change its hydrogeology. While future site-specific study may provide more detailed information, NYSDEC should discuss what is known about the potential formations to give the public an understanding of where underground injection disposal could occur. In addition, the Department should evaluate the prevalence of abandoned wells which could provide pathways for injected waste to reach the ground surface or shallow aquifers.

In its study, NYSDEC should examine how permeability affects how fast fluids can enter formations and how much fluid can be injected underground without causing excessive pressure. NYSDEC should determine which geochemical parameters should be tested for in the HVHF wastewater, and should specify water quality standards for formation waters in any stratum proposed for receipt of injected wastewaters, because, following injection, those waters will not be useable for other purposes without substantial remediation or treatment. The analysis should also include an assessment of whether the injected fluid, as specified in proposed 6 NYCRR § 750-3.12(f)(3)(iii), would react with formation fluid either to seal the pores or to create a different constituent that could be more hazardous if it were not contained in the formation. In addition, NYSDEC should study flow layers near the base of injection wells as well as methods to identify and properly plug any abandoned wells in the area in which the deep well injection facility is proposed.

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[53] 2011 NYSDEC, RDSGEIS, Pages 5-131, 5-132.

[54] Brine Disposal Well Summary, NYSDEC, http://www.dec.ny.gov/energy/29856.html (last visited January 11, 2013).

Recommended Addition to 6 NYCRR § 750 to Address Stormwater Impacts on Stream Crossings

Prior Comment and Response: Neither the proposed regulations nor the draft SPDES HVHF GP address surface impacts associated with stream crossings by access roads and pipelines. In our 2012 Recommendations, we commented on how stream crossings and associated water quality impacts have not been fully addressed by the RDSGEIS and are specifically not included in the draft SPDES HVHF GP. [Adams & Sitler Report at 5-6.]We also recommended that NYSDEC codify regulations to control and mitigate these adverse impacts. NYSDEC has not responded to these concerns. Currently, it is unclear how many stream crossings may be anticipated and how significantly these crossings will impact water quality and aquatic systems. NYSDEC should place in regulation requirements that address stream crossings to ensure that proposed crossings are constructed and maintained properly and do not impact water quality.

Recommendation: NYSDEC should develop robust regulations establishing requirements to address surface impacts associated with stream crossings. NYSDEC should prepare a new draft SGEIS, or a draft supplement to the RDSGEIS, that includes estimates of the anticipated extent of road crossings of streams and wetlands, an evaluation of the potential environmental impacts of these crossings, individually and cumulatively, and avoidance and mitigation measures that can be incorporated into the proposed regulations. In addition, NYSDEC should revise Part IV, *Contents of the Construction SWPPP*, of the SPDES HVHF GP to include a defined documentation process that requires the applicant to reduce the number and extent of stream crossings. This documentation process also should include mapping requirements and narrative that documents the need for each stream crossing, as well as explanation as to why any individual stream crossing cannot be reduced or combined.

Recommended Addition to 6 NYCRR § 750 to Address Stormwater Discharges from Related Infrastructure

Prior Comment and Response: Neither the regulations nor the draft SPDES HVHF GP that addresses stormwater discharges contained any provisions related to gathering lines, compressor stations, or compressor station access roads. NYSDEC has not addressed our 2012 Recommendations, which suggested that the SPDES HVHF GP and the required SWPPP address construction and stormwater discharges related to gathering lines, compressor stations, and compressor station access roads, or clarify how these discharges will be addressed under another permit, and that the RDSGEIS provide a process for regulation and mitigation of land disturbances associated with these construction activities. [Adams & Sitler Report at 5-6.] We also recommended that NYSDEC provide for control and mitigation of these disturbances in proposed regulations. These requirements must be codified in regulation even if included in the SPDES HVHF GP or other permits to ensure that HVHF infrastructure is properly constructed and maintained without adversely affecting water quality.

Recommendation: NYSDEC should develop robust regulations that address stormwater discharges related to gathering lines, compressor stations, and compressor station access roads. NYSDEC should prepare a new draft SGEIS, or a draft supplement to the RDSGEIS, that includes consideration of the anticipated disturbance and well pad density on a watershed basis, proximity to streams and anticipated stream crossings, and potential individual and cumulative effects on stream health. The new draft RDSGEIS or draft supplement to the RDSGEIS also should include a process for regulation and mitigation of land disturbances associated with these construction activities. In addition, NYSDEC should revise the SPDES HVHF GP and the required construction SWPPP to include construction and stormwater discharges related to gathering lines, compressor stations, and compressor station access roads, or clarify how these discharges will be addressed under another permit.

Other Regulatory Gaps - RCRA Waste Exemption

Revised Proposed Regulation: NYSDEC does not propose to remove the exemption of gas development wastes from the definition of hazardous wastes pursuant to 6 NYCRR § 371.1(e)(2)(v) ("The following solid wastes are not hazardous wastes: [. . .] drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil, natural gas or geothermal energy"). This is so despite the fact that, under the Environmental Conservation Law's expansive definition, these wastes may "pose a substantial hazard to human health and the environment." ECL § 27-0901(3)(b).

Under the federal Resource Conservation and Recovery Act ("RCRA"), New York State has the authority to adopt definitions and regulations of hazardous waste that are more stringent than the federal standards. By its express terms, RCRA establishes a floor rather than a ceiling. RCRA provides that "[n]othing in [the statute] shall be construed to prohibit any State or political subdivision thereof from imposing any requirements, including those for site selection, which are more stringent than those imposed by [the federal program]."[55] Courts have regularly held that it is squarely within the states' authority under RCRA to "adopt regulations more stringent than those imposed by the federal government."[56]

Defining liquid and solid wastes from gas development operations as hazardous waste, and subjecting them to hazardous waste regulation, is necessary to protect the health and welfare of the citizens of New York. Hydraulic fracturing wastewater and solid wastes can be highly dangerous and thus their regulation presents significant environmental benefit. Common additives used in hydraulic fracturing and found in flowback and other development wastewaters include: surfactants, friction reducing chemicals, biocides, scale inhibitors, polymers, cross linkers, pH control agents, gel breakers, clay control agents, and propping agents. Many of these additives contain chemicals that are known or potential carcinogens, as are some of the contaminants mobilized from the formation during fracturing.[57] Analysis of flowback water from Pennsylvania and West Virginia, for example, found the known carcinogen benzene present in nearly half of all flowback water and at average concentrations nearly *one hundred times* the maximum acceptable containment level established by USEPA.[58] This alone is highly dangerous to human health. According to the Occupational Safety and Health Administration, "[r]epeated or prolonged exposure to benzene, even at relatively low concentrations, may result in various blood disorders, ranging from anemia to leukemia, an irreversible, fatal disease."[59] Further, the true extent of the risk associated with flowback water is still unknown as many of the compounds found in fracturing fluids (and thus returned in wastewater) are not publically disclosed because they are currently protected as trade secrets.[60]

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[55] 42 U.S.C. § 6929 (2013).

[56] *Nat'l Elect. Mfrs. Ass'n v. Sorrell*, 272 F.3d 104, 113 (2d Cir. 2001). *See also Old Bridge Chems., Inc. v. N. J. Dept. of Envtl. Prot.*, 965 F.2d 1287, 1296 (3d Cir. 1992); *N. Haven Planning & Zoning Comm'n v. Upjohn Co.*, 753 F. Supp. 423, 429 (D. Conn. 1990), *aff'd*, 921 F.2d 27 (2d Cir. 1990).

[57] Natural Res. Defense Council, Petition for Rulemaking Pursuant to Section 6974(a) of the Resource Conservation and Recovery Act Concerning the Regulation of Wastes Associated with the Exploration, Development, or Production of Crude Oil or Natural Gas or Geothermal Energy 9 (2010) [hereinafter "NRDC Petition"], *available at* http://docs.nrdc.org/energy/files/ene_10091301a.pdf.

[58] *Id.* at 9–10; *see also* N.Y. Dep't of Envtl. Conservation, Draft SGEIS 5-104 (2009).

[59] U.S. Dep't of Labor Occupational Safety & Health Admin., *Substance safety data sheet, Benzene*, Occupational Safety and Health Admin., *available at* http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10043.

[60] NRDC Petition at 10.

Prior Comment and Response: NYSDEC's response to Comment 3833—requesting that the hazardous waste exemption for gas production wastes be eliminated—asserts that "[t]he proposed regulations and permits provide provisions to prevent significant adverse impacts from mismanagement of high-volume hydraulic fracturing wastes." [Response 3833]. NYSDEC offers "secondary containment for flowback fluids and standby vacuum trucks," "setback requirements," the permitting of transporters, a "Waste Tracking Form," and SPDES requirements as examples. These represent a piecemeal approach to the problem and do not compare to the ECL's comprehensive 'cradle to grave' regulation of hazardous waste.[61]

Moreover, the newly added requirements for waste characterization prior to disposal in underground injection wells pursuant to revised proposed 6 NYCRR 750-3.12(f)(iii) would, by operation of the federal Commerce Clause, be restricted to wells located in New York State. This means that there would be no correlative requirement for waste characterization for wastewater destined for disposal in underground injection wells outside of New York, or for any other means of disposal of liquid or solid wastes within the state. There is no justification for this unequal treatment. All wastes destined for disposal—whether inside or without New York—should be characterized to determine their hazardousness. Removing the hazardous waste exemption in 6 NYCRR §371.1(e)(2)(v) would accomplish this end.

NYSDEC also asserts that "[r]egulating high-volume hydraulic fracturing wastes as hazardous wastes would unnecessarily increase the cost of regulation with little, if any, additional environmental benefit." [Response 3833]. DEC adduces no evidence that treating flowback water as hazardous waste will significantly increase the costs of regulation. On the contrary, the trend in the last 20 years of oil and gas development has been towards new waste management technologies and practices that are both safer and less costly than their predecessors.[62] These include new waste disposal technologies,[63] new waste reduction technologies,[64] and new substitutes for toxic materials.[65] There is no evidence that any additional regulatory costs would be unnecessarily excessive, especially given the known and unknown health risks posed by hydraulic fracturing wastes.

Finally, NYSDEC asserts that regulating flowback water as hazardous waste "would [] likely eliminate the recycling of flowback water." This fear is unfounded. Since 2008, USEPA regulations implementing RCRA have promoted recycling of hazardous waste by establishing conditions whereby recycled hazardous waste may be exempt from regulation as solid waste under RCRA. Therefore, NYSDEC can define gas wastes as hazardous, and still promote recycling, without running afoul of RCRA.

Recommendation: NYSDEC should remove the exemption of gas development wastes from the definition of hazardous wastes pursuant to 6 NYCRR § 371.1(e)(2)(v).

Other Regulatory Gaps – RDSGEIS Mitigation Not Included In Regulation

Revised Proposed Regulation: The revised proposed regulations do not include a number of RDSGEIS mitigation measures.

[61] *See generally* ECL §§ 27-0101–17-0109, 27-0301–27-0307, 27-0900–27-0926, 27-1101–27-1115 (2013).

[62] NRDC Petition at 32.

[63] *Id.* at 32–34.

[64] *Id.* at 34–36.

[65] *Id.* at 36–37.

Recommendation: NYSDEC regulations should be revised to include all the RDSGEIS mitigation measures, including, but not limited to the following:

Requirements found in Proposed Supplementary Permit Conditions for HVHF that are not found in NYCRR as listed below:

1. A visual impacts mitigation plan consistent with the SGEIS.
2. A greenhouse gas ("GHG") emissions impact mitigation plan consistent with the SGEIS.
3. A Department-approved transportation plan that does not provide relief from any local requirements authorized by or enacted pursuant to the New York State Vehicle and Traffic Law.
4. Water well analysis must be performed by an ELAP-certified laboratory.
5. Access roads must be placed as far away from unleased property. (The proposed NYCRR requires access roads to be placed back from water resources, inhabited private dwellings and places of assembly, but not unleased property).
6. Authorization under the Department's General Permit for Stormwater Discharges Associated with High-Volume Hydraulic Fracturing ("HVHF GP") must be obtained prior to any disturbance at the site.
7. Surface water and stormwater runoff must be diverted away from the pit.
8. A copy of the SWPPP must be available on-site and available to Department inspectors while HVHF GP coverage is in effect. HVHF GP coverage may be terminated upon the plugging and abandonment of all wells on the well pad in accordance with Department-issued permits.
9. Two feet of freeboard must be maintained at all times for any on-site pit.
10. Lighting and noise mitigation measures as deemed necessary by the Department may be required at any time.
11. A system for recording, documenting and retaining the results of all pressure tests and inspections conducted during drilling and/or completion operations. The results must be available to the Department at the well site during the corresponding operation, and to the Department upon request at any time during the period up to and including five years after the well is permanently plugged and abandoned under a Department permit. If the well is located on a multi-well pad, all pressure testing records must be maintained and made available during the period up to and including five years after the last well on the pad is permanently plugged and abandoned under a Department permit. The record for each pressure test, at a minimum, must identify the equipment or casing being tested, the date of the test, the minimum and maximum test pressures in psig, the test medium (*e.g.*, water, brine, mud, air, nitrogen) including its density, test duration, and the results of the test including any pressure drop;
12. Consultation with the Department's Division of Materials Management ("DMM") is requires prior to disposal of any cuttings associated with water-based mud drilling and pit liner associated with water-based mud drilling where the water-based mud contains chemical additives. Any sampling and analysis directed by DMM must be by an ELAP Certified Laboratory.

13. The operator must follow applicable best management practices ("BMPs") for reducing direct impacts at individual well pads described in Section 7.4.1.1 of the SGEIS.

14. The operator must fully implement the Invasive Species Management Plan described in the approved application materials.

15. The operator must follow applicable best management practices ("BMPs") for reducing the potential for transfer and introduction of invasive species described in Section 7.4.2.2 of the SGEIS.

16. Periodic radiation surveys must be conducted at specified time intervals during the production phase for Marcellus wells. All surveys must be conducted in accordance with NYSDOH protocols.

17. Diesel fuel used in drilling and completion equipment engines will be limited to Ultra Low Sulfur Fuel ("ULSF") with a maximum sulfur content of 15 ppm.

18. There will not be any simultaneous operations of the drilling and completion equipment engines at the single well pad.

19. The maximum number of wells to be drilled and completed annually or during any consecutive 12 -month period at a single pad will be limited to four.

20. The emissions of benzene at any glycol dehydrator to be used at the well pad will be limited to one ton/year as determined by calculations with the GRI-GlyCalc program. If wet gas is encountered, then the dehydrator will have a minimum stack height of 30 feet (9.1m) and will be equipped with a control devise to limit the benzene emissions to 1 Tpy.

21. Condensate tanks used at the well pad shall be equipped with vapor recovery systems to minimize fugitive VOC emissions.

22. During the flowback phase, the venting of gas from each well pad will be limited to a maximum of 5 MMscf during any consecutive 12 -month period. If "sour" gas is encountered with detected H_2S emissions, the height at which the gas will be vented will be a minimum of 30 feet (9.1m).

23. During the flowback phase, flaring of gas at each well pad will be limited to a maximum of 120 MMscf during any consecutive 12 -month period.

24. Wellhead compressor will be equipped with NSCR controls.

25. No uncertified (*i.e.*, EPA Tier 0) drilling or completion equipment engines will be used for any activity at the well sites.

26. The drilling engines and drilling air compressors will be limited to EPA Tier 2 or newer equipment. If Tier 1 drilling equipment is to be used, these will be equipped with both particulate traps (CRDPF) and SCR controls. During operations, this equipment will be positioned as close to the center of the well pad as practicable. If industry deviates from the control requirements or proposes alternate mitigation and/or control measures to demonstrate ambient standard compliance, site specific information will be provided to the Department for review and concurrence.

27. The completion equipment engines will be limited to EPA Tier 2 or newer equipment.

28. Particulate traps will be required for all Tier 2 engines. SCR control will be required on all completion equipment engines regardless of the emission Tier. During operations, this equipment will be positioned as close to the center of the well pad as practicable. If industry deviates from this requirement or proposes mitigation and/or alternate control measures to demonstrate ambient standard compliance, site specific information will be provided to the Department for review and concurrence.

29. Monitoring and Reporting. Passby flows must be maintained instantaneously. Determinations of allowable removal rates will be made based on comparisons with instantaneous flow data.

    a. Description of Gage Types.

    Tier I - Gage data in this category is collected by the permitee immediately downstream of the water withdrawal location using streamflow gage equipment capable of accurately measuring instantaneous flow rates as approved at the discretion of the Department.

    Tier II - Gage data in this category is obtained from acceptable USGS gages that must be located at a point in the same watershed where the drainage area at the gage is from 0.5x to 2.0x the size of the drainage area as measured at the withdrawal point. The catchment area must not have altered flows unless the instantaneous flow measurements can take into account the alterations.

    Tier III - Gage data in this category is obtained from USGS gages that are either outside the acceptable distance within the same watershed or are in adjacent watersheds that possess similar basin characteristics. The use of these "surrogate" watersheds are the most inaccurate account of stream flow and should be used only as approved at the discretion of the Department.

    b. All streamflow records used in determining the instantaneous passby flow rates should be measured to the nearest 0.1 cfs at 15-minute increments. Water withdrawal rates must be reported as instantaneous measurements to the nearest 0.1 cfs at 5-minute increments. Reporting is required annually to Department in Microsoft Excel or similar electronic spreadsheet/database formats.

    c. Violations and Suspension of Operations. Water withdrawal operations will be suspended immediately upon determination that the required passby flow has not been maintained. The Department has the right to modify passby flow requirements if water quality standards are not being met within a watercourse as the result of a water withdrawal. Failure to submit annual reports, filing of inaccurate reports on water withdrawals, and continuing to withdraw water after a determination that the required passby flow has not been maintained, are all considered separate violations of this permit and the Environmental Conservation Law Article 71-1305(2).

30. Operators developing well sites in Forest and Grassland Focus Areas that involve disturbance in a contiguous forest patch of 150 acres or more in size or in a contiguous grassland patch of 30 acres or more in size must:

    a. Implement mitigation measures identified as part of the Department-approved ecological assessment;

b. Monitor the effects of disturbance as active development proceeds and for a minimum of two years following well completion; and

c. Practice adaptive management as previously unknown effects are documented

Appendix A

TECHNICAL MEMORANDUM

Changes in the 100-Year Floodplain in Areas Potentially Affected by Hydraulic Fracturing

January 8, 2012

Prepared for: Catskill Mountainkeeper
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SUMMARY

The New York State Department of Environmental Conservation ("NYSDEC") has proposed that high volume hydraulic fracturing ("HVHF") operations be disallowed within designated 100-year floodplains. The floodplain will be as designated on a Flood Insurance Rate Map as developed by the Federal Emergency Management Agency ("FEMA"). Many FEMA maps are out-dated and may not accurately describe likely current and future flooding events in the areas proposed for HVHF development. Flooding of HVHF facilities, including well pads and waste storage facilities, could present a significant risk of contamination to surface and groundwater. Using the FEMA 100-year floodplains is therefore inadequately protective. A more conservative and protective approach would be to instead preclude HVHF development within 500-year floodplains, which likely better represent the areas that are at real risk of flooding.

Even before considering the effects that climate change has on the current maps, the maps contain much undisclosed uncertainty because of inaccuracies in estimating the design flood, usually the 100-year or 500-year return interval flood, inaccuracies in measuring the stream sections over which the hydraulic calculations will be completed, and various modeling assumptions. Beyond these sources of uncertainty, climate change will likely result in larger and more frequent storms, such as the recent Tropical Storms Lee and Irene and Hurricane Sandy,

with more intense rainfall which will increase flooding, runoff and change the stream plan and profile by causing erosion and sedimentation. Today's 100-year flood may occur much more frequently in the future with global warming and the 100-year flood may be a much larger event. It is very possible that floodplains will change substantially and likely become larger. In the Northeastern United States, and particularly in the Susquehanna and Delaware River watersheds, precipitation has increased over the past century and will increase over the next century. Flood flows are projected to continue to increase.

It is therefore likely that many of the FEMA floodplain maps substantially underestimate the actual 100-year floodplain. That underestimation is likely to become greater with time as global warming increases flood flow rates. Utilizing them as the basis for establishing boundaries for restricting gas development facilities is taking a substantial risk that facilities will in fact be subject to significant flooding events. Developing regulations for potentially polluting facilities that will exist for the next fifty years or longer without properly considering climate change exposes New Yorkers to unnecessary and avoidable risks.

Society will, of necessity, adapt to climate change because it is occurring and will likely become worse. Adapting to climate change impacts that cannot be prevented will require adaptive management over all aspects of society. Knowingly placing facilities that could be sources for substantial contamination in outdated 100-year floodplains is the opposite of the type of future planning needed for climate change adaptation. The NYSDEC should amend its proposed regulations to disallow HVHF operations within 500-year floodplains; this would help account for the uncertainties in floodplain mapping, observed changes in flood flow rates, and projected changes in floods in the future due to climate change.

INTRODUCTION

The NYSDEC has proposed that HVHF operations be disallowed within designated 100-year floodplains (proposed 6 NYCRR §560.4(a)(4) and §750-3.3(a)(3)). The floodplain would be as designated on a Flood Insurance Rate Map as developed by FEMA (6 NYCRR § 750-3.2(b)(1)). Appendix 1 in NYSDEC (2011) lists the available FEMA maps for different areas as affected by proposed HVHF operations. Some of these floodplain maps are up to 36 years old.

Hurricane Sandy, which occurred in late October 2012, has refocused attention on the damages which can be caused by natural disasters, including floods. Sandy was the largest hurricane by area affected at one time ever recorded in the Atlantic Basin and brought tropical storm force winds to more of the Atlantic Coast than any other storm in history. Tropical Storm Lee occurred just after Hurricane Irene in September 2011 and caused the worst flooding in at least 40 years in parts of northcentral Pennsylvania, in the middle of the Pennsylvania Marcellus Shale gas play, and in the Catskill Mountains and across southern New York where the State is proposing to allow hydraulic fracturing. While no given event can be blamed on climate change, Sandy and Lee are certainly examples of the types of tropical storm events to be expected in the future. Tropical storms are only one type of flood-producing event that could be increased by global warming.

In addition to changing climate and flooding, there are many reasons why floodplain maps may understate by large amounts the actual 100-year floodplain (Bales and Wagner 2009; Smemoe et al 2009; Merwade et al 2008). It is also likely that climate change will increase the size of floods affecting river channels. Flood risk analysis with climate change suggests that up to 20% of the world's population could eventually be affected by increased flooding (Kleinen and Petschel-Held 2007). Flood flows and frequency have increased in some areas targeted for gas development since the floodplain maps were prepared, including the Delaware River Basin (Brandes and Kucz 2007).

This technical memorandum briefly reviews the development of FEMA floodplain maps and discusses their sources of uncertainty. It also discusses trends in flood flows over the 20th century, and before, as well as future projections as to how floodplains may be affected by climate change. Because flooding also happens outside of floodplains, it considers the roll of geomorphic change caused by global warming in the overall targeted watershed.

FEMA FLOODPLAIN MAPPING

FEMA is the federal authority that establishes 100-year floodplains, generally for flood insurance purposes. Many other governmental entities, including the NYSDEC in its proposed HVHF regulations, use FEMA maps to establish floodplain areas in which certain development is precluded. If the maps are inaccurate (Merwade et al. 2008), or if they are out-of-date due to increased flood flows, regulations based on them may not achieve their intended goals.

A floodplain map for a given return interval flow is a map of all of the riparian terrain that would be underwater while a river passes at that flow rate. A return interval is the average amount of time that would pass between floods exceeding a given flow rate; a 100-year flood is often used for development purposes. In general terms, a floodplain is determined as follows (adapted from Merwade et al. (2008)):

1. Estimate a design flow (*e.g.* 100-year flow) using a calibrated hydrologic model with precipitation input or through statistical analysis.
2. Determine cross-sections in the river being mapped; this is done by surveying the river, by using digital elevation models, or by manually estimating cross-sections from a map.
3. Use a hydraulics model to estimate water surface elevations for the given flow and cross-sections.
4. Plot the water surface elevations on a base topographic map. The land underneath the plotted water surface elevations is the floodplain.

Smemoe et al. (2007) show that there is so much uncertainty around the use of a single line to designate the flood plain that they recommend that resource managers use a probabilistic estimate. Uncertainty in the final map is due to uncertainty in all of the many factors that go into making the map; climate change can affect the first two items above the most. The following discussion is based on Bales and Wagner (2009), Merwade et al. (2008), and Smemoe et al. (2007).

The design flow is uncertain because of the estimation methods. The best data is a flood flow record at the site of interest. A rule of thumb is that there should be about twice as many years of record as in the design storm, meaning that 200 years is really necessary to have an accurate prediction for a 100-year event. Adding paleoflood data, or estimates of flows that occurred prior to recorded data, to the database can increase the precision of long-return-interval flood estimates (England et al. 2003, Stedinger and Cohn 1986). Flood frequency analysis is based on fitting the flood data to a probability distribution, but there are uncertainties associated with the fitting methodology. If there are no observations at the site, meaning the site is not a gaging station, which is usually the case, the design flood is usually based on a regression analysis of sites in the area. Statistical estimates using probabilistic estimates add much uncertainty to the estimate. Additionally, the unavoidable fact is that the watersheds used to develop the regression relationship have different size, geology, soils, topography, and rainfall distributions, and therefore cannot truly be considered to have been drawn from the same population of floods.

Climate change may increase the frequency and magnitude of floods from a watershed, thus rendering any database used for estimation or for developing the regression equation non-stationary (Milly et al 2008); this means that the average and/or variance of the flood flows may change. It essentially means that the population of floods that controls the probability distribution describing future flood events has changed from the population used to establish today's estimate of a given return interval flood.

An alternative method is to use hydrologic modeling, usually rainfall runoff modeling. This is a model in which the input is precipitation and output is a flow rate or hydrograph. The model parameters, or state variables, are used to represent watershed characteristics, infiltration, and antecedent conditions. Precipitation dynamics are the intensity and duration of the storm and antecedent conditions are the wetness of the soil prior to the design storm. In addition to the problems with estimating these parameters, the big assumption is that the return interval of the computed flow equals the return interval of the input storm precipitation. Obvious problems with this assumption include the antecedent conditions being the same and the within-storm precipitation distribution being appropriate (not necessarily spaced to give the maximum runoff). In the Northeast, these items could be seasonally dependent, so seasonal considerations may also apply.

The cross-sections used for floodplain mapping could also change due to global warming. Large floods could erode the banks or place sediment in ways that could change substantially the channel and surrounding terraces (Stinchcomb et al. 2012). Hydraulic analyses would yield a different water surface elevation dependent on the changed channel for the same flow.

Two other sources of uncertainty are not directly climate-related. The first is the accuracy with which the cross-sections can be determined; this uncertainty will decrease with improved mapping and surveying techniques. The second is the assumption that the flow is steady through the length of river being analyzed. In reality, it is rare for a river to have a level water surface all the way across its cross-section and it is also rare that the flow rate is exactly the same at all points along a river reach.

Actual floodplain maps show the difference between those completed 30 years or more ago and those more recently completed. Figures 1 through 3 are created from FEMA floodplain maps along the Susquehanna River in Broome County in 1981 and along the Delaware River and a tributary in 2011, respectively. More recent maps (Figures 2 and 3) show more detail. A noticeable difference between the 100-year and 500-year floodplains is that the 500-year may just be a little wider than the 100-year but also that it fills in areas that may be above the water level in the 100-year flood. The restriction from developing gas wells within the 100-year floodplain would allow gas wells in the areas within the floodplain boundaries that are just higher than the water level. During the 500-year flood, most of the areas within the 100-year floodplain are filled in with water and the general boundary is spread horizontally a little further. The tributary in Figure 1 clearly meanders within the 500-year floodplain but some of the terraces on the meander bends are actually above the 100-year but within the 500-year floodplain. In Pennsylvania, operators have even developed Marcellus Shale gas wells within the existing 100-year floodplains (Figure 4). There is clearly a need to restrict development near the streams.

HISTORIC TREND IN FLOODS

The Northeast has had several significant climate trends over the 20th century (Barron 2001).

- The area has been prone to natural disasters related to weather and climate, including floods, droughts, heat, and severe storms.
- Temperature along the coast has increased about 4° F over the century.
- Precipitation has also increased up to 20% over the century, with an increase in the extremes.
- The amount of the region experiencing drought at any given time has increased.
- The period between the first and last dates with snow on the ground has decreased by 7 days over the last 50 years.

The back-to-back Irene and Lee storms and the three major floods in the Delaware River Basin in a 22 month period between 2004 and 2006 (September 2004, April 2005, and June 2006) are examples of the area being prone to more flood disasters, which have become worse over large basins. Very large floods, in excess of 100-year return intervals, from the largest basins have increased through the 20th century (Milly et al 2002). Paleoflood data on the Susquehanna River has shown that larger floods have occurred in the past than were observed at the gage near Harrisburg (England et al. 2003).

Table 1 shows the flood flows recorded at four stream gages with long records and how those flows compare with computed 100-year flows (Brandes and Kucz 2007; Schopp and Firda 2008) at those gages. At three of the four gages—Riegelsville, Belvidere, and Port Jervis—two of the recent floods exceeded the 100-year flood computed with flow records up to 1985. Using flow data through 2006, the 100-year flood is higher than the 2004 through 2006 flows. Six of the highest seven floods in 300 years have occurred in the past century (Schopp and Firda 2008) and three floods that have occurred from 2004 through 2006 were in the top five floods since 1903 at the four gages listed in Table 1. Estimated 100-year floods on the Delaware River have increased by from 15 to 20 percent since the FEMA flood maps were prepared in 1985 (Brandes and Kucz 2007) (Table 1). The 50- and 25-year floods increased by 12 and 9 percent, respectively. Consequent increases in the stage at the gaging stations ranged from 1.4 to 3.3 feet, dependent on the station. This is substantial evidence that flood flows are increasing in the past ten or more years and also in the past 60 years.

Table 1: floods recorded in 2004, 2005, and 2006 at four stream gages along the Delaware River and estimated 100-year and 500-year flood flows for those gages. Peak flow data obtained from http://nwis.waterdata.usgs.gov/usa/nwis/peak/, accessed 1/5/13.

Gage***	Riegelsville	Belvidere	Port Jervis	Barryville
2004	216,000	184,000	151,000	112,000
2005	262,000	226,000	166,000	118,000
2006	254,000	225,000	189,000	151,000
1985 100-year Flood*	232,444	208,167	165,239	125,743
2006 100-year Flood*	267,568	242,821	189,129	152,014
2006 500-year Flood **	358,000	334,000	273,000	188,000

* - Brandes and Kucz 2007

** - Schopp and Firda 2008

***: Riegelsville, #01457500

Belvidere, gage #01446500

Port Jervis, gage # 01434000

Barryville, gage #01428500

Computed 500-year flood flows are from 19 to 31% higher than the 100-year flood flows. The difference in the computed floodplain depends on the shape of the valley and river channel. As noted in the discussion above about Figures 1 through 3, in a canyon, the depth and flow velocity would increase substantially but the width of the channel would not appear substantially wider on the map. In a broad flat valley, the water level may rise only a few feet between the 100-year and 500-year flows but substantially spread further across the valley. This additional flooding could inundate wells that have been constructed between the 100-year and 500-year floodplains.

In the Catskill Mountains, regional annual mean air temperature increased significantly by 0.6°C per 50 years over the 20th century (Burns et al 2007). The greatest increases and largest number of significant upward trends at different stations were in daily minimum air temperature. Daily maximum air temperature showed the greatest increase during February through April, whereas daily minimum air temperature showed the greatest increase during May through September. Regional mean precipitation increased by 5.4 inches in 50 years, nearly double that of the regional mean increase in runoff. Regional mean potential evapotranspiration increased by 0.7

inches in 50 years, about one-seventh that of the increase in precipitation amount. The increased evaporation prevented the runoff from increasing commensurately with the increase in precipitation (Burns et al. 2007). Peak snowmelt generally shifted from early April at the beginning of the record to late March at the end of the record, consistent with a decreasing trend in April runoff and an increasing trend in maximum March air temperature. The supply of water to reservoirs therefore increases earlier in the year.

In contrast, Zhu and Day (2005) found that base flow, total streamflow, and runoff had decreased at various stations across Pennsylvania, with only a weak linkage to changes in climate. They attributed the contrasting results to unmeasured watershed factors, such as urbanization or forestry. Zhu and Day (2005) did not analyze peak flows so their study does not contradict other studies documenting higher floods.

The general increase in floods and flood flows in the Northeast, particularly, in the Catskills region and northeastern Pennsylvania probably corresponds to the increase in extreme precipitation and storm intensity that has been observed through the 20th century (Trenberth 1999). The processes that can lead to more intense storms include increased moisture content of the atmosphere or advective moisture flux into the storm cell. Evaporation from the surface within a cell may increase but the added moisture is miniscule compared to the amount of water in the atmosphere. In some watersheds, however, other land use changes may have affected the flows; this includes primarily the increased urbanization of the watershed or changes in forest cover, which can magnify the impacts of increased rainfall in ways that make it very difficult to ascertain the precise cause of increased flooding (Zhu and Day 2005, Schreider et al. 2000).

CLIMATE CHANGE AND THE FUTURE TREND IN FLOODS

Projections of changes in climate in the Northeast for the next century include the following, which suggest more change in precipitation than in temperatures (Barron 2001):

- The area has among the lowest rate of projected future warming.
- Winter minimum temperatures are likely to increase the most, with model-projected increases ranging from 4° to 5° F with up to 9° F increases expected near the coast.
- Daily maximum temperatures will change the least, but the largest change will occur near the coast.
- Projected precipitation increases range from none to about 25% over the century.
- Precipitation variability will also increase.
- Model guidance is poorest, or most variable, for scenarios concerning changes in the frequency and intensity of winter storms.

Global warming enhances precipitation because much of the radiation reflected back to the earth by greenhouse gases warms the surface and increases evaporation, which increases the water vapor content of the atmosphere (Trenberth 1999). The warmer atmosphere can also hold more moisture which should lead to increased extreme rainfall events (Trenberth 1999, Karl et al. 1995). Because precipitation rates exceed evaporation rates by many times, the upper limit to potential rainfall rates depends on the amount of moisture in the atmosphere at the beginning of the storm and the total amount depends on how much can be transported into the storm cell (Trenberth 1999).

In the Delaware River Basin, projections into the future suggest that annual runoff will increase at one and a half to two times the rate of precipitation, temperature dependent (Frei et al 2002). If temperature increases with no change in precipitation, runoff may decrease about 6% for every degree Celsius of temperature increase (Frei et al. 2002); this estimate essentially confirms the much older estimate of McCabe and Ayers (1989) that runoff would be reduced by 9 to 25% for a 2 to 4 degree Celsius increase in temperature with constant precipitation. The agreement between forecasts should increase the confidence in those forecasts.

Most flood predictions assume that climate is stationary, meaning that the statistics of storm depths, including the average and standard deviation, remain constant with time. However, both paleo studies and climate change predictions show that climate is anything but stationary (Milly et al. 2008; Knox and Kundewicz 1999). Small changes in the statistical distribution of storms in a basin can lead to large changes in the predicted response (Knox and Kundewicz 1999), at least until the watershed and ecosystems have adapted to the new climate regimes (Eagleson 1982, Bull 1991). In the Northeast, there are a variety of conditions which can lead to extreme flooding (Barron 2001):

- Rapid melting of snow due to warming after a big storm.
- Spring snow melt following heavy winter snowfall.
- Heavy rainfall on frozen ground that limits percolation and drainage.
- Major summer thunderstorm systems.
- Major precipitation event associated with tropical cyclones.

Global warming enhances all of these processes, in large part due to enhanced advective moisture transport from the nearby oceans. Both the Atlantic and Gulf of Mexico are prolific moisture producers in the Northeast; moisture can flow from the Gulf over 1000 kilometers in a day so that increased evaporation there due to warmer sea temperatures vastly increases the moisture source to the Northeast.

A watershed's response to increased extreme events depends on how the watershed has evolved due to the warming climate and overall increased precipitation (Blöschl et al. 2007). For example, a watershed that has had its forest cover increase and thicken due to increased annual precipitation may not respond differently to an extreme event than it would have previously. If the frequency of that extreme event has increased, however, the subsequent higher amounts of runoff, erosion, and sediment transport may change the floodplain considerably and lower the return interval associated with a given flow rate. In other words, today's 100-year flood may be the 20-year flow in 2050 and the stream channel may be similarly adjusting.

Winter flooding can increase in places because warmer temperatures lead to more moisture and more rain events. Snowstorms that occur at warmer temperatures may be heavier also because of increased moisture. Rain-on-snow events could become more frequent and intensify flooding (Trenberth 1999). As noted, storms on frozen ground can have more runoff for a given amount of precipitation, which can occur due to a period of freezing temperatures followed by an influx of warm air. This is particularly possible in the Northeast because many storms already occur near the freezing threshold (Burakowski and Wake undated).

Knutson et al (2010) summarized both statistical studies and forward-looking model studies in an attempt to determine the long-term changes expected in tropical cyclones. They estimated that the frequency of tropical cyclones with global warming will actually decrease by from 6 to 34 percent due to an increase in midlevel wind that causes shear and prevents cyclone formation. However, cyclone intensity, and therefore the number of category 3 to 5 storms, will increase. They also predict the amount of rainfall associated with cyclones, especially in the center 100 kilometers, is likely to increase by 20%.

Although it is mostly outside of the New York Marcellus Shale area, coastal flooding will increase even more due to sea level rise and other global warming effects on the ocean. Current 100-year high water marks will be exceeded at least once every 30 years by 2050 (Kirshen et al 2008). In New York City, projected sea level rise is 15, 20, and 21 cm for scenarios of low, medium, and high rates of continued carbon emissions (Yin et al 2009). Because the oceans control the downstream base levels in large rivers, sea level increases will affect flood levels upstream including possibly into areas potentially affected by HVHF.

The general consensus therefore is that flood flows will increase with global warming in the Northeast, including those areas targeted for HVHF in New York. The rate of increase may also exceed the rate that the stream channels can adjust to pass the flows. Additionally, near-floodplain developments may prevent the channel from expanding as necessary. Industrial facilities, such as HVHF wells or waste storage facilities, may feature contaminant sources that could overflow and/or be washed away by the increased flooding, presenting a significant risk of contamination to surface and groundwater supplies.

WATERSHED PROCESSES

Floodplain mapping includes only the primary channels through a valley. Watersheds, consisting of smaller drainages and wetlands, control the flow and much of the sediment that a watershed produces in most floods. Also, being outside the mapped floodplains, the runoff and erosion that occur on a hillslope can present a risk of contamination from any gas development facilities. It is at small scales that climate variability and landscape management most affect the flow pathways from a watershed (Blöschl et al. 2007).

Climate change alters the thresholds for change at a watershed scale (Bull 1991). Floods cause erosion and headcuts to form. A headcut is a point where severe erosion causes a small cliff or waterfalls to form in the profile of the stream; usually the headcut will move rapidly upstream which effectively rejuvenates the watersheds. A rejuvenating watershed is one in which the bases of the streams are rapidly changing due to erosion. As floods currently characterized as extreme become more frequent, the ability of a watershed to pass a given flow decreases. Once a given flow exceeds a threshold along a given drainage, a headcut may form and start moving up through the watershed causing widespread rejuvenation. Extreme sedimentation or channel movement may occur. Flooding and erosion could affect facilities constructed near these drainages.

Rejuvenating watersheds also have more landslides, which can affect landscapes away from the floodplains. Landscapes are more prone to small landslides during long-duration moderate or high intensity rainfall event because the landslides occur after rainfall infiltration can fill the soil and allow it to move (Jacobson et al. 1989). Once an area has had a large storm with substantial soil movement, it may take a long time until the area can fail again (Jacobsen et al. 1989).

There is a feedback loop among climate change, flooding, and wetlands in small watersheds as well (Pitchford et al. 2012). The wetlands mitigate flooding until global warming destroys the wetlands. Wetland vulnerability to climate change depends extensively on their position in the watershed (Winter 2000). The most vulnerable wetlands are in mountainous or other upland areas because they tend to depend on runoff (Winter 2000). In this context the wetlands decrease flooding and the water storage essentially maintains wetland function. If storm intensity increases, hillslope erosion will cause sediment to reach the wetlands which, with time, will decrease their capacity to hold runoff. Increased temperatures may lower the wetland water and nearby groundwater level more quickly, thereby making more storage available for floods, at least until the wetland fills with sediment. Groundwater typically supports the wetlands nearest the streams (Winter 2000). If global warming decreases stream base flows or recharge to the floodplain, wetland plants could die and decrease the cohesive strength of the stream channel thereby rendering them more easily eroded. Erosion of the stream channel, in turn, changes the morphology of the stream, moving the floodplain boundaries.

DISCUSSION AND CONCLUSION

This memorandum discusses numerous factors of climate change and floods that indicate that existing floodplain maps probably substantially underestimate the area that will be affected by 100-year floods both presently and in the future, and therefore do not provide an appropriate basis for delineating areas in which HVHF facilities should be precluded. In some areas, the floodplain maps are over 30 years old and flood records since that time have shown that the FEMA design flows are too small. Without even considering climate change, the maps are uncertain because of the inaccuracies in estimating the design flood, inaccuracies in measuring the stream sections over which the hydraulic calculations will be completed, and various modeling assumptions. If climate change results in more intense rainfall and runoff or changes the stream cross-sections substantially it is very possible that the floodplains will change substantially. To decrease the risk, NYSDEC should not allow HVHF facilities within the 500-year rather than the 100-year floodplain. As shown on Figures 1 through 3, using the 500-year floodplain may primarily prevent gas wells from being located on high ground that would be surrounded by water during the 100-year flood flow.

In the Northeastern United States, and particularly in the Susquehanna and Delaware River watersheds, increased precipitation has been measured over the past century and is projected to further increase over the next century. Most likely the future increases will take the form of greater intensity of rare storms, including hurricanes. As storms become larger and affect larger areas, more of a given watershed may become affected. Larger floods may not be due to substantial increases in runoff per area for small to mid-size watersheds but rather could be due to larger storms producing similar runoff from larger areas which combine to create larger events at downstream locations (Milly et al. 2002).

Using out-of-date FEMA floodplain maps as the basis for regulating the location of HVHF facilities is not minimizing risk because those maps are likely based on a population of rainfall/runoff data that no longer applies due to changing climate. The insurance industry, one of the most conservative businesses in existence (Adger et al. 2005), has begun to adapt to climate change because their bottom-line depends on it (Weiss 2012, Adger et al. 2005). There can really be no better indicator of increased risk due to natural disasters, including flooding and hurricanes, than interest by the insurance companies.

Permitting polluting industrial facilities to be developed in areas that have the potential to flood, *i.e.*, existing 100-year floodplains, and thus could be sources for substantial contamination, is the opposite of the type of future planning needed for appropriate climate change planning and adaptation. Utilizing the 500-year floodplains as the basis for HVHF regulation is more conservative and provides a more appropriate level of protection. This will help account for the uncertainties in floodplain mapping, observed changes in floods, including many recent floods that have exceeded the currently-mapped 100-year flood, and projected changes in floods in the future due to climate change.

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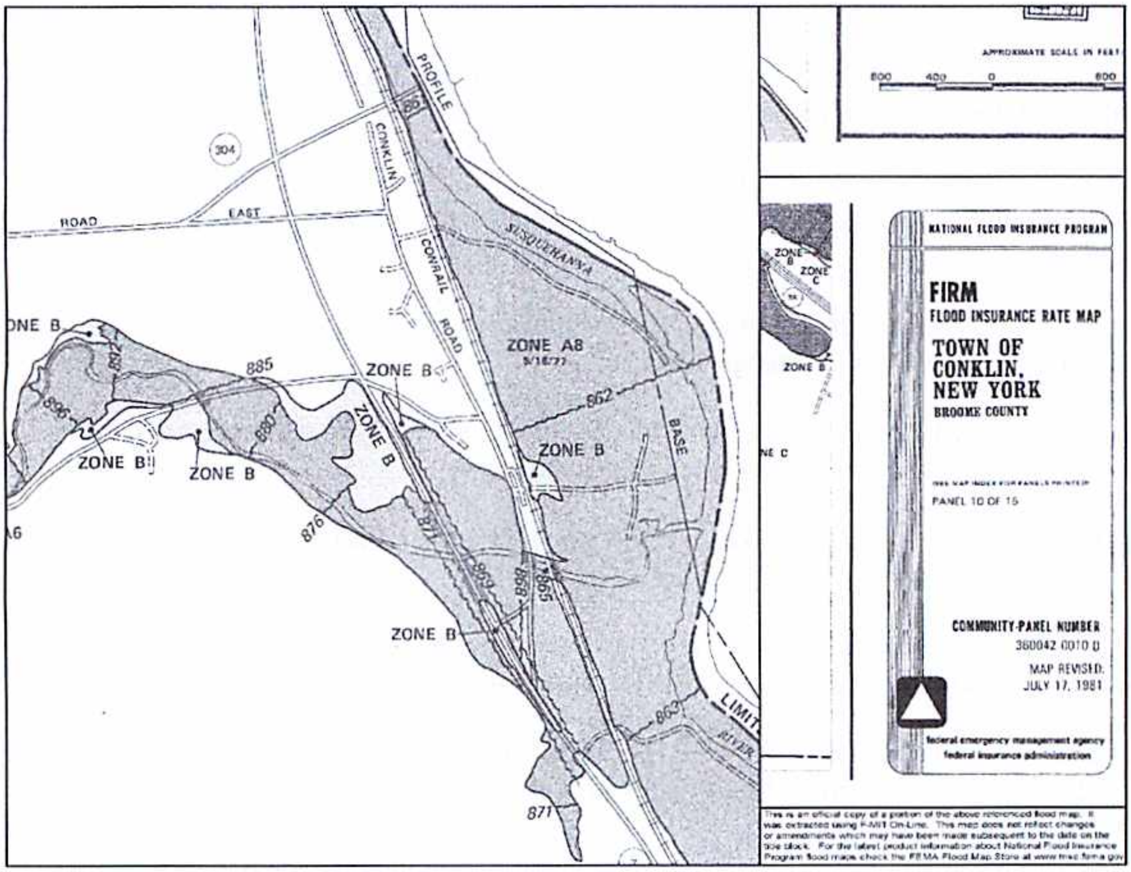

Figure 1: FEMA Floodplain Map, Conklin, NY. Zone B is the area between the 100-year and 500-year flood lines.

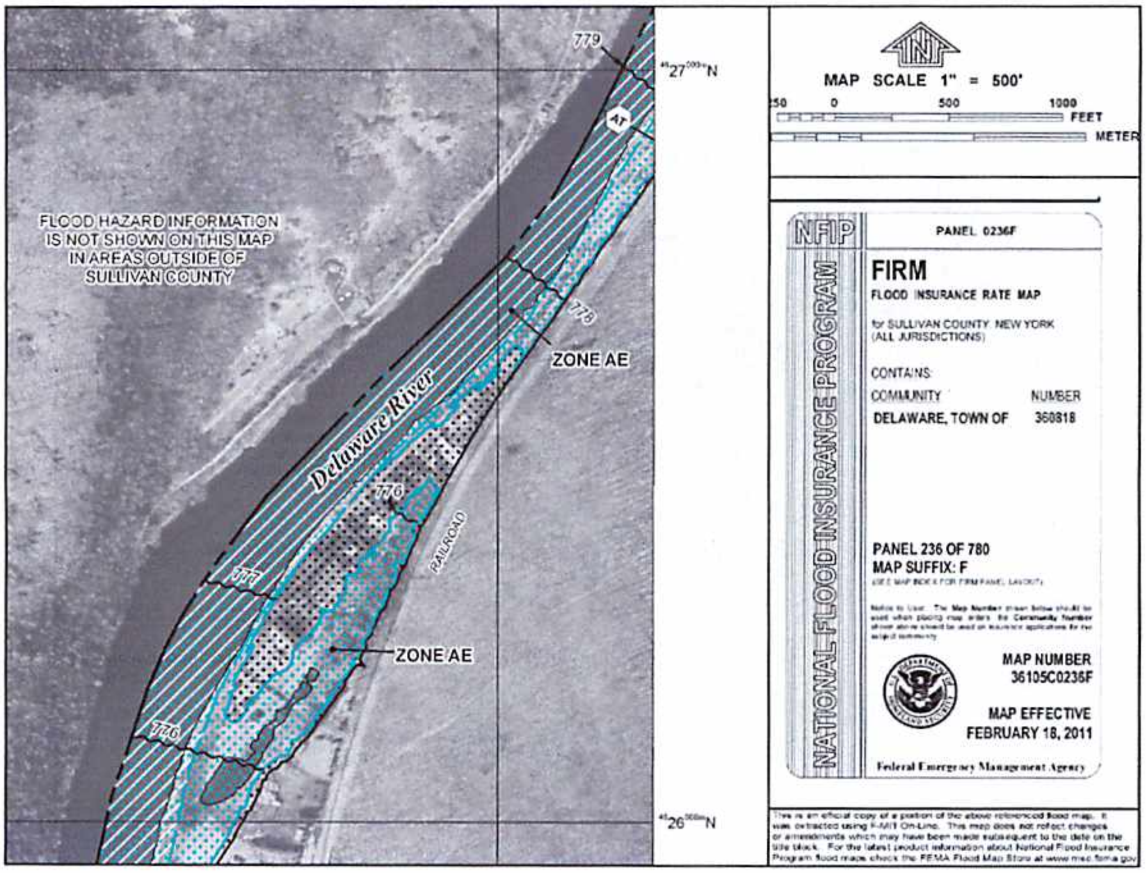

Figure 2: FEMA Floodplain Map, Delaware, NY. Blue dots represent the 100-year floodplain and the black dots represent the 500-year floodplain. The cross-hatch is the flood channel which is the area where no encroachment is allowed because it would change the floodplain.

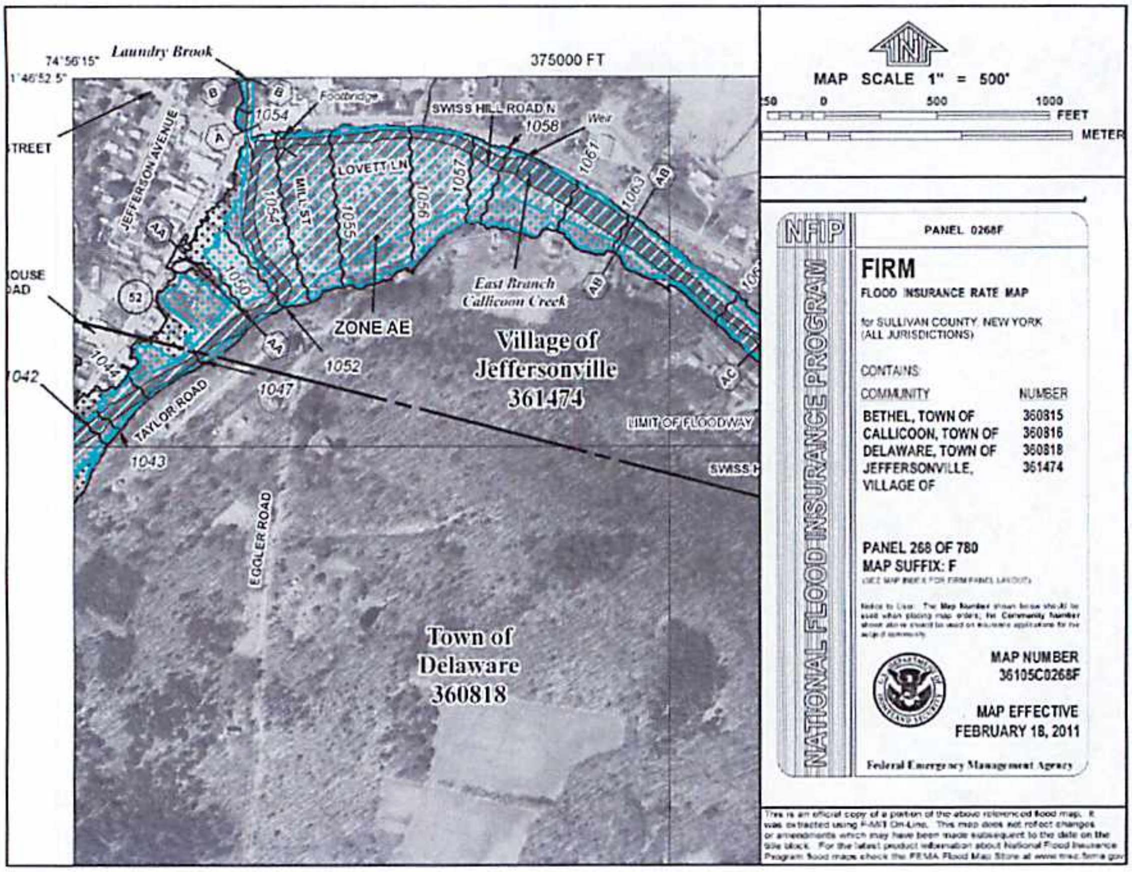

Figure 3: FEMA Floodplain Map, Sullivan County, NY. Blue dots represent the 100-year floodplain and the black dots represent the 500-year floodplain. The cross-hatch is the flood channel which is the area where no encroachment is allowed because it would change the floodplain.

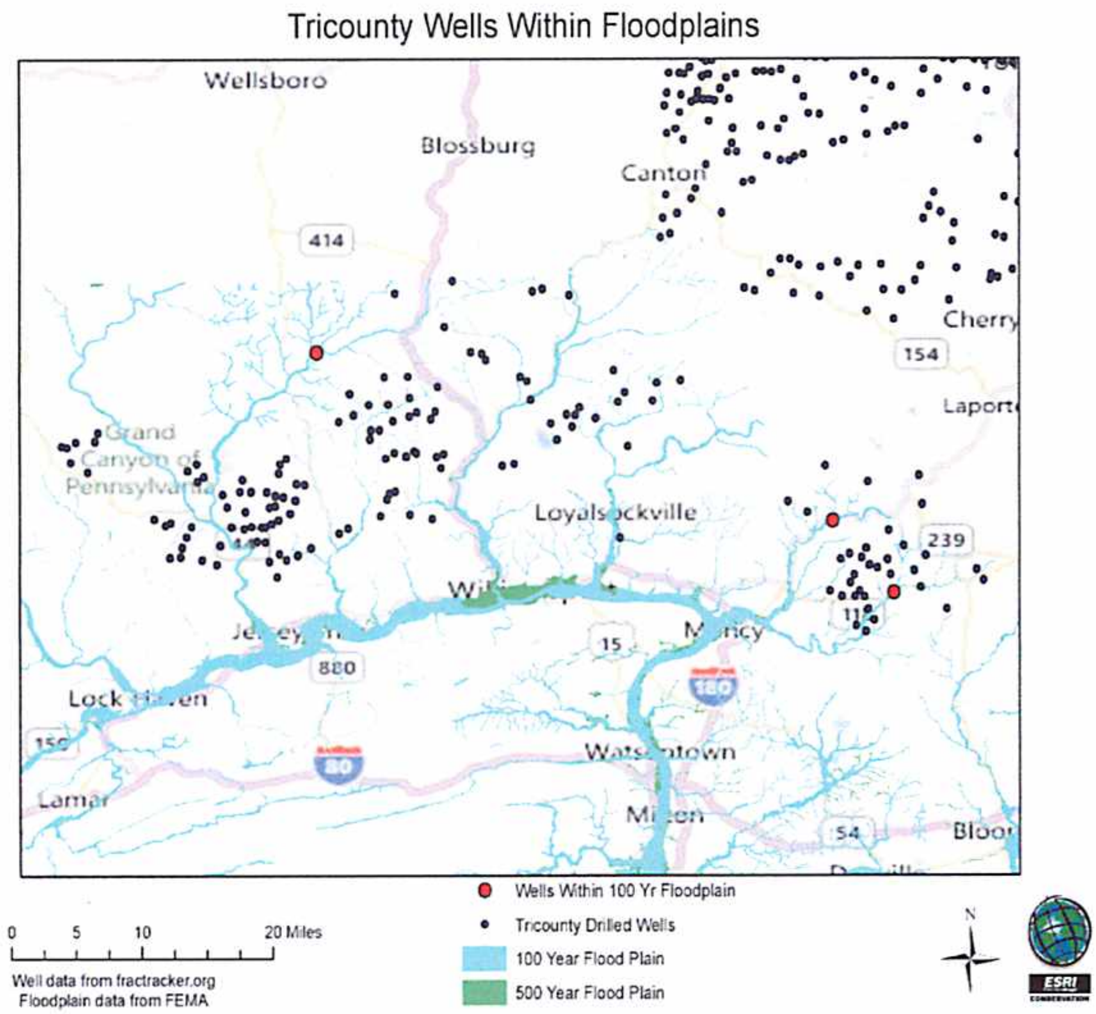

Figure 4: Map of Marcellus Shale Wells and FEMA Floodplain Maps for Bradford, Lycoming, and Sullivan Counties, Pennsylvania. Prepared by Avi Allison, Earthjustice.

Appendix B: Comparison of Term Definitions Between Proposed Regulation 6 NYCRR § 750-3.2(b) and the SPDES General Permit for Stormwater Discharges from HVHF

§ 750-3.2(b)	HVHF SPDES General Permit
Casing means pipe, typically made of steel, placed in the drilled hole of a well of an oil and gas well.	**Casing** means steel pipe placed in a well.
Closed-loop tank system means a pitless drilling system where all drilling fluids and cuttings are contained at the surface within piping, separation equipment and tanks.	**Closed-loop drilling system** means a pitless drilling system where all drilling fluids and cuttings are contained at the surface within piping, separation equipment and tanks.
Construction Phase means the phase between commencement of surface soil disturbance associated with the construction of access roads, well pads, and other appurtenances and Construction Phase Completion.	**Construction Phase** means the construction of access roads, wellpad, and other appurtenances.
Construction SWPPP means the stand-alone stormwater pollution prevention plan that includes best management practices and other requirements to control the pollution of stormwater during both construction of the well site and post-construction at the well site.	**Construction SWPPP** means the stand alone stormwater pollution prevention plan that includes best management practices and other requirements to control the pollution of stormwater during construction and post-construction.
Cuttings or samples means chips of rock cut by the drill bit and brought to the surface by the drilling fluid.	**Cuttings or samples** means chips of rock cut by the drill bit and brought to the surface by the drilling fluid. They indicate to the wellsite workers what kind of rocks are being penetrated and can also indicate the presence of oil or gas.

§ 750-3.2(b)	HVHF SPDES General Permit
Drilling fluid means mud, water, brine, or other fluid, including air, pumped down the drill string which acts as a lubricant and coolant for the drill bit and is used to carry rock cuttings back up the wellbore. It may also be used for pressure control in the wellbore and to drive a mud motor and bit for directional drilling.	**Drilling fluid** means mud, water, or air pumped down the drill string which acts as a lubricant for the bit and is used to carry rock cuttings back up the wellbore. It is also used for pressure control in the wellbore.
Final stabilization means all soil disturbance activities have ceased and a uniform, perennial vegetative cover with a density of at least eighty (80) percent has been established or other equivalent stabilization measures, such as sod, permanent landscape mulches, rock rip-rap or washed/crushed stone, have been applied on all disturbed areas that are not covered by permanent structures, concrete or pavement.	**Final stabilization** means all soil disturbance activities have ceased and a uniform, perennial vegetative cover with a density of eighty (80) percent has been established or other equivalent stabilization measures.
Flowback means liquids and solids produced during initial completion and clean up of the well or clean up of a well following re-fracture or workover of a well.	**Flowback** means return of fluids, used in the stimulation process, to the surface.
Freeboard means the distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.	**Freeboard** means the height above the recorded high-water mark of a structure designed to hold water. In the case of pits, freeboard is the extra depth left unused to prevent any chance of overflow.

§ 750-3.2(b)	HVHF SPDES General Permit
High-Volume Hydraulic Fracturing Phase (HVHF Phase) means the phase following Construction Phase Completion and through completion of Partial Site Reclamation. This phase includes well drilling, high-volume hydraulic fracturing, and on-site handling and treatment of HVHF wastewater produced until all wells planned for that well pad have been completed.	**High-Volume Hydraulic Fracturing Phase (HVHF Phase)** means 1) the phase between the construction project completion and the Production Phase; and 2) any subsequent restimulation event. This includes well drilling, high-volume hydraulic fracturing, well stimulation and on-site handling and treatment of return flow.
HVHF general permit means a SPDES permit issued pursuant to section 750-3.11 of this Part.	**HVHF general permit** means a SPDES permit issued pursuant to section 750-3.21 of this Part.
HVHF SPDES permit means an individual SPDES permit for HVHF operations (individual HVHF SPDES permit) or an HVHF general permit.	**HVHF SPDES permit** means an individual or general SPDES permit for HVHF activities.
HVHF SWPPP means the stand-alone stormwater pollution prevention plan required by a SPDES permit that includes structural and non-structural best management practices and other activity-specific requirements to control the pollution of stormwater during the HVHF Phase and the Production Phase.	**HVHF SWPPP** means the stormwater pollution prevention plan required by a SPDES permit that includes structural and non-structural best management practices and other requirements to control the pollution of stormwater during the HVHF Phase and the Production Phase.

§ 750-3.2(b)	HVHF SPDES General Permit
Hydraulic fracturing means the act of pumping hydraulic fracturing fluid and a proppant into a formation to increase its permeability.	**Hydraulic fracturing** means the injection of fluids under pressure into a well in order to induce fractures in the target formation. Proppant which may be injected with the fluid holds the fractures open when the fluid is withdrawn. The procedure increases permeability of the rock near the wellbore and improves production.
Partial site reclamation means (a) when all of the equipment, materials and BMPs associated with the HVHF Phase have been removed, (b) surface disturbances not associated with production activities have been scarified or ripped to alleviate compaction prior to replacement of topsoil, and (c) all the disturbed areas have been stabilized after topsoil replacement, in accordance with the Partial Site Reclamation Plan submitted pursuant to Part 560.3(a)(17) of this Title, as adopted on XX, 20XX. Partial reclamation and final reclamation of any well pad and access road must be done in conformance with the plans approved by the department.	**Partial site reclamation** has occurred after all planned wells at the well pad have been completed and a Department inspector verifies that the drilling/fracturing equipment has been removed; pits used for those operations have been reclaimed and surface disturbances not associated with production activities have been scarified or ripped to alleviate compaction prior to replacement of topsoil. Reclaimed areas must be seeded and mulched after topsoil replacement and vegetative cover reestablished that will ultimately return the site to pre-construction conditions.
Plugged and abandoned (plug and abandon) means the permanent abandonment of a well bore including the placing of all bridges, plugs and fluids therein.	**Plugged and abandoned (plug and abandon)** means to permanently close a well with cement plugs.

§ 750-3.2(b)	HVHF SPDES General Permit
Proppant means a material such as sand or ceramic particles that is carried in suspension by the fracturing fluid and that serves to keep the induced fractures open when fracturing fluid is withdrawn after a fracture treatment.	**Proppant** means a granular substance (sand grains, aluminum pellets, or other materials) that is carried in suspension by the fracturing fluid and that serves to keep the cracks open when fracturing fluid is withdrawn after a fracture treatment.
Reserve pit means a lined, mud pit in which a supply of drilling fluid has been stored, or a waste pit, usually an excavated pit.	**Reserve pit** means a mud pit in which a supply of drilling fluid has been stored, or a waste pit, usually an excavated pit. It may be lined to prevent soil contamination.
Storage means the holding of a material, container or equipment at a well site.	**Storage** means the holding of a material, container or equipment at a site, not including the amount of material brought to the site for immediate use.
Temporary stabilization means that exposed soil has been covered with material(s) to prevent the exposed soil from eroding. The materials can include, but are not limited to, mulch, seed and mulch, and erosion control mats (e.g. jute twisted yarn, excelsior wood fiber mats).	**Temporary stabilization** means that exposed soil has been covered with material(s) as set forth in the technical standard, New York Standards and Specifications for Erosion and Sediment Control, to prevent the exposed soil from eroding. The materials can include, but are not limited to, mulch, seed and mulch, and erosion control mats (e.g. jute twisted yarn, excelsior wood fiber mats).
Watershed means the region drained by, or contributing water to, a stream, lake, or other body of water.	**Watershed** means an area of land that drains into a body of water, such as a river, lake, reservoir, estuary, sea or ocean.