Appendix C: Draft SGEIS Surface Spill Contamination Analysis

The draft SGEIS released by NYSDEC on September 30, 2009 was supported by several consultant reports prepared for New York State Energy Research and Development Authority (NYSERDA). Chapter 1 of the report prepared by Alpha Environmental Consultants provided analyses of surface contamination scenarios within the watershed that could occur during natural gas development.[46] The evaluation estimated the potential for exceeding maximum contaminant levels (MCL) in individual West-of-Hudson reservoirs, at the Catskill and Delaware Aqueduct outlets, and within the NYC distribution system (Hillview Reservoir). The analysis considered contamination due to an acid spill, a non-acid chemical spill, or a spill of flowback water. All analyses assumed that the mass of contaminant was introduced directly into a reservoir, with no spill detection or mitigation, no soil adsorption, and no evaporation. The analyses were structured as simple dilution calculations in which the contaminant mass was completely and instantaneously mixed with the volume of one or more reservoirs.

Undiluted Non-Acid Chemical Spill

Undiluted fracture fluid chemicals, volumes, and concentrations used for the analysis were based on confidential data submitted by natural gas operators to NYSDEC. The analysis considered two fracture fluid mixtures provided by industry sources and focused on chemicals in those mixtures with MCLs. These chemicals are identified in Table C-1. Concentrations and volumes were not revealed in the report. It was assumed that the total amount of chemicals needed to fracture a well was released directly into an individual reservoir (at 1/3 storage level) and mixed instantaneously. The analysis was structured as a simple dilution, and was repeated for the mass of chemicals associated with one, two, and eight wells.

Table C-1: Representative Fracture Fluid Mixes and MCLs from Alpha Report

Mix 1	NYSDOH Part 5 MCL (mg/L)	Mix 2	NYSDOH Part 5 MCL (mg/L)
2,2,-Dibromo-3-Nitrilopropionamide	0.05	2,2,-Dibromo-3-Nitrilopropionamide	0.05
Alcohols C9-11, ethoxylated	0.05	C12-15 Alcohol, Ethoxylated	0.05
Ethoxylated C11 Alcohol	0.05	Ethoxylated Castor Oil	0.05
Methanol	0.05	Isopropanol	0.05
Ethylene Glycol	0.05	Propylene Glycol	1

The analysis was conducted for individual West-of-Hudson reservoirs, for the Catskill outlet into Kensico, the Delaware outlet into West Branch, and for water entering Hillview. Individual reservoir analyses indicated that MCLs could be exceeded in all of the West-of-Hudson reservoirs for most of the contaminants (except propylene glycol). The number of wells required to result in MCL violations ranged from one to eight, with smaller reservoirs being more susceptible. A spill equivalent for a single well resulted in an MCL being exceeded at Schoharie and Neversink Reservoirs. A spill equivalent for two wells resulted in one or more MCLs being

[46] dSGEIS, Alpha Technical Report, *Survey of Regulations in Gas-Producing States, NYS Water Resources, Geology, New York City Watershed, Multi-Well Operations, and Seismicity.*

exceeded at Schoharie, Neversink, Rondout, and Cannonsville Reservoirs. A spill equivalent for eight wells resulted in all reservoirs exceeding one or more MCLs.

The analysis for the Catskill outlet into Kensico, the Delaware outlet into West Branch, and for water entering Hillview was conducted in a similar fashion, except that for these three scenarios, the mass of contaminant was mixed with the entire contents of upstream system components. Thus the results for the "Kensico" scenario are based on the contaminant mass divided by the combined storage in Ashokan and Schoharie. Similarly, "West Branch" results are based on dilution with the volume of the four Delaware reservoirs, and "Hillview" results are based on dilution with the total volume of the Catskill and Delaware reservoirs, West Branch, and Kensico.

These latter scenarios have very limited utility, since conceptually they could only apply when the contaminant mass is introduced at the uppermost reservoir in a system of reservoirs in series (e.g. the "Kensico" scenario is conceptually valid for Schoharie). All other scenarios are conceptually flawed and do not pertain to a physically possible scenario (e.g. under the "West Branch" scenario, a spill into Rondout would be instantaneously mixed with the volume of Cannonsville, Pepacton, and Neversink, all of which are located upstream of Rondout).

Given the errors inherent in the analysis provided as support for the dSGEIS conclusions, an alternate analysis was performed using fracturing chemical data and assumptions presented in the Alpha Report.[47] The sensitivity of the NYC water supply to acute spills of fracturing chemicals was examined by calculating the mass of fracturing chemicals required to violate an MCL at Kensico Reservoir. Both the dSGEIS analysis and the following analysis are structured as simple dilution calculations that assume the chemical mass enters a reservoir directly and is completely and instantaneously mixed with its contents.

Consistent with dSGEIS assumptions, reservoirs were assumed to be one-third full. Such low storage levels would only be expected to occur under severe drought conditions. However, the one-third full assumption is equivalent to the more realistic situation in which the reservoirs are relatively full and the contaminant mass mixes with only one-third of the reservoir's volume as a result of short-circuiting. Complete mixing in reservoirs with volumes as large as NYC's is not a reasonable assumption under most circumstances. Short-circuiting due to stratification, density currents, and prevailing flow patterns is considered more typical.

Two spill scenarios were considered, the key difference between them being the volume into which the chemical mass is diluted:

- Scenario 1 dilutes the contaminant mass with the contents of Kensico Reservoir. This represents a situation in which a load of fracturing chemicals spills into Rondout and the chemicals short-circuit into the intake chamber and are conveyed downstream to Kensico Reservoir.
- Scenario 2 dilutes the contaminant mass with the contents of Kensico and Rondout Reservoirs. This represents a situation in which a load of fracturing chemicals spills into Rondout or a proximate tributary and mixes completely with the contents of Rondout and

[47] dSGEIS, Alpha Technical Report, *Survey of Regulations in Gas-Producing States, NYS Water Resources, Geology, New York City Watershed, Multi-Well Operations, and Seismicity*, Section 4.8 and Tables 4.3 – 4.5.

Kensico. This is also representative of the impact of spill into Cannonsville, Pepacton, or Neversink Reservoirs that occurs near their respective intake structures.

Under these simple dilution assumptions, the mass of chemical required to violate an MCL is simply the product of the reservoir volume and the MCL, which is 0.05 mg/l for all chemicals considered here. To gauge the number of wells or hydraulic fracturing operations associated with the mass of chemical required to violate an MCL, data from the dSGEIS analysis was used to develop an estimate of the mass of each chemical required to fracture one well.[48] This data is presented in Table C-2, along with an estimate of the mass of chemicals required to violate an MCL in Kensico, expressed in terms of fracture job equivalents, for both Scenarios 1 and 2.

Table C-2: Fracturing Chemical Spill Scenarios for Kensico Reservoir

Chemical *0.05 mg/l MCL for all chemicals*	Estimated mass required to fracture one well (kg)	Fracture job equivalents required to exceed MCL	
		Scenario 1 (dilution with volume of Kensico)	Scenario 2 (dilution with volume of Kensico + Rondout)
2,2,-Dibromo-3-Nitrilopropionamide (1)	3019	0.6	1.7
Methanol (1)	1565	1.2	3.2
Ethylene Glycol (1)	1110	1.7	4.6
C12-15 Alcohol, Ethoxylated (2)	1110	1.7	4.6
Ethoxylated Castor Oil (2)	555	3.5	9.1
Isopropanol (Isopropyl Alcohol) (2)	555	3.5	9.1
Ethoxylated C11 Alcohol (1)	555	3.5	9.1
Alcohols C9-11, Ethoxylated (1)	391	4.9	12.9
(1) dSGEIS Frack Mix 1 (2) dSGEIS Frack Mix 2			

For Scenario 1, the mass of chemicals associated with just one to five hydraulic fracturing operations could be sufficient to violate an MCL at Kensico Reservoir. For Scenario 2, the mass of chemicals associated with two to thirteen hydraulic fracturing operations could be sufficient to violate an MCL at Kensico Reservoir. These findings indicate that the sensitivity of Kensico Reservoir to spills of fracturing chemicals is substantially higher than presented in the dSGEIS.

This analysis should not be taken to indicate that these or comparable spill scenarios would constitute an imminent threat to public health. In the event of a major spill, operators would respond immediately upon learning of the event and take appropriate operational measures to protect the water supply, including water quality sampling, adjusting intake levels, reducing flow rates or taking reservoirs off-line, etc.

Though this analysis has focused on MCLs, it is important to note that water quality contamination is important in and of itself, even if it does not trigger an MCL violation.

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48 Due to confidentiality requirements the dSGEIS analysis does not present data on the mass composition of additives or the mass of additives or constituent chemicals required to fracture a well. The scenarios presented in the dSGEIS analysis do provide sufficient information to back-calculate the mass of chemicals required to fracture a well.

NYCDEP's mission is not to supply water that merely meets regulatory limits but "to reliably deliver a sufficient quantity of *high quality drinking water* and to ensure the *long term sustainability* of the delivery of this most valuable resource."[49]

Discussion of Assumptions

The Alpha report indicates that an actual MCL violation for any of the modeled scenarios is highly unlikely due to the conservative assumptions used in the analysis. Whereas some of the assumptions (e.g., drought conditions, no spill detection) are conservative, others (e.g., complete mixing) are not. The plausibility of assumptions used in the Alpha analysis is discussed below.

Complete/instantaneous mixing in reservoirs – Complete mixing in reservoirs with volumes as large as those in the NYC system may be a reasonable assumption under limited circumstances, but short-circuiting, stratification, or spills in proximity to inlet structures must be taken into consideration. Even within the confines of simple dilution analysis, the methods used to evaluate the possibility of MCL violations at downstream system components (e.g. West Branch, Kensico, Hillview) is conceptually flawed.

Spill directly to a reservoir – Given the large volume of heavy truck traffic required to develop the Marcellus formation and the proximity of state highways to all West-of-Hudson reservoirs, it is not unreasonable to assume that at some point a chemical spill results in direct contamination of a reservoir.

Drought conditions (reservoirs at 1/3 of full capacity) – The Barnett shale has been under development for 15 years and may continue to be developed for many more. It is not necessarily "conservative" to anticipate a spill occurring during a drought during the multi-decade timeframe anticipated for development of the Marcellus formation. Further, it does not require a declared drought for one or more reservoirs to be drawn down.

No spill detection or attempt at mitigation – This assumption is not necessarily "conservative" with respect to identifying impacts associated with spills. As it is reasonable to assume that hundreds or thousands of wells may be drilled in the watershed, and billions of gallons of wastewater generated and trucked to disposal sites, it is also reasonable to expect that some spills will go undetected due to negligence, human error, or intentional misconduct (see e.g. Dimock, PA incident).

Evaluation of individual chemicals with MCLs – Operators submitted to NYSDEC chemical compositions of nearly 200 products containing almost 300 chemical constituents. The TEDX database tabulated data on 450 products containing over 300 constituents. The industry is continuing to develop new products at a much faster rate than can be incorporated into water quality regulations. The absence of an MCL for a particular chemical does not guarantee it cannot degrade the water supply and result in adverse health impacts to consumers.[50]

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[49] NYCDEP-BWS Mission Statement.

[50] NYSDOH attempts to address this issue through the 0.05 mg/L MCL for Unspecified Organic Contaminant (UOC), which are any organic chemical compound not otherwise specified in Subpart 5-1. The dSGEIS analysis did not evaluate the risk of exceeding the UOC MCL from the sum of organic contaminants found in fracture fluid mixtures.

Chemical quantity present on-site is sufficient for up to eight wells – Given the large volumes of chemicals needed to fracture hundreds or thousands of wells in the region, well pads or other sites may be used to store large volumes of material for efficient distribution to other sites. Therefore it is reasonable to assume that sites in the watershed may store volumes of chemicals larger than that needed for a single well on a single pad. Further, this "conservative" assumption fails to consider the need to transport fracturing additives from central storage or supply facilities to individual well pads, and the associated risk of introducing concentrated chemicals directly into watershed streams or reservoirs as a result of vehicle accidents. The results presented in Table C-2 indicate that the chemicals needed for one or two fracturing operations could be sufficient to exceed MCLs for some chemicals.

No soil adsorption and no evaporation – Hydraulic fracturing requires specialized chemicals to manipulate the physical properties of fracture fluid. Therefore, of the hundreds of potential chemicals available for fracture operations, many of the chemicals will be unaffected by evaporation or soil adsorption. One example, 2,2,-Dibromo-3-Nitrilopropionamide, which was evaluated as part of both fracture fluid mixes, is toxic and does not readily evaporate, volatilize, or adsorb to soil particles.[51]

Summary

It is acknowledged that the chances of every assumption provided in the NYSERDA analysis occurring simultaneously are low. However, every assumption does not need to hold true for a spill to result in significant adverse impacts to source water quality.

NYCDEP seeks to operate its water supply system to provide water of the highest quality possible. All spills will require NYCDEP operations staff to take remedial action, potentially including taking contaminated reservoirs offline, regardless of the potential for an MCL violation. This may result in significant impacts to the reliability of the system, depending on the frequency, timing, and location of the incident(s), and can be expected to affect public confidence in the ability of watershed protection efforts to ensure the purity of the water supply. Additionally, accidents and spills in the watershed have the potential to negatively impact NYCDEP's Filtration Avoidance Determination. This is true for both large acute spills and for a chronic level of smaller effectively mitigated spills.

[51] Material Safety Data Sheet, Dow Chemical.