

## Executive Summary

This report presents the results of an assessment performed by the New York City Department of Environmental Protection (NYCDEP) and its consultants, the Joint Venture of Hazen and Sawyer, P.C., and Leggette, Brashears and Graham, Inc., evaluating potential impacts to the NYC water supply resulting from development of natural gas resources in the Marcellus shale formation. The Marcellus<sup>1</sup> shale is one of the largest potential sources of developable energy in the U.S. and covers an area of 95,000 square miles; the New York State portion is approximately 18,700 square miles. The Catskill and Delaware watersheds that provide 90 percent of New York City's unfiltered drinking water supply are underlain by relatively thick sections of the Marcellus that are expected to have high gas production potential and be targeted for development. Within the watershed, there are approximately 1,076 square miles that are not currently protected and are potentially available for the placement of well pads, impoundments, chemical storage, and other elements of natural gas drilling.

### Development Activities

Based on densities of development in other shale gas formations in the United States, the area of unprotected or nominally developable land in the watershed, and the number of wells needed to efficiently exploit the resource, it is estimated that between 3,000 and 6,000 gas wells could be constructed in the watershed in the next two to four decades. Initial rates of development would be relatively low (5 to 20 wells per year), but could escalate rapidly to 100 to 300 or more wells per year under favorable economic and regulatory conditions.

Extraction of natural gas from the Marcellus and other shale formations relies on horizontal drilling and high-volume hydraulic fracturing (fracking). A Marcellus well in the New York City (NYC) watershed region would likely be drilled vertically to a depth of 4,000 to 6,000 feet, and extend horizontally a comparable distance through the target shale formation. Natural gas extraction requires that the shale be hydraulically fractured along the lateral portion of the well to increase the permeability of the shale and allow gas to flow into the well at economically viable rates. The fracturing process involves pumping three to eight million gallons (MG) of water and 80 to 300 tons of chemicals into the well at high pressures over the course of several days. Roughly half the injected solution returns to the surface as "flowback" water containing fracturing chemicals plus naturally occurring and often very high levels of total dissolved solids, hydrocarbons, heavy metals, and radionuclides. Flowback water is not amenable to conventional wastewater treatment, and must be disposed of using underground injection wells or industrial treatment facilities. The region currently has insufficient treatment and disposal capacity to handle the expected wastewater volumes.

Water for the fracturing process is typically drawn from surface water bodies and trucked to the drill site; local groundwater supplies may also be used if available. Hauling of water, wastewater, and equipment to and from the drill site requires on the order of 1,000 or more truck trips per well. The entire process, from site development through completion, takes approximately four to ten months for one well. Multiple horizontal wells are typically drilled from a common well pad roughly five acres in size. One multi-well pad can accommodate six or more wells and can

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<sup>1</sup> It should be noted that there are other gas-bearing formations such as the Utica Shale that may be targeted for development in the future.

recover the natural gas from a spacing unit covering a maximum of one square mile. New York requires that all wells from a pad must be drilled within three years of the first well, so sites will experience a relatively high and constant level of heavy industrial activity for at least one and up to three years. The fracturing process may be repeated multiple times over the life of a well to restore declining gas production rates. Wells will generally discharge poor quality brine water from the target formation over their useful life.

Table ES-1, described in more detail in Section 4.1, illustrates the magnitude of cumulative water, wastewater, and chemical volumes associated with large-scale hydraulic fracturing operations for a 6,000 well “full build-out” scenario, with and without refracturing.

**Table ES-1: Cumulative Water, Wastewater, and Chemical Volumes Associated with Hydraulic Fracturing**

Parameter (units) <i>Estimate (source)</i>	Without Refracturing	With Refracturing	
		10-Year Interval	5-Year Interval
Total Number of Wells	6,000	6,000	6,000
<b>CUMULATIVE BASIS</b>			
Total Number of Frack Jobs <i>Full build-out, high scenario</i>	6,000	24,000	48,000
Frack Chemicals Used (tons) <i>1.0% of fracture fluid</i>	1,000,000	4,000,000	8,000,000
Waste TDS (tons) <i>100,000 mg/l TDS (dSGEIS)<sup>2</sup></i>	12,510,000	27,522,000	47,541,000
<b>ANNUAL BASIS<sup>1</sup></b>			
Water Demand (mgd) <i>4 MG per frack job</i>	3.6 to 5.5	5.5 to 8.2	11.7 to 14.2
Wastewater Production (mgd) <i>50% Flowback + 0.075 MG/yr Produced Water</i>	2.6 to 3.5	3.9 to 5.3	6.7 to 8.4
Waste TDS for Disposal (tons/day) <i>100,000 mg/l TDS in waste (dSGEIS)<sup>2</sup></i>	1,100 to 1,500	1,600 to 2,200	2,800 to 3,500
Water Req'd to Dilute TDS to 500 mg/l (mgd)	500 to 700	800 to 1,100	1,300 to 1,700
Frack Chemicals (tons/day) <i>1.0% of fracture fluid</i>	150 to 230	230 to 340	490 to 590
Notes: 1. Ranges describe the median and the maximum of the annual average values for each development year. Data for the no-refracturing scenario are drawn from the 20-year period of well development. Data for the refracturing scenarios are drawn from the full 60-year period of development and refracturing. 2. The dSGEIS reports median and maximum values of TDS as 93,200 mg/l and 337,000 mg/l, respectively. The concentration of TDS in flowback reportedly increases with time. The determination of median value may include relatively low concentration samples from initial flowback.			

**Potential Impacts**

The West-of-Hudson watershed is a pristine, largely undisturbed landscape, with only minimal industrial activities. These natural and land use factors combine to yield water of very high quality with little or no chemical contamination. Natural gas well development in the West-of-Hudson watershed at the rates and densities observed in comparable formations will be accompanied by a level of industrial activity and heightened risk of water quality contamination that is inconsistent with the expectations for unfiltered water supply systems.

Intensive natural gas well development in the watershed brings an increased level of risk to the water supply: risk of degrading source water quality, risk to long-term watershed health and the City's ability to rely on natural processes for what is accomplished elsewhere by physical and chemical treatment processes, risk of damaging critical infrastructure, and the risk of exposing watershed residents and potentially NYC residents to chronic low levels of toxic chemicals. In addition to surface risks to the watershed, extensive hydraulic fracturing of horizontal wells will present subsurface contamination risks via naturally occurring faults and fractures, and potential alteration of deep groundwater flow regimes, as indicated by the geological cross-section presented as Figure ES-1.

Each of these risks is discussed in greater detail in this document. They have been identified based on review of the progression of natural gas development in other areas, documented incidents of surface water and shallow groundwater contamination associated with natural gas resource development, and review of regional geological features. NYC operates over 100 miles of water supply tunnels west of the Hudson River, the construction of which provided direct experience with respect to faults and deep fluid migration through bedrock. The assessment of risks to the City's water supply system takes into account seepages of methane and deep formation water, and faults and other natural geological features encountered during tunnel construction. As shown in Figure ES-2, water supply tunnel routes intersect numerous geological faults and fractures, many of which extend laterally for several miles, and vertically through several underlying geological strata. Each of these features represents an existing potential pathway for fluid migration.

The difficulty of remediating diffuse contamination and other risks once allowed into the environment, and the potentially catastrophic consequences of damage to critical water supply infrastructure, make clear that a conservative approach towards natural gas drilling in the NYC watershed and in the vicinity of infrastructure is warranted. In short, the rapid and widespread industrialization of the watershed resulting from natural gas drilling would upset the balance between watershed protection and economic vitality that the City, its State and federal regulators, and its upstate partners have established over the past 15 years.

Development of natural gas resources using current technologies thus presents potential risks to public health and would be expected to compromise the City's ability to protect the watershed and the continued, cost-effective provision of a high-purity water supply. A robust assessment of risks from drilling would consider site-specific factors assessed on a well-by-well basis and would consider detailed knowledge of local fracture, infrastructure, hydrologic, and other conditions at a finer scale than watershed-level analysis. In recognition of the possibility that horizontal drilling and hydraulic fracturing may one day be allowed to proceed, measures for reducing some, but not all, risks to water quality and water supply infrastructure are summarized in an appendix.

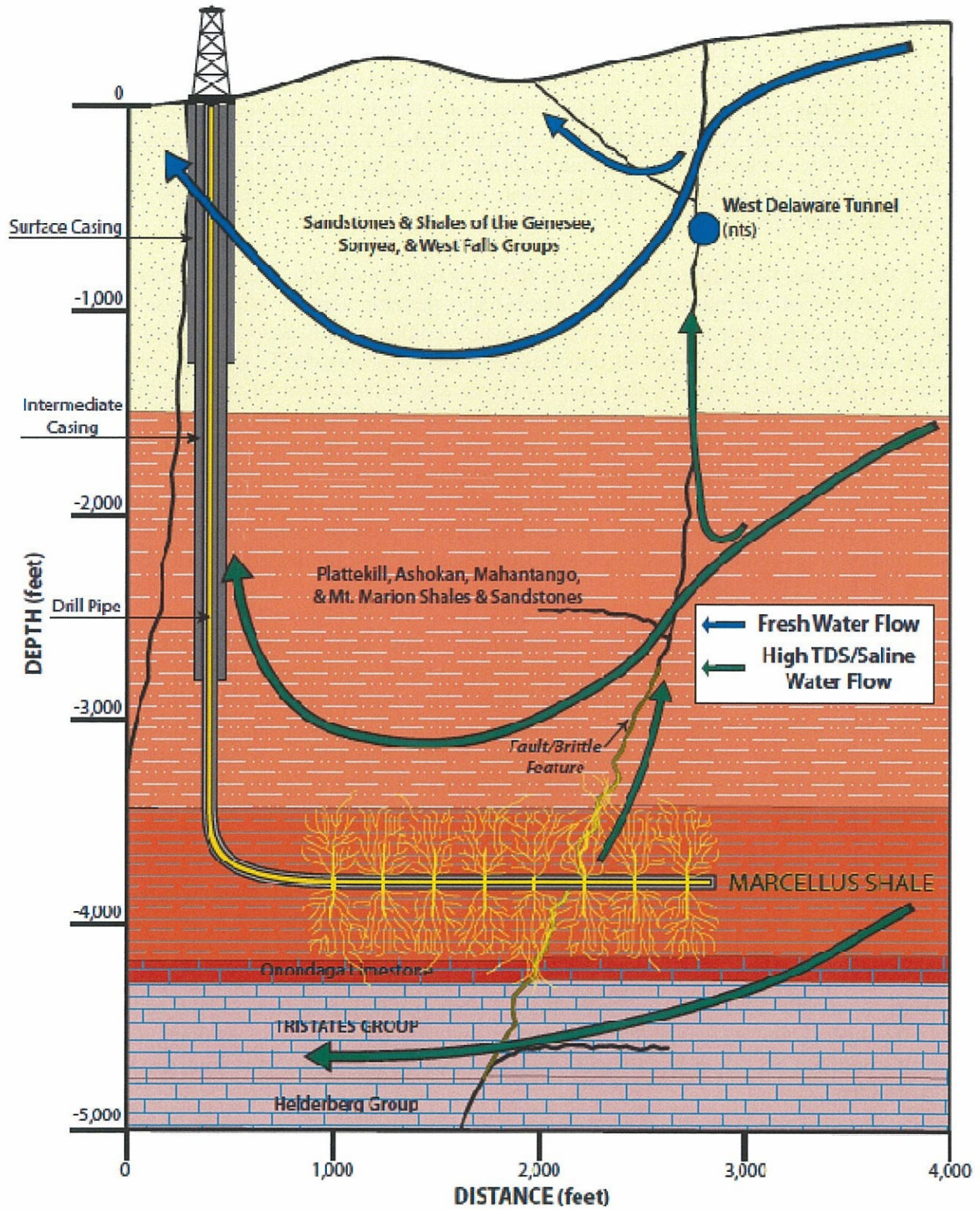


Figure ES-1: Potential Flow Disruption and Contamination Mechanisms

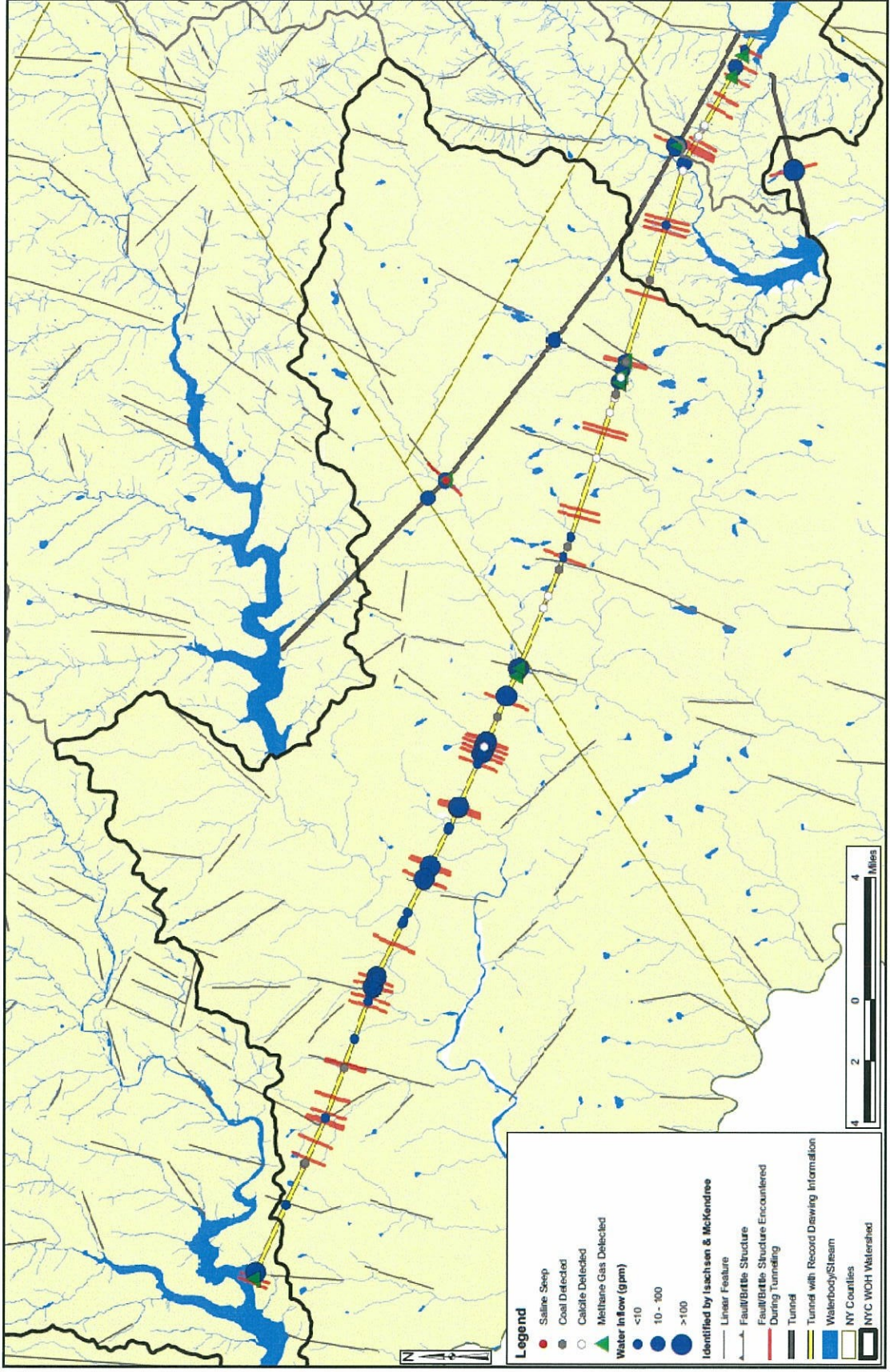


Figure ES-2: Map of the East and West Delaware Tunnels and Neversink Tunnel

