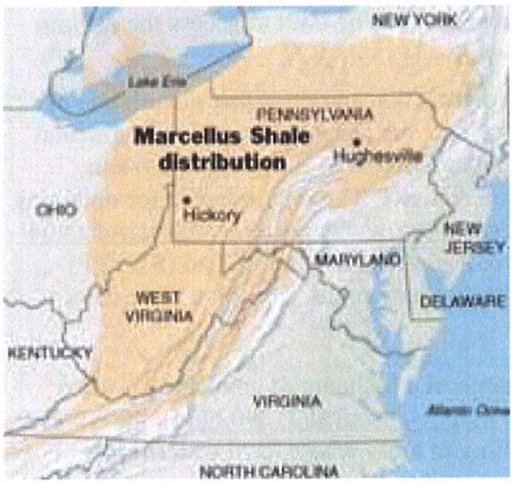
NEW YORK STATE WATER RESOURCES INSTITUTE

Department of Earth and Atmospheric Sciences

1123 Bradfield Hall, Cornell University
Ithaca, NY 14853-1901
http://wri.eas.cornell.edu

Tel: (607) 255-3034
Fax: (607) 255-2016
Email: nyswri@cornell.edu

The Marcellus Shale and Natural Gas



Some layers of rock underlying New York State contain large quantities of **natural gas (methane)**, including the Marcellus shale and the Utica shale. Shale is rock formed from sediments consisting primarily of very small, clay size particles; it is essentially mud turned into stone. The natural gas is found in the very tiny pores in the shale. To exploit this gas reserve, gas must travel from through these tiny pores to the well bore. Because of the tiny size of the pores, the gas does not naturally move fast enough for conventional well drilling techniques to be commercially viable. Due to a relatively new drilling approach, called horizontal hydraulic fracturing (or hydrofracking), which allows much more gas to be recovered from a well compared to previous methods, many new wells are now being drilled in the Marcellus shale in Pennsylvania and potentially in New York. The New York State draft Supplemental Generic Environmental Impact Statement (dSGEIS) indicates that the recoverable reserves of gas in the Marcellus shale could be as great as 489 trillion cubic feet (http://www.dec.ny.gov/energy/45912.html). To put this in perspective, in 2008 U.S. natural gas consumption was about 23.2 trillion cubic feet.

Hydrofracking is a common technique used in constructing or reviving wells drilled for either water or gas. Basically, water is forced down the well bore under very high pressures and this causes many fine fractures to form or expand in the rock around the well bore. In the case of the Marcellus shale, the natural fractures in the rocks are vertical. Therefore, a vertical well, even with hydrofracking, does not access many fractures. Having the well access many fractures is important, because the gas travels from the pores to the spaces in the fractures, where it can then more rapidly move to the well bore. Drilling into the shale horizontally at the bottom of the vertical well bore and then hydrofracking results in a well bore that intersects many more fractures than could occur with a single vertical well bore. For a diagram of this process go to http://www.propublica.org/special/hydraulic-fracturing.

For the Marcellus shale, New York State recently enacted a law establishing a spacing unit for a single well for horizontal drilling as 40 acres plus any acreage necessary to maintain a 330 foot setback (distance from property line to vertical or horizontal well). This implies a maximum number of wells of 16 per square mile. In addition, multiple wells for horizontal drilling can be established on 640 acres (which equals one square mile). The purpose of this larger spacing unit is to allow several vertical gas wells to be drilled from a central pad and expand out horizontally in different directions. Given the potential density of wells, there is concern not only about the impact of individual wells, but also about the cumulative impacts of gas well drilling construction, water withdrawals and waste water disposal on water resources. The dSGEIS fails to address cumulative impacts of gas well drilling and despite significant criticism of this failure it is not clear that the final SGEIS will address this issue (see, for example, http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_final_12-22-09.pdf and http://www.lwvny.org/advocacy/legAction/LWVNYS_SGEIS123009.pdf).

Runoff During Construction of Gas Wells

All construction sites, as they involve the disturbance of the natural surface, are vulnerable to high levels of runoff during heavy rainfall events, which not only can erode the construction site, but cause pollution in streams, ponds and lakes downstream from the construction site. Before drilling a gas well, a drilling pad must be constructed that can be as large as 5 acres. This pad serves as the surface for the operation and storage of large equipment and containers during drilling. After the well is drilled, much of this area can be reclaimed, as the equipment required to maintain a gas well is small relative to that required to drill a gas well. In addition, frequently a road needs to be built to access the drilling pad and completed gas well.

In 2003, the United States Environmental Protection Agency required construction activities that disturb one or more acres of land to have a stormwater discharge permit. In New York State, the Department of Environmental Conservation (DEC) issues this discharge permit, known as a State Pollutant Discharge Elimination System General Permit (SPEDES) for Stormwater Discharges from Construction Activity. The requirements for obtaining such a permit from the DEC are among the most progressive in the nation (http://www.nywea.org/clearwaters/04-2-summer/spdes.cfm). Before construction can commence, a Stormwater Pollution Prevention Plan (SWPPP) must be developed for the construction site and implemented before construction begins. This plan must meet specific technical standards for stormwater management.

If the construction activity or post-construction runoff causes the discharge of a pollutant of concern to a water identified as an impaired water body for that pollutant (http://www.dec.ny.gov/chemical/31290.html), the SWPPP must be certified by a licensed professional. In addition to gas well drilling in areas where local waters are classified as impaired water bodies due to the presence of nutrients or sediments, there is particular concern regarding gas well drilling in the Susquehanna River Basin. This basin feeds into the Chesapeake Bay, which is an impaired water body. New York State is committed, as part of its Chesapeake Bay Tributary Strategy, to reduce nitrogen, phosphorous and sediments entering the Susquehanna and Chemung Rivers (http://www.dec.ny.gov/lands/33279.html). Therefore, it is particularly important that new construction sites not serve as a significant source of pollutants in the Susquehanna River Basin.

The Federal Energy Policy Act of 2005 exempted gas well site activities from the need to have stormwater discharge permits. However, the dSGEIS indicates that site specific SWPPPs will be required for each well site. Since most construction is permitted at the municipal level, it has been the responsibility primarily of municipalities in New York State to monitor and enforce the SWPPPs. At this point, it appears that it is the responsibility of the DEC's Division of Mineral Resources to approve, monitor and enforce the SWPPP's of each gas well drilling site. It is not clear that the Division has enough staff for this task or that this should be a major focus for this division.

The SWPPP is to include plans for secondary containment of all chemicals used in drilling and hydrofrackking, as well as plans for training personnel and ensuring adequate materials are on site to address any spills. However, it appears that the dSGEIS does not requiring that all drilling waste (drilling muds, cuttings and flowback waters) be fully contained on site. Rather, drilling waste and flowback waters can apparently be stored in open, albeit lined, pits on site except on floodplains and the NYC watershed. It is not clear why full containment should not be required for all sites. Clearly, open pits are vulnerable to erosion and overflowing during extreme rainfall events. Though full containment cannot ensure that drilling wastes and flowback water will not enter surface or groundwater, it would decrease the risk of this occurring.

Water Withdrawals for Hydrofracking

Water required for hydrofracking shales in other regions of the US appears to be in the range of 3 to 9 M gallons per well (Jim Williams, USGS). The Susquehanna River Basin Commission indicates that 4 to 7 million gallons of water per well are being used for hydrofrackking operations in the Marcellus shale in Pennsylvania (http://www.srbc.net/programs/docs/ProjectReviewMarcellusShale(NEW)(1_2010).pdf).

Water withdrawals for hydrofracking need to be understood in the context of other water withdrawals. Estimated water withdrawals for the Great Lake States in the year 2000 for public water supplies was 10.2 billion gallons per day. Water withdrawals in 2006 by the Bolton Point Southern Cayuga Lake Intermunicipal Water Commission (from Cayuga Lake) were 2.83 million gallons per day, by the City of Ithaca (from Six Mile Creek) 3.90 million gallons per day, and by Cornell University (from Fall Creek) 1.43 million gallons per day (http://www.boltonpoint.org/images/DWQR_2007.pdf). Seen in this context, to hydrofrack a gas well would require the amount of water the City of Ithaca withdraws from Six Mile Creek in one day. Many people are unaware that in the United States, more water is withdrawn to cool power plants than for any other use. Estimated water withdrawals used to cool power plants in the Great Lake States in the year 2000 was 53.7 billion gallons per day (http://pubs.usgs.gov/fs/2008/3032/pdf/fs2008-3032.pdf). In addition, scrubbers on coal burning thermoelectric power plants in the Susquehanna River Basin can consume 4 to 5 million gallons of water per day (http://www.srbc.net/programs/docs/Marcellus%20Legal%20Overview%20Paper%20(Beauduy).pdf.PDF).

A major concern in permitting gas wells is to assure that water for hydrofracking is withdrawn at a rate and location that will not disrupt other users and ecosystem services. The most appropriate locations for water withdrawals from the public's perspective may incur substantial additional costs in hydrofracking, as there is an economic incentive, due to the cost of transporting water, to obtain water for hydrofracking as close to a drilling site as possible.

Given the potential density of gas wells needed to exploit the Marcellus shale, the likelihood that many of the wells will be located in upper reaches of watersheds, and the need for large quantities of water in a relatively short period of time, there is legitimate concern regarding the over exploitation of water, even if this impact is temporary.

Regulating Withdrawals in Different Basins

Gas wells in the Marcellus shale in New York State will be primarily located in the Susquehanna and Delaware River Basins. Water withdrawals from both surface and groundwater in these basins are under the jurisdiction of interstate basin commissions. Both commissions have clearly established their authority to permit the use of any water in their basins for developing gas wells. Furthermore, they have identified cumulative impacts and impacts on water quality, in addition to local impacts on water supplies, as key concerns (http://www.srbc.net/programs/docs/ProjectReviewMarcellusShale(NEW)(1_2010).pdf, http://www.state.nj.us/drbc/naturalgas.htm). Both Commissions have long experience with regulating water withdrawals in their basins.

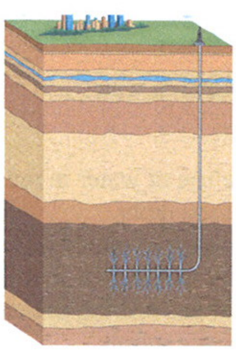
The Susquehanna River Basin Commission (SRBC) estimates that the cumulative consumptive use of water in the Susquehanna River Basin for shale gas well hydrofracing could be 28 mgd, or ~5% of current total daily consumptive use in the basin. The SRBC has since indicated that this value may be too high, as they assumed no reuse of flowback water for hydrofracing, which is now occurring in Pennsylvania. This evaluation suggests that the annually available basin wide surface water resources are sufficient to support likely rates of gas drilling in the Marcellus. However, regulations are needed to mitigate environmental and possibly drinking water supply impacts of cumulative water withdrawals during specific times and within specific stream systems. The SRBC has implemented changes in its permitting process to address water withdrawals for hydrofracing while requiring that minimum levels of passby flow to maintain adequate stream ecosystem services. The Delaware River Basin Commission (DRBC) has the authority to implement comparable regulations in the Delaware Basin.

In New York State, the Marcellus shale extends into the Great Lakes Basin and Hudson River Mohawk Basins. Unlike the Susquehanna and Delaware basins, water withdrawals in these basins do not require a permit, unless the water is to be used as a drinking water supply. Recently, New York passed legislation requiring that all water withdrawals of more than 100,000 gallons per day must be reported to the DEC (http://www.dec.ny.gov/lands/55509.html). NYS Bill A8806 (relating to the implementation of water withdrawal permits, http://assembly.state.ny.us/leg/?bn=A08806) or an analogous bill would need to be enacted, staff hired and permitting process developed for the DEC to effectively mitigate the cumulative impacts of water withdrawals in the currently unregulated basins. The DEC should undertake a comprehensive, comparative analysis of passby flow regimes to serve as a basis for establishing criteria for maintaining designated uses for streams in these basins. The methods proposed in the dSGEIS are old (1970s), from a different hydrologic region (New England), and combined in ways that have not been assessed for outcomes. As presented now, the "natural flow regime method" and the aquatic base flow method for ungauged streams (i.e. maintain 0.5 cubic feet per second of flow per square mile of drainage area) suggest different acceptable levels of passby flow on the same stream. An analysis of 10 USGS gauged streams in the Susquehanna and Chemung basins indicated none had mean August flow exceeding the minimum 0.5 cubic feet per second of flow per square mile of drainage area, implying that no water could be withdrawn from any of these water bodies during August. However, the natural flow regime method would permit removals in August since this method allows use of all water exceeding 30% of the mean flow. Because Marcellus Shale gas exploitation will be water use intensive, the narrative New York streamflow protection standard (6 NYCRR Part §701.2-3) needs to be advanced to a numeric and justified instream flow.

If the goal is to only withdraw water above a target level, there must be an accurate gauging of flow. There were no specifications in the dSGEIS for gauging flow in the unregulated basins. In addition, different points on the same stream may be used to supply water for hydrofracking more than a single well, and water withdrawals may be occurring for other uses. If there is no coordination among multiple withdrawals, streams could be overdrawn, yet it is not clear how such cumulative withdrawals will be managed outside of the Susquehanna and Delaware Basins. Also, it is not clear how groundwater withdrawals will be regulated outside these areas.

Limiting stream water withdrawals is only one component of minimizing the negative consequences of water withdrawals for hydrofracking. Minimally, hundreds of truck trips between the source of the water and the well site will be required to have sufficient water available on site for hydrofracking. Places where water will be removed need to be carefully considered, not only in terms of adequacy for water withdrawals, but also in terms of adequacy of roads, capability to store on site thousands of gallons of water, appropriate protection of the water body through reasonable setbacks for truck loading pads, impact of truck traffic on local residents, etc. These issues are not addressed in the dSGEIS.

Impacts on Water During Well Drilling



The Marcellus Shale in New York lies 3000 to 5000 feet below the surface. In the area of New York underlain by the parts of the Marcellus shale likely to be exploited for natural gas, groundwater suitable for human use is generally at depths of less than 500 feet. Even though there is groundwater at deeper depths, this water is generally too high in salts or other solutes to be used for drinking, irrigation and most industrial processes. Therefore, most of the concern regarding the potential impact of the process of gas drilling on groundwater resources is focussed on drilling through the first several hundred feet in areas that contain utilized groundwater aquifers. The New York State Department of Environmental Conservation (DEC) requires drillers to use only air or freshwater when drilling through freshwater aquifers (http://www.dec.ny.gov/docs/materials_minerals_pdf/dgeisv1ch9.pdf)

As drilling proceeds, the bore hole created is cased and sealed to surrounding rock with cement. From the surface to the depth of potable groundwater, the bore hole will be sealed with multiple casings. If the bore hole is not properly sealed, it is possible for water in aquifers near the surface to leak into lower aquifers, or water from deeper aquifers, water used in drilling muds and hydrofracking to move into surface aquifers. Hence, it is very important that the bore hole be well sealed. The New York State Department of Environmental Conservation (DEC) mandates casing and cementing (http://www.dec.ny.gov/energy/1536.html) of well bore holes. Since any water from higher layers that enter the gas play would likely have to be pumped out, it is also in the interest of the gas well owner that the bore hole be well sealed.

In addition, wells or well pads must be a prescribed distance (known as a setback) from municipal water wells (1000 to 2000 feet), reservoirs and controlled lakes (300 feet), streams, ponds and private wells (150 feet) (dSGEIS 7.1.12).

Some Marcellus shale gas wells could be located within the boundaries of the watershed in which New York City has reservoirs. The city has several concerns regarding gas well drilling within their watersheds including the possibility of fractures existing or being created that would allow for seepage from the Marcellus shale into their water supply system and contamination of their water reservoirs from gas well activities at the surface (http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_final_12-22-09.pdf).

Waste Management of Cuttings, Drilling Fluids, Flowback and Produced Water

Cuttings and Drilling Fluids/Muds

When a well is drilled, the 'cuttings' of drilled rock need to be removed from the well bore. The cuttings, the drilling fluid or mud (to lubricate the drill and help remove the cuttings), and water in the bore hole are brought to the surface where the cuttings are then separated from the fluid, which will be reused in the drilling process. The cuttings and remaining fluids are generally stored in a drilling pit. In New York State, there are specifications regarding the construction of these pits, including a requirement that all pits be lined with plastic to avoid polluted water in the pit entering the soil and shallow groundwater. As mentioned in the Runoff section, it appears that the dSGEIS does not require that all drilling waste (including drilling muds, cuttings and flowback waters) be fully contained on site. Rather, drilling waste and possibly flowback waters can apparently be stored in open, lined pits on site except on floodplains and the NYC watershed. It is not clear why full containment should not be required for all sites.

Drilling muds will be used in drilling in the Marcellus shale zone. According to the Oil and Gas Accountability Project, "drilling fluids or muds are made up of a base fluid (water, diesel or mineral oil, or a synthetic compound); weighting agents (most frequently barite is used); bentonite clay to help remove cuttings from the well and to form a filter cake on the walls of the hole; chrome lignosulfonates and lignites to keep the mud in a fluid state; and various additives that serve specific functions, such as biocides, diesel lubricants and chromate corrosion inhibitors….Drilling muds that circulate through the well and return to the surface may contain dissolved and suspended contaminants including cadmium, arsenic, and metals such as mercury, copper and lead; hydrocarbons; hydrogen sulfide and natural gas, as well as drilling mud additives, many of which contain potentially harmful chemicals (e.g., chromate, barite)."
(http://www.earthworksaction.org/pubs/OGAPMarcellusShaleReport-6-12-08.pdf)

Drill cuttings consist of a mixture of the different types of rocks through which the well is bored. As horizontal drilling will occur through the Marcellus shale, the cuttings from this shale will make up a reasonable portion of the total cuttings. These cuttings may be acidic and have the potential to mobilize metals in the cuttings or the soil to which they will be potentially exposed. Additionally, the Marcellus shale contains naturally occurring radioactive materials (NORMs), including radium. A 1999 investigation of NORMs in oil and gas wells found that the concentrations of NORMs on oil and gas production equipment and wastes pose no threat to the public health and the environment. (http://www.dec.ny.gov/docs/materials_minerals_pdf/normrpt.pdf). More recently, the DEC measured radiation from various Marcellus shale sources and concluded that NORMS "do not indicate an exposure concern for workers or the general public associate with Marcellus shale cuttings" (dSGEIS, 5-31).

Hydrofracking Fluids

Hydrofracking fluids are injected into wells under pressure in order to create cracks or fractures in the rock formation. These cracks accelerate gas flow out of the rock and into the well. Hydrofracking fluids are created by adding a proppant (commonly sand) to water. The role of the proppant is to keep the cracks from resealing once the hydrofracking fluid is withdrawn from the well. In addition to the proppant, several types of chemicals are added to the hydrofracking fluid to serve a number of purposes.

- A friction reducer is added to reduce the friction pressure during pumping operations.
- A surfactant is used to increase the recovery of injected water into a well.
- A biocide is used to inhibit the growth of organisms that could produce gases (particularly hydrogen sulfide) that could be dangerous as well as contaminate the methane gas.
- Scale inhibitors are used to control the precipitation of carbonates and sulfates.

There is considerable controversy about the possible effects of the chemicals added to the hydrofracking fluids. On the one hand, the gas industry indicates that the chemicals they use are commonly used in other industries (see, for example, (http://www.fortunaenergy.com/upload/media_element/26/01/microsoft-word---chemical-descriptions-for-marcellus-shale-wells-fortuna-_2_.pdf) . On the other hand, included in the list in the dSGEIS of over 200 chemicals that may be used in hydrofracking are at least two known carcinogens: benzene and formaldehyde. For other compounds, such as xylene and to a lesser extent monoethanolamine, some information suggests carcinogenic activity, but the literature is not in agreement. Table 6-13 of the dSGEIS also lists heavy naptha as a material likely to be used. Heavy naptha is not a unique compound, but rather a mixture of many hydrocarbons, including several that are carcinogenic. Benzene is a high-risk carcinogen and was found in nearly half of all flowback waters (Table 5-9) from Pennsylvania and West Virginia (14/29 samples) at concentrations ranging from 15.7 to 1950 μg/L, with an average of 479.5 μg/L. This average number is nearly 100 times the maximum contaminant level (5 μg/L) established by the EPA. The maximum concentration was nearly 400 times higher. Even if one considers a dilution or attenuation factor, as is done at superfund sites, of as much as 100, it is possible that mishandling of flowback water could contaminate nearby aquifers or groundwater at levels that could exceed a Maximum Contaminant Level (MCL) established by the EPA.

Other compounds of concern in fracking fluids are nonylphenol and octylphenol ethoxylate surfactants which can be degraded by microbes to become endocrine disruptors that mimic estrogen and may adversely affect the health of terrestrial and aquatic wildlife. The ethoxylate portion of these compounds are easily removed by microbes and result in the formation of nonylphenol and octylphenol which are both weakly estrogenic. Normal monitoring of the parent compounds used in fracking fluids would not pick up the presence of these degradation products. Based on the similarity to other environmental exposure scenarios, it is reasonable to expect them to be present any time the parent surfactants are used in the environment. Exposure to these compounds, even at extremely low concentrations (μg/L) can cause feminization of fish.

Requiring the use of less hazardous alternative compounds (aka substitution) is a well accepted method of risk mitigation. Many drilling companies phased out the use of benzene in the 1990s so it should be possible for those working in the Marcellus Shales to do the same. In order to reduce the risk of contamination associated with spills or storage failure, the use of benzene and other petroleum distillates in drilling fluids should be disallowed since functional alternatives exist. Alternative surfactants to nonylphenol and octylphenol ethoxylate exist so banning these compounds should not pose an undue burden on drilling companies.

Flowback

After hydrofracking, the hydrofracking fluid is withdrawn from the well, and to the extent possible, from the formation. Currently in Pennsylvania, about 15% of the hydrofracking fluid returns to the surface within 2 to 8 weeks (http://www.srbc.net/programs/docs/ProjectReviewMarcellusShale(NEW)(1_2010).pdf); this is referred to as flowback water. The rest of the water is presumably strongly absorbed by the shale and will only slowly return to the surface, primarily as water vapor, over the life of the gas well. The flowback water can be reused in hydrofracking other wells or disposed of as waste water.

The Marcellus shale is of marine origin and naturally contains high levels of salt and NORMS, some of which will dissolve in the hydrofracking fluid and be brought to the surface in the flowback water. This waste water will likely contain high levels of total dissolved solids (mostly salt or sodium chloride) and NORMS, as well as added chemicals and/or their degradation products. There are three ways this water, now considered industrial waste water, can be disposed: 1) underground injection, 2) municipal sewage treatment facilities (POTWs) that have an approved pretreatment program for industrial waste, and 3) private industrial waste treatment facilities. The sites available for underground injection of waste water are limited, and there are concerns that in certain locations underground injection may induce seismicity. POTWs must pretreat the waste water to the extent that the waste stream does not damage the sewage treatment system and does not exceed its permitted capacity to release pollutants to receiving waters. POTWs are generally not effective in removing salts from waste water, so there is concern that individual and cumulative releases to surface waters from treated, yet salt enriched, waste water could, from individual or cumulative releases, disrupt freshwater ecosystems. Currently, there are no private industrial waste treatment facilities for handling Marcellus shale flowback water in New York State.

The issue of NORMS, primarily radium, in the flowback water needs to be considered as well. Radium in flowback water may be reduced during treatment to acceptable levels to discharge into surface waters through being retained in the solid waste. This raises the issue of where to dispose of the radium enriched solid waste from pre-treatment of flowback water or flowback water treated in private facilities. Both Louisiana and Texas regulate disposal of NORMS in solid waste from exploration and production of natural gas. It appears that NYS has this authority under NYCRR Part 360 (or 380 p7-102). However, reference is only made to standards for discharges in effluent; it is not clear whether standards exist for radium discharged in solid waste.

A 1999 report prepared for the Department of Energy (Smith et al. 1999. An Assessment of the Disposal of Petroleum Industry NORM in nonhazardous Landfills, DOE/BC/W-31-109-ENG-38-8) considered the risks of disposing of NORMs in nonhazardous landfills. The study used a scenario of 2,000 cubic meters of solid waste with 50 picoCurries (pCi) per gram disposed in a landfill and found negligible harm to landfill workers, nearby residents, and future recreational users of the landfill property. It did note that higher levels could lead to increased risks. As shown in Appendix 13 of the dSGEIS, production brine from previously sampled wells drilled into the Marcellus Shale could have radium concentrations of upwards of 5000 pCi per liter. Assuming a pretreatment process removes solids that comprise 1% of the effluent volume, including all the radium, this generates a solid with approximately 500 pCi per gram, which is 10 times the concentration used in the prior study. Although just a rough estimate, it highlights the potential for NORM levels above those even typically considered in other states when dealing with land disposal options.

Produced Water

As gas is further pumped out of a well, water naturally contained in the Marcellus shale formation may also be withdrawn. This water is often called produced water. The volume of water produced is not expected to be great; one estimate is 42 gallons of water per million cubic feet (MMcf) of gas produced. At the end of the first year, a typical horizontal well in the Marcellus shale is not expected to produce more than 1 MMcf of gas per day; so produced water is not likely to exceed 300 gallons per week.