Framework for Assessing Water Resource Impacts from Shale Gas Drilling

by Susan J. Riha and Brian G. Rahm

In 2009, 23 percent of total energy, including 40 percent of electricity, consumed in the United States was derived from natural gas. About 88 percent was produced within the United States (with most of the remainder coming from Canada). Since 2007, the proportion of domestic gas supplies from shale has steadily increased and is expected to continue to increase, relieving the need to meet demand in the near future with imports. The Marcellus Shale, which is a geologic formation found under much of southern New York, may contain more recoverable natural gas than any other shale formation in the United States. Recoverable reserves of natural gas in the Marcellus was estimated in one study to be more than 20 times the total amount consumed in the United States in 2009.

Drilling Activities

Activities associated with the recovery of natural gas from shale have significant impacts on water resources and, therefore, necessarily draw the attention of water resource regulators and managers. These activities include establishment and construction of multi-acre drill pads; vertical drilling, often through potable groundwater supplies; and horizontal drilling through the shale gas formation for possibly thousands of feet. During these operations, millions of gallons of water need to be acquired and transported to the drilling site, mixed with a number of chemicals, and pumped in stages under pressure into the well bore in order to fracture the rock (hydraulic fracturing). Some of this water, which has now interacted with native constituents of the shale formation, is relatively quickly brought back to the surface (flowback water), where it is sometimes reused for hydraulic fracturing of other gas wells. Flowback water that is not reused, as well as water that is returned to the surface over the life of the gas well (produced water), must be stored and then treated. The constituents removed or remaining after treatment of wastewater must be disposed of either in landfills or by injection into deep wells.

Water resource regulators and managers are concerned with minimizing the impacts associated with the above activities. However, developing a clear understanding of potential impacts is difficult given the array of activities and risks that occur during shale gas development. Anecdotal reports of contaminated wells and fish kills attract attention, but are difficult to evaluate without a more comprehensive understanding of shale gas drilling impacts. To help provide clarity, and to assist regulators and managers, the New York Water Resources Institute has developed a relatively simple framework for considering important water resource impacts from natural gas drilling.

Categorizing Water Impacts

One simple way to categorize gas drilling impacts on water resources is to distinguish between impacts that are instigated through activities taking place at the surface and those caused by activities occurring below ground.

Surface activities include:

- well pad, road and pipeline construction
- water withdrawals (whether from surface or groundwater)
- treatment and disposal of flowback and produced wastewaters
- surface spills that may occur during transportation, storage and handling of chemicals and waste

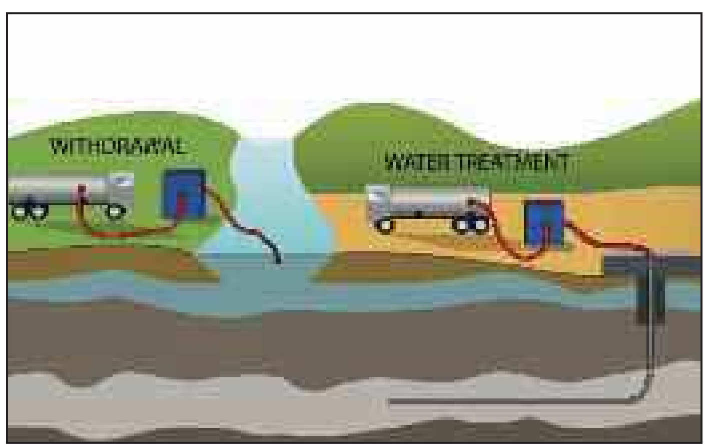
Subsurface activities include:

- drilling, casing and fracturing
- underground injection of waste

The distinction between surface and subsurface activities that impact water resources could be useful in determining who should be responsible for regulating various aspects of shale gas drilling. Gas drilling impacts on water resources can also be classified as arising from ***deterministic*** or ***probabilistic*** events. Deterministic events are certain to occur and their magnitude is directly related to the extent and pace of gas drilling development. Deterministic events, such as water withdrawals and wastewater production, can be anticipated, planned for, and closely regulated. Probabilistic events can be anticipated in the sense that they are likely to occur at some point, but their occurrence and consequences are highly uncertain over time and space. The likelihood of a probabilistic event occurring must be inferred or estimated using historic data associated with similar events, if it is available. Probabilistic events include surface runoff, spills and leaks, as well as subsurface events related to gas well integrity. The distinction between deterministic and probabilistic events could be useful for developing and prioritizing strategies for preventing, mitigating and monitoring for water resource impacts.

Impacts from Deterministic Events

Deterministic events generally occur at the surface, and reflect the overall pace and magnitude of drilling activity. Water withdrawal, and the subsequent storage, handling and treatment of water and waste fluids all represent deterministic events. They are a necessary part of shale gas drilling activities, and so it is in the best interest of both industry and regulators to have accurate data and comprehensive strategies for addressing the water resource impacts of these activities. Clear policies regarding when and where water withdrawals will be permitted and how disposal of waste fluids will occur provide industry with planning certainty. From the perspective of policy makers and regulators, water resource impacts as a result of deterministic activities represent an opportunity to influence the pace of gas drilling activity through established permitting and compliance



Graphic by Laura Buerkle

Deterministic events are certain to occur and their magnitude is directly related to the extent and pace of gas drilling.

systems. Central to the success of minimizing or mitigating the impact of deterministic events on water resources is the availability of accurate data regarding water volumes being used, as well as descriptions of waste fluid flows and compositions.

The water withdrawal permitting structure established by the Susquehanna River Basin Commission (SRBC) is a good example of how the impacts of shale gas water withdrawals can be evaluated in the context of basin wide consumptive use of water. The SRBC system addresses the spatial and temporal impacts of water withdrawals by managing and in some cases restricting locations and timing of withdrawals so as to ensure minimum required passby flows *(see SRBC's article, page 28)*. A similar system should be established in other river basins of New York outside of the Susquehanna and Delaware Basins.

Throughout the Marcellus Shale region, a major challenge remains the handling and treatment of flowback and produced wastewaters. In New York, gas drilling flowback water has usually been stored in open, albeit lined, pits but some companies drilling in the Marcellus in Pennsylvania are now using closed loop systems in which all wastewater, at least at the drilling pad, is containerized. Currently, gas drilling flowback and produced water from more traditional gas drilling activities is either treated at permitted POTWs (publicly owned treatment works) or shipped to specialized treatment plants in other states. Due to the high concentration of total dissolved solids (TDS) and overall volume of fluids produced from Marcellus Shale activities, however, it appears that most POTWs are not likely to be interested in or capable of treating these new wastewaters, due in part to possible disruption of the treatment process that shale wastewater may cause. Additionally, to remove the soluble salts contained in flowback and produced water requires using evaporation or reverse osmosis and, therefore, will not generally be removed in a POTW but could be released to surface water if sufficiently diluted.

Mobile or temporary water treatment plants, designed specifically for treating water from shale gas operations, could be built in New York. In the face of increasing reuse of flowback and produced wastewaters by companies seeking to increase the efficiency of their operations, a temporary or flexible approach to developing these facilities might be particularly appropriate. If the wastewater is desalinized, the question of the disposal of brine remains. Reinjection of brine into other geologic formations is a possibility, but sites for reinjection in Pennsylvania and New York are apparently limited.

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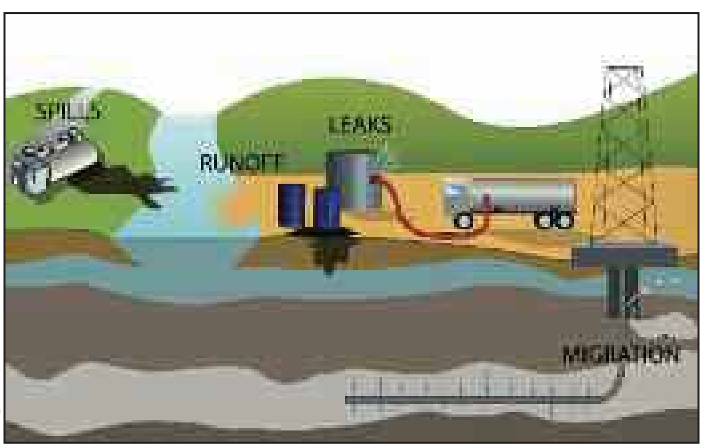

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Probabilistic events are likely to occur, but their occurrence and consequences are highly uncertain over time and space.

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Disposal of solid wastes, including drilling muds and cuttings, as well as suspended solids recovered from wastewaters, also remains a concern. Due to inherent characteristics of the Marcellus Shale in southern New York, these wastes are likely to contain elevated levels of naturally occurring radioactive materials (NORMs) and so may not be acceptable for disposal in non-hazardous landfills. More experience and testing will be needed as Marcellus Shale activity grows to determine if solids disposal will require special consideration.

Impacts from Probabilistic Events

Probabilistic events arising from gas drilling activities at the surface that have the potential to impact water resources are not fundamentally different than those of other industries. Surface impacts essentially result from leaks and spills, which can be defined as any unintended release of hazardous material. While spills may result from a wide variety of activities, they can be simplified by categorizing them according to the risk they pose to water resources. Regardless of where a spill originates, three basic characteristics should be considered: ***containment, toxicity and volume.***

If a spill is contained, there is little chance it will pose a threat to water resources. Uncontained spills, such as those that enter soils or water bodies, must be further evaluated.

Toxicity refers to the degree to which a material can damage organisms, while volume simply describes the quantity of material released. These last two parameters can be used together to determine the risk any uncontained spill may pose. Highly toxic spills present a risk regardless of their volume. Conversely, high volume spills may pose a risk regardless of their toxicity. Viewing spills as a combination of these characteristics - containment, toxicity and volume - results in a reasonably simple and robust approach to assessing and minimizing the risk an event poses to water resources.

Preventing spills from impacting water resources requires containment. Some industry operators and service companies are developing and implementing best management practices with respect to containment, and efforts should continue until such practices are routine. The extra effort to build containment measures into storage and handling areas onsite is worthwhile when compared to the potential negative consequences of spills. However, some spills cannot be contained, and must be managed and remediated in other ways. Timely data on toxicity and volume of spills is essential for the mobilization of effective spill responses from both industry and regulators. A fast, reliable and transparent reporting system is crucial for making sure that all stakeholders have the right data to respond to spills effectively. Reducing or restricting the use of highly toxic chemicals and taking precautions against high volume spills are additional preventive actions that could minimize risk to water resources.

Subsurface probabilistic events that have the potential to impact water resources may not be as likely to occur as surface events, but appear to be the type of events that most concern the public. Direct contamination of groundwater as a result of fracturing procedures appears to be highly unlikely. However, subsurface impacts as a result of faulty well bore cementing practices and improper balancing of well pressures can and has occurred. While these events may be rare, they can have significant impacts on drinking water sources, resulting in elevated levels of methane and turbidity, as well as other constituents associated with gas drilling and shale formation fluids.

Testing of private drinking water wells pre and post gas drilling is necessary for establishing a link between drinking water quality and drilling related impacts. Industry, regulators, and private and academic institutions all appear to recognize the value of this type of monitoring and have helped to make it an increasingly accepted practice. Regulators could take other precautionary steps to reduce the risk of subsurface impacts, such as requiring cement logs to ensure the integrity of the well and the proper separation of drilling fluids and drinking water. Also, the use of highly toxic chemicals in drilling and hydraulic fracturing could be discouraged or in some cases banned to further reduce risk to water resources.

Moving Forward Using Protective Management

The framework presented here can be used to help stakeholders better understand the wide range of events associated with shale gas drilling that will or could potentially impact water resources. Distinguishing between deterministic and probabilistic events associated with shale gas activity is important from both a public policy and communications perspective. Deterministic events (water withdrawal and waste disposal) can be managed and regulated to minimize or avoid impairments to surface and groundwater, as well as to control and monitor the scale and pace of development. Regulations and best practice guidelines should also be developed to reduce or minimize the impact of probabilistic events on water resources, and should be carefully focused on those events of relatively high likelihood and risk.

Unfortunately, events having negative impacts on water resources will occur. There will also continue to be events that capture the public's attention. However, events of interest to the public may not always match events that generate negative impacts. It is likely that the public will suspect that events have occurred when they have not, and it is also possible that industry will dismiss the possibility of certain events despite strong public sentiment to the contrary. Therefore, it is and will remain a challenge to communicate the true risks associated with events while conveying a sense of oversight and safety with respect to shale gas drilling activities.

Though efforts to encourage drinking water testing and development of surface water monitoring systems are unlikely to prevent or change the occurrence of certain negative events, they are nevertheless likely to be helpful in communicating the role of water resource regulators and managers to the public. Creation of a highly accessible and informative database that includes reports on gas well permits, inspections and chemical spills is also important for addressing the perceived risks to water resources of gas drilling, and should be a top priority within New York.

Moving forward, New York has the opportunity to learn from and improve upon its own history with gas drilling, as well as the more recent experience of Pennsylvania with the Marcellus Shale. Industry and regulators can employ systems that address and manage the range of possible negative impacts on water resources associated with shale gas drilling, as well as develop transparent monitoring and reporting systems that ensure the public that shale gas drilling is occurring in a manner that protects our water resources.

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