Appendix G

Risks from water withdrawal for UGWD

Scope

This section evaluates risks from the withdrawal of water for use in unconventional gas well development (UGWD). The specific focus of this section is water withdrawal, rather than subsequent storage, use and reuse of the withdrawn water, which are considered in other sections.

Background

Large quantities of water are required for UGWD, particularly during high-volume hydraulic fracturing (HVHF). According to an estimate for UGWD in the Pennsylvania portion of the Susquehanna River basin, fresh water withdrawals from permitted surface water sources are typically used, and the next most significant source is purchase from public water systems (Abdalla, 2011). Other potential water sources include on-site groundwater resources and treated waste water. Literature sources estimate that 2-5 million gallons of water are usually required for each well through completion of HVHF, and note that total water volumes depend on factors such as well depth, length of laterals, and number of HVHF stages (Nicot & Scanlon, 2012; Ernstoff & Ellis, 2013). Permit applications received by the Maryland Department of the Environment (MDE) in 2009-2012 estimated daily water usage of 20,000 gallons per well during well drilling and total water usage of 3-7 million gallons per well for HVHF.

As noted below, this assessment assumes that an average of five million gallons of water is required for each well through completion of HVHF.

Fresh water demands may be reduced by on-site water reuse, technological advances which improve efficiency of water use during hydraulic fracturing, and, where possible, use of alternatives such as brackish water (NGWA, 2014).

Relevant steps in the process of unconventional gas well development

Phase 3: Drilling Phase

Phase 4: Hydraulic Fracturing

Risks identified

Potential impacts to local and regional water supplies

Surface water and ground water provide essential supplies for drinking water, agriculture, ecological resources, recreation and some commercial and industrial activities. At a local or regional level, water demands for UGWD could reduce availability of fresh water for existing uses as well as prospective uses. Because water may be transported to pads from off-site sources at varying distances, even from out of state, these local effects could occur anywhere. Water withdrawals could also make a particular water supply more vulnerable to impacts during and after drought conditions. These risks are not specific to UGWD. Unlike many other water uses, however, most of the water withdrawn for HVHF is removed, not only from downstream users, but from the water cycle. The compressed time frame of water demands for unconventional gas wells generally result in companies utilizing on site storage to meet the peak demands. Thus, it is important to know not only the total volume of water needed but the actual rate of withdrawal to identify potential risks on water supplies.

Potential impacts to ecological systems and aquatic species in rivers and streams

Water withdrawals for unconventional gas well development could pose a range of risks for direct and indirect impacts to ecological systems in rivers, streams, wetlands, springs and seeps by reducing flow and related effects. Water withdrawals from surface and groundwater systems can adversely affect aquatic ecosystems. Changes in water levels and streamflow regimes affect the quantity and quality of stream habitat, water chemistry (temperature, DO), and critical life history periods (spawning). These cumulative effects from hydrologic alteration on the composition of stream assemblages are well documented in a variety of hydrologic and ecological systems (Dewson et al., 2007; Bradford & Heinonen, 2008; Poff & Zimmerman, 2010). Numerous examples were reviewed generally within an exhaustive literature review on flow-ecology alteration relationships and specifically as they related management of the hydroecological integrity of Maryland's streams (Ashton, 2013). Carlisle et al. (2011) reported that increasing deviation from expected minimum flows resulted in a higher proportion of biological impairment. Experimental reductions in stream flow resulted in fewer invertebrates, insects, and EPT (Ephemeroptera, Plecoptera and Trichoptera) taxa compared to an unaltered stream (Wills et al., 2006). Large, consumptive water uses in the Great Plains have been responsible for major shifts in fish assemblages and are projected to substantially fragment and reduce habitat under current withdrawal scenarios (Gido et al., 2010; Falke et al., 2011). In a recent study in the New Jersey Pinelands, Kennen et al., (2014) found that modeled reductions in groundwater through increased withdrawals would result in degradation of the macroinvertebrate community. In a large spatial analysis of Maryland Biological Stream Survey and water withdrawal data, a negative relationship was observed in several biological metrics and the abundance of select fish species as the magnitude of water withdrawal increased within a watershed. In that preliminary analysis, the effect of flow alteration was not readily distinguishable from other natural (stream size) or anthropogenic (urbanization) variables; however, that was not a goal of the study.

Literature sources also note the uncertainty of flow-ecology relationships and that consideration of single biological or hydrological end points are not sufficient to maintain healthy, functioning aquatic ecosystems (Lytle & Poff, 2004; Arthington et al., 2006). Rapid expansion of natural gas development may pose a threat to surface waters, and it is inadvisable to allow large consumptive withdrawals in watersheds of streams with valuable natural resources (e.g., Use-Class IV, Tier II, protected species, etc.) (Entrekin et al., 2011).

Risks to ecological systems and aquatic species may come from direct withdrawals of water from rivers or streams, or from withdrawals of ground water that feeds rivers or streams (Ernstoff & Ellis, 2013; NGWA, 2014). Ecological systems and aquatic species in rivers and streams that are sensitive to low-flow or drought conditions would be most vulnerable to these impacts, particularly if high volumes of water are withdrawn over relatively short time periods. Water quality impacts could include changes in temperature, oxygen levels and flow rates that would adversely affect aquatic species. For example, if surface water sources are utilized, there is potential for adverse impacts to mussel species. Brook trout populations are limited by stream flow and water temperature (Heft et al., 2006), particularly during the summer and fall seasons. In Maryland, these seasons coincide with the lowest annual flow rates and the highest annual water temperatures. Published literature describes the negative impacts of reduced flow and increased water temperatures on brook trout life history needs, survival, growth, reproduction, and population levels (Hakala & Hartman, 2004). Currently, brook trout populations in Maryland are extremely fragile, with less than 40% of historic habitat still occupied, and the majority of these populations are at extremely reduced levels. The experience of resource professionals including Maryland Department of Natural Resources (DNR) biologists and the currently available literature suggests that surface and/or groundwater withdrawals have the potential to impact not only the hydrology of Maryland's brook trout streams, but also limit the ability of Maryland's existing brook trout streams to support brook trout (Weltman-Fahs & Taylor, 2013). Furthermore, special concern should be paid to potential water withdrawals in low-flow periods (typically during summer months) because many of Maryland's brook trout streams are close to exceeding maximum temperature tolerances for brook trout during this period. Weltman-Fahs and Taylor (2013) suggest that further decreasing flows for water withdrawals during this time will limit the amount of habitat available to not only fish, but many other aquatic organisms as well. Reducing flow during this critical period has the effect of further increasing temperature due to increased exposure of bottom substrate to sunlight. Higher water volume can buffer this effect and prevent reflective heat from warming the water, but at low flows the heat impacts the bottom and more readily transfers into the water column resulting in increased water temperatures and lower dissolved oxygen. Conversely, low flows during the winter increases the risk of anchor ice forming which can cause reproduction failure for trout and other finfish in shallow streams.

Potential impacts on recreational activities

The lakes, streams and rivers of western Maryland are heavily used for boating, fishing, swimming and other water-related activities. In the case of Deep Creek Lake, the demand for water for snow-making, boating and fishing compete with each other and power generation. The water appropriation permits for Deep Creek Lake have been written to balance these competing needs. The competing uses for any water resource should be considered in developing a water appropriation permit.

Factors influencing risks of UGWD-related water withdrawals

Risks to water supplies from water withdrawals will depend on multiple factors, including baseline characteristics and status of individual water supplies, connections and relationships between water supplies, existing uses of the water supplies, and whether one or more related water supplies serve as the common supply for development of multiple gas wells. Additional considerations include the timing of gas well development and the variability of water demands. Since large volumes of water are not required after HVHF has been completed, water demands for individual gas wells will be temporary. However, staggered development of multiple gas wells using a common water supply would increase the duration of water withdrawals when compared to that required for an individual gas well. Water availability may be particularly impacted if withdrawals from a common water supply for convergent demands of multiple gas wells coincide with peak demands from other uses of the same water supply (Nicot & Scanlon, 2012). Additionally, water needs for unconventional gas wells may vary over space and time, even within the same geographic area (Nicot & Scanlon, 2012), so it may be difficult to predict water demands in a scenario where multiple gas wells rely upon a common water supply that, in turn, supports other competing uses. The above considerations would also interact with precipitation status, changes in population, and changes in land use.

Western Maryland's water supply

In the potential productive portion of the Marcellus Shale region in Maryland (Garrett County and western Allegany County) the population relies on private wells and springs, community water supply wells and springs, and withdrawals by community water systems from streams, rivers and reservoirs. An estimated two thirds of Garrett County residents (21,000) obtain water from individual groundwater supplies. Groundwater is also the primary supply for public water systems in Garrett County, accounting for service to about 6,400 of the 9,200 residents served by community water systems. There are a total of 15 community water systems in Garrett County. The largest serves the Town of Mountain Lake Park and the smallest serves a small mobile home park.

In contrast, Allegany County residents are more likely to receive water from a public water system. More than 90% of the County's population is served by a public water system. A significantly higher percentage of the County's population (85%) is estimated to be served from a surface supply. Several communities in Allegany County obtain their water from withdrawals in Garrett County (Frostburg, Westernport and a portion of Midland Lonaconing's supply). Water from the City of Cumberland serves many of the surrounding areas.

Significant non-potable uses include, in descending order: withdrawals for hydroelectric generation (from Deep Creek Lake); manufacturing (such as the paper mill in Luke); mine dewatering (predominantly coal); releases to support cold water fisheries, and fish hatchery operation. As noted above, recreational uses (e.g., golf course irrigation, snow making, white water rafting, boating and fishing) are also among the important non-potable uses that might be impacted by water withdrawal for UGWD.

Risk Mitigation: Current regulations and Proposed BMPs

Existing regulatory framework

Maryland laws and regulations governing water withdrawals are designed to protect water supplies and the users of water supplies. Specific consideration is given to aggregate changes and cumulative impacts in the context of both current and future appropriations in a given area. Water appropriation permits are required for any activity that withdraws water from the State’s surface waters or ground waters, unless the specific activity is exempted from the permit process. Withdrawals of groundwater less than 5,000 gallons per day, as an annual average, are exempted if certain criteria are met. Withdrawals of more than 10,000 gallons per day, as an annual average, may require detailed analyses, such as aquifer testing, as part of the permit application.

Water appropriation permits include specific limits that are intended to prevent excessive water withdrawals, including withdrawals over a short time period. All groundwater permits have two limits; these include an annual average and a daily average during the month of maximum use. Withdrawals of surface water also have two limits: these are an average annual limit and a maximum day limit. Impacts to other uses are evaluated based on peak withdrawal rates. A permit may contain a condition requiring the permittee to stop or reduce water use when directed to do so by the Department during a drought period or emergency. The Department may condition approval of a surface water appropriation or use permit on the permittee's provision of low flow augmentation to offset consumptive use during low flow periods to protect other users of the water and to protect the resource. A surface water appropriation or use may be conditioned on the maintenance, by the permittee, of a required minimum flow past the point of appropriation to protect other users of the water and to protect flora and fauna within the watercourse; new surface water permits have screening requirements (1 millimeter) and intake velocity requirements (0.5 feet per second) to minimize potential of the withdrawal for removing or harming small fish, fish eggs or other small aquatic organisms.

Water appropriation regulations can be found in the Code of Maryland Regulations, Title 26, Subtitle 17.06 (COMAR 26.17.06).

Recommended Best Practices

The Best Practices report states that water sufficient for HVHF could likely not be obtained without a water appropriation permit, considering the relatively small amount of water withdrawal that would require a permit (MDE & DNR, 2014, pp. 31-32). The report also notes that MDE and DNR feel that existing criteria used to evaluate water appropriation applications are adequate to address water withdrawals for UGWD (MDE & DNR, 2014, p. 32). In addition, a generalized water appropriation plan will be required for the Comprehensive Gas Development Plan (CGDP) that identifies the proposed locations and amounts of water withdrawals needed to support the plan. MDE will use this information to identify any proposed appropriations that may not be granted due to supply, environmental, public health or other restrictions, and will allow the applicant to revise the CGDP.

Proposed BMPS that would address potential impacts from UGWD-related water withdrawals are outlined below.

- An invasive species plan is required for drill permits to prevent introduction of any invasive species, including pathogens.
- Includes a survey for invasive species must be done at water withdrawal sites.
- Contains procedures for avoiding transfer of species by clothing, boots, vehicles, water transfers, restoration materials, etc.
- Avoids using waters from areas known to have invasive species present.
- Recycling to reduce water appropriation needs
- 90% of flow back and produced water to be recycled unless applicant can demonstrate that it is not practicable
- To occur on the pad site of generation

Evaluation of risks

Table 1 in the Methodology section of the *Risk Assessments* document presents two development scenarios for UGWD in Maryland determined by the Regional Economic Studies Institute (RESI) of Towson University. Scenario 1 assumes 25% extraction with 150 total wells drilled, an average of 15 new wells per year, and a range of 6-29 new wells per year; scenario 2 assumes 75% extraction with 450 total wells drilled, an average of 45 new wells per year, and a range of 12-72 new wells per year (ranges taken from Figures 12 and 13 of the RESI report). The following figure presents estimates of water volumes required for UGWD under each scenario, using the assumption of five million gallons of water per well:

Figure: Estimates of total water demand for UGWD in Western Maryland

SCENARIO 1 (25% EXTRACTION)

Estimate based on average number of new wells per year:

15 new wells per year x 5 million gallons per well = 75 million gallons per year

Estimate based on maximum number of new wells per year:

29 new wells per year x 5 million gallons per well = 145 million gallons per year

SCENARIO 2 (75% EXTRACTION)

Estimate based on average number of new wells per year:

45 new wells per year x 5 million gallons per well = 225 million gallons per year

Estimate based on maximum number of new wells per year:

72 new wells per year x 5 million gallons per well = 360 million gallons per year

Under Scenario 2, the estimated volume of water required during the year with the highest number of new wells is 360 million gallons, or 0.99 million gallons per day (mgd) as an annual average. If all of this water were withdrawn over a six month period, the corresponding volume would be approximately 1.98 mgd. The following are included to place these volumes into a regional context for water use and availability:

- The largest public water system in the region is the City of Cumberland, which withdraws water from Pennsylvania. According to an MDE Water Management Administration database, this system's average use is about 2.5 mgd and the plant design is about 15 mgd.
- The largest streams in the area where UGWD would be expected to occur are the Youghiogheny River and North Branch of the Potomac River. A table of mean monthly flows at the North Branch and Friendsville gage is available from the web interface of the U.S. Geological Survey's National Water Information System. This interface presents monthly data in cubic feet per second and is available at http://waterdata.usgs.gov/nwis/. Using a conversion of 1 mgd = approximately 1.54 cubic feet per second, the lowest recorded monthly flow for the Friendsville gage since 1990 is 49.8 cubic feet per second, or 32.3 mgd, in September 1991. The lowest value since 2005 is 69.4 cubic feet per second, or 45.1 mgd, in September 2010. Under Scenario 2, water demands for UGWD during the year with the highest number of new wells (approximately 1.98 mgd if all activity took place during six months) would represent 6.1% of the flow recorded in September 1991 and 4.4% of the flow recorded in September 2010.
- During a year with average precipitation, over 1.3 billion gallons of water falls on Garrett County, on average, each day (MDE & DNR, 2014).

At the level of a single unconventional gas well, risks related to water withdrawal are generally expected to be low and infrequent (Ricardo, 2013). The New York State Revised Draft Supplemental Generic Environmental Impact Statement states that, on an individual basis, the impact from water withdrawal is low, and estimates that even the cumulative withdrawal at peak HVHF activity would increase statewide fresh water demand by only 0.24% (NYSDEC, 2011, p. 6-10). However, a statewide estimate may not reflect local impacts, and the implications of this estimate would not necessarily apply in Western Maryland. Even a single well could pose risks if it uses water that is withdrawn from an already-stressed water supply, particularly if HVHF-related withdrawals coincide with other factors such as drought or peak demand from competing uses. Furthermore, habitat and sensitive species that are particularly dependent on a certain water supply could be impacted from water withdrawals for even one well.

The overall level of risk associated with water withdrawals could be highly variable since it will be based on specific local conditions. However, Maryland's current water appropriation regulations and permitting process should serve to reduce the impact of water withdrawals, particularly because of consideration of aggregate changes and cumulative impact for both current and future appropriations. Attention to key factors will be necessary to prevent or reduce impacts to local water supplies, ecological systems and sensitive aquatic species, and recreational activities. These include a) consideration of the real-time water demands of HVHF as they relate to other uses and to impacts on habitat and sensitive species; and b) integration of existing knowledge with consideration of unpredictable conditions in order to inform the appropriations process. Additionally, the recommended best practice of the CGDP for multiple-well planning could help identify risks associated with water withdrawals. CGDPs could provide early insight into concerns and problems that will be raised during the permit application process, including the cumulative impacts on water supply from existing and proposed appropriations.

While the anticipated impacts from UGWD-related water withdrawals are likely to be variable, the probability and consequence framework presented in Figure 1 (Section III of the core document) can be used to consider these potential impacts during UGWD phases relevant to water withdrawal. The following findings assume that a) the existing regulatory framework is in effect, and b) the above BMPs may serve to avoid or minimize the adverse impacts discussed above:

Impacts from water withdrawal for drilling (Phase 3)

The probability of adverse impacts to local and regional water supplies, ecological systems and aquatic species, and recreational activities is expected to be low. If adverse impacts occur, the consequences are expected to be minor.

Rationale for findings: The existing water appropriation permitting process considers current and future cumulative impacts of water withdrawals and is expected to prevent excessive withdrawals during well drilling, so the probability finding is low. Impacts that occur despite the permitting process are expected to be of minor consequence because relatively modest volumes of water are required for drilling.

Impacts from water withdrawal for hydraulic fracturing (Phase 4)

The following findings apply to multiple-well scenarios with staggered well development, where HVHF of multiple wells may occur simultaneously with drilling of multiple wells.

Impacts to local and regional water supplies: The probability of adverse impacts to local and regional water supplies is expected to be low. If adverse impacts occur, the consequences are expected to be moderate.

Rationale for findings: The existing water appropriation permitting process considers aggregate changes and cumulative impacts in the context of both current and future appropriations, and permits include both daily and annual limits on average withdrawal volumes. The permitting process is expected to prevent excessive withdrawals that could impact local and regional water supplies, including high-volume withdrawals over a relatively limited time period, so the probability finding is low. Additionally, implementation of area-specific CGDPs for multi-well planning should provide valuable input for consideration of cumulative impacts from water withdrawal. Because large volumes of water are required for HVHF, impacts that occur despite the permitting process have the potential to be of moderate consequence to other uses of local and regional water supplies.

Impacts to ecological systems and aquatic species: The probability of adverse impacts to ecological systems and aquatic species is expected to be medium. If adverse impacts occur, the consequences are expected to be moderate.

Rationale for findings: Many aquatic species may be sensitive to relatively minor decreases in water levels or flow which would not otherwise cause appreciable impacts on local and regional water supplies or recreational activities, so the probability finding is moderate. Similarly, impacts that occur despite the permitting process could be of moderate consequence to aquatic species. If withdrawals occur in the headwater areas of Use Class III streams and Tier II waters, impacts have the potential to be of serious consequence to aquatic species.

Impacts on recreational activities: The probability of adverse impacts on recreational activities is expected to be low. If adverse impacts occur, the consequences are expected to be moderate.

Rationale for findings: Consideration of current and future cumulative impacts in the existing water appropriation permitting process is expected to prevent impacts to recreational activities, so the probability finding is low. Because large volumes of water are required for HVHF, impacts that occur despite the permitting process are expected to be of moderate consequence to recreational activities.

These findings are also presented in the Table 1 and Table 2 below.

Table 1: Probability, consequence and risk findings for drilling (Phase 3)

Impact	Probability	Consequence	Risk Ranking
Local and regional water supplies	Low	Minor	Low
Ecological systems and aquatic species	Low	Minor	Low
Recreational activities	Low	Minor	Low

Table 2: Probability, consequence and risk findings for hydraulic fracturing (Phase 4)

Impact	Probability	Consequence	Risk Ranking
Local and regional water supplies	Low	Moderate	Low
Ecological systems and aquatic species	Medium	Moderate	Medium
Recreational activities	Low	Moderate	Low

Suggestions for Additional Mitigation

The following measures could be considered in order to reduce risks from UGWD-related water withdrawals beyond the anticipated protections of the existing regulatory framework and the proposed BMPs:

1. Each Maryland county providing water for UGWD establishes one or more semi-permanent access points for UGWD-related water withdrawals at a source with large capacity. County access points could reduce risks by allowing focused implementation of the regulatory framework and targeted monitoring for withdrawal-related impacts. It would also reduce the risks associated with withdrawals from smaller streams. If storage is provided, water could be accumulated over time and could facilitate the use of a pipeline to transfer water.

2. Require that applicants obtain third-party modeling of affects of withdrawals proposed for Tier II and Use III waters, using protocols to be developed by DNR. The purpose of this requirement would be to

provide data necessary to evaluate the potential impacts to aquatic habitat and species as well as downstream recreational activities.

3. Ecological and/or recreational protection needs are identified by the Maryland Department of Natural Resources for consideration in the water appropriation permitting process. The existing regulatory framework could be strengthened by requiring specific identification of potential impacts to ecological systems by DNR, so that those potential impacts can be explicitly addressed.

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