Natural Gas Well Development in the Marcellus Shale: The Use of Fresh Water and Beyond

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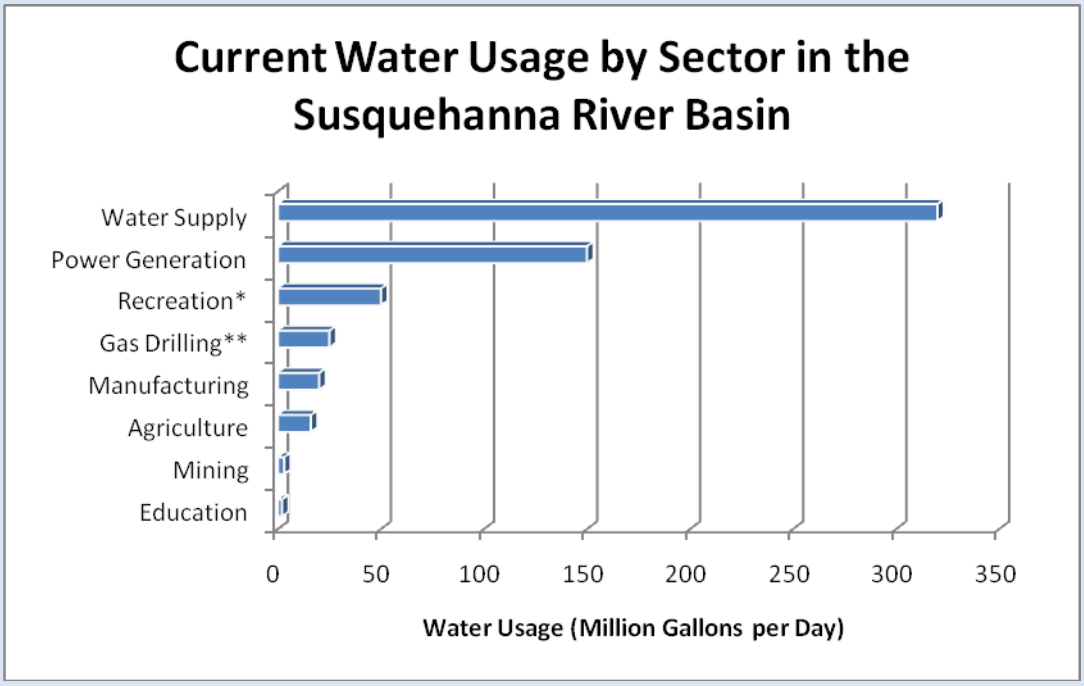
Q: How much water does the industry use to develop the Marcellus Shale?

- Each well uses approximately four to seven million gallons of water during the completion stage of the well, otherwise referred to as fracturing or "fracing".
- Very small amounts of water are used for the drilling (about the amount of a typical swimming pool) and the other phases of the well.
- It is projected that the natural gas industry will withdraw approximately 25 million gallons of water per day (mgd) for the development of the Marcellus Shale.

Q: That seems like a lot of water for each well! How does that compare to the water usage of other industries in Pennsylvania?

- Based on numbers compiled over several decades within the Susquehanna River Basin which comprises virtually half the state of Pennsylvania, the following water volumes are consumed daily in Millions Gallons per Day (mgd):



*Recreation consists primarily of golf courses and amusement parks.
**Gas drilling data is projected use; actual use in 2009 was 1.0 mgd.

Q: What measures are taken by the industry to ensure that too much water is not being removed from the stream, thus impacting aquatic species?

- In order for the natural gas industry to remove water from a stream, they must first get a permit to do so. The permit process is extensive. First, either Pennsylvania's Department of Environmental Protection (PA DEP) or the Susquehanna River Basin Commission (SRBC) conducts an evaluation of whether a project would cause adverse impacts to the other water uses, fish, wildlife, or other living resources or their habitat, recreation and stream flows. Next, the industry hires qualified professional hydrogeologists to evaluate and prepare an application for water withdrawal.

Figure 1. Biodiversity monitoring at a potential site for water withdrawal.

Q: So what science really goes into the calculations of water withdrawal, to prove that impacts to aquatic life will not occur?

There are two types of water withdrawal approvals: Q7-10 and Passby Flows.

- For a Q7-10 (Q7-10 stands for the 7 day average flow of a 10 year low flow condition) withdrawal, the drilling company is allocated less than 10% of the Q7-10 of the stream flow. This is a very small amount of water, otherwise referred to as a *de minimis* standard. This type of water withdrawal is allowed to operate 24/7.
- In a Passby Flow Conditional Withdrawal, upstream and downstream water uses are analyzed to calculate the safe yield of the stream for aquatic life. A withdrawal can only occur during higher flow conditions of the stream. When lower flow conditions exist, the withdrawal must stop until the stream flow increases again. In order to monitor the daily flow of a stream (also part of the conditions associated with withdrawal permit approval), we monitor USGS stream gages or install a weir system.

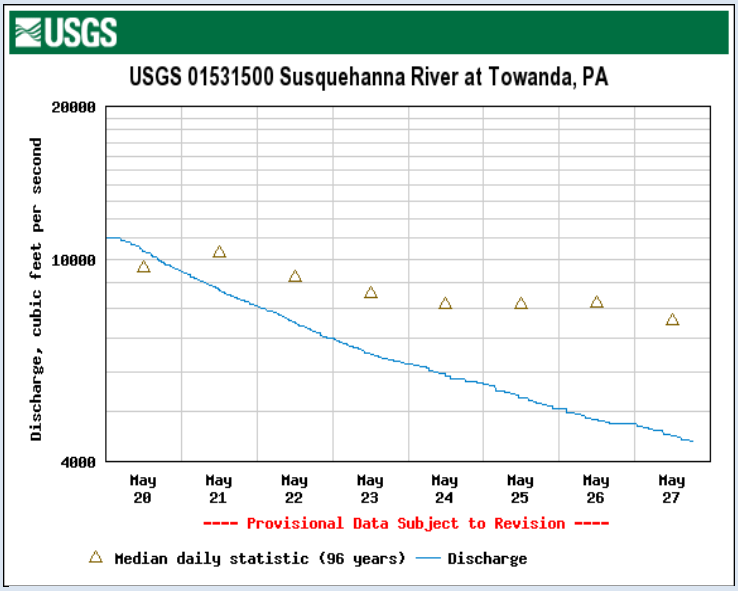


Figure 2. An example of real-time stream gage data for a Susquehanna River site in Bradford County, Pennsylvania. Source: http://waterdata.usgs.gov/pa/nwis/rt.

Q: How does the industry treat water prior to disposal?

Figure 3. A centralized freshwater impoundment where water is stored for hydraulic fracturing operations.

- The current treatment technology, which has been used for many years to treat gas well wastewater from both Marcellus wells and shallow wells, consists of treatment unit processes, in series, to accomplish the following:
    - Skim off any oil or floating substances,
    - Allow heavy bulk solids to settle out,
    - Neutralize the wastewater, to precipitate metals like iron and manganese,
    - Add chemicals to precipitate other metals, like Barium,
    - Add polymers and other chemicals to aid in precipitation,
    - Aerate the wastewater to oxidize any organics,
    - Filter the final effluent for clarity,
    - Dispose of the filtered materials and sludges in permitted landfills.
- This technology produces a very clear and metal-free salty water, the salt content of which ranges from about 1 to 2 times that of sea water (sea water salinity averages 35 ppt).
- Commercial wastewater treatment facilities that use the technologies listed above must undergo a strict permitting process with Pennsylvania's Department of Environmental Protection before they can accept and treat gas well wastewater from the gas companies. After permits are approved, these facilities are allowed to discharge treated wastewater either to large publically owned sewage treatment plants, or directly to large streams, where, in both cases, the salt content is greatly diluted to in-stream levels that are safe for humans and aquatic life.

Q: What can be done to remove the salt, or other additives used or found in the fracing fluid? Are the concentrations too low to be problematic?

Figure 4. An evaporation plant for removing salt from flow back wastewater.

- Actually, the salt in the frac flowback wastewater originates in the shale formation. It is not a major additive used to prepare the fracing water.
- In order to remove the salt, a very energy and cost-intensive treatment process that uses evaporation and distillation of the water must be used. The clean salty water that is produced by conventional treatment (as described above) must be pumped into pressure vessels that use a heat source as well as heat produced by compression of vapors, to evaporate the water out of the wastewater. The water vapor is then cooled to produce a product which is essentially

distilled water, with some minor impurities in it. The byproduct is a very concentrated salt brine which can be taken to a crystallization plant to produce salt crystals, or which is disposed in deep underground injection wells that safely put the concentrated brine into confined deep underground horizons.

- Current salt concentrations, at the current amount being produced, are not problematic for discharge in our larger rivers and streams, where there is ample dilution. Environmental agencies in the state, however, are concerned that, if there is an expansion of the volume of wastewater produced, the salt content could be problematic. Their concern is coupled with the apparent desire of some wastewater business entities who have applied to discharge treated gas well wastewater on smaller streams or on those that already have some salt in the background water chemistry, and thus have less dilution capacity. They are looking to new evaporative technology to be employed in those situations.
- For the most part, other chemicals that are added to the raw fracing water (such as biocides to control bacteria, scale inhibitors, friction reducers, and oxygen scavengers) are spent and de-natured in the harsh conditions down-hole in a frac job. Any of the broken down chemical additives that emerge with the frac flow back are further treated and removed in the conventional treatment processes.

Q: Is most of the wastewater recycled back into the watershed? If not, where does it go?

- It takes about 5 million gallons of water to fracture a Marcellus gas well, and about 0.5 million gallons flows back out of the well as wastewater. Whenever there is a future frac job in the reasonable vicinity of one that is being flowed back, most of the Marcellus operators will briefly store and then re-use at least a good portion of that 0.5 million gallons, by providing some rudimentary treatment to it (like filtration) and then blending it with the fresh water source for the new frac job.

About 60% of the freshwater resources for Marcellus well drilling will be re-used in future fracing operations.

- However, some of the final portion of the flow back from a frac job is not suitable for blending, and sometimes it is too costly or un-wise to store flow back for extended periods of time. In this case, the wastewater is taken to treatment plants, as described above, for discharge, or to underground disposal wells, for disposal. As mobile treatment and localized fixed facility treatment and central storage concepts emerge, a much greater percent of the flow back and other wastewaters on the well pad are expected to be re-used.

Figure 5. A mobile treatment truck used for onsite wastewater recycling.

Q: How does the industry minimize the risk of transporting invasive species during operations? Can you focus on a particular species, i.e. the zebra mussel, and briefly outline the use of biocides, or other technologies the industry uses to prevent invasive species from being drawn up with the water for fracing operations?

- For all freshwater sources that are used by Marcellus operators, an Invasive Species Disinfection and Best Management Practice Plan is a required part of the Metering Plan, which must be approved by the regulatory agencies before a source can be used. These Plans provide procedures that haulers and pumpers of water must follow, when moving their equipment from one body of water to another. Any equipment that touches the water from a source must go through the following steps, before it is used on another water body:
    - Clean, rinse, disinfect, and dry – remove all small debris, visible plants, fish and aquatic life, mud, dirt, and water.
    - Disinfection is accomplished by soaking equipment in bleach or quaternary ammonium products, or by using hot water (above 140°F).
    - This 4-step process is used in areas where there is no potential for the disinfection products of removed materials to re-enter the water body, and where any rinses can be managed and disposed of as wastewaters.

- In addition, intake screens on surface water withdrawal equipment are designed to prevent the entrainment (trapping) of all but the smallest species. Also, air gaps are incorporated into the connection between the water intake points and any equipment used to store and haul away the water, to prevent any materials in a haul truck from backflowing and re-entering the waterbody.

Figure 6. An intake screen in a river where water is being withdrawn for hydraulic fracturing.

- The industry is currently working with the regulatory agencies on improving the design of intake screens, the management practices, and the standard disinfection procedures to ensure that all pathways for all invasive species are thwarted in a safe and effective manner. While few problems have emerged to date on this issue, the Marcellus operators consider it a serious environmental management need.