Exploring Water Use

Water storage for completion operations in Pennsylvania

August 2015
Part 1

Summary of Concerns: The use of water to hydraulically fracture shale formations.

Energy is necessary to develop, process and distribute water resources, and conversely, water is essential to energy resource development. As a result, water and energy are interdependent. Water is essential to all of the communities in which Anadarko operates and is an essential component to produce shale gas. The majority of water used for each well occurs during the drilling and completion phase, which generally lasts two to eight weeks (including hydraulic fracturing operations) depending on the geology and number of completion stages. On average, 10,000 to 20,000 m³ (~3-5 mln gallons) of water are used to hydraulically fracture a horizontal well, which is also determined by the geology and lateral length of the well. This volume is a relatively small amount in comparison to other sectors that consume water, such as municipal, agriculture and power generation.

Because of the interdependence of water and energy resource development, today most oil and natural gas companies conduct extensive research into water sourcing when undertaking new projects. This research can include studies on water quality, the quantity of available water, and how water withdrawals will affect the local hydrologic cycle, water availability, local community water demands and ecosystems. Baseline or benchmark data is often used to evaluate water quality and source reliability.

Key Facts:
1. The oil and natural gas industry uses a variety of sources and qualities of water, from brackish to fresh water.
2. On a life-cycle basis, shale gas is a water-efficient fuel source for power generation.
3. Shale gas development can generate additional water to the surface.
4. The industry continues to innovate, as well as develop and implement technology to conserve water and increase water efficiency.

Water-management trends in shale gas:

A collaborative effort of 17 oil and natural gas companies called the Energy Water Initiative (EWI), recently issued a report¹ that provides an overview of 12 companies’ best practices for water management in the United States. The EWI case studies identified the following water-management trends:

- Development and improvement in fracturing chemistry enables industry to use non-freshwater sources
- Treatment technology innovation continues to make produced water reuse more feasible
- Improvements in water conveyance for gathering and distribution reduce truck traffic
- New water storage designs provide flexibility and reliability in alternate, non-freshwater sourcing
- Transparency improves relationships with communities, industry and regulators
- Dedicated water staff within exploration and production organizations improve water-management planning, technical support and performance

Part 2
Detailed information regarding perceived concerns about the water volumes used for hydraulic fracturing.

Water scarcity is often defined as water demand exceeding water supply. Water scarcity concerns increase as areas experience continual population growth and/or drought conditions. Increasing energy production from shale plays has resulted in concerns being raised about impacts on limited water supplies.

The American Water Works Association, a non-governmental organization focused on water science and education, highlights concerns regarding the intensity of water use as follows:

Intensity of water use is an important consideration, as the need for water in the life cycle of a well tends to occur in short but intense bursts. These could temporarily put significant strain on water resources. The oil and gas industry is researching improved water-recycling techniques as well as methods to use high-salinity water that public water systems wouldn’t usually use. These techniques are likely to reduce risks to water over-consumption if they prove feasible and are fully implemented.3

International and national agencies are actively discussing and researching the nexus between and interdependencies of water and energy. For example, the International Energy Agency for the first time included the water for energy relationship in the World Energy Outlook for 2012. The U.S. Department of Energy commissioned an initial report in 2006 and has sponsored an annual conference focused on the energy water nexus. The U.S. Environmental Protection Agency included water usage in the congressionally requested Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. Also in 2012, the U.S. Government Accountability Office published a detailed report on the same topic: Energy-Water Nexus; Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production. All of these actions focus on the same concept; to quote the Ground Water Protection Council (a non-governmental organization focused on local groundwater issues):

Water and energy are basic needs of civilization. Our use of each relies on and affects the availability of the other, and, as populations grow, our demand for both will continue to increase at accelerating rates.

The industry is engaged in the above efforts and is working to develop strategies and technologies to lessen impacts in water-stressed areas.

Source: Energy Water Initiative, 2015
Key Fact 1
The oil and natural gas industry uses a variety of sources and qualities of water, from brackish to fresh water.

The majority of water use occurs during the early exploration and drilling phase of shale gas production. Water is a necessary input and byproduct of shale gas production. A small amount of water is needed for drilling and the more significant quantities of water are used during completions, or hydraulic fracturing, commonly called fracking, operations. Given the density of shale rock formations, hydraulically fracturing the wells is necessary to create pathways for oil and natural gas to flow to the production well.

Hydraulic fracturing is a temporary process. The drilling and completion (including hydraulic fracturing) phases of a well is a short period generally two to eight weeks, compared to an expected 20 to 40 years production lifetime of a well. An average 10,000 to 20,000 m3 (~3-5 mln gallons) of water are necessary to hydraulically fracture a multi-stage shale well. The volume and quality of water used, is generally driven by the reservoir characteristics and well design. The reservoir characteristics will vary by region and play.1

The types of water sources that are used by the oil and natural gas industry (for hydraulic fracturing) typically fall into three categories: potable water (freshwater), oil and natural gas generated water (produced and flowback water), and other alternative water sources that are generally not usable by the public (brackish or non-potable water). The choice among sources depends on a variety of factors such as volume, availability, source-water quality, competing water uses, economics and regulatory requirements.

Potable Water Sources: Typically this type of water includes freshwater from a groundwater source, surface water (from a lake or river) and municipal water supplies. Water is drawn from these sources over time in accordance with agreements and regulatory requirements and stored for use when a greater amount of water is necessary. A regular and slow withdrawal rate, can minimize impacts on water sources that are also used by communities.

Produced water: Reused and recycled water used in oil and natural gas operations is typically flowback and produced water from the company’s operations. There are few instances of operators using other produced water sources, such as municipal and industrial. In an effort to reduce the use of freshwater sources, the industry is increasing the amount of flowback and produced and brackish water in hydraulic fracturing.

There are several key factors that operators must consider concerning the reuse of produced water, including the: quantity of produced water; duration and consistency of produced water; produced water quality; target formation characteristics; scale of the operation; and cost to reuse the water. Operational logistics such as fluid-handling capabilities, transportation considerations, storage capabilities and access to treatment locations or on-site treatment options, will influence the ability to reuse produced water.\textsuperscript{4}

The availability of flowback and produced water is dependent on the amount of water that returns from the fracturing process and formation. The EWI Case Studies report provides information on produced water generation, including:

Water used for hydraulic fracturing may stay in the target formation, though some will return to the surface as produced water along with oil, gas or natural gas liquids (NGLs or condensate). During this flowback process, the produced water flow rate is comparatively higher than long-term produced water rates.

Water production varies by region and play. It can range anywhere from 10% to more than 100% of the total volume of water used for the hydraulic fracturing operation and may include naturally occurring formation water that also returns to the surface.\textsuperscript{5}

The use of flowback and produced water is also dependent on the type of fracturing fluids being used for that play. The primary fracturing fluid systems are slickwater, crosslink or crosslinked gels, and a combination of slickwater and crosslinked gels (hybrid). The selection of the fracturing fluids is based on a variety of factors. The fluid systems are designed based on the characteristics of the target formation and fluids, make-up water source and other considerations. The use of recycled flowback and produced water will be more likely in a slickwater hydraulic fracture.

"Produced water recycling is becoming more viable because fracturing technologies are becoming more tolerant of lower-quality water."\textsuperscript{6} In addition, the industry continues to improve upon the various fracturing technologies, allowing for an increased use of higher-salinity brines. The technological and economic viability of treatment options can vary considerably and are influenced by fracturing fluid type (slickwater or gel system), reservoir characteristics and location-specific factors. Another consideration is the availability of produced water to treat and transport logistics.

For instance, the treatment and associated cost necessary in the water generated in the Marcellus Shale area is far less than the treatment required in the Haynesville Shale due to compositional character of the producing formation’s water.\textsuperscript{7} In other areas, there is so little produced water generated, that the cost of recycling it is not feasible. Thus, the reuse of flowback and produced water can replace the use of fresh water from other sources, but only if it is a technologically and economically viable option for the formation.

Non-potable water sources: Brackish or non-potable water is considered publicly unusable without significant treatment. Typically, brackish water is high in salinity, but less than high-saline brine, and has total dissolved solids (TDS) levels from 1,000 parts per million (ppm) or higher. In the early exploration phase, operators will use water with lower TDS for hydraulic fracturing. For shale plays that are beyond the phase of early

\textsuperscript{4}ERM, Recovered Water Management Study in Shale Wells, 2014.
\textsuperscript{7}Mantell, Hydraulic Fracturing Study: March 2011 Technical Workshop on Water Resources Management, 2011.
exploration, the use of brackish and recycled produced water is becoming an increasingly feasible option due to the advancement of chemical additives and water-treatment technologies.

Operators are also starting to experiment with other wastewater sources, for example acid mine drainage in the Appalachian Basin, gray water from municipal treatment systems in the Maverick Basin and purchased effluent from a municipality near the Denver-Julesburg Basin. Pre-treated seawater is also being explored as an alternative water source for hydraulic fracturing. However, the viability of any alternative water source is dependent upon factors such as the fracturing fluid type considerations, water treatment and water-transportation costs (e.g. proximity to an ocean).

Examples of alternative water sourcing:
The following are more specific examples of alternative sources of water to fresh water in developed (not exploratory) plays:

 In the Greater Natural Buttes area in Utah (U.S.), Anadarko was recognized by the state and a federal commission for the Anadarko Completions Transportation System. This innovative water-management program creates temporary staging sites on existing natural gas well locations that treat recycled flowback water to be used for hydraulic fracturing and move the filtered water directly to the next operation via temporary pipelines. The pipelines use existing pad locations and rights-of-way that minimize additional surface disturbance, truck traffic and associated emissions.

 In a play located in Oklahoma and Kansas (U.S.), another producer operates the AquaRenew project in the Mississippi Lime to recycle water. Salt-tolerant friction reducer allows the reuse of 100% produced water with minimal treatment. The TDS of this produced water is approximately 200,000 ppm.8

 In 2013, an operator in Pennsylvania began utilizing discharge water from a historic coal mine in Tioga County near its operations for hydraulic fracturing operations.

In summary, the amount of fresh water used in shale gas development is not significant in most areas of operation. Where water availability is a concern and the use of produced or brackish water is technologically and economically viable, operators continue to decrease the amount of fresh water used. In areas of new exploratory development, operators tend to use cleaner water. Once a play is better understood and further developed, operators typically evaluate other sources of water.

8http://www.chk.com/Media/Publications/ThePlay/Pages/Summer2013.aspx
Key Fact 2
On a life-cycle basis, shale gas is a water-efficient fuel source for power generation.

Increased water use for hydraulic fracturing is due to the increased demand for clean-burning fuel. Comparative analysis research from Scanlon et al, 2014, concluded that “although the public perception is that there are huge water demands for hydraulic stimulation of shale wells, research results quantifying how much water is used per unit of energy produced indicate that water use oil production ratios (WORs) for unconventional oil production are within the lower range of those for conventional oil production, considering the well lifetime.”

Therefore, increased water use in recent years for hydraulic fracturing is attributable to expanded oil and natural gas production using hydraulic fracturing and not because hydraulic fracturing is more water intensive per unit of oil or natural gas production. One of the unique challenges to water management for shale oil and gas production is that the use of water is front loaded in the shale gas development process. Water is used in the drilling and fracturing stage, so there is a relatively large upfront water usage over a few days or weeks, after which the natural gas is produced for an average lifetime of 20 to 30 years.

Hence, concerns of water stress due to shale operations are likely to be local and limited in time. According to industry guidelines, these local water sourcing concerns are mitigated by considering sustainability factors (environmental, social and economic) and respecting the rights and needs of other local water users when designing water-management systems to support shale oil and gas operations. Early analysis of local water availability should be taken into account when preparing water-management plans for the production of oil and natural gas from shale formations.

Volumes Produced Between 2007-2012

“...The total U.S. oil production increased by 29% between 2007 and 2012, and U.S. gas production increased by 22% during those years. However, during the same period, U.S. water production increased by less than 1%.”

Source: Veil, April 2015.

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9 Scanlon et al, Comparison of Water Use for Hydraulic Fracturing for Unconventional Oil and Gas versus Conventional Oil, 2014.
12 OGP/IPIECA Good Practice Guidelines for the Development of Shale Oil and Gas, December 2013.
**Lifecycle water use for power generation from natural gas is low:** Electric power generation is by far the largest industrial user of water worldwide and largely exceeds water resources used for the extraction of the resource, such as natural gas. For example: The amount of water needed to fracture and operate one well for one decade is estimated to equal the amount of water needed to run a 1,000 MW coal-fired plant for 12 hours.\(^\text{13}\)

A number of studies have recently been published on water intensity of energy resource extraction and power generation. According to the Virginia Water Resource Research Center, “Energy extraction technologies for coal, natural gas, oil, biofuels and synthetic fuels are very diverse with a wide range of water-use efficiencies. Natural gas production is the most water efficient.”\(^\text{14}\)

A literature review on the water intensity of energy resource extraction and the conversion to electricity by the Belfer Center for Science and International Affairs concluded that natural gas-fired combined cycle power plants (CCGT) have some of the lowest consumption of water per unit of electricity generated. Compared to other fossil fuels, experience from the U.S. has shown that the water intensity from hydraulically fractured shale wells to produce natural gas is relatively low: 0.6 - 1.8 gal/MMBtu (million British Thermal Units) for shale gas compared to 1 to 8 gal/MMBtu for coal mining and washing.\(^\text{15}\)


\(^*\)GTL = gas to liquids; CTL = coal to liquids

*The above diagram summarizes the extensive literature review by the U.S. National Renewable Energy Laboratory\(^\text{16}\) and provides generalized ranges for the water use for each type of fuel source per power generation technology. The researchers conclude that “water withdrawal and consumption factors vary greatly across and within fuel technologies, and water consumption factors show greater agreement when organized according to cooling technologies as opposed to fuel technologies.”

Key Fact 3
Shale gas development can provide additional water to the surface.

Water use in shale gas development can be consumptive (water does not return to the surface water system) or in a manner that the water returns to the surface water system (return flow). Depending on the formation, an operator can see from 10% to significantly more than 100% of the water used returning to the surface, with an average of 10 to 40% of the fluid returning to the surface.

By volume, water is the largest component of the materials used in hydraulic fracturing operations. Depending on the nature of the geological formation, from 10 to 70% of the water used for hydraulic fracturing is recovered during the first two to five weeks of hydrocarbon production. Typically, there are regulatory requirements for the collection, management, transport and disposal of produced water. In certain shale gas plays, operators are able to treat and discharge or evaporate produced water into the hydrogeological cycle. However, a certain percent of the water is likely to be lost to the hydrogeological cycle.

In addition, the combustion of natural gas results in the release of water vapor into the hydrogeological cycle. When natural gas (such as methane) is burned to generate power, it must be combined with oxygen, and water vapor is one of the products (Mantell, Hydraulic Fracturing Study: Technical Workshop on Water Resources Management, March 2011).

It has been estimated that approximately 10,000 gallons of water vapor are produced for each million cubic feet (Mcf) of gas combusted:

- One cubic foot of methane = approximately 0.041 pounds at one atmosphere of pressure and 25°C (methane = 0.656g/L @ 25°C, 1 atm)
- One billion cubic feet of methane = approximately 41,000,000 pounds
- One pound of methane, in a combustion reaction with oxygen yields 2.25 pounds of water (all as gases, except the energy)
- One billion cubic feet of methane, when combined with oxygen, yields 92,250,000 pounds of water
- 92,250,000 pounds is approximately 11,000,000 gallons or 41640m³ of water (water weighs 8.34 pounds per gallon MOL)
- If a shale gas well yields 1 Bcf in its productive life, the burned gas would release 41640m³ of water to the atmosphere
- Approximately 20,000m³ (170,000 bbls) of water is used to fracture one shale gas well

As the model below illustrates, combusting natural gas generates carbon dioxide (CO₂) and water; however, because CO₂ emissions are about half of those associated with combusting coal, the U.S. has seen significant reductions in CO₂ emissions as more electric power generation has transitioned from coal to natural gas. As a result, in 2015, CO₂ levels had been reduced to levels not seen since the early 1990s.

While on a macroscopic level the water returned to the water cycle from natural gas combustion is substantial, it may not relieve water availability concerns on a local level. The water vapor released during natural gas combustion may be stored in the atmosphere, but does not necessarily fall as precipitation onto the same water bodies or land surfaces (aquifer recharge areas) in the vicinity from where it was withdrawn.

Source: American Chemical Society
Key Fact 4
The industry continues to innovate to conserve water and increase water efficiency.

The oil and natural gas industry is based on continual improvement of operations and technologies, which includes the use, conservation and management of water as a resource. Every play and geological feature are different. Also, the project phase will influence the operational practices. For example, during the early exploration phase more standardized designs and water with lower total dissolved solids are used until the geologic conditions are better understood.

There are several industry initiatives with the primary goal of evaluating water use and identifying alternative and innovative approaches. These efforts are recognized by non-profit organizations such as American Water Works Association, which states:

“The oil and gas industry is researching improved water-recycling techniques as well as methods to use high-salinity water that public water systems wouldn’t usually use. These techniques are likely to reduce risks to water quantity if they prove feasible and are fully "implemented."”

Such industry efforts include:

• The EWI, which was formed in 2012, evaluates and understands the impacts of water use from oil and natural gas development on communities. The EWI is comprised of 17 oil and natural gas operators and has focused research on the water life cycle of shale and tight gas production.

• The International Petroleum Industry Environmental Conservation Association (IPIECA), which created a multi-disciplinary Water Working Group to improve the understanding of how and why water is an important resource.

• The U.S. Department of Energy (DOE) and the Ground Water Protection Council (GWPC) collaborations on nexus between energy and water; according to Nancy Johnson with the U.S. DOE, “continuous technology innovation can strengthen our capability to meet the Nation’s energy demands, and protect and conserve valuable water resources.”

The following are examples of continuous improvements in the use, management and conservation of water in shale gas development:

• Researching and developing water treatment and reuse technologies: The industry’s continued research and development of water treatment technologies enables greater recycling and reuse of produced water during the project’s development phase. There are several examples of produced water from formations being reused by oil and natural gas operators.

• Working to increase the use of non-fresh water: In a number of shale gas operations in the North America, operators are beginning to use saline or brine water instead of fresh water in hydraulic fracturing. There are also examples of operators using other industries’ and municipalities’ wastewater.

• Reducing the loss of water: Operators are taking measures to reduce the evaporation of stored water through the use of white colored liners and adjusting the dimensions of the storage ponds to limit the surface area between water and air.

• Analysis of the use of alternative sources of water: The Marcellus area formed a focus group through the Marcellus Shale Coalition to analyze the potential of utilizing acid mine drainage as a water source.

Key Resources:


Summary: This paper focuses on water treatment, transport and disposal as key concerns in shale gas development, including national trends and specific information relating to the Pennsylvania region of the Marcellus play.


Summary: This guidance document describes many of the current industry best practices used to minimize environmental impacts associated with the acquisition, use, management, treatment, and disposal of water and other fluids associated with the process of hydraulic fracturing. This document focuses primarily on issues associated with the water used for purposes of hydraulic fracturing and does not address other water management issues and considerations associated with oil and gas exploration, drilling, and production. It complements two other API Documents: one (API Guidance Document HF1, Hydraulic Fracturing Operations—Well Construction and Integrity Guidelines, First Edition, October 2009) focused on groundwater protection related to drilling and hydraulic fracturing operations, which specifically highlights recommended practices for well construction and integrity of hydraulically fractured wells, and the second (API Guidance Document HF3, Surface Environmental Considerations Associated with Hydraulic Fracturing, publication pending, but expected in 2nd Quarter of 2010) focused on surface environmental issues associated with the hydraulic fracturing process.


Summary: Description of various water management challenges associated with shale gas production and how they are managed in the Marcellus Shale.


Summary: This report quantifies the amount of water used per unit of energy produced between shale oil and gas wells in the Eagleford and Bakken plays compared to conventional oil production. It was concluded that although public perception is that there are huge water demands for hydraulic fracturing, water use for unconventional oil and gas production is in the lower range of water used for conventional oil plays. Therefore increased water use for hydraulic fracturing is related to increased energy production instead of perceived increased water intensity of the stimulation technique.


Summary: This report covers: (1) what is known about the potential impacts of oil shale development on surface water and groundwater, (2) what is known about the amount of water that may be needed for commercial oil shale development, (3) the extent to which water will likely be available for commercial oil shale development and its source, and (4) federal research efforts to address impacts to water resources from commercial oil shale development. The report examined environmental impacts and water needs based on discussions with the Department of Energy (DOE), Department of the Interior (Interior), and industry officials.

Summary: This paper and presentation is an update to “Deep Shale Natural Gas: Abundant, Affordable and Surprisingly Water Efficient” originally developed for the 2009 Groundwater Protection Council (GWPC) Water/Energy Symposium in Salt Lake City, Utah. Since the original development of the paper and presentation, shale gas development and utilization of water resources and produced water recycling has evolved. This paper will discuss the water efficiency of deep shale natural gas compared to other energy resources using the most up-to-date operational data for shale gas development and will include a discussion on the current successes in produced water reuse and recycling.


Summary: This paper discusses the many challenges the oil and gas industry face working in Pennsylvania while they expand developments in the Marcellus Shale.


Summary: The objectives of the case studies were to: illustrate the diverse, regional water resource challenges the industry faces; and share innovative strategies and lessons learned that individual companies have developed to continually evolve stewardship practices with EWI’s members and stakeholders.


Summary: An overview of current and potentially viable recovered water management practices for shale oil and gas operations.
Other Resources


- Ground Water Protection Council, for U.S. Department of Energy


- Marcellus Shale Coalition; Conference on Feasibility and Challenges of Using Acid Mine drainage for Marcellus Shale Natural Gas Extraction; 2011.


