Oil & Natural Gas Technology

DOE Award No.: DE-FE0000797

Technology Status Assessment Report

Comprehensive Lifecycle Planning and Management System for Addressing Water Issues Associated With Shale Gas Development In New York, Pennsylvania and West Virginia

Submitted by:
Arthur Langhus Layne-LLC d/b/a ALL Consulting
1718 South Cheyenne Ave
Tulsa, OK 74119

Principal Author: J. Daniel Arthur, P.E.

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

Office of Fossil Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Current State of Technology

Summary of Existing Industry/Sector

Natural gas production from hydrocarbon rich shale formations, known as "shale gas," is one of the most rapidly expanding trends in onshore domestic oil and gas exploration and production today[i]. Tremendous natural gas resource potential has been identified in shale basins across the U.S., with one of the largest being the Marcellus Shale in the Appalachian Basin. Recoverable gas resources in the Marcellus are estimated to exceed 500 trillion cubic feet[ii].

As shale gas development has proceeded in the Marcellus area, which includes parts of New York, Pennsylvania, and West Virginia, the most prominent environmental issue is water supply, use, and disposal. Water issues may threaten to significantly delay or slow development of this important resource[iii, iv, v]. In New York, permitting for horizontal shale gas wells and wells using large volume hydraulic fracturing has been halted pending the completion of a Supplemental Generic Environmental Impact Statement under that state's environmental law. Many of the issues being addressed in that Statement are water-related[vi].

Shale gas has become economically producible principally due to advancements in two technologies: horizontal drilling and large volume hydraulic fracturing. The amount of water needed to drill and fracture a horizontal shale gas well generally ranges from about 2 million to 5 million gallons, depending on the formation characteristics. With potentially hundreds of wells to be drilled each year as development proceeds, the water demands can be significant, although they collectively represent less than one percent of total water demand in the region[vii].

The water management lifecycle for shale gas wells has several phases. First, the water supply must be obtained, either from surface or ground water sources, possibly augmented by recycled or waste water. That water must then be transported to and stored at or near well sites. While some of this water is used in the drilling process, the bulk of the fresh water used is mixed with small amounts of chemical additives and pumped under pressure into the subsurface to hydraulically fracture the rock and allow the gas to flow to the well. Thirty to seventy percent of the fracture water is produced back up the well bore and must be disposed of in an approved manner, generally through underground injection, treatment and discharge to surface waters, or recycled for additional fracturing operations or other industrial uses.

Every step of this water lifecycle is regulated. In the Marcellus region, two river basin commissions, the Susquehanna River Basin Commission (SRBC) and the Delaware River Basin Commission (DRBC) permit withdrawals from the surface waters of their respective basins. Although they work closely with the states, they are independent regulatory bodies and may limit water volumes and withdrawal locations both volumetrically and seasonally.

The public, non-governmental organizations (NGOs), politicians, and government agencies have expressed great concern about water use and disposal associated with shale gas development. One issue is the sheer volume of water used and the resulting impact on regional water supplies and environmental values, such as aquatic species and wetlands. There is also concern about the chemicals that are added to fracturing fluid, which, while only about 1 percent of the total volume, have raised concerns about their impact on health and the environment as some portion remains underground following well stimulation and the remainder must be treated for disposal or reuse. The result is an evolving regulatory regime that impacts both producers and regulators, adding costs and uncertainty for both. A large part of the uncertainty is associated with not having sufficient information on the whole lifecycle of water that is used in the shale gas development process. Operators need to plan for adequate water supplies and disposal options for all of their wells over a period of several years. Regulators have a great need for tools that will help them understand, forecast, and plan for future activity, and to analyze the impacts of all of the development that will be occurring in an area.

In addition, water management practices in the Marcellus region are evolving as development accelerates and constraints are becoming apparent. For example, because there is limited water treatment and disposal capacity in the region, producers are increasingly investigating recycling and reuse opportunities. Water transport options are also being scrutinized because the cost of transporting water, both fresh water and used water, can exceed the cost of the water itself. Thus, more producers are putting in temporary pipelines to substitute for more expensive trucking. One producer is using rail cars to transport produced water to injection wells. This changing situation requires quick analysis and decision making to keep abreast of circumstances, minimize costs, and manage water use effectively.

Technologies/Tools Being Used

Currently, planning and management of water supply, use, and disposal is performed on a piecemeal basis by both operators and regulators. Producers analyze the water needs for groups of wells, for a single multi-well pad or groups of pads, and plan for supply, transport, and storage of fresh water, and disposal or reuse of the produced water that flows up the well after a fracturing job. One of the largest operators in the region currently uses at least three separate in-house systems for water management, addressing well drilling, well completions, and fluid disposal separately. These systems do not communicate with each other. Additionally, other systems (most are currently are in the development phase) address various stages of the water lifecycle, these are discussed below:

Water TRAC-H2O Resources-LLC

Water TRAC is an Internet based water tracking system that uses satellite, manned check stations, and Global Positioning System (GPS) for real-time tracking of the movement of water from source to well and then disposal/reuse. The analogy is like a package tracking system used by UPS or Fedex. Currently the system is in development and their website did not state an expected release date. This system would use manned check stations to verify pick-up and delivery for water transported by truck which is then monitored by GPS for movement with the data posted real-time to a website for producers and regulators use. The system's primary use would be to track water for well drilling and fracture treatments. Additionally, water quality, volume and lease destination would be archived for five years.[viii]

Integrated Framework for Treatment and Management of Produced Water-Colorado School of Mines (CSM)

CSM, Kennedy/Jenks Consultants and Argonne National Laboratory, as well as an Industry Advisory Council, through a project funded by RPSEA, are developing an integrated guidance framework that will link the composition of produced water to beneficial use applications. This framework's goal is to identify the most cost-efficient, environmentally sound, and most beneficial strategies for management and treatment of produced water from Coal Bed Methane (CBM) operations. Deliverables for this project include a Water Quality Tool, Process Facts Sheets, Treatment Technology Selection Tool, and Beneficial Use Tool.[ix]

Watershed Analysis Tool (WAT)-Interstate Oil and Gas Compact Commission (IOGCC) and ALL Consulting (ALL)

The WAT was developed through funding by DOE-Office of Fossil Energy - National Energy Technology Laboratory (NETL) to aid oil and gas companies with difficult decisions related to how to manage produced water in a manner that is fiscally responsible to the company, socially acceptable to the public, and environmentally responsible over the life of the project. The Tool utilizes producer inputs and assumptions to prepare the following:

- Water Balance-used to identify the merits of a proposed water management portfolio in terms of managing the projected maximum amount of water produced.
- Economic Analysis-has two components: 1. Cumulative cost of up to ten different proposed water management portfolios to compare both the capital and operational cost of the various projects; 2. Sensitivity analysis to allow the user to adjust assumptions related to cost for a "optimistic", "most likely", and "worst case" scenarios.

- Water Mixing-the results of the mixing model can be used to aid in the development of relevant and realistic National Pollutant Discharge Elimination System (NPDES) discharge limits while protecting the watershed as a whole when discharging treated and/or discharged water to receiving waters such as a river.[x]

Produced Water Management Information System (PWMIS)-NETL

NETL's PWMIS is an online resource for technical and regulatory information for managing produced water. The PWMIS is organized into four primary categories:

- Introduction to Produced Water-describes what produced water is and the general constituents that are commonly present in the water
- Technology Description-provides a listing of methods and technologies that are used
- Federal and State Regulations and
- Technology Identification[xi]

Produced Water Treatment Catalog and Decision Tool-ALL Consulting/Ground Water Protection Council (GWPC)

ALL Consulting is developing a Produced Water Catalog and Decision Tool that will help shale gas and Coal Bed Natural Gas (CBNG) producers make cost effective water management decisions with an emphasis on management options that will allow for beneficial use of the water. The scope of this project is to develop and post a catalog of treatment technologies that describes capabilities, limitations and costs of various treatment technologies and to develop a tool that will recommend water management options based on location (regulations and geology), water quality, and water quantity.[xii]

Capabilities of Current / Developing Technologies

The following table highlights the relationship of the technologies and tools to the elements of the water lifecycle:

Comparison of Technologies and Tools	Water Lifecycle Elements									
Tech/Tools	CBNG (C) or Shale (S)	Planning	Permitting	Supply	Transport	Storage	Use	Recycle	Benefit Use	Disposal
Water TRAC	S			X	X	X		X		X
Framework	C								X	X
WAT	C/S	X						X		X
PWMIS	C							X		X
Catalog/Tool	C/S	X						X	X	X
Lifecycle	S	X	X	X	X	X	X	X		X

As shown in the comparison table, most of the technologies and tools that are currently available or are under development are geared towards CBNG and focus primarily on produced water beneficial uses and disposal. While these technologies and tools are useful to the CBNG industry they don't address the unique needs of shale gas development, mainly planning, permitting, water supply, transport and storage within one integrated system.

The Water TRAC system addresses the physical tracking of water being drawn from a source and transported to the site and then to disposal. While this system would help in management of water resources, it does not have a modeling or forecasting capability. In addition, the system, as described, is perceived to have a high cost due to the manned booths at the source and site, as well as the satellite GPS tracking. Furthermore, the Water TRAC system does not have an integrated regulatory component that will allow cumulative impacts forecasting by regulators or permit planning and tracking for operators.

Development Strategies

Why New Technology and Research is Required

The cost of water management is a significant limiting factor in shale gas development. Regulatory agencies require that producers develop a water management plan for shale gas development. For example, Pennsylvania requires a "Water Management Plan" before a drilling permit is issued, but that plan addresses only water sourcing issues[xiii]. Also, water users must register with the state agency under Chapter 110 of the Pennsylvania Code[xiv]. However, again, this relates only to water withdrawal. In the Marcellus region, the river basin commissions take a watershed view of cumulative withdrawals and may require a plan for disposal of the water after it is used. Therefore, without sound decision tools for managing this water throughout the water lifecycle, some gas projects may become uneconomic and this will have the effect of reducing domestic energy production.

Problems to be Addressed in this Research Project

There are no publicly available tools that allow either operators or agencies to track and analyze water use from withdrawal to disposal along with all of the alternatives for transporting, storing, and treating that water. A system is needed to analyze the water material balance through the whole process, along with costs, disposal capacity needs and scheduling, and environmental and community impacts (e.g., impacts on surface water bodies, or on roads and traffic) and to allow the user to minimize costs or impacts through the analysis of alternatives. There is no existing system that combines this analytic capability with permit information, such as permit requirements or other constraints, and permit application and compliance tracking.

Future

What Barriers will the Research Overcome

This project will overcome the barriers of lack of information throughout the water lifecycle and the barrier of not having an easy way to analyze and weigh the tradeoffs in various management approaches throughout the process in a single application. As more of the nation's natural gas supply comes from unconventional sources, water management is playing an ever increasing role in project economics.[xv] As operators consider the wide range of source, transport, storage, use, reuse, and disposal options, the complex interplay of those options, capital costs, operating costs, state regulatory requirements and federal requirements can quickly become overwhelming. In many cases the time required to investigate all of these options is prohibitive and operators just continue to do what they have always done or turn to a service company that provides them with the option that makes them the most money.

Impact on the U.S. Domestic Gas Supply Industry

This modeling system will have myriad benefits for industry, government, and the public. For industry, it will allow planning all water management operations for a project or an area as one entity to optimize water use and minimize costs subject to regulatory and other constraints. It will facilitate analysis of options and tradeoffs, and will also simplify permitting and reporting to regulatory agencies. The system will help regulators study cumulative impacts of development, conserve water resources, and manage disposal options across a region. It will also allow them to track permits and monitor compliance. The public will benefit from water conservation, improved environmental performance as better system wide decisions are made, and greater supply of natural gas, with attendant lower prices, as costs are reduced and development is assisted through better planning and scheduling. Altogether, better economics and fewer barriers will facilitate recovery of the more than 500 trillion cubic feet of estimated recoverable natural gas resource in the Marcellus Shale[xvi, xvii].

Deliverables (Tools, Methods, Instrumentation, Products, etc.)

The deliverable for this project shall be a water management modeling system that will be available for download from the project website or an FTP address. The system's design will be interactive modules designed to individually analyze the systems and options available in each phase of the water management lifecycle. Each module will embody the processes involved with the respective phases of water management as well as the alternatives available. For example, water supply may include several different surface water sources, ground water well, municipal water sources, other purchased water, and private stock ponds. Each alternative will include fixed and operating costs, as well as constraints imposed by regulations, agreements, or permits. The user will supply data for the chosen analysis or project area, or use publicly available data. The user will also supply any necessary assumptions for which data may not be available, such as percent and production profile of fracturing fluid that is recovered, as well as the salinity profile of that water over time.

References

[i] Ground Water Protection Council (GWPC) and ALL Consulting. (2009, April). Modern Shale Gas Development In The United States: A Primer. Prepared for U.S. Department of Energy Office of Fossil Energy and National Energy Technology Laboratory.

[ii] Engelder, T. (2008). The Pennsylvania State University. *Appalachian Gas Reserves*. http://www.pagaslease.com/pdf_downloads/Platts%20Engelder%20Presentation(v2)%20(2008).pdf Presented at the Platts Appalachian Gas Conference in Pittsburgh, PA. October 29-30 2008. Accessed: November 2008.

[iii] BradyDale. (2008, December 18). *Marcellus Shale: An Economic Boom Sending Its Dregs Downstream To Philadelphia*. Message posted to Young Philly Politics (http://youngphillypolitics.com/marcellus_shale_economic_boom_sending_its_dregs_downstream_philadelphia).

[iv] Corio, Emily. (2008, December 5). *Water Woes From Marcellus Drilling*. West Virginia Public Broadcasting. Available online: http://www.wvpubcast.org/newsarticle.aspx?id=6618.

[v] Lustgarten, Abrahm. (2008, July 22). *New York's gas rush poses environmental threat*. ProPublica. Available online: http://www.propublica.org/feature/new-yorks-gas-rush-poses-environmental-threat-722.

[vi] New York Dept. of Environmental Conservation (NY DEC). (2009, February 6). Final Scope For Draft Supplemental Generic Environmental Impact Statement (dSGEIS) On The Oil, Gas And Solution Mining Regulatory Program.

[vii] Susquehanna River Basin Commission (SRBC). (2008, May). Deer Creek water availability study. Publication No. 256. Available online: http://www.srbc.net/pubinfo/techdocs/Publication_256/PubNo256DeerCreekWaterAvailabilityStudy0508.PDF.

[viii] H2O Resources, LLC. (2009). Water TRAC website. Accessed October 21, 2009. Available online: http://watertrac.com/

[ix] Colorado School of Mines. (2009, August 26). *An Integrated Framework for Treatment and Management of Produced Water*. PowerPoint presentation prepared for Industry Advisory Council Workshop.

[x] IOGCC and ALL Consulting. (2006, October). *A Guide to Practical Management of Produced Water from Onshore Oil and Gas Operations in the United States*. Prepared for the National Energy Technology Laboratory.

[xi] NETL, Produced Water Management Information System. http://www.netl.doe.gov/technologies/PWMIS/ Accessed October, 2009.

[xii] GWPC and ALL. (2008, September). *Statement of Project Objectives for the Produced Water Treatment Catalog and Decision Tool*.

[xiii] Pennsylvania Department of Environmental Protection (PA DEP). (2009, April 20). Water Management Plan Example Format Instructions for Marcellus Shale Gas Well Development.

[xiv] ARM Group Inc. (2007, winter). State water plan update. *Resource News & Views: Information for the Environmental and Engineering Industry*, v. 7, no. 1. Available online: http://www.armgroup.net/pdfs/2007Vol7Jan.pdf.

[xv] IOGCC and ALL Consulting. (2006, October). *A Guide to Practical Management of Produced Water from Onshore Oil and Gas Operations in the United States*. Interstate Oil and Gas Compact Commission. Prepared for the National Energy Technology Laboratory.

[xvi] Seeking Alpha. (2008, July 13). *Pennsylvania's Marcellus Shale: Welcome to America's Next Energy Boom*. http://seekingalpha.com/article/84730-pennsylvania-s-marcellus-shale-welcome-to-america-s-next-great-energy-boom .

[xvii] Engelder, T. (2008). The Pennsylvania State University. *Appalachian Gas Reserves*. http://www.pagaslease.com/pdf_downloads/Platts%20Engelder%20Presentation(v2)%20(2008).pdf Presented at the Platts Appalachian Gas Conference in Pittsburgh, PA. October 29-30 2008. Accessed: November 2008.

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

13131 Dairy Ashford, Suite 225
Sugarland, TX 77478

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681