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Topical Report

Phase I Topical Report for Comprehensive Lifecycle Planning and Management System for Ad-dressing Water Issues Associated With Shale Gas Development in New York, Pennsylvania, and West Virginia

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Phase I Topical Report for Comprehensive Lifecycle Planning and Management System for Addressing Water Issues Associated With Shale Gas Development in New York, Pennsylvania, and West Virginia

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Abstract

The report describes the water issues and needs associated with Marcellus Shale gas development that were identified during the site visits and meetings conducted by ALL Consulting. It also presents the initial system design concepts that have been developed to guide the creation of the Lifecycle model in a way that will address those issues and needs.

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Executive Summary

The objective of this project is to develop a modeling system to allow operators and regulators to plan all aspects of water management activities associated with shale gas development in the states of New York, Pennsylvania, and West Virginia ("target area"). The water management activities considered for the project include items such as water supply, transport, storage, use, reuse, and disposal. The model will be developed to support planning, managing, forecasting, permit tracking, and compliance monitoring.

The project is a breakthrough approach to represent the entire shale gas water lifecycle in one comprehensive system with the capability to analyze impacts and options for operational efficiency and regulatory tracking and compliance, and to plan for future water use and disposition. It will address all of the major water-related issues of concern associated with shale gas development in the target area, including water withdrawal, transport, storage, use, treatment, recycling, and disposal. It will analyze the costs, water use, and wastes associated with the available options, and incorporate constraints presented by permit requirements, agreements, local and state regulations, etc.

By using the system to examine the water lifecycle from withdrawals through disposal, users will be able to perform scenario analysis to answer "what if" questions for various situations. The system will include regulatory requirements of the appropriate state and regional agencies and facilitate reporting and permit applications and tracking. These features will allow operators to plan for more cost effective resource production. Regulators will be able to analyze impacts of development over an entire area. Regulators can then make informed decisions about the protections and practices that should be required as development proceeds.

This report summarizes the activities undertaken to gather information on the water issues that exist in the Marcellus and the needs of operators and regulators in terms of effectively managing that water. The report presents the issues and needs and presents an initial design plan that will guide model development while additional information is being collected and while final design details for the model are being determined.

Approach

To gather information on water issues and water management needs of both regulators and operators, ALL Consulting conducted more than 12 site visits within the targeted Marcellus shale states of New York, Pennsylvania, and West Virginia. These site visits included visits to water treatment plants, water disposal facilities, well-sites, and discussions with service companies. The well-site visits included observation of water withdrawal and storage facilities, pre-completion activities, and post-completion management of produced water. ALL met with state regulators and River Basin Commission personnel, both in person and via telephone. ALL also met with individual land-owners, land-owner organizations, and industry organizations. In addition, ALL leveraged other NETL project activities to gather information about shale gas water issues in general from visits to numerous regulatory agencies and production sites in other shale gas basins as well.

The meetings and visits took place over the course of the first year of the project. The meetings and visits in the Marcellus included:

- Susquehanna River Basin Commission (SRBC)
- Delaware River Basin Commission (DRBC)
- New York Department of Environmental Conservation (NY DEC)
- Pennsylvania Department of Environmental Protection (PA DEP)
- West Virginia Department of Environmental Protection, Office of Oil and Gas (WV OOG)
- Independent Oil and Gas Association of New York (IOGA NY)
- Independent Oil and Gas Association of West Virginia (IOGA WV)
- Pennsylvania Land Trust Association (PALTA)
- National Association of Royalty Owners (NARO)
- Chesapeake Energy
- Hess Natural Gas
- Universal Well Services, and
- BJ Services

The information from these visits was compiled and analyzed to understand the water management lifecycle, to identify the important water issues, and to identify the management needs that could be addressed by the model. These issues and needs were then reviewed to develop the initial system design for the model.

Results and Discussion

Water Management Issues and Needs Associated with Marcellus Shale Gas Development

Water management issues in the Marcellus shale play are associated with every stage of shale gas development and can impact operator's costs and ability to get permits. These water management issues include identifying the amount of water needed, procuring that water, transporting it to the drill pad, on-site storage, and disposing of produced water. In addition to actual management of the water, concerns over potential environmental and community impacts create public concern. Some of these issues are directly related to water resources and some are more indirectly related water management, (e.g., potential dust and traffic impacts that may result from the trucks used to haul water).

All of these issues affect shale gas development. While the effects of some of the issues are widespread, affecting almost all wells, some may be very localized. In addition, the importance of a given issue may vary based on regulatory jurisdiction and may vary over time based on level of drilling activity or media attention. Because each of the issues is important in some settings and to some stakeholders, any attempt to set relative priorities would be inappropriate and may appear to trivialize issues that are very important in some settings and for some stakeholders. Further, it was determined that setting relative priorities for these issues would not further the goals of the project. Accordingly, all of the issues included below are considered high priority issues.

After identifying the high priority water issues, ALL examined the issues to identify the water management needs that might be addressed by the model. Not all of the issues identified could be readily addressed by the model as it is now envisioned. These issues were, nonetheless, recorded, and are described below in recognition of the fact that new ways to approach these issues may be identified as the model begins to take shape.

It should be noted that the use of the model by regulatory agencies is only intended to encompass withdrawal planning and cumulative impacts analysis. Accordingly, regulatory agency needs are only discussed in relation to water withdrawals.

Water Withdrawals

Water withdrawals for high volume hydraulic fracturing (HVHF) are seen as a concern for both communities and the environment. For many individuals, talk of "millions of gallons" of water being withdrawn sounds ominous because they are not aware of the size of other withdrawals for municipal, agricultural, recreational, or power generation needs. Shale gas production at the height of development activity is generally less than 1% of total withdrawals and on a regional basis does not pose a major threat to overall water availability. On an annual basis, the total amount of water withdrawn will not have a noticeable effect on water availability for existing uses.

Impacts from surface water withdrawals can occur if not properly planned. Withdrawals from small rivers and streams can significantly affect stream flow and harm aquatic life and local recreation. Withdrawals from larger rivers can create these same impacts if taken during periods of low flow such as late summer or in periods of drought, therefore, planning is essential and having more than one source is advantageous.

Water authorities will typically impose pass-by-flow restrictions on operators coupled to their withdrawal permits. Regardless of the volume of water that has been approved for withdrawal, pass-by flow restrictions ensure that withdrawals do not reduce streamflow below the level that would be experienced under drought conditions. The permits often have pass-by flow conditions which require monthly evaluations and additional metering, pumping and communications equipment. Furthermore, depending on the pass-by-flow method imposed, monthly thresholds could be considerably different, possibly resulting in interrupted withdrawals. Operators must carefully plan and monitor withdrawals to ensure compliance.

> **Needs:** Companies need a mechanism to project water needs based on development plans and to plan their water acquisition based on those needs. The projections need to be able to accommodate operator-specific projections of the amount of water needed for each well, and acquisition plans must be able to incorporate both fresh water withdrawals and reuse of produced water. In addition, the acquisition planning must incorporate not just the amount of water needed, but the timing of those needs and evaluate the need for and timing of any additional withdrawal permits that may be needed. The planning horizon should be variable to accommodate different operators' needs and to allow for both near-term and longer-term planning. All of these projections need to incorporate the different regulatory jurisdictions that may be covered in a given planning unit.

Regulatory agencies need a mechanism to evaluate the cumulative impacts of withdrawals. This cumulative impact evaluation capability needs to be highly variable in order to incorporate different development scenarios in terms of both the number of wells to be drilled in a time period and the location of those wells. Agencies need the ability incorporate data on existing take points and permitted withdrawals along with projected take points and withdrawal amounts.

Storage of Fresh and Produced Water

Water for fracturing operations must be stored prior to the fracture operation. This can occur at well-specific impoundments or at central impoundments. Central impoundments that feed multiple wells or well-pads can be used to store large volumes of fresh water, thus allowing for withdrawals in wetter periods, smaller, more frequent withdrawals, and withdrawals from multiple water sheds. Central impoundments, however, also create other concerns. By moving water from one watershed and storing it in another, it is possible to inadvertently allow or speed the spread of invasive aquatic species and may subvert control efforts that are underway. In addition, these impoundments result in more extensive surface disturbance, which results in vegetation loss, including deforestation, habitat loss, and potential impacts to threatened and endangered species.

Storage of produced water must be planned and managed to prevent release of high TDS water onto land surfaces or into surface water bodies. Some have also voiced a concern that produced water stored in surface impoundments may result in air emissions of fracture chemicals that could affect human health.

Needs: Operators need the ability to plan for storage of fresh water for fracture operations whether that is through tanks, pad-specific impoundments, or central impoundments. Storage needs would be based on projected per-well water requirements and the projected drilling schedule for multiple wells on a pad and/or other pads planned for the area.

Operators also need the ability to plan for temporary storage of produced water in tanks or in surface impoundments pending final distribution. Once again, storage needs will depend on projected drilling schedules and planned disposal options.

HVHF Fracture Fluid Chemicals

Fracture fluid chemicals are an issue for several reasons.

- Potential for underground drinking water contamination – during fracture operations.
- Potential for surface water contamination – potential for spills during surface handling of chemicals prior to injection and spills of produced water that may contain fracture fluid chemicals.
- Human health effects – potential exposure of workers and near-by residents.

A major point of contention surrounding each of these issues is that the fracture fluid mixtures are considered proprietary and the specific chemicals used and the volume and concentration of the chemicals are not consistently reported to the public. NGO's and some citizens are concerned that if they don't know what is in the fracture fluids they cannot assess their risk or properly treat any exposures that may occur. They also assert that the chemicals must be worse than they are being told; otherwise, there would be no secrets.

Industry generally responds that the chemicals that are used are widely known and consist of chemicals that people encounter in their daily lives - it is only the exact mixture of chemical used in a particular well that is not known. A number of states, such as Colorado, Wyoming, Pennsylvania, and Ohio, have established or are considering laws that require disclosure of chemicals used in fracturing to the state regulatory agency.

> **Needs:** While proper handling of chemicals and fracture fluids is required to prevent contamination, storage and handling of chemicals is subject to state and federal environmental and safety regulations, and handling of fracture fluids is simply a matter of equipment/pipe line integrity for the short distance and time from the hopper to the well. Planning for chemical acquisition and for equipment design and maintenance is beyond the scope of this project. Accordingly, there do not appear to be any water management needs associated with fracture fluid chemicals that would be directly addressed by the model.

Groundwater Protection

A major concern is the protection of fresh groundwater aquifers. Several groups have made dire predictions of wide spread ground water contamination from HVHF. They assert that the chemicals in fracture fluids will contaminate drinking water. In discussing groundwater contamination concerns with shale gas, concerns with hydraulic fracturing for coal bed natural gas (i.e., shallow gas) are often inappropriately mixed in, confusing the issue. Industry points to the fact that ground water aquifers are protected by multiple layers of casing and cement as well as thousands of feet of intervening rock strata in the case of the Marcellus Shale. They also point to the fact that the fracture job only lasts for a matter of days. Afterward, there is no artificial pressure applied that would drive the fluid into other zones. Industry also regularly points to the earlier EPA study that states that there have been no documented cases of drinking water contamination from hydraulic fracturing.

Several recent incidents of methane and other contaminants in water wells have led to increased attention to this issue. While these contamination incidents have not been shown to have resulted from the hydraulic fracturing process itself, the fact the incidents are associated with shale gas wells, or other wells that have been hydraulically fractured, keeps the issue of groundwater protection related to shale gas development in forefront.

> **Needs:** While proper handling of chemicals and fracture fluids is required to prevent ground water contamination, the operation of the fracture stimulation process itself, is beyond the scope of this project. Accordingly, there do not appear to be any water management needs associated with ground water protection that would be directly addressed by the model.

Surface Water Protection

Although chemical additives generally represent less than 1% of the total fracture fluid volume, even 1% of 5 million gallons is still a large volume of chemicals. The potential for spills from truck accidents during transport to the site and on-site storage prior to injection are potential sources of risk to drinking water, wildlife, and livestock. Industry responds that chemical handling is a widely understood and regulated industrial practice and that no additional regulations are needed. Nonetheless, some groups are calling for specific regulations for surface handling of hydraulic fracturing chemicals.

> **Needs:** While proper handling of chemicals and fracture fluids is required to prevent surface water contamination, storage and handling of chemicals is subject to state and federal environmental and safety regulations, and handling of fracture fluids is simply a matter of equipment/pipe line integrity for the short distance and time from the hopper to the well. Planning for chemical acquisition and for equipment design and maintenance is beyond the scope of this project. Accordingly, there do not appear to be any water management needs associated with surface water protection that would be directly addressed by the model.

Human Health

Concerns about human health effects have been raised regarding acute and chronic exposures to hydraulic fracturing chemicals for both workers and the public. Several groups, including The Endocrine Disruption Exchange (TEDX), have asserted that many of the chemicals used as HVHF additives are highly toxic to humans and wildlife. TEDX has published a list of over 400 chemicals (about 250 unique) used by the oil and gas industry, many of which they allege are highly toxic. These groups assert that lack of full disclosure of hydraulic fracturing chemicals makes it impossible for individuals or health care professionals to accurately assess both the risk and extent of health effects that result from such exposures.

Acute exposures are most likely to affect workers through spills or other incidents on the well pad prior to the fracture operation. Acute exposure pathways for the public are likely very low.

Concerns about potential chronic exposures involve both pre-completion storage of chemicals and post-completion management of produced water. Concerns about chronic exposures from pre-completion activities primarily involve fugitive emissions from storage tanks or from produced water temporarily stored in open pits.

> **Needs:** While proper handling of chemicals and fracture fluids is required to prevent human exposures, there do not appear to be any water management needs associated with human health that would be directly addressed by the model.

HVHF as Disposal

Another issue raised with injection for HVHF is that it is in fact *de facto* disposal since only a fraction of the fluids are recovered. Industry and regulators frequently state that 15 – 30 % of the volume of fracturing fluids injected in the Marcellus is recovered in the first few weeks (sometimes referred to "flowback"). NGOs claim that the fluids remaining underground are free to contaminate ground water. In most wells, some water continues to be produced for months or years, or even throughout the entire life of the well. There are no published data on how much water is ultimately recovered from Marcellus wells and how much of that water is HVHF injected water vs. formation water. In addition, industry argues that any fracture fluids pose very little risk of contamination due to the protections afforded by well construction and intervening rock strata.

Another concern related to the low fracture fluid recovery rates is that of the potential to diminish available fresh water supplies. Any fresh water used to create the fracture fluid that remains underground is no longer available to the hydrologic cycle, thus reducing the total volume of fresh water available to the surface environment. This is compounded by the need for additional fresh makeup water requirements for subsequent fracture operations.

> **Needs:** While proper handling of chemicals and fracture fluids is required, there do not appear to be any water management needs associated with HVHF as a disposal mechanism that would be directly addressed by the model.

Produced Water Management and Disposal

Concerns with produced water include on-site management of the water brought to the surface as well as how the water is ultimately disposed.

Shale gas produced water in the U.S. is generally disposed of through treatment and/or underground injection. Underground injection through brine disposal wells is the preferred disposal method, but local stratigraphy does not always provide formations appropriate for large scale disposal. Disposal wells may be commercial disposal wells or may be privately owned and operated. Some NGO's assert that underground injection of wastes is not a long term solution, but merely creates a long term liability, but this issue is generic to oil and gas production, not unique to shale gas or to HVHF.

Public concerns about the amount of water used for HVHF operations, coupled with the lack of adequate disposal capacity, have caused some operators to explore treating and/or re-using the produced water. Produced water may be treated for discharge to surface water or may be treated and re-used in subsequent fracture operations.

Treatment may involve any one of several technologies depending on the intended use of the water. In some areas, produced water has been sent to municipal treatment plants and then returned to surface water bodies. This has been discouraged or outlawed in many areas because the treatment process does not remove any salts; it merely dilutes the water before release. In some cases water can be treated through reverse osmosis or thermal distillation to a low enough TDS level that the water can be discharged to the land or to surface waters. This is an expensive process and still results in a concentrate that must be disposed of. In still other cases, water may be treated through thermal evaporation merely to reduce the volume of water that must be injected.

Many operators are exploring the re-use of produced water from one well in the fracture fluid for another well. With minimal treatment, some produced waters can be blended with fresh water and re-used. This approach helps to address water availability concerns by reducing the volume of fresh water that must be withdrawn. As an added benefit, it can also reduce transportation and disposal costs.

Needs: Operators need the ability to both predict and track the volume of fluids produced from the well over time. Operators also need to be able to track where that water goes in terms of the volumes treated, disposed, and/or re-used and the where those volumes of water are taken. For water that is reused, operators also need to be able to evaluate the impacts of that reuse on reduced withdrawal requirements.

Water Transportation

Transportation of water can create a number of issues including cost to the operator and potential community impacts. Transportation of water by truck can potentially result in water-related community issues for several reasons. While some traffic issues are common to all oil and gas development, truck traffic can be significantly increased for hydraulically fractured wells. This truck traffic can create noise and dust issues for near-by residents. In addition, if the truck traffic is not managed to avoid local rush-hours, residents can be seriously inconvenienced. Another traffic related impact is damage to city and local roads that were not built for the weight or volume of traffic associated with shale gas development. This is especially a problem in areas new to oil and gas development where tax structures are not in place to ensure that increased oil and gas activity results in the tax income needed to maintain roads. Use of multi-well pads can reduce the overall impact and allow improvements to certain roads that limit the extent of road impact; however the impact is concentrated and extended for those residents near the pad or near water take point.

Transportation of water by pipe is increasing in some areas. In some areas overland pipes or "fast-lines" can be used, while in other areas, especially where longer transport distances are involved, buried pipes must be required. Some of these pipes may require permits and buried pipes, in particular, must be carefully planned to ensure lowest cost and longest use.

Needs: While traffic, *per se,* is not a water issue, its potential community impacts are closely tied to water withdrawals and transportation of produced water. Operators need to be able to assess distances from take points to well pads and from well pad to final disposition or re-use in order to evaluate the tradeoffs between trucking and piping the water. Operators also need to be able to evaluate the potential benefits of reusing produced water in terms of reducing the cost of transportation and the potential community impacts.

Naturally Occurring Radioactive Material (NORM)

NORM can be brought to the surface with produced water from some shale formations. The NORM can be concentrated in pipe scale, tank sludge, or remain in the produced water. If the produced water is treated, NORM in produced water could also be concentrated in sludges or treatment concentrate at the treatment facility. Radiation levels are typically below exposure limits for workers, but there is some uncertainty about whether NORM produced water from some formations may require special handling. NGO concerns have generally focused on the risk to public. Multiple studies on NORM in conventional produced water have shown that the risk to the public is negligible due to the low levels of radiation and due to lack of an exposure pathway. Whether it is a true health risk or not, the term "radioactive" generates highly emotional concerns for the public, making this an issue cannot be dismissed lightly. At this point there is little data available on NORM associated with Marcellus shale development.

> **Needs:** Given the lack of data on NORM in produced water in the Marcellus, it is not clear that the model needs to include any functions dealing with NORM at this time. If NORM is determined to be a concern, operators will need the ability to flag any water that is determined to be a concern and to separately track that water to its final disposition.

Initial System Design

After analyzing the known water management issues associated with Marcellus Shale development in the target area, an initial draft of the design of the Lifecycle Water Management Model was created based on anticipated user needs. In crafting the design, consideration was given to using low cost, readily available platforms that would facilitate creating and using the model as well as allowing future modifications by third parties. In addition, it was determined that the application would not be web-based in order to avoid data security issues for proprietary information. The initial system design includes modules and their interactions, input and output requirements, user interfaces, initial data structure, modeling requirements, development software options, and hardware requirements.

The system will be created to be used in both stand-alone and client/server installations. The stand-alone application would be installed on a single work station, while the client server application would use a backend (database) installed on a centralized server and the application installed on work stations connected to the database. The client/server installation would allow larger companies to ensure that water from take-points or in impoundments is not committed to different wells by different engineers.

Programming of the application will be to be done with Microsoft's dotNet studio which will allow for rapid application development and flexibility in making modifications. Additionally, using a dotNet development strategy will produce an application that is operating system agnostic. The application will be packaged in an .exe that the user will download and install through the use of a "wizard".

The application will consist of modules related to water withdrawal (sourcing), transportation, storage, use, treatment, reuse, and disposal. Using a "switchboard" menu screen, the model will address all phases of the water management lifecycle and will allow users to specify input parameters, objectives, schedule, etc. Each of the modules will interact by transferring results or parameters to the other modules as needed.

Inputs and results will be stored in the database that each module will draw from for population of data in other modules. The database will be relational to the extent that each module will draw from common data elements and if new data needs to be collected for that module, then a form will be presented for data input which will then store the data in the database. The model will allow users to input water volume needs in the sourcing module and see expected disposal volume at the end of the lifecycle or the objective of other phases. Scenario analysis will allow users to compare various alternatives such as pace of development, central vs. distributed facilities, and reuse vs. treatment options.

A permit module will also be incorporated to allow tracking of planned and existing withdrawal permits. Tracked data elements will include, at a minimum, the permit number, the permit period, take point location, and permitted volumes.

Reports will be generated by the data stored in the database. The reports will either be specific to a module or may, at the user's discretion, be generated as a single report broken down by module. The reports will list inputs and results and will be available in a variety of formats.

Conclusion

Research into the water issues and needs confirmed the strong need for the Lifecycle model. All work under the project is progressing as planned, and the model should provide a much needed tool to help ensure that the Marcellus Shale is developed in a way that brings this important resource to market while protecting human health and the environment.

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