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The Many Topics within THE MARCELLUS SHALE

Water Reuse Considerations for Marcellus Shale Development

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Over the past few years, much has been made about the economic opportunities that the Marcellus shale has brought to the region. Of equal importance to those opportunities are the environmental and process innovations that have been developed in the Marcellus due to Pennsylvania's environment and stringent regulatory framework. One such innovation is the advancement of processes and infrastructure that allow operators to continuously reuse water. Range Resources and Atlas Energy, recently acquired by Chevron U.S.A., Inc., have taken leadership roles to pioneer the implementation of these processes and infrastructure.

There are seven major factors to be considered when creating an effective and successful water reuse program, they are:

- Characterize the water to be utilized based on the water balance;
- Determine the target formation's geochemistry;
- Define flowback and produced water treatment strategies;
- Develop a fracturing fluid chemistry design that is compatible with the treated water and the formation geochemistry;
- Develop a completion engineering design to complement the treated water, formation geochemistry, and rock mechanics;
- Coordinate logistics to minimize infrastructure requirements and ensure cost-savings;
- Conduct a comprehensive compatibility analysis that integrates all of the aforementioned components.

Water Impoundment Pond. Photo Courtesy of Range Resources.

The intention of this paper is to define the water balances associated with hydraulic fracturing from an operator's perspective and to review the considerations required to institute an effective water reuse program. Each of the seven major factors are worthy of technical review that is beyond the scope of this paper so we will only briefly describe them here.

The Water Balance

To establish an effective water reuse program the operator must first understand the water balance. For Chevron's current completion schedule of one well per week, each fracture stimulation operation is designed to use a mixture of approximately 39 percent recycled water (flowback/produced water combination) and 61 percent fresh water in order to achieve the goal of 100 percent reuse of all of the company's flowback and produced water. It should be noted that Atlas has been engaged in completing natural gas wells in Pennsylvania since 1968 and thus has more produced water available than most operators.

For Range Resources' current completion schedule of 2.8 wells per week, each fracture stimulation operation is designed to use a mixture of approximately 19 percent recycled water (flowback/produced water combination) and 81 percent fresh water to achieve the 100% water reuse goal.

Atlas Energy internally developed a patent-pending process to address the challenges of implementing a water reuse policy that Chevron continues to use today. As of December 2010, Atlas was reusing 100 percent of its flow back water and 71 percent of its produced water while utilizing the patent-pending process. Today, Chevron has a goal to achieve 100 percent produced water reuse and 100 percent flowback water reuse by the end of 2011.

Range Resources holds the distinction of being the first operator in the Marcellus Shale to initiate a recycling program; collecting recycled water since January 2009 and completing their first well utilizing recycled water in August of 2009. Range Resources relies on simple, cost effective, and market proven technologies to condition flowback and produced water for reuse. For the calendar year 2010 Range Resources reused 95.7% of flowback water and 54.3% of produced water; 99% of the produced water not reused was sent to salt water disposal wells. Range Resources targets reuse rates of 99% and 85% respectively for flowback and produced water in 2011.

Characterizing All Water Sources Based On the Water Balance.

As previously described, understanding the water balance is of paramount importance in characterizing the contributors to the ultimate blend of water to be used. Water characterization is dependent upon a relevant sampling protocol, sample preservation protocol, a full a full analysis of anions, cations, and other testing protocols relevant to end use.

Defining Formation Geochemistry

It is not enough to characterize the water sources used to conduct hydraulic fracturing operations. The formation water and geochemistry should be defined to determine what potential interactions can occur with the water utilized and fracturing fluid chemistry deployed. Formation geochemistry can vary widely throughout the play.

Flow Back and Produced Water Treatment Definition

Shale reservoirs are termed unconventional since they have ultralow permeability. A key principal in Range Resources reuse program is that, before fracturing, the Marcellus Shale does not contain any mobile water. Therefore any water recovered from the well is the original source water used in fracturing operations.

Chevron believes there is potential to connect to mobile water in the Huntersville Chert. A key belief of Chevron is that within their flowback they have the polymeric suspension that should be broken in order for reuse to be successful. Reuse of flow back water without breaking the polymeric suspension may result in blinding of critical gas migration pathways. There are many proven processes available for breaking the polymeric suspension including clarification and filtration. Of the technologies that do work, great care must be made to understand the potential interactions that can happen as the result of the treatment. Some treatments result in residual sulfate, pH, or metals incompatibilities, for example. The treatment techniques must result in a water quality that is compatible with the fracturing fluid chemistry deployed and the formation.

Fracturing Fluid Chemistry Design

Many companies have voluntarily reduced the number of Material Safety Data Sheet (MSDS) Section 2 listed components in their fracturing fluid formulations. Range Resources and Chevron are leaders in voluntary disclosure of fracturing fluid chemicals deployed.

Various chemical formulations can be utilized in hydraulic fracturing. PADEP has listed a comprehensive list of the many possible additives on their website. In reality, for a simplified slick water fracture treatment, only a handful of additives are required. For Range Resources, a typical additive package consists of diluted volumes of friction reducers, scale inhibitor, a biocide, and in some treatments, a diluted hydrochloric acid package. For Chevron, the additive package also typically consists of diluted volumes of friction reducers, scale inhibitors, a biocide and in all cases a diluted hydrochloric acid package. For both operators, typically 99.9% of the frac fluid is water and sand. Utilizing acid mine drainage for hydraulic fracturing represents a significant opportunity to improve Pennsylvania surface water quality. Due to high sulfate levels, increased use of mine water can change the fracturing fluid chemistry formulation requirement in order to be fit for purpose.

Reclaimed Well Pad Site. Photo Courtesy of Range Resources.

Completion Engineering Design.

There are numerous considerations where completion engineering design is concerned. The fracturing fluid friction reducer design has to match the operator's desired velocity at the perforations. This velocity is dependent on a variety of factors including rock properties, perforation efficiency, near wellbore effects, and far field effects. The mechanical properties of the shale can vary widely throughout the Marcellus play. The viscosifier has to match the carrying requirement for the specific proppant and proppant concentration desired.

Logistics

Having an on-site water reuse process allows operators to transport flowback and produced water to other local fracturing operations via direct piping or trucking. This avoids transporting flow back or produced water to centralized treatment facilities, thereby reducing water transportation. The cost of transporting water utilized for hydraulic fracturing is one of the highest cost activities encountered by the operator. Not only are there direct costs associated with water transportation, but there are also a myriad of indirect and intangible costs associated such as; road repairs, increased traffic on rural road, air emissions, and safety concerns. Given that produced water is only generated at 2 to 20 barrels per day from many different wells, a well program and site design that facilitates local collection and reuse of the water is important to reuse economics. An equally important benefit of lowering water transportation is minimizing environmental and community impact.

Final Compatibility Analysis

There may be chemical compatibility issues that arise when developing a reuse program and thus different considerations are made depending upon an operator's technical philosophy. For example, Range Resources believes that there are three key compatibility considerations for source water used in fracturing operations: Scale potential, bacteria, and permeability issues. With regard to scaling, as previously discussed Range Resources believes that there is essentially no mobile water contained within the Marcellus Shale and therefore many of the typical scaling mechanisms are not present; the remaining potential can be mitigated using minimal amounts of scale inhibitor. The second consideration is potential for biological growth and fouling; bacterial growth is controlled through the use of biocides. The final consideration is that the Marcellus shale has extremely low permeability; the pores within the shale are so small that they are virtually impossible to plug off with water-based particulates. Based on these considerations, Range Resources believes that the Marcellus Shale is extremely forgiving with respect to completions water quality in general and readily facilitates a reuse program with minimal source water conditioning.

On the other hand, Chevron has determined that more than half of its completions in vertical Marcellus wells produced free formation water from connection to the Huntersville Chert. In this circumstance, the treatment technique for flowback and produced water should produce a final water product that is compatible with the other water sources utilized, the formation water, the formation geochemistry, and the fracturing fluid chemistry deployed. Chevron has found that simple Langelier Saturation Index (LSI) calculations on the pre-frac water to model scale only take into account potential for carbonate scales when the risk of barite scale formation is the highest risk Chevron encounters. Therefore, Chevron uses more thorough scale models to adequately model compatibility. The pre-frac water should be modeled for compatibility with the formation water in such calculations. Fracturing fluid additives should be tested for compatibility with each other, with formation water, and at formation conditions. Break down properties should be determined for friction reducers as some friction reducers may form gels at formation conditions that have the potential to foul critical gas migration pathways.

Conclusion

In summary, there are seven major considerations that need to be made to in order to create an effective water reuse program.

Although Chevron and Range Resources each use different techniques within their respective reuse strategies; both reap the environmental benefit of high recycle rates and the economic benefit of low implementation costs. Chevron's implementation costs are between $0.25 to $0.50 per barrel, while Ranges Resources implementation costs are between $0.26 - $0.45 per barrel. The authors believe it is likely that virtually all produced water and flowback water generated in Pennsylvania will be reused by the end of 2012. **PE**

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