

# How Technology and Water Converge in the Economics of Oil and Gas Production

Understand water management in unconventional plays.

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Advances in exploration and energy extraction techniques—including horizontal drilling and hydraulic fracturing—are changing the U.S. energy economy. Horizontal drilling facilitates unconventional access to gas and oil reserves that were unavailable using conventional vertical drilling. Most of the large volume gas and oil reserves are difficult to develop because they are contained in deep, tight sands, shale and other unconventional reserves.

However, many of these reserves can be accessed using hydraulic fracturing, which involves the injection of water, sand and chemicals at high pressure across the horizontal well as deep as 10,000 feet below the surface. This fractures the shale and other unconventional formations and allows gas and oil to flow up and out of the well, with significant volumes of water. A well produces three to nine barrels of water, on average, for each barrel of oil produced.<sup>1</sup>

One significant economic benefit from these techniques is the increased production of shale natural gas, which is a precursor to important intermediate chemicals that are used in a wide range of commercial products. Shale gas now accounts for more than one third of the U.S.'s natural gas production and is considered one of the most significant energy developments in the past 50 years.

Hydraulic fracturing and proper water management across the process requires a range of process instruments—including flow meters, level sensors, overflow protection and a range of analytical measurements.

## Water Management

The primary fluid used in hydraulic fracturing is water and the completion process can require from 2.75 – 8.25 million gallons per well. For example, the Marcellus Shale uses 80,000 gallons of water per well for drilling and 4,000,000 gallons for hydraulic fracturing, for a total volume of 4 to 8 million gallons per well. With this requirement, the significant expansion of unconventional oil and gas development requires reliable water resources and effective management to control costs, which are a significant component of upfront capital investment and ongoing lease operating expenses.



Water management can be defined within five major unit-operations: sourcing, transportation, storage, treatment and disposal. Figure 1 illustrates this and shows that water is ultimately injected in disposal wells or recycled within the process.

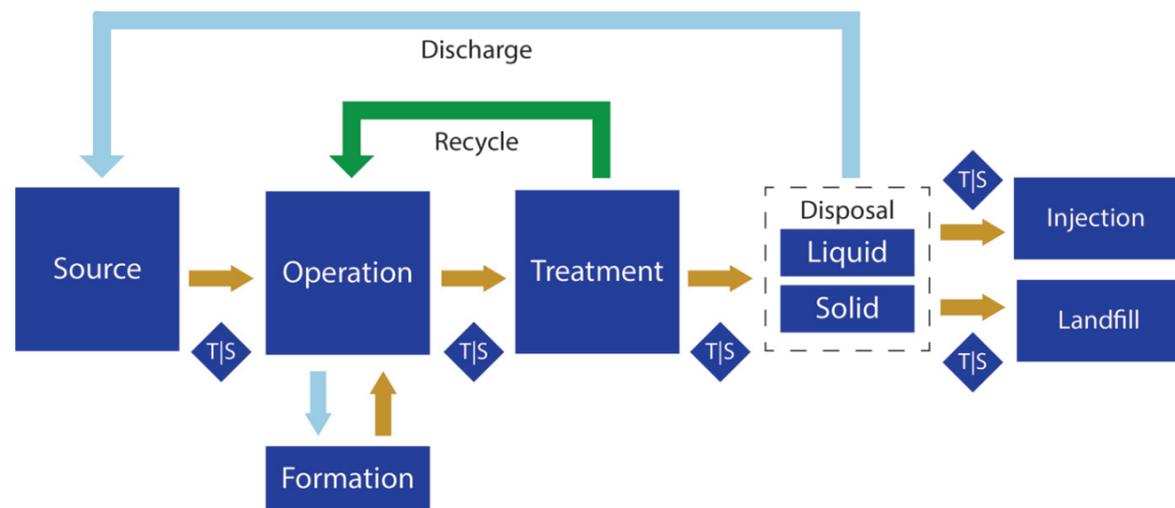


Figure 1. Water flow in hydraulic fracturing and production. Source: HIS and Cap Resource: The Future of Water in Unconventionals—Water Management Strategies in the Continental U.S.

Three different water management methods exist:

- Once through and disposal
- Treatment and reuse
- Treatment and discharge

Within the “Operation” block of Figure 1, four different types of water-based fluids are associated with hydraulic fracturing—drilling mud, hydraulic fracturing fluid, flowback water and produced water. Different water management requirements and instrumentation are associated with the control and processing of each water type.

Different treatment processes have been developed and new processes are constantly evolving to treat and reuse/recycle as much of this water as possible to conserve and improve operational efficiencies and reduce costs. Treating flowback and produced water is much less expensive than the high cost of water acquisition and the transportation of contaminated water to treatment facilities.

## Drilling Mud

Drilling mud cools the drill bit and facilitates the transport of rock cuttings to the surface during drilling operations. Most drilling mud is comprised of water, sand and chemical reagents to regulate mechanical properties and provide environmental protection. Water in drilling mud must be managed to ensure the proper density, viscosity and chemical properties of the mud.

A key analytical measurement in drilling mud is pH. Low pH aggravates corrosion. Online pH monitoring ensures that corrosion is minimized. In this environment, pH measurement is difficult because of abrasion and mineral deposits that have the potential to block a pH probe’s reference junction. The use of an ion specific field effect transistor (ISFET) pH probe (see Figure 2) reduces the potential for probe damage and provides longer sensor life.



Figure 2. ISFET pH probe

An ISFET probe is constructed with a solid sensor and is typically made of polyether ether ketone. The pH sensing element is a field effect transistor that responds to the presence of the hydrogen ion, producing a signal proportional to pH. Despite the robust nature of the sensor, it must be removed frequently to clean off mineral deposits. Drilling mud is commonly delivered to the drill bit using progressive cavity pumps. These pumps are able to handle solids and slurries without adverse effects on fluid viscosity.

## Hydraulic Fracturing Fluids

Hydraulic fracturing fluids are typically made up of 9 percent sand and 91 percent water in solution. Sand used in fracturing is engineered to be spherical, reducing friction and maintaining a structure in the formation that facilitates fluid flow through the sand matrix. Approximately 99 percent of the liquid used consists of water. The remaining liquid, less than 1 percent, is comprised of additives (see Figure 3). Additives play a key role in hydraulic fracturing fluid dynamics. They reduce friction, fight microbes, control pH and prevent equipment corrosion.

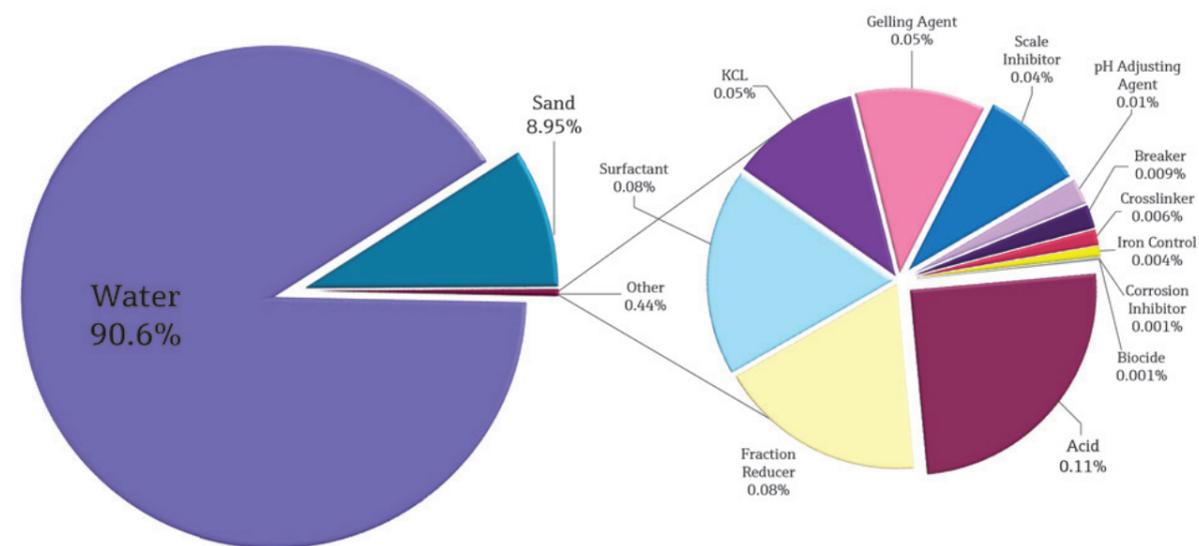


Figure 3. Typical makeup of hydraulic fracturing fluid. Source: Modified from Bohm et al., All Consulting, 2008



Image 1. Coriolis mass flow meter

Hydraulic fracturing fluid is blended and combines sand, water and additives in exacting combinations. It is then injected at high pressure deep into the well. Precise blending of the additives is achieved using Coriolis mass flow meters (see Image 1). Coriolis mass flow meters measure fluid flow in mass rather than in volume. Mass flow allows for precise control of the additives relative to the mass of the water and sand.

In addition to mass flow blending, control of the additive blend’s pH can be accomplished with digital pH measurement. Digital pH sensor technology allows for the remote calibration of the sensor under controlled conditions and simple replacement onsite, using a sealed, inductively coupled connection that protects the sensor signal under harsh environmental conditions.

Pumps used to send fracturing fluid down the wellbore are critical to the success of the hydraulic fracturing process. Reciprocating plunger pumps have been used for decades to propel the water, sand and chemicals into a well at pressures as high as 15,000 psi and flow rates above 100 barrels per minute. These pumps are evolving with increases in size, horsepower ratings and pressure capabilities to meet the increasing demands as drilling migrates into more complex geological formations.<sup>2</sup>

## Flowback Water

Water used to fracture the well recycles back to the surface and is referred to as flowback water. During the completion process, volumes can range from 0.5 to 1.2 million gallons per well per week. As a well achieves completion, flowback water slowly transitions to produced water.<sup>3</sup>

Flowback water may contain hydrocarbons, fracturing sand and pieces of plastic/metal/cement from drilling. As the well comes online, the water can be difficult to manage because of the varying flow rates and composition. With proper instrumentation, both flowback and produced water can be treated in close proximity to well sites for reuse, reducing costs and decreasing the dependency on fresh water sources.

## Produced Water

Produced water is collected along with hydrocarbons during the well's production life. Produced water includes a mixture of the following:

- Liquid or gaseous hydrocarbons
- Dissolved or suspended solids
- Produced solids, such as sand or silt
- Recently injected fluids and additives that may be in the formation as a result of exploration activities

Typically the volume, chemistry and suspended solids are stable throughout the well's life. Produced water flows can range from 30 to 500 gallons per day for each well. Given the limited availability of water, hydraulic fracturing operations are now reusing produced water to decrease the demands on local water sources and reduce the overall cost and challenges of disposal. Of the costs associated with produced water management, transferring water from a well site to a processing facility or a disposal well is the greatest component. Costs for transporting water can be more than \$3 per barrel. The development of onsite produced water processing facilities can dramatically reduce these costs.

Produced water handling and treatment represents an \$18 billion cost to the oil and gas industry in the U.S. alone, and is the single largest waste stream challenge facing the industry. The cost of disposing produced water ranges from a low of \$0.08 per barrel to a high of \$12 per barrel. By contrast, water for agricultural irrigation can be as low as \$0.004 per barrel and municipal drinking water costs in the range of \$0.04 per barrel. The price of cleaning produced water is up to 300 times greater than treating municipal water and 3,000 times greater than agricultural irrigation water.<sup>4</sup>

Produced and flowback water can be processed onsite or transported to a central processing site. While a central processing site can be leveraged across multiple well sites, a portion of the transportation costs still exist.

A typical produced/flowback water process (see Figure 4) employs four basic steps:

**Pre-treatment** This step includes the removal of large particles and oil/water separation. At a central processing facility, water is delivered by truck and is pumped into storage tanks using centrifugal pumps. Tank levels are monitored using guided wave radar and are protected with overflow sensors. This stage incorporates filters with differential pressure measurement to monitor filter status. Conductivity sensors are employed to monitor the oil content and the effectiveness of the requisite oil/water separation process.

**Main treatment** Using a range of processes—including biocide addition and different coagulation and flocculation steps—total suspended solids and total dissolved solids are reduced, including iron. Once the compounds begin to coagulate, a sludge thickening process is employed to remove the solids.

**Polishing** Using filters, ultra-small and dispersed hydrocarbons are removed. In this process, differential pressure is again used to monitor filter status.

**Tertiary treatment** This final, optional step can produce a high-quality effluent stream. Evaporation technology is being employed to produce a higher quality distillate that can meet or exceed secondary drinking water quality standards.

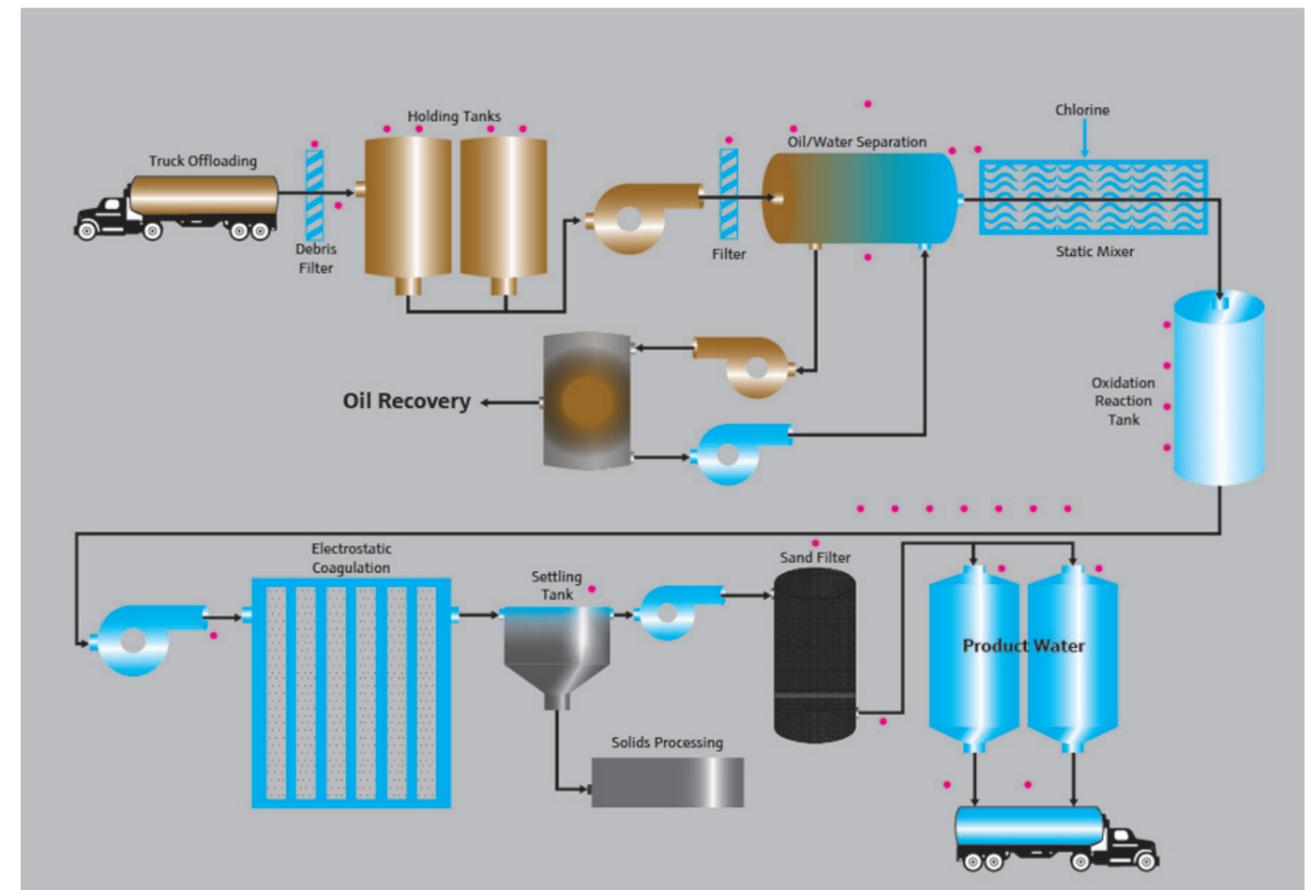


Figure 4. Typical flowback/produced water process

Throughout this process, analytical instruments are employed to control this process. Level sensors are used in holding tanks and settling tanks with high-level overflow protection sensors. Where oil and water coexist in a tank, radar level is used to detect the actual interface.

Flow measurement technologies in produced water processing include magnetic and ultrasonic. Magnetic flow meters are not suited for flow streams with high oil content because oil is not conductive. In these applications, ultrasonic flow meters are the technology of choice.

## Conclusion

Horizontal drilling and hydraulic fracturing are making significant impacts on the availability of energy resources, including natural gas and oil, but are also adding significantly to the demands of water in the production process. Improvements in operational efficiencies and reductions in the use of fresh water resources can be achieved by applying recycling technologies for all water associated with the production process.

Drilling, completion and production can employ water management solutions that incorporate state-of-the-art technologies including flow, level, pressure and analytics. In addition to reducing water consumption, applying these technologies can create a sustained competitive advantage by reducing capital investment and operating expenses.

## References

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