In the first half of 2013 there were more than 17,000 wells drilled in the US, with nearly half of those drilled in the Williston and Permian basins and the Eagle Ford shale, according to the Baker Hughes well count. More than half of the total completions in these areas currently rely on the use of crosslinked gel as a method of increasing the viscosity of water so that it will effectively carry proppant into the reservoir.

Each of these regions is arid, and the water demand to support hydraulic fracturing programs can be a strain on local water supplies. Concurrently, operators are producing flowback fluid and produced fluid (waste-water) from these same wells, which is most commonly disposed of via saltwater disposal wells. Many operators are now seeking to reuse this wastewater as frac fluid, which offsets the industry’s use of freshwater resources, reduces the cost associated with acquiring fresh water, replaces the need to add potassium chloride (KCl) for clay stabilization in the reservoir, and in some cases may be a cheaper alternative than disposal.

**Problem**
Compatibility between wastewater and completion chemicals has been an obstacle to wastewater reuse. Crosslinked gel fracturing fluids are complicated and require sophisticated engineering to ensure an appropriate design. Though the industry has made significant strides in advancing salt-tolerant crosslinked gel fluids, the chemical combinations must still be adjusted to match water quality.

During a crosslinked gel frac, the timing of the crosslink must be delayed for a few minutes until it is out of the mixing equipment. The primary challenge in reusing flowback fluid from one crosslinked gel frac on another is the carryover of the crosslinker – commonly a boron-containing compound – that can prematurely crosslink the gel. To combat this, the pumping company will add a boron inhibitor such as an alcohol that will delay crosslink for a few minutes. When recycling flowback fluid, it is critical to monitor boron levels in real time and adjust inhibitor dosage appropriately.

In crosslinked gel fracs the pumping company can manage changing water quality from one well to the next; however, the water quality must remain consistent throughout each well since a well is the most reasonable unit for logistical planning. This allows the pumping company to have the requisite chemicals onsite prior to the start of each well.

There are several different entities involved in water management for a frac. The introduction of multiple water streams of varying quality has precipitated the need for a fluid-blending quality assurance and quality control (QA/QC) system.

**FIGURE 1.** The graph shows the fluid volume for each stage of a completion in the Permian basin.
(Images courtesy of Hydrozonix)
Solution

The gel frac recycle and control (G-FRaC) system provides QA/QC of water blending for crosslinked gel completions. This system defines the appropriate blend based on pretesting waters to be blended, blends the fluid streams to the correct volumetric ratios, monitors fluid quality parameters in real time during the frac, and synchronizes the water transfer and pressure-pumping companies with the operating company’s completion design.

The system process involves the following steps:

- Waters to be used on a frac are identified. This step may involve multiple water sources, including fresh surface or ground water, flowback fluid, produced fluid, or even brackish ground water. The fluid might be dynamic (flowing from a well) or static (sitting in a storage vessel);
- Water sitting in tanks is circulated and agitated prior to testing. Often, water managers will scoop water from the top of a static tank only to find that the water quality is much different once it is disturbed. Therefore, when taking samples of the water from a vessel, it is paramount to first agitate the water;
- Samples are taken and analyzed. Three constituents provide the minimum effective combination of parameters that can be relied upon to help ensure a successful crosslinked gel fluid and measured in real time in the field. Total dissolved solids (TDS) give an indication of the overall water quality. Chloride is tracked to ensure that the required KCl equivalency goal is met. Boron is a critical constituent to track in real time because of crosslink timing interference;
- The operating company and the pumping company agree on the requisite water quality for the completion, which is then communicated to the G-FRaC system operator;
- The system actively controls the volumetric ratio of the different water sources by controlling pump rpm;
- The frac system operator conducts consistent field tests throughout the frac to determine levels of TDS, chloride, and boron; and
- The G-FRaC system operator provides critical real-time feedback to the water-transfer company and the pumping company to ensure that the

![FIGURE 2. Boron levels for each stage of a completion in the Permian basin are tracked.](image)
water is blended on the fly in accordance with the plan.

**Case study**

A large independent operator in the Permian basin sought to use wastewater as 30% of its 110,000-bbl 12-stage crosslinked gel well completion. Every barrel of water the operator reused on the frac lowered its operating cost by reducing trucking and disposal costs and by eliminating the need for a clay-stabilizing additive.

The total fluid volume pumped downhole during the job was 107,559 bbl – 75,400 bbl of fresh water and 32,159 bbl of wastewater – resulting in 30% of the frac fluid being composed of wastewater. Figure 1 shows the fresh water and wastewater by volume per stage. The graph also shows the actual percentage of wastewater used on the job, which stayed between 28.4% and 30.7% on a stage-by-stage basis.

Figure 2 compares the boron levels of the wastewater to those of the final blended fluid for each stage. The boron level for each stage was between 27 mg/l and 36 mg/l, which was a very manageable range for the pumping company. TDS and chloride results show the same general trend. These results represent predictable, consistent water quality blended from two very different water sources on the fly using the G-FRaC system. From multiple successful system deployments, Hydrozonix is confident that the results are repeatable in many different operational scenarios.

Wastewater reuse can potentially provide operators with substantial cost savings from the reduction of wastewater trucking and disposal, the elimination of clay stabilization additives, and the reduction of freshwater acquisition cost. The successful reuse of wastewater on crosslinked gel fracs will hinge on the operator’s ability to blend different water sources to ultimately achieve a blended water quality that is consistent and predictable for the pressure-pumping company. The G-FRaC system offers a scientific method for controlling water quality on a crosslinked gel completion – one of the industry’s most vexing challenges.