Remedial Wells Reap 40-Fold Benefit from Horizontal

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Summary

Radian International LLC last year demonstrated in Plaquemine, LAthat a single high-efficiency well could replace as many as 40 to 45 vertical wells at one of the largest industrial ground water remediation projects in the US. Technical advances in directional drilling and control equipment and application of "best practices" in the petroleum industry made the project at Plaquemine a success.

One of the advances in the directional drilling industry utilized at Plaquemine is mixed metal hydroxide (MMH) drilling fluid. Even though MMH-based fluid may cost up to 25 percent more per barrel than commonly used bentonite muds, its performance in remedial wells far outweighs the difference in initial cost.

Drilling Fluids for Horizontal Remediation Wells

Horizontal boreholes drilled for environmental remediation applications are typically quite fragile, as most target zones consist of unconsolidated materials. Well depths typically range from 3 to 200 feet and lengths may extend over 1100 feet. The selection of a proper drilling fluid is critical to ensure a successful horizontal well installation.

When traditional bentonite muds are used at shallow depths for environmental applications, an overbalanced condition often occurs. The higher pressure required to maintain high flow rates for hole cleaning tends to push the bentonite into the formation. Subsurface contaminants can be spread by the overbalanced drilling fluid and at very shallow depths the fluid can "frac out" to the surface due to the unconsolidated nature of most shallow formations.

A Page from the Oil Patch

Bentonite muds have proven less than ideal for directional drilling for many applications. The petroleum industry, like utility river-crossing and remediation industries, first used bentonite muds for horizontal drilling. Bentonite by itself is not shear-thinning and must be pumped at high rates to maintain the required carrying capacity. High pump velocity can also lead to hole erosion. Bentonite's swelling characteristics can also plug pores near the wellbore and significantly restrict reverse-flow permeability, a measure of formation damage (Figure 1).

In an attempt to increase carrying capacity and reduce wellbore hydraulic pressure, the petroleum industry shifted to beneficiated bentonites (treated with organic polymer to adjust apparent viscosity). Ultimately, these beneficiated muds were shown to damage the formation. Although they improved drilling rates, they tended to reduce overall efficiency by reducing formation backflow, up to 90 percent reduction (Figure 1). Elaborate completion washes and stimulation fluids were often required.

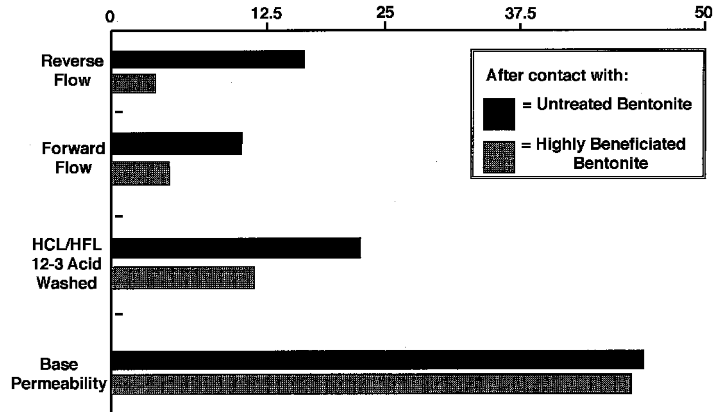

Figure 1
Permeability of a Washed Berea Sandstone (mD)

Advent of Shear-Thinning Drilling Fluids

In the past few years, the petroleum industry has essentially solved these problems through the adoption of specific shear-thinning drilling fluids. When pumped at high flow rates through the narrow drill string they exhibit low viscosity. But after passing through the bit into the wider cross-section annulus, the flow rate drops dramatically and the fluid thickens.

The higher viscosity significantly improves the suspension of solids, while reduced flow pressure significantly reduces the risk of mechanical "frac out" to the formation. At the same time, higher viscosity helps maintain the wellbore when unconsolidated formations are encountered. High shear-thinning fluids protect the near borehole, either physically or chemically, by preventing plugging of pores (Figure 2).

Well	Mud Type	Flowback
1	Drilled with Standard Bentonite Mud	120 BPM*
2	Drilled with Xanthan Gum / Sized Salt	255 BPM
3	Drilled with MMH / Clay	275 BPM

* Barrels per minute

Figure 2
Offset Horizontal Well Production

Shear-thinning fluids are typically based on
- 1) MMH and unbeneficiated clay or
- 2) xanthan gum and sized insoluble salts.

Both systems may require the addition of fluid-loss agents for certain formations.

Remedial Wells continued from page 4

For the xanthan gum system, the gum is the viscosifier and the salt sets up a filter cake between the formation and the gum. In an overbalanced drilling condition, however, excessive xanthan can push into the formation, clogging and damaging pores.

The MMH system relies on the use of unbeneficiated bentonite. As shown in Figure 3, unbeneficiated bentonite gives better flowback. The MMH reacts with the clay and forms a non-damaging adduct. Optimum downhole rheology and well flowback can be achieved using recommended formulations.

Both systems give near-wellbore reverse permeability of 80 to 90 percent of the base permeability while dropping the necessary downhole velocity by 50 to 75 percent. For an 8” wellbore, this means flow rates can be reduced from about 300 gallons per minute (gpm) with plain bentonite to just 75 gpm with an MMH system. Concurrently, flowback can be improved 200 to 300 percent.

Because downhole pressure is also dramatically reduced, so is the risk of “frac out.” In addition, the unique shear-thinning properties of MMH system suspend solids in a fragile gel when drilling ceases, so no special clean out is required when drilling resumes. Less torque is required for start-ups and maintenance, so there is less energy consumption and wear-and-tear on the equipment.

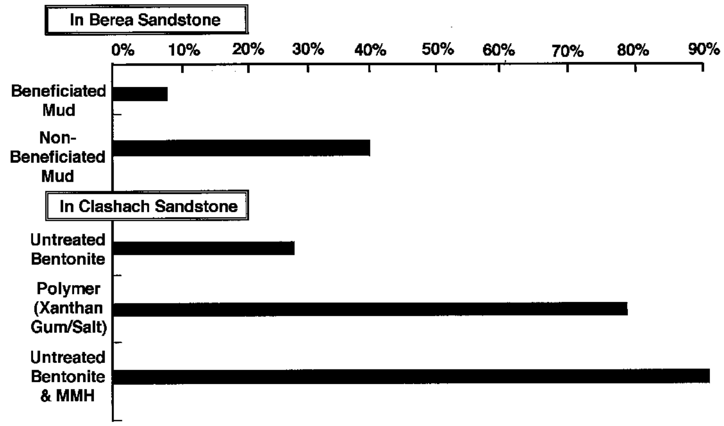

Figure 3
Permeability Recovered as a Percentage of Initial Value

For environmental applications, one of the highest priorities should be maintaining the integrity of the borehole. When the cost of a single “frac out” can more than offset the entire cost of the drilling mud, it makes sense to select the fluid that best fits the application. Shear-thinning drilling fluids are ideally suited for horizontal drilling applications. They make drilling easier, improve flowback rates, and reduce the chance of spreading of contamination.

Horizontal Wells: An Innovative System

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Horizontal wells have recovered approximately 75,000 gallons of free product in six months of operation at Miami International Airport. The site is located at one of the airport concourses that had leaking underground jet fuel lines. It is estimated that 120,000 gallons of fuel leaked into the surficial oolitic sand unit where the water table averages 6 feet (ft) below land surface (bls).

Recovery of free product from formations with similar aquifer characteristics is usually very difficult; conventional vertical extraction systems are not a viable alternative. An innovative dual-phase extraction horizontal well system was designed to maximize free product recovery. OHM Corporation designed the overall system and subcontracted Horizontal Technologies, Inc. to install seven trenched horizontal wells (650 feet total length).

Each trench is completed with two parallel horizontal well casings. The system is designed to induce a trough of depression during pumping of the lower extraction line. The trough of depression induces movement of the free product to the lowest elevation that occurs above the extraction line. This enables increased recovery of free product from the upper extraction line.

The wells are designed to extract dissolved phase constituents through a lower (13.5 ft bls) horizontal ground water extraction line and free product from an upper (8.5 ft bls) horizontal pipe (Figure 1). The lower well casing is constructed of 6-inch diameter HDPE screen with a high hydraulic conductivity sand pack from 14 ft. bls to 9 ft. bls. The upper well casing is constructed of 12-inch diameter slotted HDPE installed in a gravel pack from 9 ft. bls to the water table (at ~6 ft). The two lines are connected to a common vertical riser that is fitted with a submersible pump and free product recovery pump.

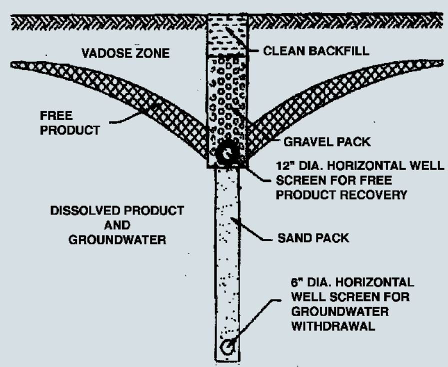

Figure 1
Dual Phase Contaminant Recovery

The remediation is projected to occur in two phases: 1) free product recovery / ground water extraction and 2) soil vapor extraction / ground water extraction. After free product is removed from the upper extraction line during the first phase, the line is used for soil vapor extraction. Ground water recovery continues during both phases of remediation. Current ground water extraction rate is 125 gpm, however rates as high as 500 gpm have been projected.