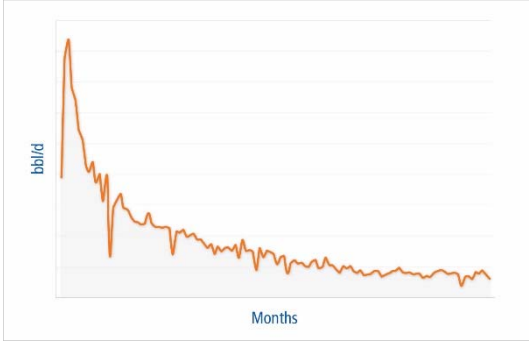
Boosting Recovery

Improve ultimate recovery using a limited entry waterflood system

The combination of drilling horizontal wells and multi-stage stimulation enabled unprecedented access to unconventional resources. This combination of technologies made developing formerly uneconomic plays profitable and resulted in a sharp increase in drilling.

Production rates decline exponentially – some Bakken and Shaunavon wells are estimated to decline as much as 85% within the first year[1]. Although infill drilling is used to offset the declining production, reserves are inevitably left behind.



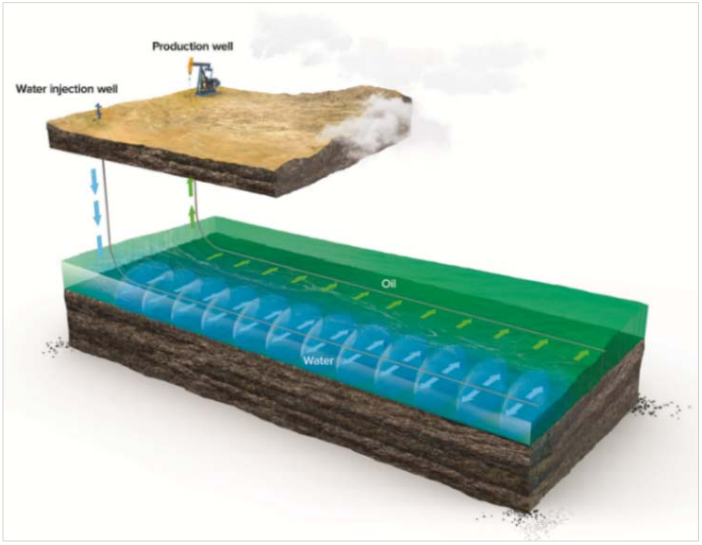
Typical production decline

Waterflooding is another technique to offset declining production. Most waterflood fields use vertical injectors, but operators have recently begun converting horizontal production wells into injection wells. The same zonal isolation principles that improved reservoir coverage for multi-stage completions are leading the way for a significant boost in waterflooding efficiency. Multiple injection points along a lateral are shown to improve sweep efficiency, leading to increased production.

[1] Saskatchewan Research Council, from http://www.jwnenergy.com/article/2017/4/waterflood-technology-advancing-saskatchewans-tight-oil-plays/

WATERFLOODING OVERVIEW

Waterflooding has been used since the 1930s to increase and maintain reservoir pressure, while increasing production. It is a secondary recovery technique that improves production by injecting water into the reservoir. This can be accomplished by converting producers into injectors, or drilling new wells specifically for injection. The injected water is typically enhanced with chemicals to reduce injection pressures and improve water wetting, "sweeping" untapped oil reserves towards producing wells.



As with most subsurface solutions, waterflooding must be customized to the specific region of the reservoir to be both economic and effective. Some considerations in balancing design with costs include:

- Reservoir modeling to maximize hydrocarbon recovery
- Integrating wellbore monitoring such as pressure and temperature gauges

Waterflooding is a dynamic process and is managed as part of a reservoir's life cycle[2]. The time it takes to see the benefits depends on when in the reservoir's life waterflooding begins.

If the reservoir has been heavily depleted, the pressure response will take much longer. For example, vertical injection wells often operate for several years before the production benefits can be seen.

[2] http://petrowiki.org/Waterflooding

Waterflooding Challenges

Most injection wells use bullhead injection below a single injection packer. Similar to hydraulic fracturing without zonal isolation, this technique can result in uncontrolled distribution where typically one section of the reservoir is overflooded. This creates a non-uniform front that can lead to poor sweep efficiency.

Uncontrolled distribution leading to overflooding in some areas and a non-uniform front.

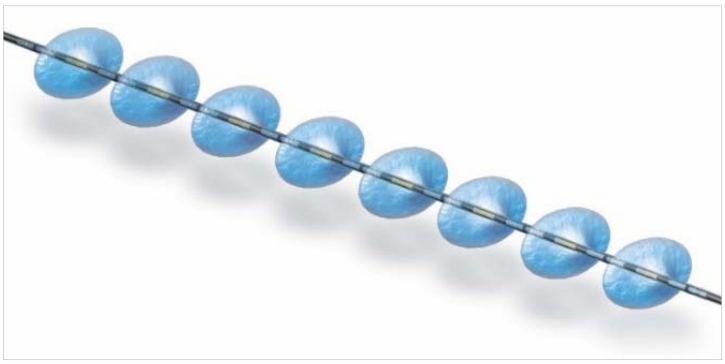
For certain reservoirs, such as those with relatively low permeability and sufficient frac gradient, injection without zonal isolation can give good results. However, this type of uncontrolled injection can often lead to premature water breakthrough and higher than expected water cuts in nearby producing wells. Not only is this counterproductive, it is also time-consuming and expensive to determine and resolve breakthough flow paths. In a well with no zonal isolation, an intervention would be needed to find and isolate the area.

Limited Entry Injection System

The Packers Plus limited entry injection system is designed with specialized outflow control devices that evenly distribute injection fluid throughout the lateral of the injection well. Packers are used for isolation.

These systems can be installed in barefoot wells, as well as those installed with cemented liner or open hole systems. Injection is intended to be part of a long-term solution, and has been designed to be simple to install, retrieve, and reconfigure. Operators can expect a significantly better production response using limited entry distribution compared to bullhead injection.

The Packers Plus limited entry injection system is customized for each well. Using drilling and completion data, each system is designed to optimize the placement, number, and size of entry points. One major design priority is the prevention of fluid breakthrough to producing wells, and this is done through software modeling and simulation, accounting for parameters such as:



Limited entry injection system using packers for zonal isolation for even fluid distribution throughout the lateral.

- Reservoir permeability and porosity
- Target injection rates and wellhead pressure
- Number of entry points
- Pressures during hydraulic fracturing
- Bottomhole temperature and pressure

As nearby production wells respond over time, real-time or periodic pressure and temperature monitoring help to determine optimal reconfiguration or maintenance.

Proof of Concept

A Canadian producer began waterflooding in 2007, when multi-stage hydraulic fracturing was relatively new. After years of traditional bullhead injection, the operator began using limited entry style waterflooding.

The initial production results of the project show clear improvement. Instead of one year, a response can be seen in 6 months[3]. Estimated ultimate recoveries have tripled in some parts of the Bakken and doubled in the Shaunavon. To put this in context, a 5% increase in production could translate to an extra billon BOE of reserves[4].

[3] http://www.crescentpointenergy.com/files/18914.04-2017-CPG-Presentation.pdf

[4] 5% increase in corporate recovery factor; http://www.crescentpointenergy.com/files/18862.CPG-2016-07-presentation-WEB.pdf

The operator has since developed an integrated recovery plan by drilling parallel, closely-spaced horizontals on well pads. This way, selected wells can be converted to injection wells 1 or 2 years later. The operator is on track to double injection well conversions in 2017[5].

Sample production rate comparison, with and without waterflooding

A similar comprehensive program is in place for a different operator working in the Viking formation, which has been overwhelmingly successful to date. In 2016, an independent reserves evaluation estimated that about 700,000 BOE of the operator's reserves was attributed to waterflooding. Under the current program, 25% recovery factor in one of their waterflood areas has been achieved, with ultimate recovery anticipated to be 35-45%[6].

[5] Slide 10; http://www.theoilandgasconference.com/downloads_TOGC_2016/Crescent-Point-Energy.pdf
[6] Slide 30; http://www.rrexploration.com/pdf/RRXSept112017Presentation.pdf

CONCLUSION

Improved oil recovery using waterflooding can help lower decline rates and increase ultimate recoveries. From both simulation models and field experience, waterflooding tight oil reservoirs has sometimes nearly doubled production[7].

Waterflooding strategies and technology are improving, as seen by two operators working in the Bakken, Shaunavon, and Viking formations. Encouraging results have motivated these operators to take the next step, planning new area development with secondary recovery in mind. By drilling closely-spaced horizontal wells on pads, it is easier to selectively choose wells for conversion from production to an injection well, as well as increase sweep efficiency.

Packers Plus' limited entry injection system with stage isolation can further improve recovery. Simulation software is used to design the system to match reservoir conditions. The waterflood injection system allows for real-time temperature and pressure monitoring for each zone. Because it is retrievable and reconfigurable, operators can continually optimize their waterflood programs using the same system.

Packers Plus is an industry leader in multi-stage completion solutions for a variety of applications. The application of zonal isolation and multi-stage completion technology to waterflooding systems is yet another innovation that will help operators maximize their field's ultimate recovery.

Explore more solutions, case studies, and news at packersplus.com.

[7] Specifically, primary recovery factors; https://www.uwyo.edu/eori/_files/eor_ior_jackson_12/kerry%20-%20ior%20and%20eor%20of%20tight%20oil%20reservoirs.pdf