Unconventional Enhanced Oil Recovery Pilot Projects in the Bakken Formation*

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Abstract

Unconventional formations such as the Bakken, Niobrara, and Eagle Ford have made a significant impact on the petroleum industry over the last decade, almost doubling the US domestic oil production. These types of reservoirs contain hundreds of billions of barrels of oil in US and Canada alone, but primary recovery factors are still low, typically less than 10%. The need for enhanced oil recovery (EOR) has been documented, but most studies have focused on simulation models and lab tests. The next logical step includes field trials (aka pilot projects). Over the last 8-9 years, there have been a number of pilot tests for both water and gas injection in the Bakken. Results from these small pilots were reported to state agencies, and the first part of this presentation analyzes the available public data on these pilots. Injectivity of gas or water does not appear to be an issue in the Bakken; however, the projects, in general, show early breakthrough times and poor reservoir sweep efficiencies. There was only minor additional oil recovery, but the pilots were limited in scope and duration. No mitigating procedures were implemented to deal with the problems that occurred. This presentation also proposes methodologies for implementing second generation pilots for unconventional reservoirs. Methods are devised to improve understanding of the near well formation before injection starts, detect where fluids are entering and leaving along the lateral and correct for any associated poor sweep efficiency. We also propose long term information collecting strategies and contingency plans to deal with difficulties that may arise during the pilot. Using EOR to increase recovery from unconventional oil fields is important for the continued success of these plays, and this presentation provides a thorough analysis of implementing pilots to help do just that.

References Cited

EOG, 2016, EOG Resources Announces First Quarter 2016 Results and Successful Enhanced Oil Recovery: EOG Resources Press Release, 5 May 2016.

Hoffman, B.T., and J.G. Evans, 2016, Improved Oil Recovery IOR Pilot Projects in the Bakken Formation: SPE Low Perm Symposium, 5-6 May, Denver, Colorado, SPE 180270, 22 p.

Triepke, J., 2016, Improved Oil Recovery: OILPRO, 5/9/2016.

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Montana Tech

RMS AAPG Meeting

Billings, MT

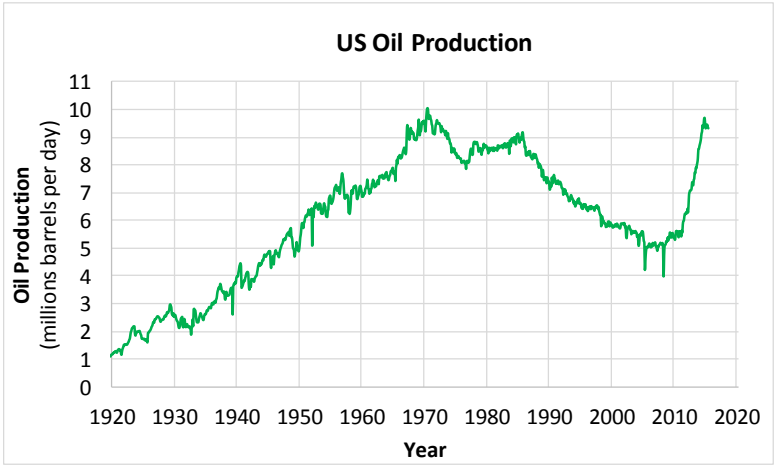
June 26-28

Outline

- **Introduction/Background**
- **Previous EOR Pilot Tests (waterfloods & gasfloods)**
  - **What worked, what didn't work and what we've learned**
- **Future EOR Pilot Tests (engineering/design aspects)**
  - **What is needed, ideas for improvements, where and when**
- **Preliminary Eagle Ford Huff-n-Puff Pilot Results**

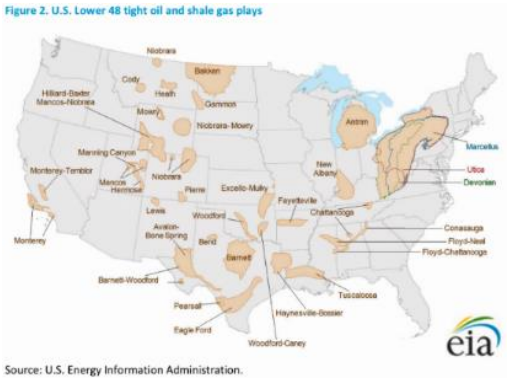
Background

Unconventional Oil Success



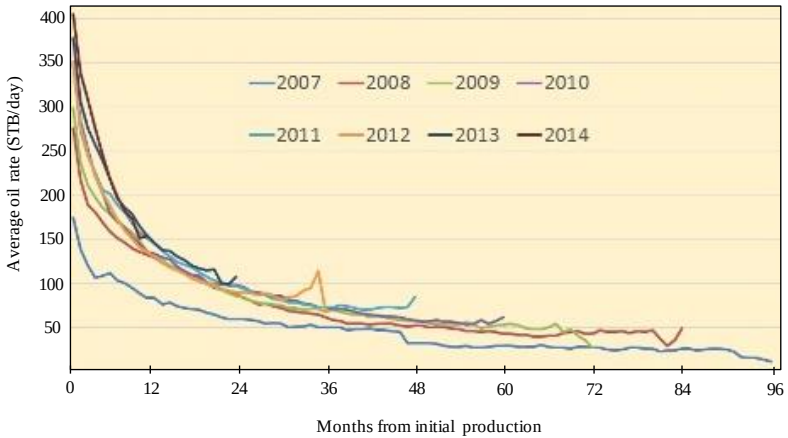
80% of increased US oil rate is from unconventional oil reservoirs

- **Billions of barrels of oil resource in unconventional reservoirs**



Background

Unconventional Oil Opportunities



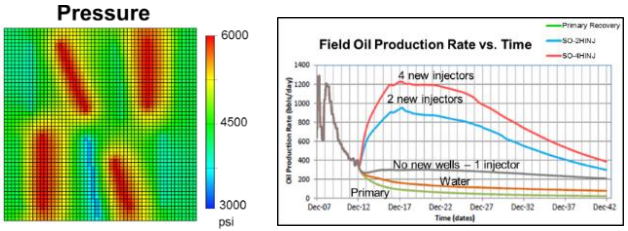
- **High initial rates, but rapid decline**
- **Low Recovery Factor (~10%)**
- **Potential for EOR**

- **Potential was Identified almost 10 years ago in the Elm Coulee field of Montana**
  - **Modeling, Experiments and Pilots**

Previous Work

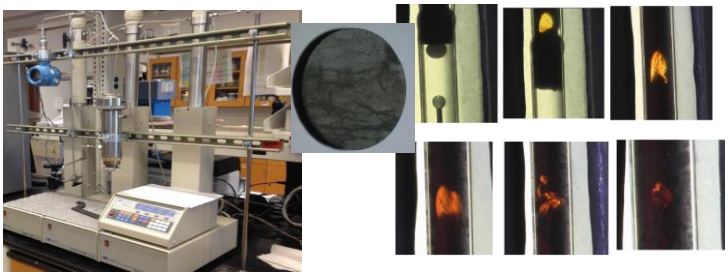
Unconventional EOR

Modeling



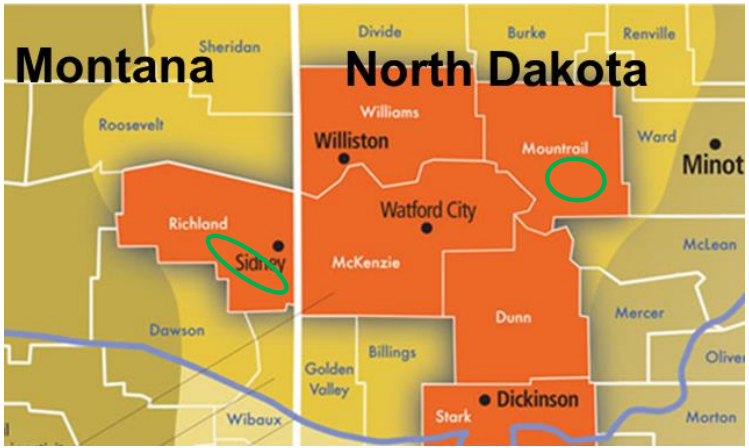
- Encouraging results
- Difficult to capture unconventional reservoirs behavior
- Over optimistic?

Experiments



- Encouraging results
- Difficult to work with ultra-low permeability
- Over optimistic?

EOR Pilot Tests - Bakken



- **Performed from 2008-2014**
- **4 Huff-n-Puff**
- **3 Continuous**

Locations

- **Richland Co., MT**
- **Mountrail Co., ND**

- 7 pilots in MT/ND Bakken (2 in MT and 5 in ND)

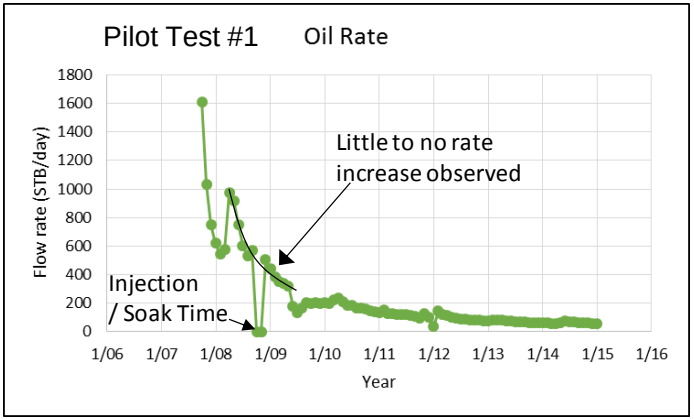
4 Gas → 3 CO_2, 1 Natural Gas

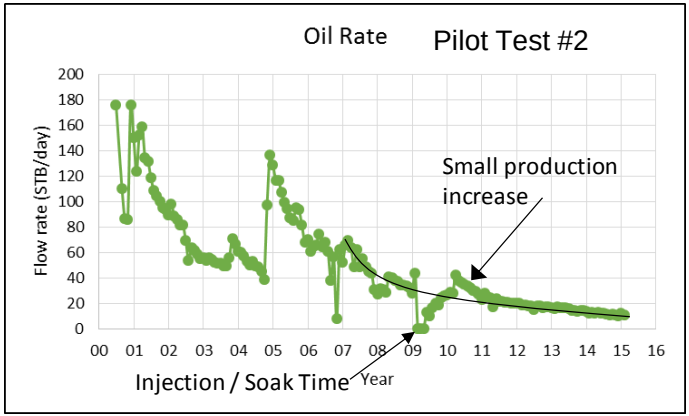
3 Water

(SPE 180270)

CO_2 Huff-n-Puff EOR

- **2 Pilot tests (one in MT and one in ND)**
- **Injection rates / pressures**
  - ~1500 Mscf/day @ 2000-3000 psi
  - 30-45 days injection, 30-45 days soak, put on production





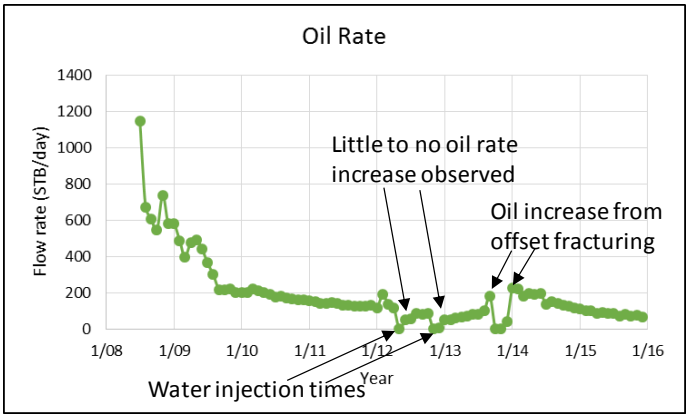
CO_2 Huff-n-Puff EOR

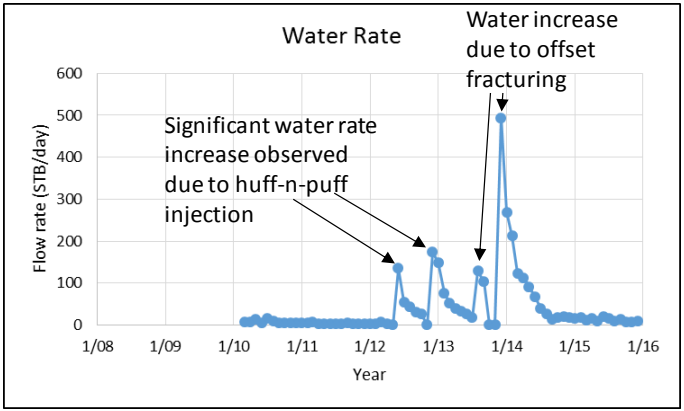
- **2 Pilot tests (one in MT and one in ND)**
- **Injection rates / pressures**
  - ~1500 Mscf/day @ 2000-3000 psi
  - 30-45 days injection, 30-45 days soak, put on production
- **Injectivity of gas is not an issue**
- **Little to no additional oil recovered**
  - **Enough Gas Injected?**
- **Injected gas observed at offset wells in <u>days</u>**
  - **Conformance control (early breakthrough time) is an issue**

Pilot Test #3 - ND

Water Huff-n-Puff

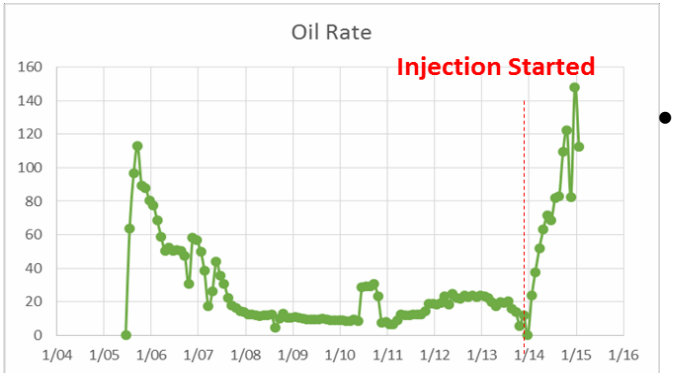
- **Injection rates**
  - ~1200 bbl/day for two ~45-day cycles (~14 day shut in)
- **No additional oil recovered**
- **"Frac-hits" complicate interpretations**

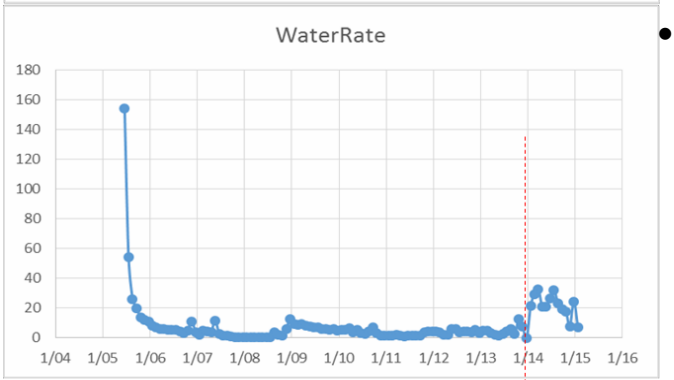




Aside

“Frac-hits” or “Well-bashing”

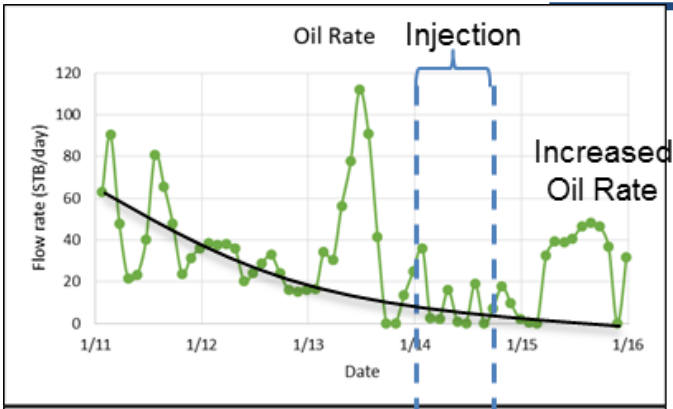


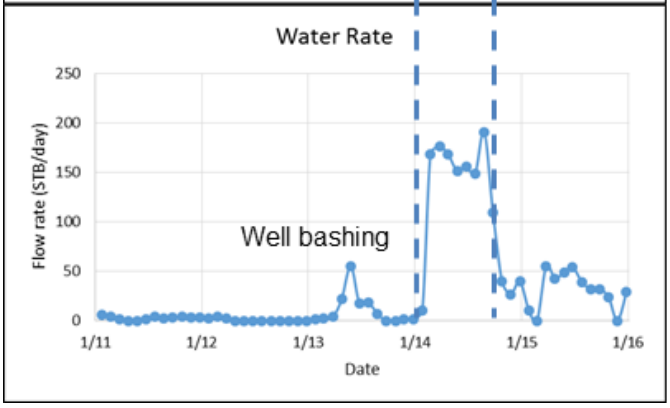


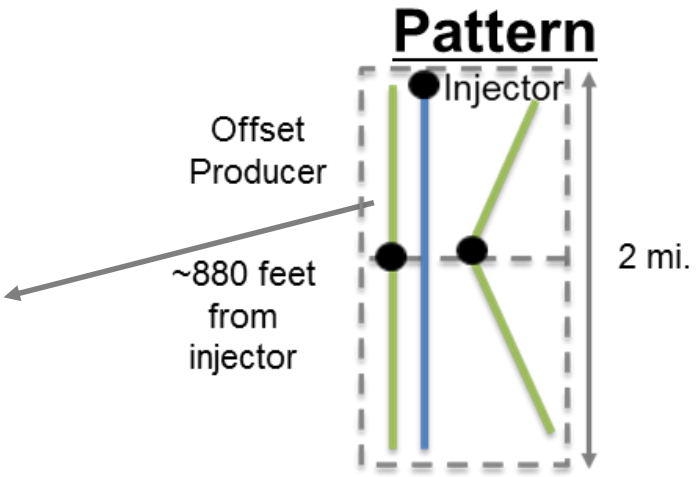
- **Fracturing newly drilled well impact production from older offset wells by fracing into the well (can be positive or negative)**
- **Most pilot offset wells were impacted by fracture interference**

Pilot Test #6 - MT

Continuous Water Injection





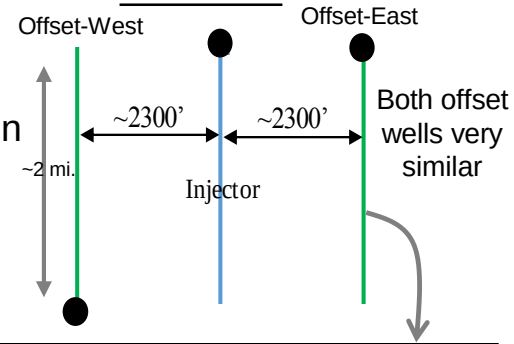


- **Injection rates**
  - ~1700 bbl/day for 3 months, then
  - ~900 bbl/day for 4 months
- **Very fast breakthrough times**

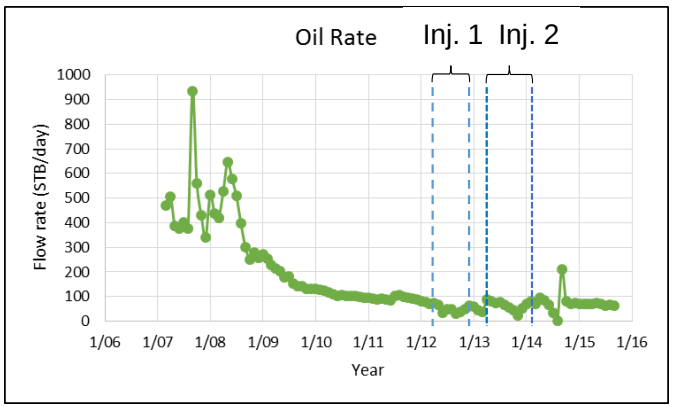
Pilot Test #4 - ND

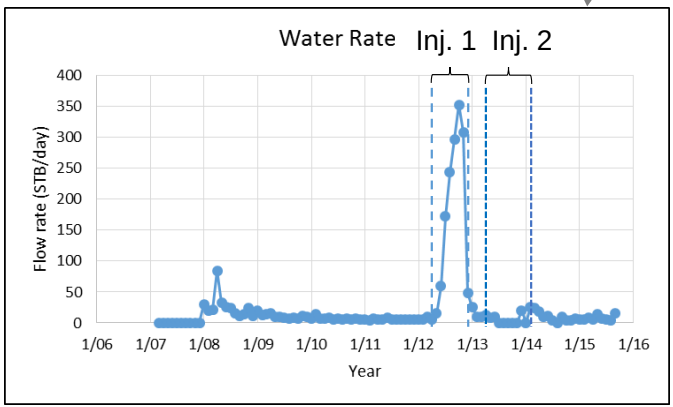
Continuous Water Injection

Pattern



- **Injection rates**
  - ~1350 bbl/day for 8 mo., then 6 mo. shut in
  - ~425 bbl/day for 10 mo.
- **Water Inj. vs Prod. Volumes**

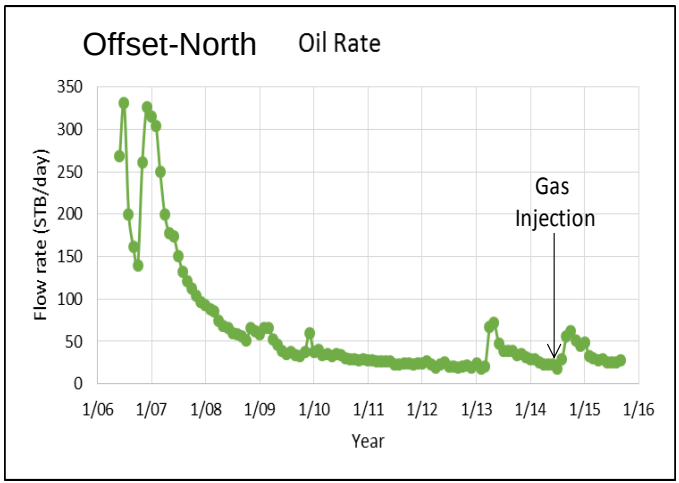


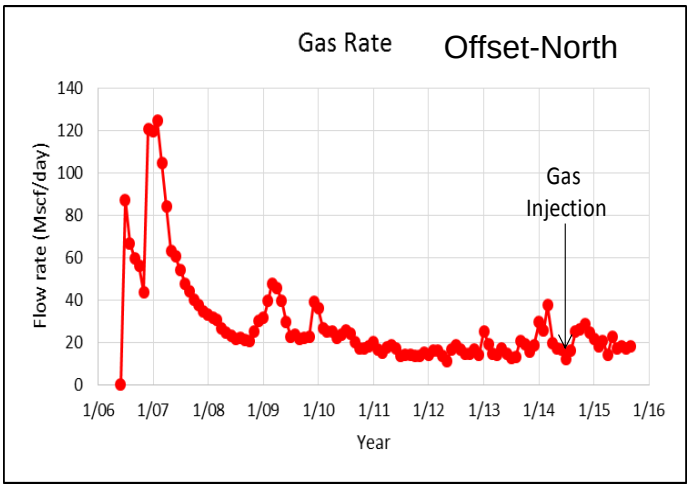


Pilot Test #7 - ND Continuous Natural Gas Injection

- **Injection rates**
  - ~1700 Mscf/day for 2 months
- **Most encouraging of all pilots**
  - All wells have increased oil production (2 wells complicated by frac hits)

Also looked at offset wells North and South of injection well





Summary – Previous Pilots

Collectively we have learned from preliminary pilots:

- **Injectivity is not really an issue (gas or water)**
- **Conformance control may be an issue**
- **Injection volumes may be low**
- **Have not observed much increase in recovery**
  - Final word … or areas to improve?

New Pilots

Phase 2 Field Trials

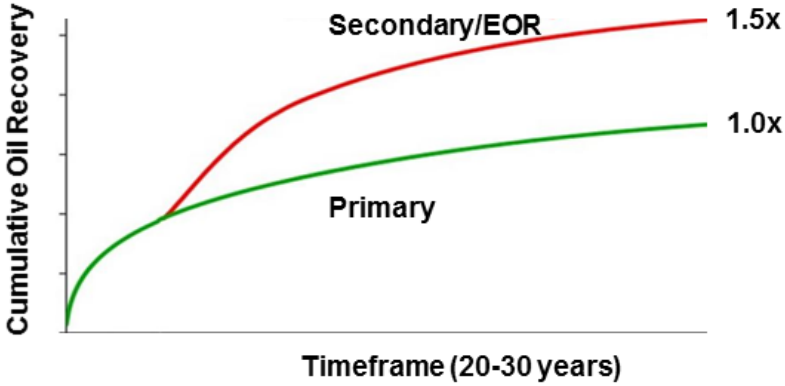
- Longer term studies (multi-year)
- More holistic approach to pilots
  - Measure and collect more data (cores, logs, fluids, etc.)
- Create a full contingency plan workflow
  - Instead of ad hoc changes as problems arise
- Evaluate conformance control options
- Optimize recovery process

Economics

The Time is Ripe

"IOR is less capital intensive than primary drilling …"

J. Triepke OILPRO, 5/9/2016



based on EOG, 2016

- **IOR cap. ~$1 million**
  - **Compressors/pumps**
  - **Flowlines**
- **New well ~$5 million**

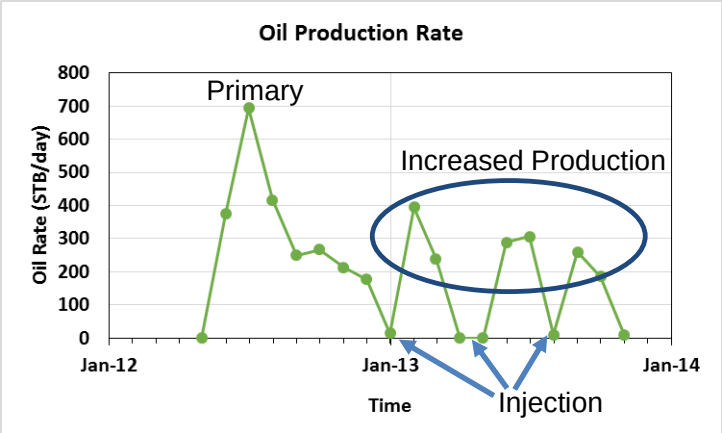
If OpEx (cost of injectant) is low enough to maintain economics?

Preliminary Results

Eagle Ford Huff-n-Puff

Pilot Test A

- **Single well test**
  - Started ~ beginning of 2013
  - 3 cycles in 2013
  - then data is masked by more lease wells coming online (Dec. 2013).



Conclusions

- **Potential is enormous** (100s of billion bbls remain)
  - But much more research is needed
- **Initial Bakken pilot indications are encouraging**
  - But limited in scope and interpretation
- **Second generation of pilots is needed**
  - Deal with bypasstration
  - Additional engineering/technology

Pilot Testing & Research

Acknowledgements / Thank You / Questions

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