SPE 195372-MS
Improving Waterflood Efficiency in the Wilmington Field Using Streamline-Based Surveillance

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OVERVIEW

• Project Motivation
• Project Framing
• Streamline Surveillance & Modeling
• Implementation and Results (2 pilots)
• Challenges
• Key Takeaways
• Next Steps
Project Motivation

**Significant Oil Price Drop:**
- Reduced capital spending
- Facility capacity constraints
- Reduced revenue

**How do we live within new reality?**

“Protect the Base” – Todd Stevens, CEO CRC

**Improve waterflood efficiency**

**Oil Price**

- 48% decrease

**Oil Price (\$/bo)**

- 2000
- 2005
- 2010
- 2015
Mature Waterflood (since 1953)

Injector Pattern Connectivity

Time Consuming to Build Simulation Models

Operating Costs
Streamline Surveillance

**Modeling Concept**

- Streamlines are drawn from source to sink (Darcy velocity field)
- Streamlines solved using total historical voidage rates + grid + spatial property maps (perm/poro)
- Unable to forecast (no transport)

**Streamline Surveillance**

- Capture current patterns
- Extract pattern metrics
- Calculate target rates
- Material balance on control volume defined by SL of I-P pair

**Goal** is to drive waterflood efficiency higher by recovering more oil for each unit volume of fluid injected
Determining Streamline Rates

\[ Q^{I-P} = \sum q_{sl}^{I-P} = 185 \frac{rb}{d} \]

\[ WAF^{I-P} = \frac{Q^{I-P}}{Q^I} \]

\[ WAF^{P-I} = \frac{Q^{P-I}}{Q^P} \]

Streamline Modeling Reference (Thiele et al, 2008)
Streamline Modeling

Date Inputs to Model

- Historical Injection & Production Rates
- Geologic features
  - Transmissibility
  - Permeability
- Open intervals
- Well Path

**Key Metrics**

- Water Rate
- Well Allocation Factor
- Oil Rate

Flux Pattern Map determined from SLs connection I-P pair.
Streamline Based Surveillance

**Workflow**

1. Build a surveillance model
2. Select a pilot area/pattern
3. Determine new target well rates
4. Align with Operations
5. Make well adjustments

**Two Pilots Implemented**

Goal is to rebalance well pairs to improve waterflood efficiency
Ranger 7 Pilot Description

- Pilot was 1 injector pattern
- 9 producing intervals (commingled)
- Injection allocated based on perm-height
- Subsidence mitigation area (Target VRR)

GOAL: reduce WOR
Chose B129IA as Pilot Pattern

B129IA Supporting Producers

Injector Efficiency

- High Efficiency
- Low Efficiency

* Data From 1/2000 to 2/2017
> 16,800 BPD of injection
> 8,400 BPD of gross production
> 51 WOR

**Ranger 7 Baseline**

15% oil decline rate

- 16,800 BPD of injection
- 8,400 BPD of gross production
- 51 WOR

**Graph:**

- **Oil Rate**
- **WOR**
- **Base Oil Decline**
Ranger 7 Implementation

Flux Pattern Maps

New Target Rates

Water Rate

Injection Efficiency

- Old Rate
- New Rate (Unconstraint)
- New Rate (Field Injection Constraint)
Ranger 7 Implementation

**Strategy**

- Scenario: total field injection constant
- Shut in 2 producers (-2,100 gross BPD)
- Decrease rate on B111AS2
- Increase injection on B129IA

Push water to move from low to higher oil cut producers
Ranger 7 Results

- 4% reduction in WOR
- Sustained water reduction (-1,950 BPD)
- Shallower oil decline rate
- Injection being diverted to lower sands (X and G sands)

New WOR-Cumulative Oil Trend
Tar 2 Pilot Description

Tar 2 Area Map

Tar Reservoir Type Log

GOAL: increase oil production by 5 – 10%

Description

- 3 main producing intervals: S, T, D sands
- Injection allocated based on spinner/ RA surveys
- Subsidence mitigation area (Target VRR)
Chose North as Pilot Area

Reasons for North:

- Controlled and bounded area
- Less development drilling
- 10 Producers & 12 Injectors
- Adjustments made by changing choke setting
> 24,700 BPD of injection
> 17,500 BPD of gross production
> 76 WOR

Tar 2 Baseline

20% oil decline rate

- 24,700 BPD of injection
- 17,500 BPD of gross production
- 76 WOR

Graph showing BPD, WOR from Jan-12 to Jun-15 with trends and data points.
Well target rate recommendations were used as guidance for directional change.

**Tar 2 Implementation**

**Strategy**

- Scenario: total injection constant
- Pseudo wells rate targets were added together
- 2 rounds of new target changes

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<th>Well Type</th>
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<th>Jul-15</th>
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Well target rate recommendations were used as guidance for directional change.
Tar 2 Results

- 27% increase in oil production
- 13% increase in injection
- 11% increase in gross production
- 76 → 87 WOR

Significantly Shallower Oil Decline Rate

2% Oil Decline Rate
Challenges

> Static geological models features affect well allocation factors

> Missed operational changes not captured (i.e. pump equipment failures, well shut ins, etc.)

> Injection rates not constant

Challenges Addressed By:

1. Monthly rate updates
2. Make rate adjustment quarterly
3. Pilot for 6 to 12 months
4. Bi-weekly operations meetings
KEY TAKEAWAYS

- Decreased Oil Decline Rate
  - Tar 2: 20% to 2%
  - Ranger 7: 15% to 5%

- Increased Oil Reserves
  - WOR – cumulative oil trend flattened

- Surveillance Tool
  - Visualize & Quantify injector patterns metrics
  - Rank injectors based on oil sweep

- Multi-layered reservoirs
  - Two methods to allocate injection: pseudo-injectors or perm-height
  - Increased injection into lower (less depleted) sands
Next Steps

Assess Scalability

- Rebalance fluid
  - Reduced 30,000 gross BPD & 180 oil BPD
    - Shut in 10 producers
  - Reduced 30,000 injection BPD
    - Adjusted 7 injectors

Validate Streamline Metrics

- Tracer study
Special Thanks

Main Team
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> David Simmons
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Questions?