ConocoPhillips’ East Vacuum Field CO₂ Update

Doug Pecore
Staff Reservoir Engineer
SENM Permian Conventional

Presented at the 24th Annual CO₂ & ROZ Conference
Midland, Texas
Dec 6th 2018
Presentation Topics

• Background
• Performance Update
• Flexibility in Operation – new WAG methodology
• Compression Expansion
• New Development – TZ/ROZ Phase 1
• Compression Optimization
• 2018 Foam Pilot
• Summary
EVGSAU Background

- Vacuum Field developed in 1938
- GB/SA unitized 1978
- Waterflooding began in 1980
- CO2 Injection commenced in 1985
- Overall RF = 48%
**EVGSAU Reservoir Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Producing Depth, feet</td>
<td>4,500 ft</td>
</tr>
<tr>
<td>Original Reservoir Pressure, psia</td>
<td>1,613 psi</td>
</tr>
<tr>
<td>Reservoir Temperature, ° F</td>
<td>105 °F</td>
</tr>
<tr>
<td>Average Porosity, %</td>
<td>11.7%</td>
</tr>
<tr>
<td>Average Permeability, md.</td>
<td>11 md</td>
</tr>
<tr>
<td>Average Net Pay. Feet</td>
<td>71 ft</td>
</tr>
<tr>
<td>Oil Gravity, ° API</td>
<td>38 °API</td>
</tr>
<tr>
<td>Original Formation Volume Factor, RB/STB</td>
<td>1.29 RB/STB</td>
</tr>
<tr>
<td>Original Oil Viscosity, cp.</td>
<td>1.00 cp</td>
</tr>
<tr>
<td>Initial Solution GOR, SCF/STB</td>
<td>465 SCF/STB</td>
</tr>
</tbody>
</table>
**Performance Update**

**Current Production Metrics**

- **Oil Production Rate**: 3,150 BOPD
- **Gas Production Rate**: 27,000 Mscfd
- **Water Production Rate**: 39,200 BWPD
- **Gas Injection Rate**: 43,000 Mscfd
- **Water Injection Rate**: 54,600 BWPD
- **Total RF**: 48 %
- **WF RF**: 16 %
- **CO2 RF**: 14 %
- **Current VRR**: 1.12 RB/RB
- **Gross CO2 Utilization Rate**: 12.9 MCF/BBL
- **HCPVI CO2**: 0.47
- **HCPVI Water**: 1.67
- **HCPVI Total**: 2.14
Performance Update

Projects
- Compression expansion has added WAG flexibility
- Increased water production handled by other COP operated WFs nearby
- TZ/ROZ Pilot (2011) - large amounts of producible gas found
- TZ/ROZ Phase 1 (2016) – similar high CO2 cut wells found
Added Flexibility in Operation

Previous Strategy: Line Drive

- Line Drive strategy implemented in 2007 out of operational necessity; no noticeable production benefit
- With compression expansion, EVGSAU returned to pattern by pattern injection based on the process of . . .
  - first ranking each pattern using eight pattern health metrics weighted for importance or impact
  - then CO2 utilization further adjusts scales the Individual pattern slug size and WAG ratio

Active WAG Management
Pattern Surveillance using Spotfire

[Graphs and charts showing production history, injection efficiency, gross CO2 utilization, injection history, WOR and GOR vs. time, and voidage replacement ratio.]
Pattern Surveillance using Spotfire

Efficiency Plot

Injection Efficiency

Production Efficiency

What is Happening?
- Flux to other Patterns
- Gas cycling occurring
- Conformance Solution

How to Improve?
- Wet Up the Pattern

What is Happening?
- Pattern may be immature or on the edge of WAG area
- Gas cycling occurring

How to Improve?
- More time on WAG
- Stimulation Opportunity
- Conformance Solution

Good Pattern
- Fluid Influx from surrounding patterns
- High GOR
- Dry up the pattern and look for conformance opportunities

Low GOR
- Dry up the pattern
- Stimulation/Pay Add Opportunities
Compression Expansion

- Total Installed Capacity: 44 MMscfd
- Liquid Recovery Technology: Ryan-Holmes
- Compression Expansion: completed for 15% under AFE due to timing and contracting strategy
- Train 1 remains fully loaded to maximize NGL recovery

Train 1
- Unit 1: 6 MMscfd
- Unit 2: 6 MMscfd
- Unit 3: 6 MMscfd
- Unit 4: 6 MMscfd

Train 2
- Unit 5: 10 MMscfd
- Unit 6: 10 MMscfd

By-Pass
- 3 MMscfd

EVLRP Ryan Holmes Liquids Recovery Plant
- 21 MMscfd

Field Inlet

Field Re-injection
TZ/ROZ Phase 1: Development

- TZ/ROZ Pilot started in 2011. 4 injectors and 2 producers
- 1 producer has cum. production = 300 MBO
- Other producer can make 5,000 MCFD gas likely from fracture
- Performed 2 conformance projects to remedy unbalanced injection vertically and high GOR
- Phase 1 sanctioned in 2015
TZ/ROZ Phase 1: Drilling Redesign

Pros:
• Eliminate trouble time associated with controlling the well and POOH to run casing.
• Casing on bottom when well TD.
• Smear Effect – Less chances of severe losses or diff sticking

Cons:
• Require TXP BTC connections & Centralization – Increase Csg Cost.
• Susceptible to buckling, casing wear and fatigue – Twist-Off.
• Slower ROP with non-motor assist and packed/stabilized assemblies.
• Cannot run OH logs

Drilled 6 wells in late 2015. Half the wells in the program encountered severe losses and flows at the same time. Halted the drilling in early 2016.

CONDUCTOR:
16”; 65.0#; H-40; @ 100’
9-5/8”; 40.0#; J-55; BTC
CSG @ 1630’; Inside “RUSTLER Form”

800’ of Severe Loss / Charged Zones

TD WELL @ 5100’
TZ/ROZ Phase 1: Drill with Casing (DwC)

- No trouble time associated with casing drilling encountered during DwC program
- Clear learning curve – continued to innovate during program
- No flows or losses encountered
- QC of tubulars imperative to prevent over-torque downside
- 31% improvement in Days from Spud over 2011 program
- 10% improvement in drilling costs over 2011 program

Tangible solution to support future development activity at EVGSAU and other EOR fields
TZ/ROZ Phase 1: Performance

- Producers on track with AFE
- Hindered by lack of OH logs
- Locating “sweet spots” through pay adds
- 3 other producers have encountered high gas rates due to fractures in lower San Andres
- Plan to run IPL logs to measure vertical conformance

Best performance in Phase 1 TZ/ROZ wells are on the flank as reservoir drops into Delaware Basin
Compression Optimization

- Revisit execution performance
- Examined 131 well files
- Found a pattern of drilling related issues
- Seismic confirms apparent facies change form N-S
- Coincides with high GOR producers

Above the line: 31% had flows or losses
Below the line: 5% had flows or losses

Symbols at BH location:
- 5 NEW W/6 S
- 6 PRODUCERS
- 17 LOSSES
- 8 FLOWS
- 54 NO ISSUES

Phase 1 Expansion Area

ConocoPhillips
1. Lower production and operating expenses by 20% by 2020 through utilization of banked CO2
2. Construct high CO2 content satellite (#7) facility south of EVLRP and pipe to Train 2
3. Re-pipe EVLRP inlet to concentrate rich gas to Train 1
4. Install isolation valve in common inlet to direct gas to desired train
Foam Pilot

CO2-Foam Process

From SPE 190312, "CO2-Foam Field Pilot Test in Sandstone Reservoir: Complete Analysis of Foam-Pilot Response" Dow Chemical, et al

Vertical Profile Modification

<table>
<thead>
<tr>
<th>Zonal % Gas Distribution</th>
<th>Baseline</th>
<th>Post Foam - 4 mo</th>
<th>Post Foam - 8 mo</th>
<th>Post Foam - 9 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper San Andres</td>
<td>23%</td>
<td>38%</td>
<td>40%</td>
<td>46%</td>
</tr>
<tr>
<td>Lovington SS</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Lower San Andres</td>
<td>77%</td>
<td>62%</td>
<td>60%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Improved Run Time

Monthly Avg. Pump Run Time % Example

Foam Pilot Pattern

ConocoPhillips
• Strong production response from dynamic WAG and use of Spotfire-based data analytics tool in pattern optimization and problem diagnosis
• Drill-with-Casing (DwC) technology allows for low-cost infill and TZ/ROZ development in future
• Upside from flank ROZ projects in possible Phase 2
• Upside from compression utilization via production and operating cost reduction
• Encouraging results from foam trial