Implementing Surveillance Tools and Processes to Improve Performance and Identify Possible Opportunities in Mature CO₂ Floods

Juan J. Nevarez
Exploitation Engineer
Agenda

- Field History
- Geologic Setting
- Reservoir Data
- Production History
- Reservoir Surveillance Process & Activity
  - Reservoir level review
  - Pattern level review
  - Well level review
- Production Surveillance Process
  - WAG management reports
  - Well testing reports
- Impact of Reservoir & Production Surveillance
  - Cambrian downspacing
  - Field performance
**Discovery:**
- 1916 by Bair Oil Company
- 269’ well in 1st Frontier Formation
- Lost Soldier No. 1 IP = 200 bopd.
- Earliest production from shallow horizons
  - Frontier, Muddy, Lakota, Morrison and Sundance

**Development**
- 1930’s: Lost Soldier Tensleep discovered
  - Well IP = at 2,435 bopd
- 1936: Wertz Field discovered
- 1947: Madison discovered
- 1975 Acquired by Amoco
- 1999 Acquired by Merit Energy Company

**Unitization**
- Wertz: 1937
- Lost Soldier 1962

**Secondary & Tertiary Floods**
- Waterfloods initiated in the mid/late 1970’s
- CO₂ Floods initiated in the late 1980’s
- **Location:**
  - Great Divide Basin
  - Northwestern edge of the Rawlins Uplift

- **Structure:**
  - Faulted anticlines
  - Eight Producing Horizons (youngest to oldest)
    - Frontier
    - Muddy
    - Lakota
    - Sundance
    - Tensleep (CO₂)
    - Darwin (CO₂)
    - Madison (CO₂)
    - Flathead (CO₂)

- **Fields:**
  - Lost Soldier:
    - 250 wellbores
    - 500 mmbbl OOIP
  - Wertz:
    - 164 wellbores
    - 250 mmbbl OOIP
<table>
<thead>
<tr>
<th>Formation</th>
<th>Lithology</th>
<th>Average Depth</th>
<th>Formation Thickness</th>
<th>Average Porosity</th>
<th>Air Perm md</th>
<th>Current Spacing</th>
<th>Res Press psi</th>
<th>Oil Grav API</th>
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<td>SS</td>
<td>5,000</td>
<td>535</td>
<td>9.9%</td>
<td>31.0</td>
<td>10 - 20</td>
<td>2,800</td>
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<td>20 -30</td>
<td>3,300</td>
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- **General Statistics**
  - 158 active producers
  - 174 active injectors

- **Facilities**
  - 9 production satellites
  - 14 injection satellites
  - Lost Soldier Main Battery (In 1995 Amoco Production Company combined production facilities)
  - Injection plant No.1 (6 positive displacement pumps each with a 40,000 bwpd capacity)
  - Bairoil CO₂ Recycle Plant – 5 Compressors- 150 MMCFPD Capacity- (200- 2200 psi)
Bairoil Faces Significant Challenges in Mid 2008

- **Reservoir Issues**
  - Production is on decline
  - WAG cycle management
  - Reservoir surveillance

- **Production Issues**
  - High GOR ratios limiting production in some wells
  - Well testing frequency

- **CO₂ Facilities Issues**
  - Limited capacity in CO₂ recycling plant
  - Preventive maintenance completed but downtime still exists
Reservoir Level Workflow

- Develop geologic model for all WAG CO₂ flooded reservoirs
- Develop updated OOIP for all reservoirs including new well data
- Utilize StreamSim’s 3D streamline simulator model for two key reservoirs
- Performance Plots in all reservoirs to identify flood maturity and efficiency
  - Production/Injection
  - % Recovery vs HCPVSI - CO₂ efficiency and maturity
  - CO₂ retention and utility factors
  - Review Pressure data over time where available
Cumulative Incremental Oil vs Cumulative CO2 Injection

Cumulative Incremental Oil, % OOIP

Cumulative CO2 Injection, % HCPV

Legend:
- LSCA
- LSDM
- LSTP
- WZTP
- WZDM
Pattern Level Workflow

- Used StreamSim’s 3D streamline simulator to develop well allocation factors and injection efficiencies

- Used Geologic Model to develop updated OOIP at the pattern level

- Linked Landmark DSS Software to Bairoil SCADA system via Procount and Merit Databases
  - Daily Production/Injection Data is automatically loaded

- Develop performance plots at pattern level to identify flood maturity and efficiency
  - % Recovery vs HCPVSI
  - CO₂ retention and utility factors
  - Injection/Withdrawal Bubble Maps
Production/Injection Bubble Map Movie
Putting Reservoir/Production Surveillance into Practice

- Collected and reviewed all historical injection profiles, last profiles had been done in 2000

- Develop a plan to conduct injection survey on all active injectors
  - All active injectors were completed within 7 months

- Utilized OOIP, Pattern performance and injection surveys data to develop new WAG setpoints and cycles volumes based on pattern maturity and efficiency

- Developed an inventory of recommendations to improve underperforming patterns
  - Conformance Work- Squeeze jobs, Selective Injection
  - Coil Tubing Work
### Conformance Candidates

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<tr>
<th>Injectors</th>
<th>Subzone</th>
<th>% of Total Perfs</th>
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<th>CO2</th>
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</table>
Injection /Production Surveillance Tools

- Merit has a robust SCADA system that provides production well testing, injection volumes and pressure data
- System provided daily reports that were utilized by field personnel to manage daily operations
- Identified a need to develop Exception Based Reports that identified patterns and wells that needed attention
  - Well Testing Report- Identified production drops & testing issues
  - Injection Report- Identified WAG switching candidates and metering issues
  - Directly link to Reservoir Surveillance Tools
Impact of Reservoir & Production Surveillance

- Helped identified downspacing opportunities in Cambrian flood
- Development of WAG Management Tool at the pattern level
- Identified and executed several conformance modification projects
- Develop surveillance tools that can be utilized in other Merit’s CO₂ WAG floods
- Arrested production decline in all reservoirs
Thank You