Reducing Risk in the Implementation of the CO2 Pilot Test in the Hall-Gurney Field, Russell County, Kansas

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Oil Recovery Conference
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Overview

• Pilot Pattern-2003
• Projected Performance
• Risk
• Uncertainty
• Development Plan to Reduce Risk and Uncertainty
• Progress to Date
Pilot Project-2003

• Goal--conduct a pilot that minimized loss but provide sufficient information to expand to commercial scale if warranted.
• Oil in the tank
• Operating experience
Pattern #6

- ~15 acre half of five spot
- One CO2 injector
- Three Producers
- Two Containment Injectors
- 0.271 BCF CO2 injected
- 4.6 year operating life
- 27,784 BO estimated recovery
Flooding Plan

• Pressure reservoir by injection of water with wells shut-in
• Must be able to reach pressure of ~1200-1300 psi (MMP) in significant portion of pattern volume
• Inject carbon dioxide in CO2 I-1 and begin pumping production wells-fluid levels controlled to obtain 500-600 psi BHP in production wells.
• Alternate water and carbon dioxide injection (WAG) to control rate that carbon dioxide moves through formation
• **Colliver No. 18 CO₂ Injector**

L-KC “C” divided into 6 Layers—three flooding cycles

• **General Properties***
  - C1: 8 md, 18.8%
  - C2: 150 md, 25.8%
  - C3: 40 md, 22.0%
  - C4: 6 md, 19.4%
  - C5: 2 md, 14.7%
  - C6: 0.3 md, 12.0%

*-* Colliver No. 18 injector exhibits better properties than average for site
Carbon Dioxide/ Water Injection
271,360 MMSCF

CO2 Injected, MMSCF

Time, years

CO2/Water Injection
Water Injection

Repressure Pilot

CO2 Injected, MMSCF

0 1 2 3 4 5 6

0 200000 400000 600000 800000 1000000 1200000
Anticipated 15 Acre Pilot Response
~20%PPV
Cumulative Oil 27,784 STB

Repressure Pilot
CO2 Injection

Time, years
Oil, STB

0 1 2 3 4 5 6

0 2000 4000 6000 8000 10000 12000 14000

Anticipated 15 Acre Pilot Response
~20%PPV
Cumulative Oil 27,784 STB

Repressure Pilot
CO2 Injection

Time, years
Oil, STB

0 1 2 3 4 5 6

0 2000 4000 6000 8000 10000 12000 14000
## Summary of Costs - 2002 Design (15 Acre)

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities</td>
<td>$918,215</td>
</tr>
<tr>
<td>Flood Operations</td>
<td>$928,658</td>
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<tr>
<td>CO2 Supply</td>
<td>$870,000</td>
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<tr>
<td>Research, Data, Tech Transfer, Administration</td>
<td>$1,698,168</td>
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<tr>
<td>Total</td>
<td>$4,415,041</td>
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</table>
Summary of Revenue Sources -
2002 Design (15 Acre)

<table>
<thead>
<tr>
<th></th>
<th>In-Kind</th>
<th>Cash</th>
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<tbody>
<tr>
<td>DOE</td>
<td>$1,702,242</td>
<td>$2,848,082</td>
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<tr>
<td>Murfin and WI</td>
<td></td>
<td>$1,566,958</td>
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<tr>
<td>Kinder-Morgan</td>
<td>$188,500</td>
<td>$54,716</td>
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<tr>
<td>U.S. Energy Partners</td>
<td>$377,000</td>
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<tr>
<td>KUCR(TORP, KGS)</td>
<td>$1,001,458</td>
<td></td>
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<tr>
<td>State of Kansas-DOC</td>
<td>$188,000</td>
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</tr>
<tr>
<td>Totals</td>
<td>$1,566,958</td>
<td>$2,848,082</td>
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<tr>
<td>Contribution</td>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>----------</td>
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</tr>
<tr>
<td>Kinder-Morgan CO2 in-kind</td>
<td>$176,384</td>
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</tr>
<tr>
<td>US Energy Partners CO2 trucked to site ($1.05/MCF from DOE funds)</td>
<td>$284,928</td>
<td></td>
</tr>
<tr>
<td>USDOE 45% Startup Costs</td>
<td>$284,928</td>
<td></td>
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<tr>
<td>USDOE 35% of LOE</td>
<td>$125,867</td>
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<tr>
<td>State of Kansas KDOC</td>
<td>$88,000</td>
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<tr>
<td>Murfin and WI Partners 55% of Startup Costs</td>
<td>331,277</td>
<td></td>
</tr>
<tr>
<td>65% of LOE except CO2 Costs</td>
<td>$233,753</td>
<td></td>
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<tr>
<td>Total</td>
<td>$1,525,162</td>
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</table>
Carbon Dioxide Pilot Flood

- Must be able to reach pressure of ~1200-1300 psi (MMP) in significant portion of pattern volume
Carbon Dioxide Pilot Flood

Pressure Management

BHP in CO2 I-1 @ 2000 psi

Injection into C10 and C18

BHP in production wells @500-600 psi
Inject carbon dioxide and water in CO2 I-1 at rates to permit completion of the flood in the project time frame.
Simulations demonstrate that confinement is possible using C18 and C10 as confinement wells.
Reservoir Risks

- Fluid injection rates in CO2I-1 adequate to complete pilot test in specified time limits?
- Good interwell continuity in \( \text{C} \) zone in pilot region?
- Development of adequate pressure bubble in pilot area?
- Isolation of \( \text{C} \) zone?
- Oil saturations less than estimated?
Financial Risks

- Capital investment in well recompletion and surface equipment would be lost if project did not move into implementation phase (there is some salvage value).
- Reduced income if projected oil recovery does not meet expectations.
- Income delayed and operating expenses increase if fluid injection and production rates are less than anticipated.
## Working Interest Partnership - Startup Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Step WI Cost</th>
<th>Cum WI Cost</th>
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</thead>
<tbody>
<tr>
<td>WI Cost to Date</td>
<td>49,686</td>
<td>49,686</td>
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<tr>
<td>Leasehold</td>
<td>71,000</td>
<td>120,686</td>
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<tr>
<td>KS Dept of Com</td>
<td>(88,000)</td>
<td>32,686</td>
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<tr>
<td>Water Supply</td>
<td>28,875</td>
<td>61,561</td>
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<tr>
<td>Colliver #12</td>
<td>29,071</td>
<td>90,632</td>
</tr>
<tr>
<td>Colliver #16</td>
<td>49,289</td>
<td>139,921</td>
</tr>
<tr>
<td>Surface Facilities</td>
<td>148,260</td>
<td>288,181</td>
</tr>
<tr>
<td>Colliver #10</td>
<td>43,096</td>
<td>331,277</td>
</tr>
</tbody>
</table>
Reducing Risk Through Project Management

- Identification of GO/NO GO points in the project
  - Recompletion of wells-multiple zones open
  - Injection rate into CO2I-1
  - Water supply
  - Interwell continuity
  - Pressurization of pilot area
  - Installation of carbon dioxide injection facilities
How should field work be managed to minimize risk due to uncertainties in the reservoir characterization and wellbore costs?
Ranking Uncertainties by Risk (Highest to Lowest)

1. Pulling liner from Colliver 16 (completed in shallow zones)
2. *Injectivity of CO2I-1*
3. Recompletion of Colliver 12-\textbf{C} zone only
4. Recompletion of Colliver 10-\textbf{C} zone only
5. *Interwell continuity between CO2I-1 and pattern wells*
6. *Re-pressurization of pilot area*
7. Recompletion of Colliver 16 into LKC \textbf{C} zone
8. Recompletion of Colliver 13 into LKC \textbf{C} zone
Field Work-Progress

Colliver 16

• Completed in shallow zone with liner
• Liner pulled-12/02
• Deepening to C zone and recompletion appears possible with no additional risk
Field Work-Progress

CO2I-1

• Short term injectivity test completed 2/7/03
• Projected stable injection rate ~140 B/D at 2000 psi BHP
Colliver 12
Open in C, G and several shallow zones
• G plugged 2/18/03
• Shallow zones isolated with liner
• C zone recompletion 3/7/03
Field Work-Progress

Colliver 10
Open in several shallow zones
• C, G plugged 10/01
• Recomplete C with tubing on packer to isolate C from shallow zones—in progress
Colliver 18

Water disposal well for lease
• Open in B and C
• Fill above C
• Shut-in 3/03 to observe effect on surrounding wells.
Water Injection System

• Water source identified and tested
  – Water supply to be drilled on the lease
• Injection system designed
  – 200 BBL storage tank
  – Triplex pump
  – Pressure control valve
  – Filter through 5 micron filter system
Field Work-Planned

CO2I-1 Long Term Injectivity Test

- Verify continuity between CO2I-1, C12, C10 and C18
- Assess capability to increase pressure in pilot region to MMP
Field Work-Planned

Colliver 16
• Deepen to C zone and obtain core
• Install liner and recomplete in C zone
• Evaluate interwell continuity with CO2I-1
Field Work-Planned

Colliver 13

Open in several shallow zones

• Bridge plug above C
• C, G comingled
• Plug G
• Install liner to isolate shallow zones
• Recomplete C with tubing on packer to isolate C from shallow zones
Field Work-Planned

Re-pressure Reservoir

CO2I-1

• Inject at BHP=2000 psi
• C18-inject at BHP=2000 psi
• Inject at BHP=2000 in C10 as needed
• Shut-in C12, C16, C13 and monitor pressure
Projected Timeline

- Water supply system developed and tested—March 24
- Long Term Injectivity Tests-CO2I-1 begin by March 24
- Initial evaluation interwell continuity -March 31
- Reservoir simulation/history match-April-May
- Decision to re-pressure reservoir -June 1 (Add Colliver 10,18)
- Decision to implement carbon dioxide injection -July 1
- Reservoir re-pressurization completed by August 24
- CO2 Injection begins August 24
Project Funding-DOE Class Revisited Program

• Budget Period 1: Reservoir Characterization and Advanced Recovery Analysis
  March 2000-March 2003
    (DOE Cost Share 45%)
• Budget Period 2: Field Demonstration and Analysis:
  April 2003- March 2008
    (DOE Cost Share 35%)
• Budget Period 3: Monitoring and Post Flood Analysis:
  March 2008-March 2009
    (DOE Cost Share 10%)