Bell Creek CO\textsubscript{2} Development Update

Presenter: Russ Welch
Sr. Reservoir Engineer
Bell Creek Field - U.S. Location

Bell Creek Field

Location:
- Southeast corner of Montana
- Northern Powder River Basin
- 84 miles NE of Gillette, Wyoming
Bell Creek Field  Powder River Co., MT

- Current Production = 975 BOPD & 45,100 bwpd (GWI=100%, NRI=85.3%)
- Discovered in 1967 and Covers 21,771 Acres (15 x 3.5 miles)
- Peak Production of 56,000 BOPD (August 1968)
- The Muddy Sandstone (only producing reservoir)
  - Depth = 4,300-4,500 ft
  - Gross thickness = 30-45 ft (Net 15-25 ft) (3-4 lenticular zones)
  - Normal Permeability ranges: 100-1,175 md (Max of 3 Darcies)
  - High porosity = 25-35% (Some Loose Consolidation)
  - STOOIP = 353.5 MMBO (32-41° API oil)
- Field was developed within 2 yrs with 450 wells. (Unitized for WF ’70-’72, ‘90)
- Current production/injection: 975 bopd & 54,000 bwipd (31 prod/50 WIW’s)
- Cumulative production totals 133.4 MMbo (37.7% recovery)
- CO₂ Flood Potential = 30-50 MM barrels oil (9-14% incremental)
Bell Creek

Muddy Structure Map

1° Dip NW

Down dip Limited Aquifer

Incised Valley Filled Shale Features

SE Updip Stratigraphic Trap
Stratigraphically trapped stacked barrier bars
Bell Creek  Production/Injection History

- **Start of Water Injection**: 8/1/’70
- **6 WF Units formed ‘70-’72**
- **Start of Water Injection**: 8/1/’70
- **Muddy Consolidated Unit formed 1/1/92**
- **SBC Unit Formed 7/1/90**
- **Encore Field Re-activation began 1/1/2000**
- **Area Wide injection permit 2/1/2005**

**Operators:**
- Sam Gary Operating Co.
- Exxon
- Richardson
- Encore
- Denbury

**Legend:**
- Green line: Oil Rate (Cal Day) (bbl/d)
- Blue line: Water Rate (Cal Day) (bbl/d)
- Black line: Water Injection Rate (Cal Day) (bbl/d)
- Red line: CO2 Injection CalDay (Mcf)
At least 7 Phases of Development (maybe as many as 10)
Bell Creek Milestones/Accomplishments

• Ordered 100 MMcfpd of Recycle Compressors. (June 2011). 48 wks to delivery.

• First two sets of soil gas & water samples have been taken by Energy & Environmental Research Center (EERC) for the Monitoring, Verification & Accounting (MVA) activity to determine background data prior to CO$_2$ injection. (Nov. ‘11 & April ‘12).

• First 2 segments of the Greencore Pipeline were completed. (Dec. 2011).

• Partnered with the EERC to drill, core and complete the 5-06 Observation Well in Phase 1. (Dec. 2011)

• Facilities site groundwork completed and electrical substation work began. (Feb. 2012).

• Environmental Assessment (EA) for Phase 1 was approved by the BLM. (April 2012). Infrastructure development and well work now underway.

• All major roadwork was completed prior to bird moratorium. (April 15-July 15, 2012).
Bell Creek  Phase 1 Federal Lease Map

Environmental Assessment Documents Required

Federal Leases

Federal Surface

5-06 OW Observation Well
Bell Creek Field

BCUD 5-06 OW Core

- Well was 100% funded by EERC.
- 110’ of full diameter core recovered with 6 core runs. (4446’-4578’).
- Also took sidewall cores in upper Muddy Sandstone zone where lost whole core occurred.

Courtesy of EERC
● Lower Muddy Sandstone whole core. 10’/box.

● 1 = zone with higher oil fluorescence.

● 2 = Thin impermeable layers and/or shale breaks.

● 3 = zones with lower oil fluorescence. Probably indicates a partially water swept interval.

Courtesy of EERC
Bell Creek Field

BCUD 5-06 OW Core

- Lower Muddy Sandstone
- Oil fluorescence in core under Ultra-Violet light.
- Note yellow fluorescence where oil is present and unswept vs swept intervals with low fluorescence.

Courtesy of EERC
Sidewall Formation Test (SFT) data were taken to determine pressures in various layers in 5-06 OW. Note pressure variations.
Bell Creek Field

Sidewall Core

- Took 47 sidewall cores in 5-06 Observation Well.
  - 4 sidewall cores taken in Niobrara (2937’, 2943’, 4111’ & 4113’).
  - 1 sidewall core taken in Mowry shale (4400’).
  - 42 sidewall cores taken in the Muddy formation. (4508.75’ to 4538.5’).
- EERC will perform routine & some special core analyses on these plugs.
  - Dielectric & stress-strain tests underway.
Bell Creek Field  Sidewall Core Analysis

Applied Geology Laboratory Data Sheet

<table>
<thead>
<tr>
<th>Effective Porosity</th>
<th>Bulk Volume (ccm)</th>
<th>Skeletal Density (g/ccm)</th>
<th>Residual Oil Saturation</th>
<th>Residual Water Saturation</th>
<th>Oil Density (g/ccm)</th>
<th>API Gravity</th>
<th>Permeability (md) (Water or Air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.38%</td>
<td>35.09</td>
<td>2.400</td>
<td>17.90%</td>
<td>30.64%</td>
<td>0.848</td>
<td>38</td>
<td>Pending</td>
</tr>
</tbody>
</table>

Formation: Muddy
Depth: 4525.5 ft
Length: 1.91 ft
Usable Length: 1.58 ft
Mass: 113.282 g
Lithology: Sandstone

Applied Geology Laboratory Data Sheet

4525 ft. Muddy Sandstone
XRD Quantitative Phase Analysis

Clays and pyrite present
Bell Creek Field  BCUD 5-06 OW Logging

- Halliburton ran open hole logs.
- Schlumberger ran cased hole logs.

Open Hole Logging Runs:
- 1. Triple Combo
- 2. XRMI/Wave Sonic
- 3. MRIL
- 4. SFT (formation test)

Cased Hole Log Runs:
- Isolation Scanner
- Gauge Depth Correlation

- Working to improve Water Saturation (Sw) calculations from logs.
- Relatively low salinity environment. < 13,000 ppm NaCl

Courtesy of EERC
3 pressure sensors installed on outside of casing ("smart casing").
- 1 in a shallow Niobrara reservoir at 4,109’.
- 2 in the Muddy SS. (@ 4,514’ & 4,534’)
1 in the Muddy SS failed to deploy perf charges (4,534’) but is reading reduced pressures. *
Purpose is to monitor reservoir pressures as CO₂ flood progresses.

June 8, 2012 data:
- Niobrara @ 4,109’: 1,351 psia
- Muddy SS @ 4,514’: 1,572 psia
- Muddy SS @ 4,534’: 1,420 psia *
Installing Cable for SMART Casing

Original Photo File Name: IMG_5412
Description: Routing fiber optic cable through wellhead

Courtesy of EERC
Monitoring, Verification & Accounting Program

Purpose: Monitor for CO$_2$ Surface leaks
Locations of sample sites
- Water samples
- Soil Gas Samples

Courtesy of EERC
Bell Creek Field  Phase 1 Operations

- Phase 1 production: 178 bopd & 6,100 bwpd from 6 producers.
- Phase 1 water injection: 11,600 bwipd from 10 active injectors.

- Environmental Assessment (EA) approved by BLM 4-3-12.
- Migratory bird, raptors, sharp-tailed grouse, etc moratoriums: 4/15 to 7/15/2012.
  - Affects ROW & road preparation for laying surface lines in southern 2/3 rds of the Ph 1 area.

- Pattern/well work:
  - 21 forty acre well spacing 5-spot patterns to be developed.
  - 28 Injection Wells. Most injection wells are complete in Phase 1.
  - 27 Producers. Down hole well work and wellhead change-outs remain.
  - Install flowlines and header systems. Lay water and CO₂ injection lines.
  - 3 active workover rigs dedicated to the field.

- Reviewing all surrounding non-Unit wells for proper P&A requirements.

- Surface facility, CTB and line expansion in progress for Phase 1.

- Working with supplier to define proper pre-CO₂ injection chemical treatment.
Bell Creek

Remaining Work

• Well Work: 3 Rigs running:
  • 8 re-entry workovers running liners.
  • 12 wellhead changeouts.
  • 3 plug and abandonments.
  • 3 new drill replacement wells.

• Facilities and surface equipment installations:
  • Compressors & buildings.
  • Pump and process buildings and equipment.
  • Two test sites to be installed.
  • Surface Injection/production line installations.
  • Tank farm to be installed.

• Power Upgrades
  • New electrical substation to be installed.
  • Transmission line upgrades.

• Shoot 3-D Seismic
Bell Creek

Well Reactivation Work

8 Liner Jobs
12 WH Changeouts

Future Injector W/O

Future Producer W/O

3 New Redrill

3 P&A

Active Injector

Active Producer

5-06 OW

BELL CREEK UNIT PHASE I

Denbury
Bell Creek  Phase 1 Prod/Inj History

1st CO₂ injection
March 2013
50 MMcfpd CO₂
27 Oil producers

13 Water Injection Wells

15 CO₂ Injection Wells

1 Observation Well

5-06 OW

Continuous CO₂ injection initially, then alternating 3 month 1:1 WAG cycles thereafter.

21, 5-spot patterns

80-acre patterns

40-acre well spacing
Bell Creek 3-D Model-Overview of Facility

- Compressor Building
- Electrical Substation
- Process Building
- Pump Building
- Tank Farm
Bell Creek – 3-D Phase 1 Seismic Acq.

• Source testing completed 2011
• Seismic shoot summer 2012
End of Bell Creek Presentation

Thank You.