Southeast Partnership Early Test Update – Cranfield field, MS

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(Regional Partnerships)

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Cranfield Field, MS

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OVERVIEW

• Background Information
• Phase II Initial Results
• Phase III Design / Status
• Summary
Cranfield in Mississippi Salt Basin

Source: Dutton and others 1993

Upper Cretaceous Tuscaloosa-Woodbine Trend – Cranfield in Mississippi Salt Basin

Source of large volumes of CO₂ via pipeline
Gulf Coast Stacked Storage Field Test

Phase 2: $4.4 million
Dedicated observation well + logging campaign
Gulf Coast Stacked Storage Field Test

Phase 3: $36 million
2 observation wells, multiple injectors, 1 Mt/yr
Various monitoring tools
OVERVIEW

• Background Information

• *Phase II Initial Results*

• Phase III Design / Status

• Summary
Phase II Initial Results
(as of 27 April, 2009)

• >600,000 Metric Tons Injected
  – EGL #7 – Observation Well
  – Slow CO$_2$ Breakthrough
  – Good Analog for Non-EOR

• Pressure – Robust Monitoring Tool

• Modeling Results
SECARB Phase II Field Test in Oil Leg

- Denbury early injectors
- Gas cap
- Oil ring
- Phase II study area
- Dedicated observation Well; + well logging in producers
- CO₂ pipeline from Jackson Dome
- 1+ MMT/year
Phase II Initial Results

- >600,000+ Metric Tons (as of 27 April, 2009)

- **Pressure – Robust Monitoring Tool**
  - *Cranfield Pressure History: Advantageous*
  - *Continuous Monitoring Strategy*
  - *Results*

- Modeling Results
Pressure history

Most EOR
- Perturbed by extraction + injection
- Poor Pressure analog for brine reservoir

Cranfield
- Discovered 1945
- Depleted, P&A 1965
- 40+ years Pressure recovery by water drive
- Similar to brine reservoir until production dominates
Cranfield Phase II: MVA instrumentation

Satellite link for continuous data monitoring.

Observation well.
Injection at Cranfield

INJECTION DATA

½ million tons
Early February
Continuous Reservoir Pressure Monitoring

Bottom Hole Pressures in EGL #7 (psia)

- Overlying Monitoring Zone
- Injection Zone

Ten Months
Pressure as tool for reservoir surveillance

Daily fluxes of CO\textsubscript{2} injection rate can be correlated with observed pressure in injection interval at observation well. These sensitivities are being incorporated in monitoring design to support goal of achieving high material balance.
Comparison of Processed Surface Pressure Sensitivity With Downhole Gauge

Tubing data corrected for Temperature and tubing fluids carries useful downhole information.

Implications for monitoring design being evaluated.
Phase II Initial Results

- >600,000+ Metric Tons
  (as of 27 April, 2009)

- Pressure – Robust Monitoring Tool

- Modeling Results
Petrel model
GEM / Eclipse simulation in Q1-2 09
Phase II GEM Model

Pressure Measurement Wells - Producers

Injection Wells
### Modeling and Observed Results From Producers

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OVERVIEW

• Background Information

• Phase II Initial Results

• *Phase III Design / Status*

• Summary
SECARB (Early) Phase III Field Test

- Denbury early injectors
- Saline aquifer within Cranfield unit
- Gas cap
- Oil ring
- CO₂ pipeline from Jackson Dome
- 1+ MMT/year
- Phase II study area
  Dedicated observation
  Well; + logging in producers
- Phase III study area
  Two dedicated observation wells in brine + in producers
Cranfield Geometric Overview

Phase II Study area

Phase III Early study area

Tuscaloosa Formation

Brine

Residual Oil

Residual Gas

Regional seal

"Heterogeneity"

2x Normal

Monitors

Injector

Producer

Monitor

A'

Denbury Cranfield unit

10,000 ft

Monitors

Injector

Injector

A
OVERVIEW

• Background Information
• Phase II Initial Results
• **Phase III Design / Status**
  – *Injecting Since 1 April, 2009*
    • FONSI Issue Late March
    • CX Issued February
  – *Extensive, Elaborate Program*
    • *Detailed Area of Study (DAS)*
    • *Geomechanical Test (GM)*
    • *Collaborative Water Geochemistry Effort*
    • *Modeling (Blind Test)*
    • *Extensive, Ongoing Reservoir Characterization*
  – Summary
Phase III Design

• DAS (Detailed Area of Study) – Ambitious Multi Physics Program

• GM (Geomechanical Test)

• Far-Field Measurements

• Collaborative Water Geochemistry Effort

• Develop Fluid Flow Model

• Reservoir Characterization – KEY
Phase III Design

- DAS – Ambitious Multi Physics Program
  - CASSM (LBNL) – Change in Acoustic Properties
  - X-Well Tomography (LBNL)
  - ERT (LLNL) – CO$_2$ < conductive than brine
  - Joint inversion (saturation, sweep efficiency)
  - Fluid sampling (U-tube)
  - DTS (LBNL / Sandia) – Thermal response
Planned Phase III Observation
“Smart Well” Construction

- Cross well array in two wells
- High injection volumes
- Far-field monitoring – tilt, microseismic, P&T, chemistry, surface seismic

- Casing-conveyed pressure sensor
- ERT – 20 electrodes
- Fiberglass non-conductive casing
- Distributed temperature

2 7/8” tubing
U-tube sampler 1/4 “SS
Seismic sources/receivers
BHP+ T

Tuscaloosa DE

BEG, LBNL, LLNL, USGS, ORNL, Pinnacle, Sandia Technologies
Phase III Design

• Geomechanical Test
  – Paired Injection / Production
  – Downhole Microseismic & Tilt
  – In-zone / out-of-zone activity: pressure and fluid migration

• Far-Field Measurements
  – RST
  – BHP
  – BHT
GM Area Location

- DRI injectors 5/08
- Planned injectors
- Phase II obs well
- Phase III obs well options
Phase III Design

• Collaborative Water Geochemistry Program
  – Near-Surface
    • University of Mississippi (Collecting Samples)
    • Mississippi State (Analyzing Samples)
    • Changbing Yang (BEG) – Fluid-rock interactions
    • Groundwater Modeling – Anchor QEA / BEG
    • Katherine Romanak (BEG) – Soil Gas
  – Deep Subsurface (Injection Zone)
    • Jiemin Lu (BEG) – Fluid-rock interactions
    • ORNL – Isotopes
Phase III Design

• Collaborative Water Geochemistry Program (cont.)

  – Deep Subsurface (Injection Zone)
    • USGS – Fluid; Organics
    • LBNL – Introduced Tracers
    • Possible Collaboration with a UK Team
Phase III Design

• Modeling – Smaller Area than Phase II
  Two Independent Efforts – Quantify Conceptual Model Uncertainty

1. BEG – JP Nicot

2. ARI (Advanced Resources International)
Phase III Design

• Reservoir Characterization – Key Input
  – BEG with collaboration from Denbury
  • Have 100+ logs – will collect more
  • Have access to 2 whole cores – will collect more
  • Have access to 3D seismic – will collect more (4D)
Core Box 1

- **Top**
- **Chert Pebble Conglomerate**
- **Braided Stream**
- **Sharp Basal Contact**
- **Bottom**
- **Marine Mudstone**
- **Lower Shoreface**
- **Shell fragments (oyster, gastropod) and Trace fossils**
Deep water table
Phase III Design / Status

• Phase III Status
  – Injecting Since 1 April, 2009
    • FONSI Issue Late March
    • CX Issued February
  – DAS Injector
    • Spud Date: Late May – Early June 2009
  – Observation Well #1
    • Spud Date: Mid-June 2009
  – Observation Well #2
    • Spud Date: Early July 2009
Progress

2006
- Site selection
  - First cored well, brine samples
  - Received seismic data

2007
- Characterization
  - NEPA CX

2008
- Site development
  - Instrumentation
  - Soil gas baseline
  - Start workover

2009
- Injection and monitoring
  - Start Phase III injection
  - Increasing number of injectors and rate per well
  - End phase II
  - Phase III Wells June-July

Phase II EOR
- Phase III Brine
Summary

• Phase II
  – 600,000+ Metric Tons Injected
  – Pressure Robust Monitoring Tool
  – Models Working / Collecting Data

• Phase III
  – Injecting Since April 1, 2009
  – Extensive, Elaborate Program
    • DAS – Ambitious Multi-Physics Effort
    • GM – In-Zone Tilt, Microseismic
    • Far-Field Measurements
    • Collaborative Water Geochemistry Program
    • Dual “Blind-Test” Modeling
    • Extensive Reservoir Characterization
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Cranfield Mississippi