SECARB Early Test Retrospective

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Early Test Research team

Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Denbury Resources
Field owner and injection system
design, management, 4-D
survey, HS&E

Sandia Technologies
Monitoring Systems
Design, Installation,
HS&E

50 Vendors
E.g. Schlumberger

MSU UMiss
Hydro & hydrochem

Core Lab
UT DoG
Anchor QEA

Federal collaborators
Via FWP

LBNL
Well-based geophysics,
U-tube and lab design
and fabrication

LLNL
ERT

USGS
Geochemistry

Curtin University, Perth

Vendors
E.g. equipment

Environmental
Information Volumes
Walden Consulting

Separately funded

ORNL
PFT, Stable isotopes

NETL
Rock-water interaction

NRAP
VSP & analysis

Stable isotopes

Stanford, Princeton, U Edinburgh, UT
PGE & ICES (CFSES), U. Tennessee, USGS
RITE, BP, CCP, Durham, AWWA

SECARB Anthropogenic
Test At Plant Barry/
Citronelle

Vendors
E.g. local landman

Vendors
e.g. equipment
Overview

• > 1 Million metric tonne / yr injection
• Quick start up = “Early test” (bridge between pilot scale and SECARB’s Plant Barry/Citronelle anthropogenic test)
• Of possible sites, Denbury’s Cranfield field scheduled for 2008 CO\(_2\) injection start was favorable:
  – Time to collect pre-injection data before injection
  – Build quickly to >1 MMT per year CO\(_2\) injection rate (sufficient to assure project metrics met & exceeded)
  – Experienced operator in CO\(_2\) EOR – low risk of permitting delay: early results for RCSP program
  – Field abandoned (40 years); pressure recovered and equilibrated
Favorable Characteristics of Cranfield for SECARB Early test

• Follow-on between Phase II and Phase III
  – Phase II lower budget experiment, single monitoring well in EOR zone
  – Used Phase II as far-field and comparison point to Phase III

• Phase III planned in water leg downdip of oil zone

• Provided RCSP experience with CO2 EOR, (grew in importance)
Less than-ideal characteristics

• CO$_2$ from Jackson Dome (not anthropogenic)
• Field commercial EOR
  – operational aspects not under project’s control
  – some data proprietary
• Research purpose only
  – Designed prior to EPA or international regulations
• Relatively complex geology both deep & near surface
• Modeling reservoir’s injection response complicated
  – by oil presence
  – injection and withdrawal complexities – managed...

Simplified by:
Focus on the DAS - brine only
Early timing - production & recycle was minimal
Developing the Experiment

- Year-long series of meetings (2007-2008)
  - designed plan
- Aligned general research objectives
  - well locations
  - selected team members
  - budget
- Designed detailed plans - major components
- Adapted to fast EOR field development
  - NEPA permitting (slow)
  - other timeline issues
    - equipment rental
    - procurement
    - cash flow (2009 “cash call”)
Project objectives

- Produce CO$_2$
- Concentrate CO$_2$
- Consume CO$_2$
- Disperse CO$_2$

False positives
- Mask signal

False negatives
- Dampen signal

Leak

Failed containment

Stored CO$_2$

Plant activity
- Organics $\rightarrow$ CO$_2$

Soil carbonate

Soil moisture

Weather fronts

Produce, consume, redistribute CO$_2$

Katherine Romanak BEG

Background “noise”

Vadose zone

Weather fronts

Stored CO$_2$

Katherine Romanak BEG
Team contributions (1)

• Denbury Onshore LLC
  – site host,
  – data,
  – access via roads,
  – permitting, well construction,
  – CO2 management

• BEG - GCCC:
  – project management,
  – reporting,
  – test design,
  – reservoir and overburden characterization,
  – fluid collection and analysis,
  – reservoir and AZMI modeling,
  – groundwater and soil gas data collection / analysis,
  – airborne EM & resistivity analysis

• SSEB – prime contractor,
  – reporting and accounting

• Sandia Technologies:
  – test well design,
  – construction oversight,
  – oilfield services procurement,
  – site HS&E,
  – project insurance & licensure

• Ol Miss, Mississippi State, & QEA-Anchor (consultant)
  – Groundwater data collection,
  – geochemical analysis,
  – aquifer coring
Team contributions (2)

- **LLNL** – Multiphase geophysics
  - Cross-well EM fielding and interpretation

- **USGS** – reservoir fluid sampling & analyses

- **Schlumberger Carbon Services**
  - Well logging
  - Cross well Seismic
  - AZMI fluid collection

- **LBNL / NRAP**
  - U-tube,
  - 3-D VSP
  - Downhole fiber optic CASSM

- **Oak Ridge NL**
  - PFT and sampling

- **University Edinburgh**
  - Noble gases

- **Local landowners**
  - Access

- **Walden Consulting**
  - NEPA
Time Lapse Resistivity Changes

Initial CO₂ Breakthrough in F2

Initial CO₂ Breakthrough in F3
Time Lapse Resistivity Changes
After Work-over in 9/2010
Contributions: Support Collaborators

- CFSES
  - rock samples for geomechanics
- NRAP
  - field site for 3D-VSP
- SIM SEQ
  - comparative modeling data set
- NETL
  - $\text{CO}_2$ EOR model data
Accomplishments

• Monitored CO₂ injection 2008 – 2015
• Injection through 23 wells, cumulative volume over 8 million metric tons
• First US test of ERT for GS (deepest)
• Time lapse plume imaging with cross well seismic, VSP, RST, & surface 3-D seismic
• RITE microseismic – none detected
• Groundwater sensitivity assessment (push-pull)
• Recognized by Carbon Sequestration Leadership Forum (CSLF) in 2010 for research contributions
• SIM-Seq inter-partnership model development test
• Knowledge sharing to Anthropogenic Test and other U.S./International CCS projects
“Early Test’s” Major Contributions

• Large volume injection bridged RCSP to current & future anthropogenic sources
• Value of AZMI pressure monitoring in demonstrating reservoir fluid retention
• Probabilistic monitoring helps history-match fluid response to injection in a complex reservoir
• Process-based soil gas method developed and demonstrated for the first time
• Demonstrated utility and site-specific limitations of groundwater monitoring
Future (1)

- Model additional scenarios incorporating uncertainties
- Forward-model seismic response
- Compare Cranfield ERT to Ketzin
- Evaluate ERT for long-term viability (distinguish noise from signal)
- Determine time-dependent capacity through modeling
- Participate in ISO 265
- Further optimize process-based soil-gas method
- Further optimize groundwater uncertainties
Future (2)

- Technology transfer
  - Deployment of monitoring strategies developed at SECARB “Early” test as well as other RCSP and international CCUS sites
  - Support for maturation of monitoring for EOR as well as saline sites through international standards, best practices, critical reviews