

# DOE Partnership Review Meeting

## Illinois Basin-EOR Sequestration Tests

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# EOR I: Huff n Puff Pilot Test

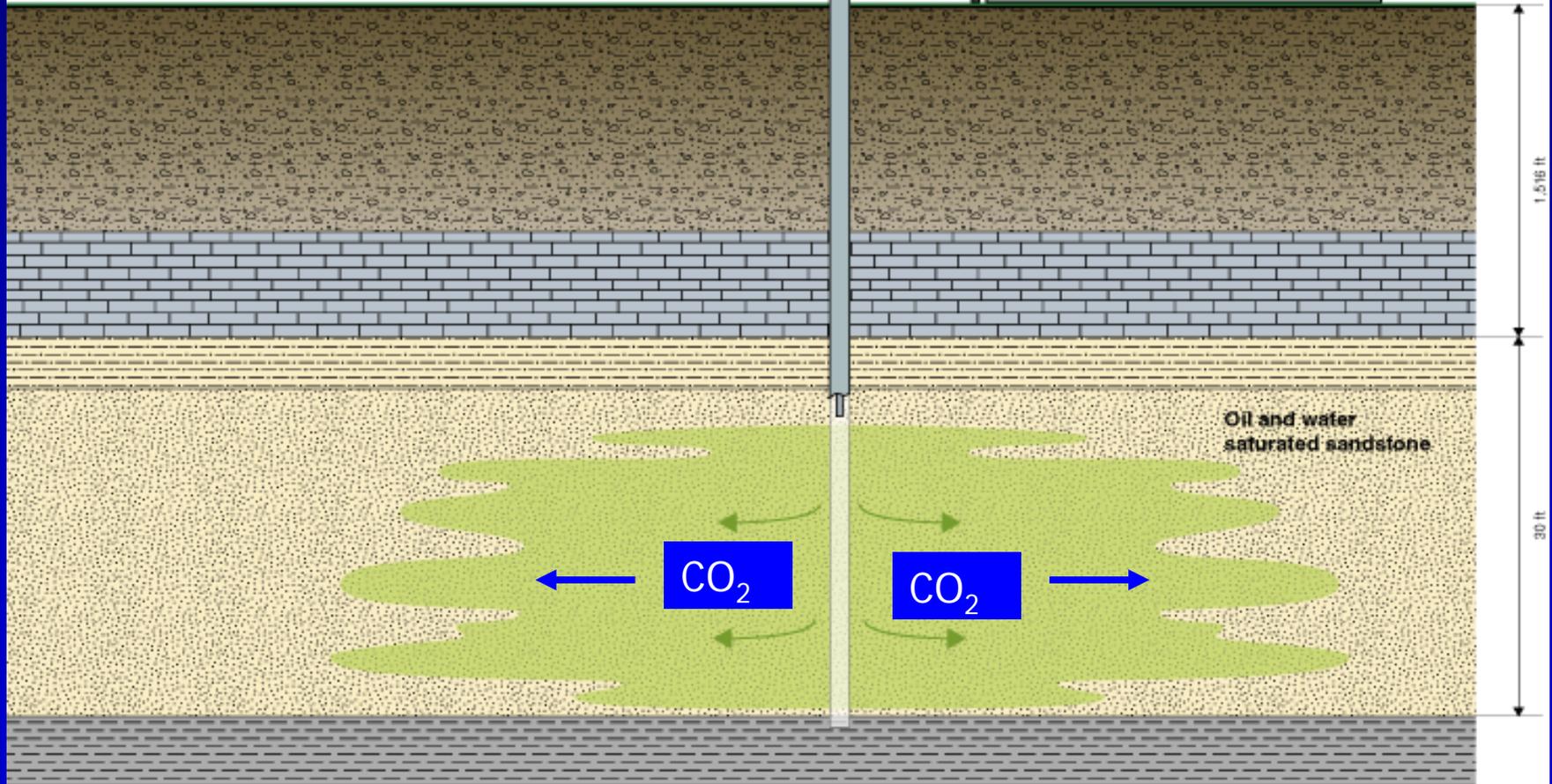
## Objective

- To conduct small scale CO<sub>2</sub> injection pilot (Single well, inject CO<sub>2</sub>, produce oil, gas, water)
  - Test injection equipment
  - Apply MMV techniques
  - Validate pilot logistics and plans
- Estimate sequestered volume and enhanced oil production

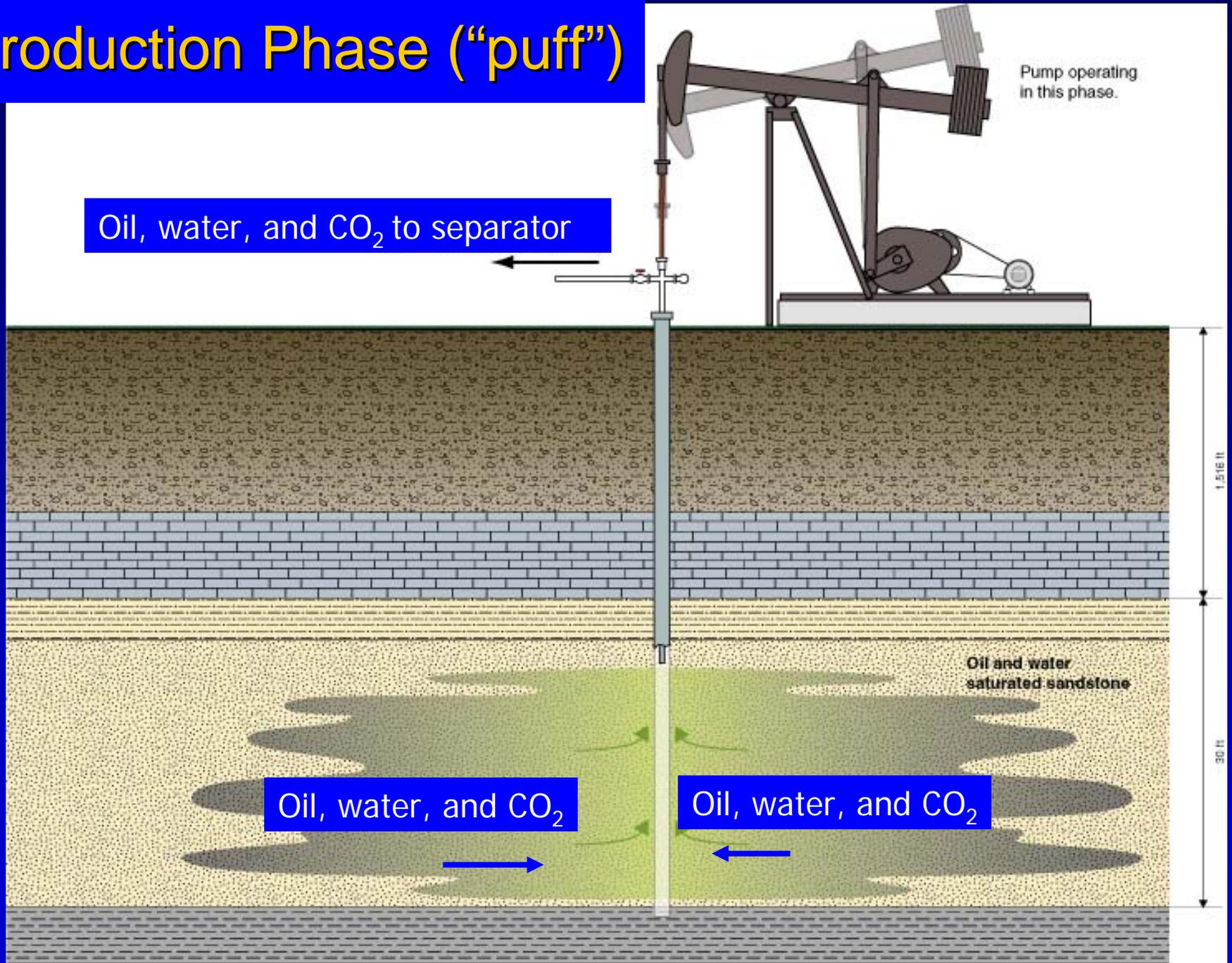
# Injection Phase ("huff")

Pump not operating in this phase.

CO<sub>2</sub> gas



# Production Phase ("puff")



# Outline

- Pre-CO<sub>2</sub> Injection
- CO<sub>2</sub> Injection
  - Inject or huff
- Post-CO<sub>2</sub> injection
  - Soak
  - Produce or puff

# Pre-CO<sub>2</sub> Injection

- Injection Site
- Injection Equipment
- Geologic/Reservoir Models
- MMV Baseline

# Pre-CO<sub>2</sub> Injection: Site Preparation

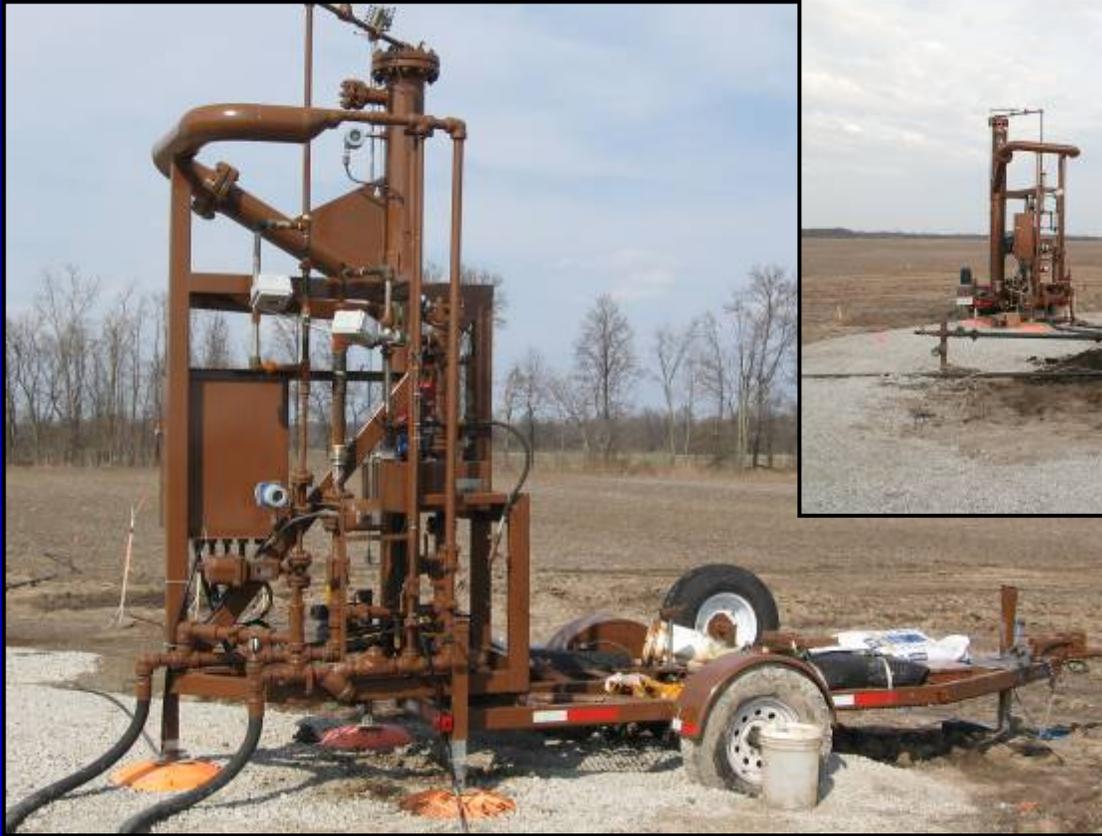


# Pre-CO<sub>2</sub> Injection: Site Preparation

- \* Pipeline: Pump skid to wellhead
- \* Roads and site pad
- \* Trailer
- \* Ambient CO<sub>2</sub> monitors
- \* Power



# Pre-CO<sub>2</sub> Injection: Equipment Preparation



- Test separator
- Data acquisition equipment

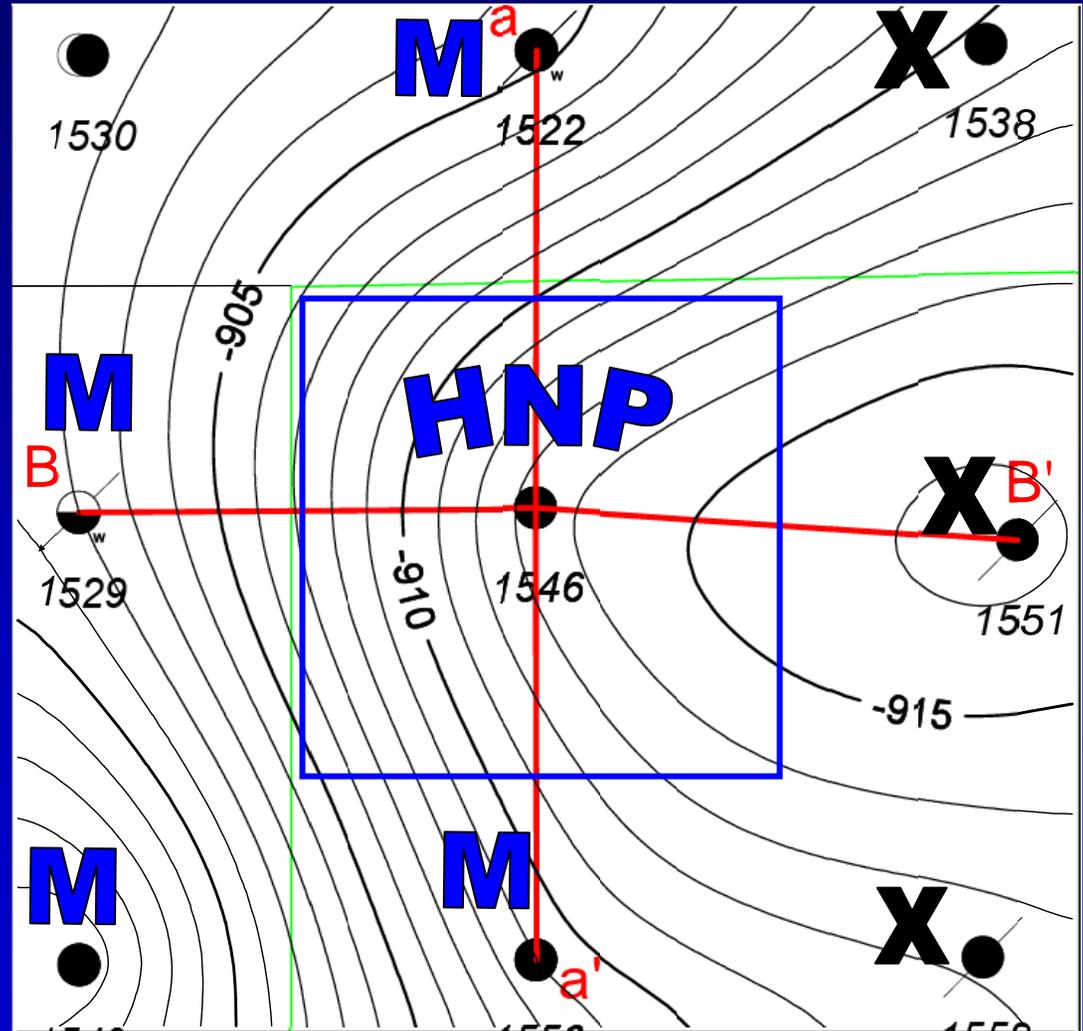
# Pre-CO<sub>2</sub> Injection: Equipment Preparation



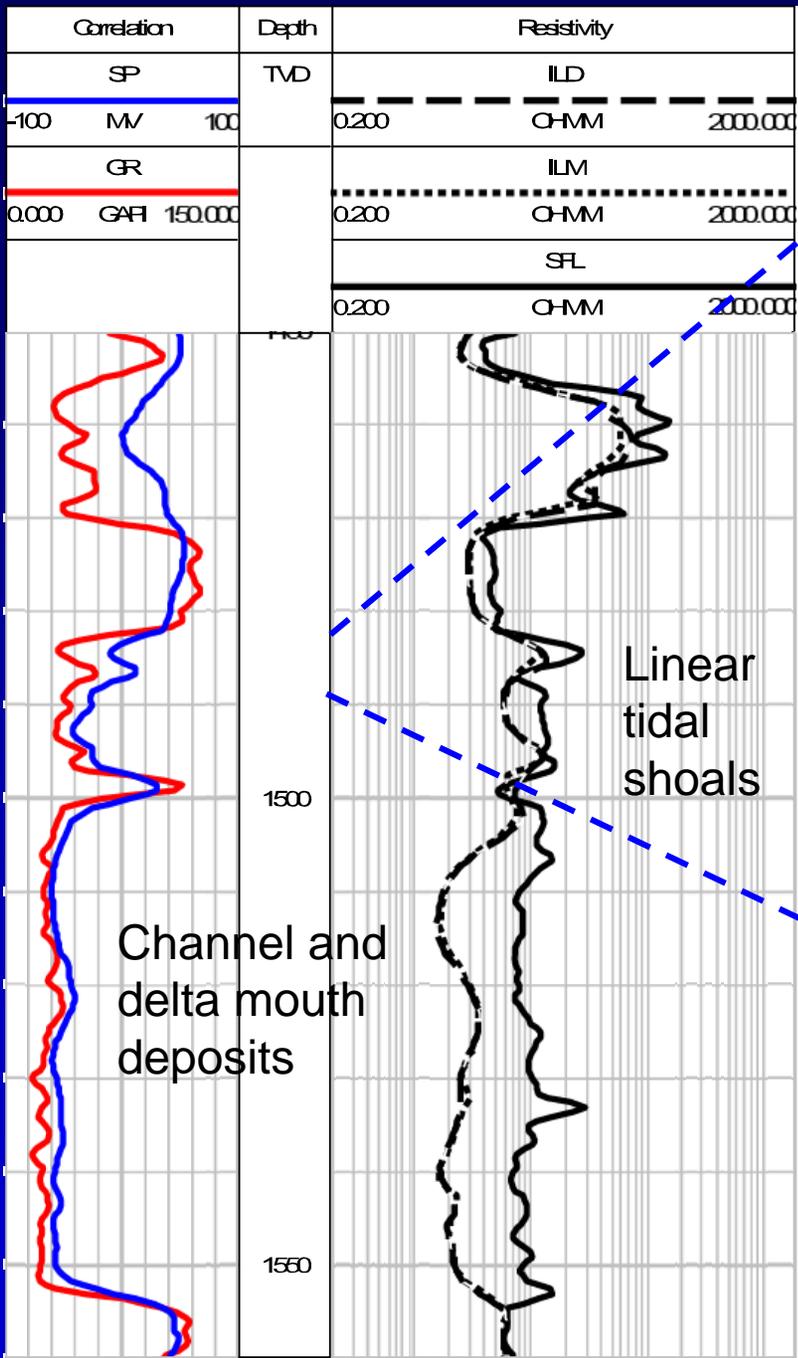
- Pumping: Storage tank, Pump skid, Heater

# Pre-CO<sub>2</sub> Injection: Geologic Models Geographix and Isatis

- Single Zone (Cypress)
- 40-acre lease
- Four Monitor wells



S S P R V C



# West-East X-Section

Carter Oil Co., The  
Coddington, F. W. 2

Carter Oil Co., The  
Owens, C. 1

Carter Oil Co., The  
Owens, C. 3

**B**



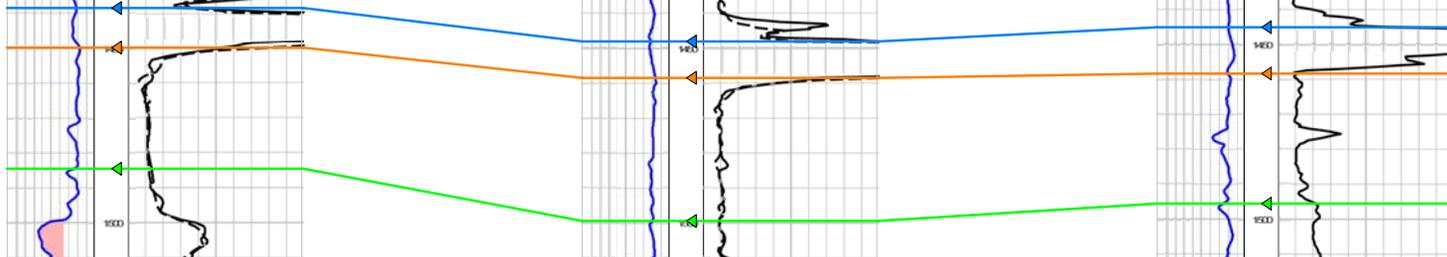
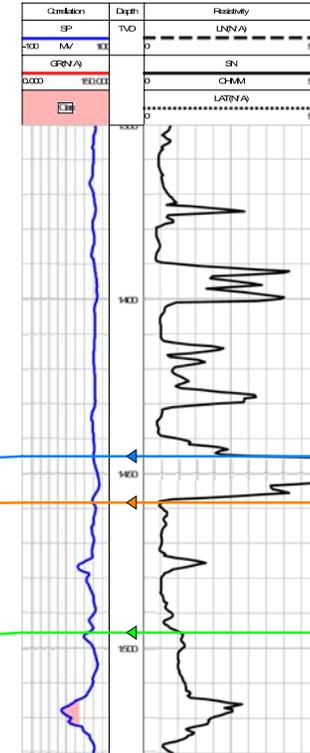
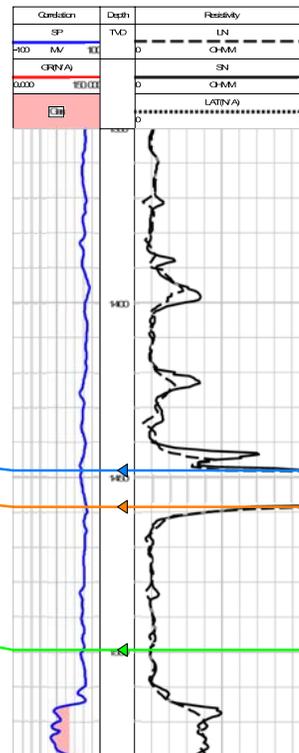
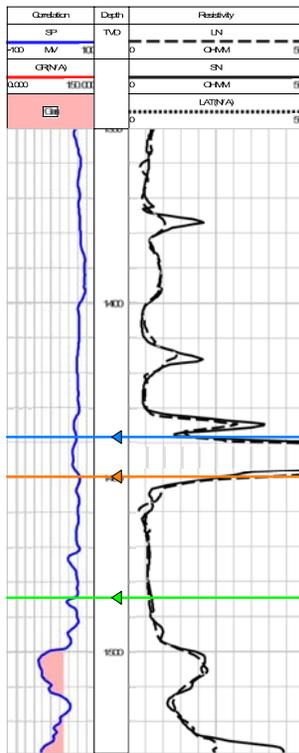
664 ft



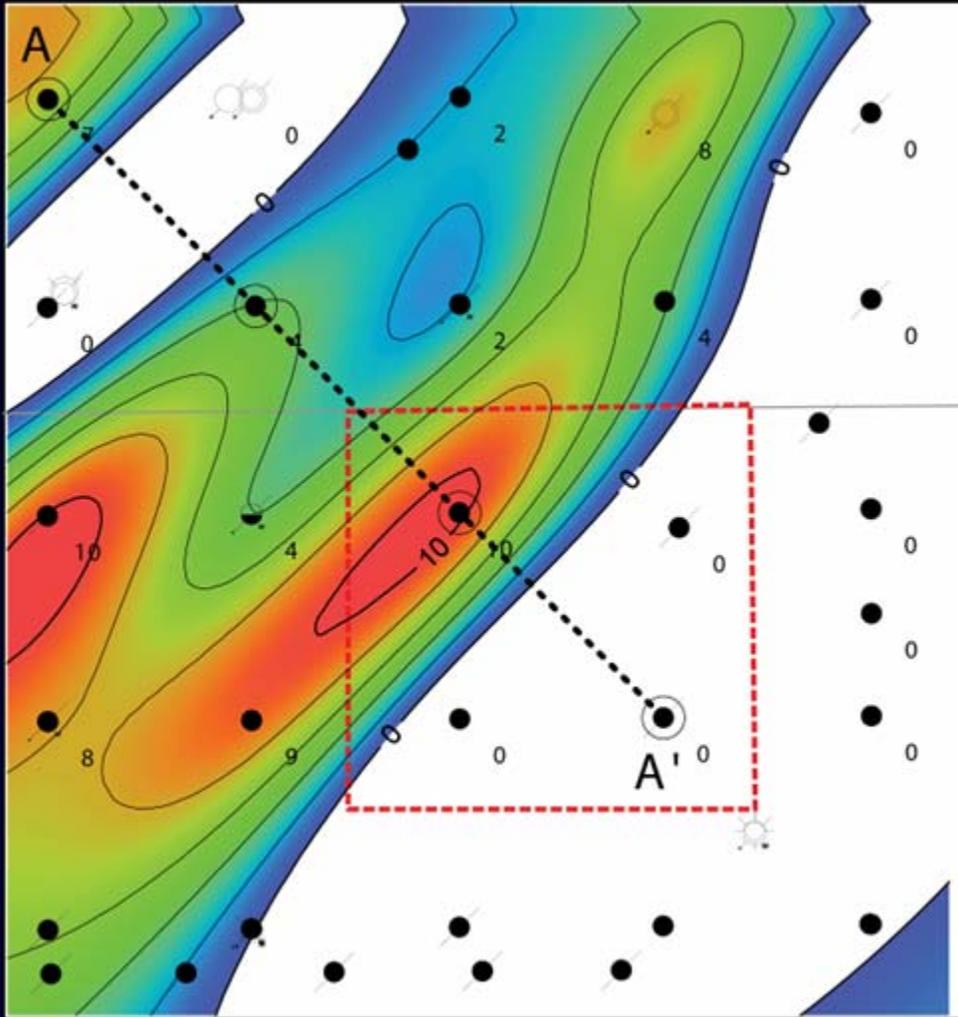
703 ft



**B'**



# Pre-CO<sub>2</sub> Injection: Geologic Models



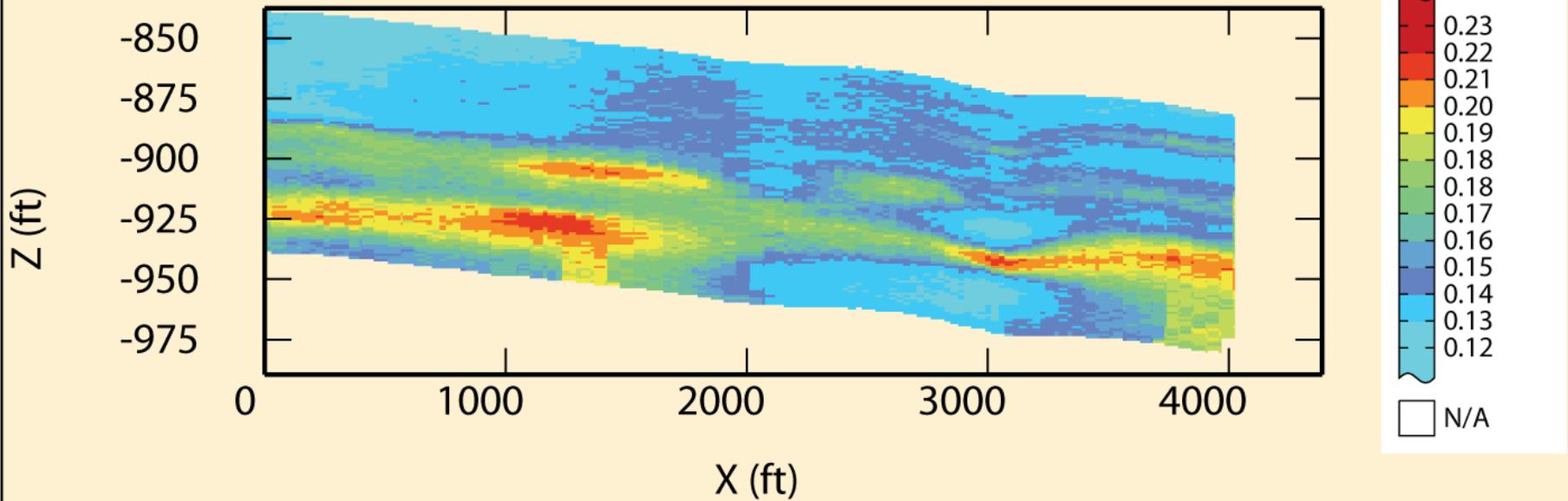
Geologic no-flow  
boundary  
suspected to the  
east and south

Continuity  
suspected NE-SW  
but formation  
looks different.

# Geostatistics: Porosity

## NW-SE X-section

NW-SE Cross Section of Final Simulation of Porosity



Isatis

# Pre-CO<sub>2</sub> Injection: VIP Compositional Reservoir Model

- 1 and 2 week soak period had negligible change in incremental oil production
- Oil rate
  - Peak increase 3.5x above base rate
  - Decline at about 0.9 bbl first week week
- CO<sub>2</sub> Injection Rate: 26 tons in 1 week

# Pre-CO<sub>2</sub> Injection: MMV Baseline

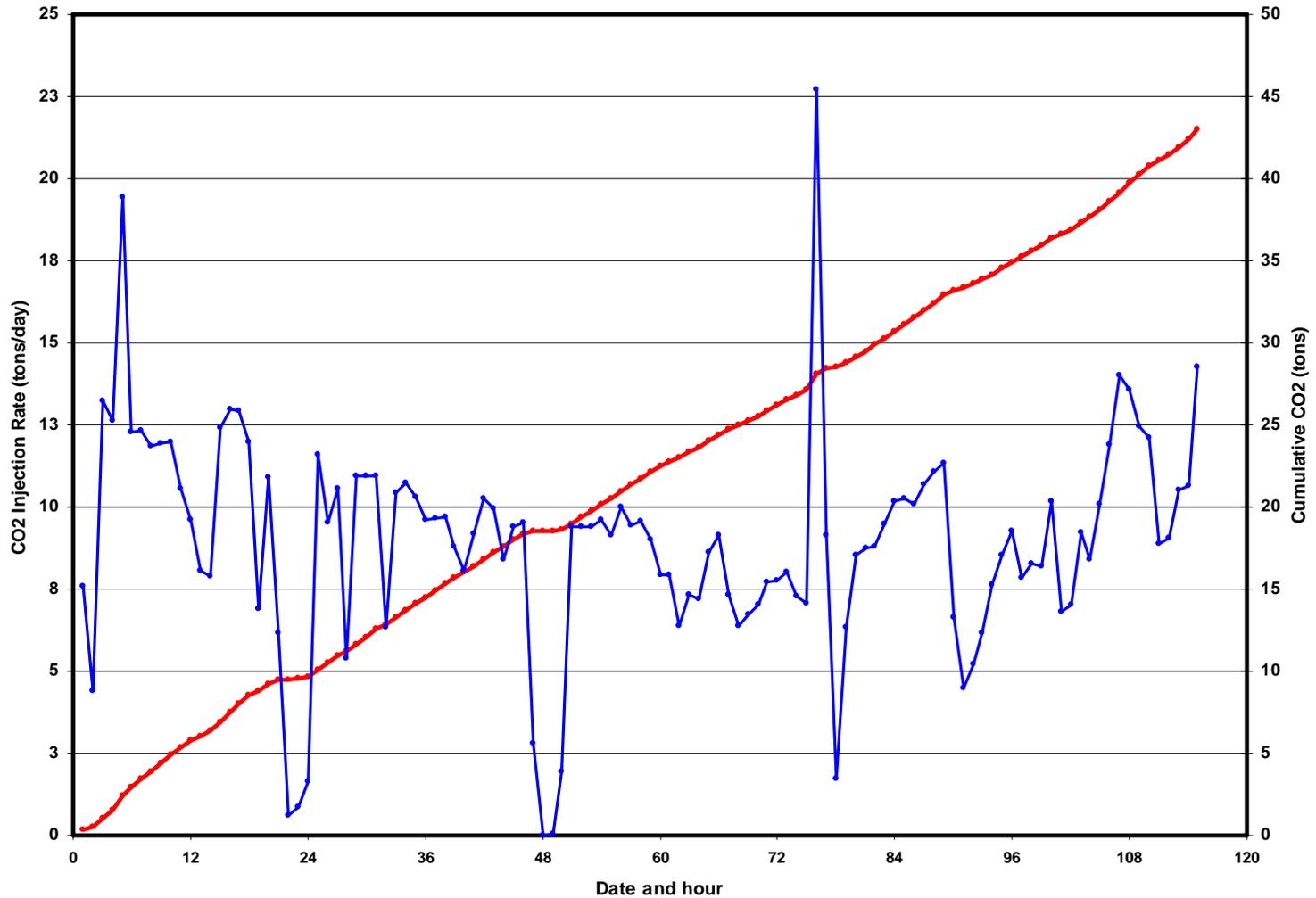
- Out of zone:
  - Ground water sampling
  - Vadose zone
  - Geophysical (EM, Resistivity, Induced Polarization)
- In-zone
  - Gas and water sampling from oil wells
  - Geologic formation pressure and temperature
  - Injection and production rates.
  - Cased hole logging

# CO<sub>2</sub> Injection

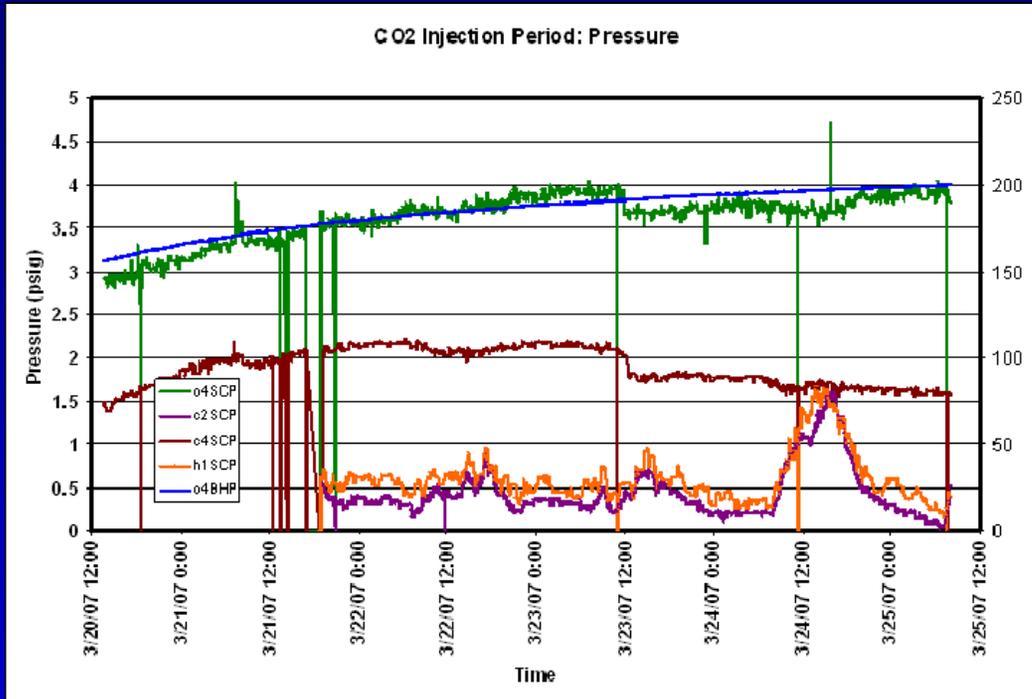
- Injection schedule
- Wells' responses during injection
  - Injection well response
  - Observation well response

# Injection Schedule

CO2 Injection Mass: 1 Hour Cumulative Totals



# Wells' Responses During Injection



- No pressure response detected in the offset observations wells
- Shut-in periods
- Production period
- Injection period

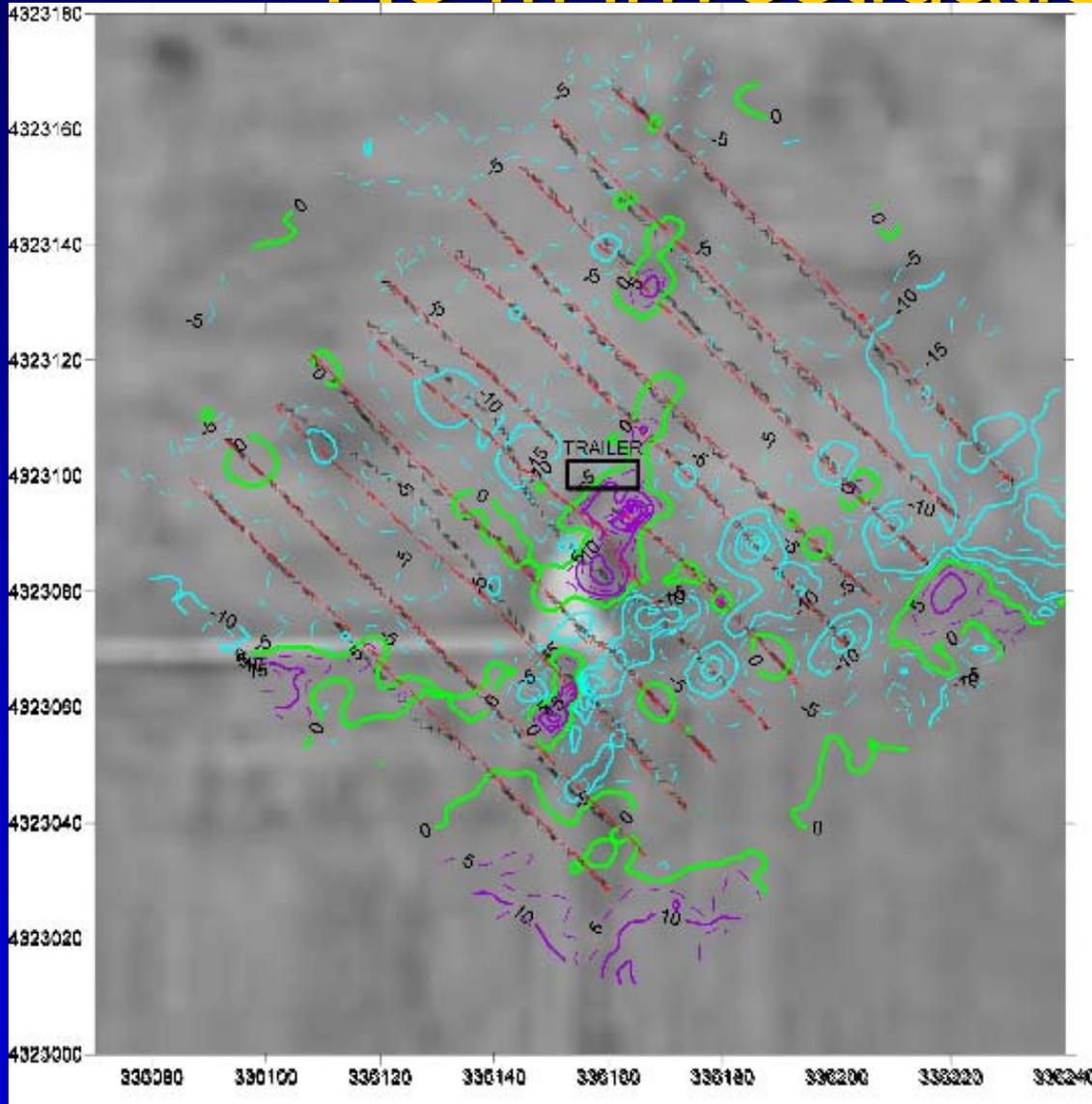
# Post-CO<sub>2</sub> Injection

- MMV: Out-of-Zone
- MMV: In zone
  - Injection well response
  - Observation wells' responses
- Corrosion: Baker Hughes CRO195

# Preliminary MMV Out-of-Zone Results

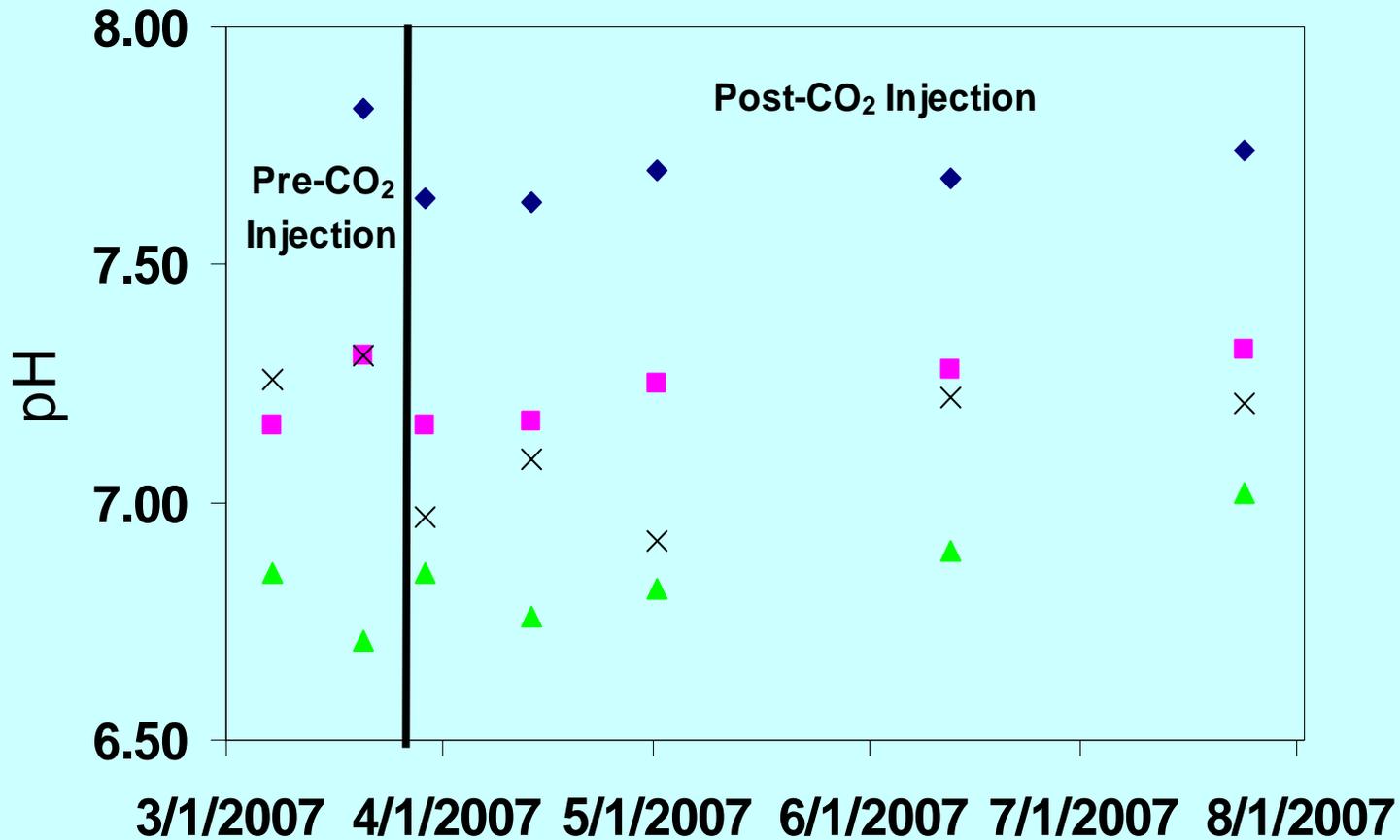
- EMC survey
- Groundwater Sampling
- Brine Sampling (HNP wells)

# Pre- & Post- EMC results 7.5 m investigation depth



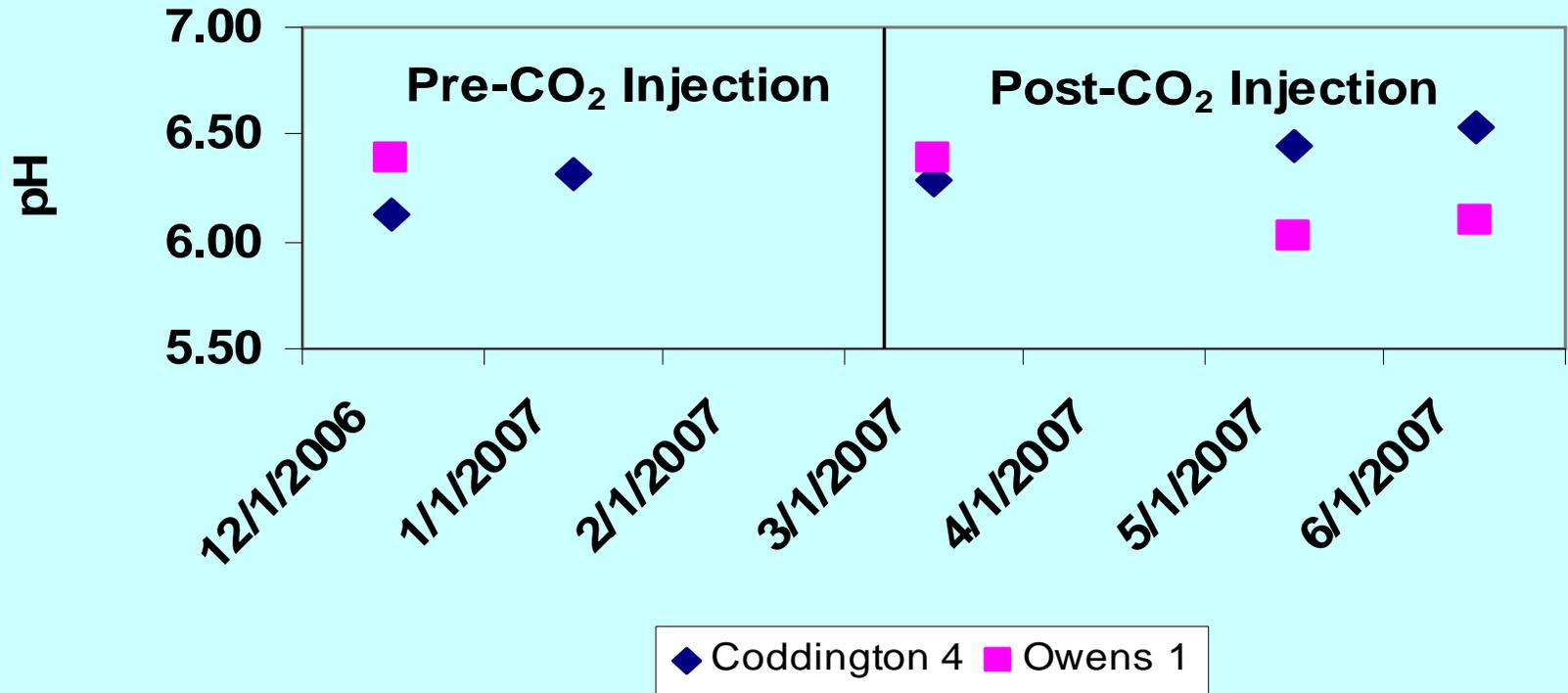
- Red and black lines show data track pre- and post-inj., respectively.
- Contours show difference in cond. pre-minus post- injection (ms/m)
- Green no dif.
- Blue neg. diff. or post > pre.
- Purple positive diff or pre > post.

# pH of Monitoring Wells



◆ Deep    ■ Shallow 1    ▲ Shallow 2    × Shallow 3

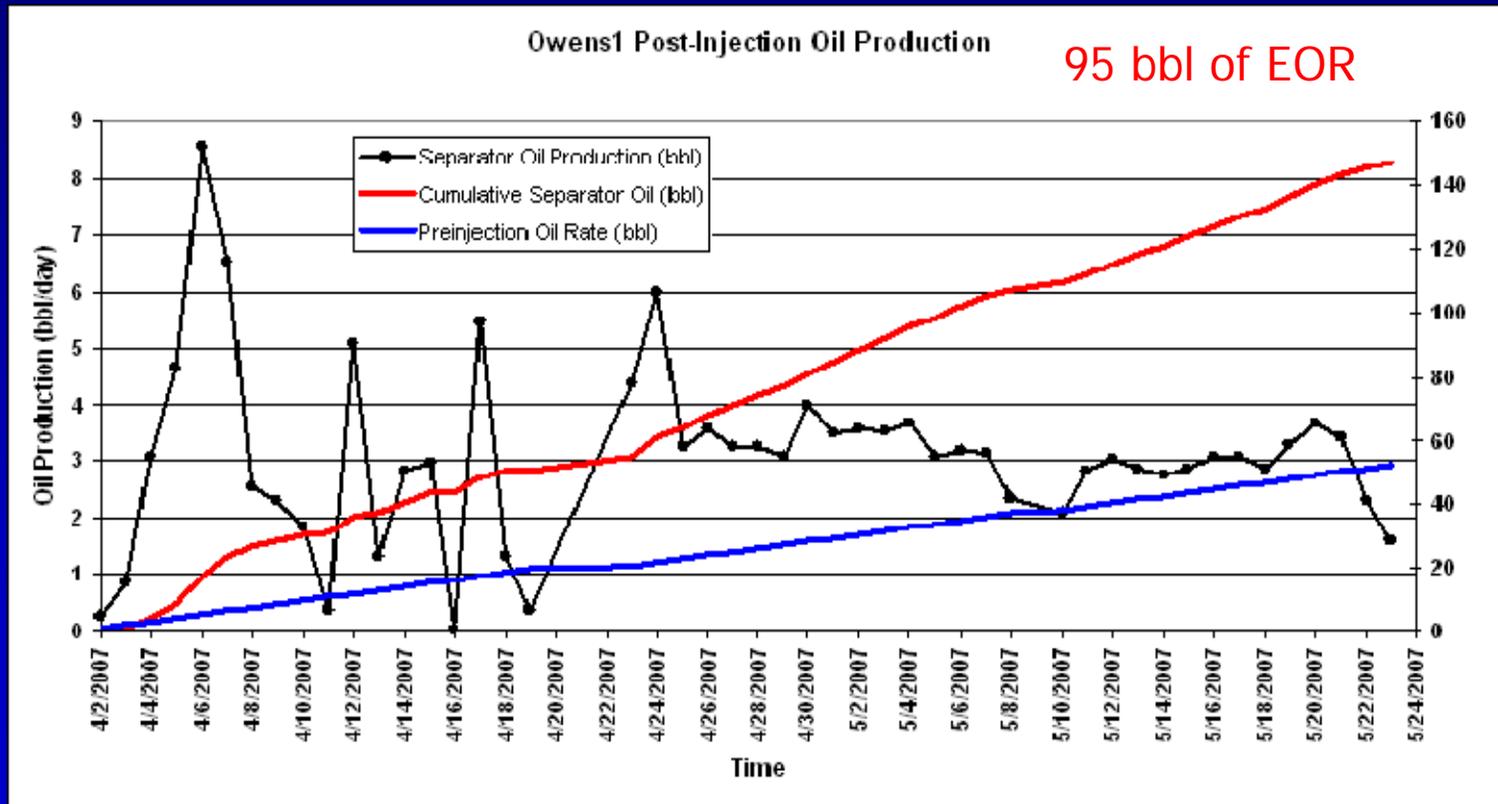
# pH of brine



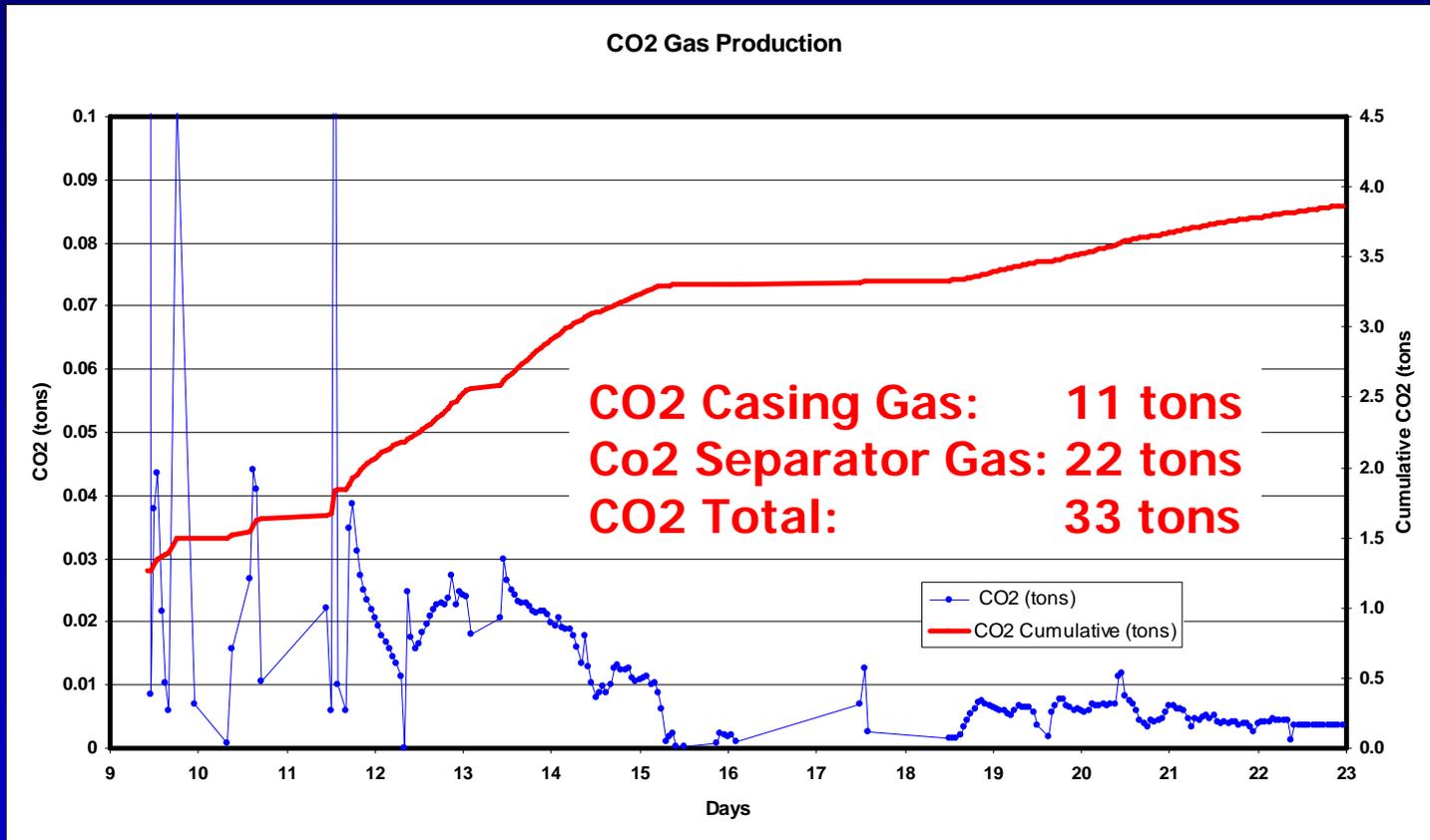
# MMV: Out-of-Zone

- Preliminary data analysis for the EOR pilot would suggest no detectable CO<sub>2</sub> leakage from the injection formation into the shallow biosphere.

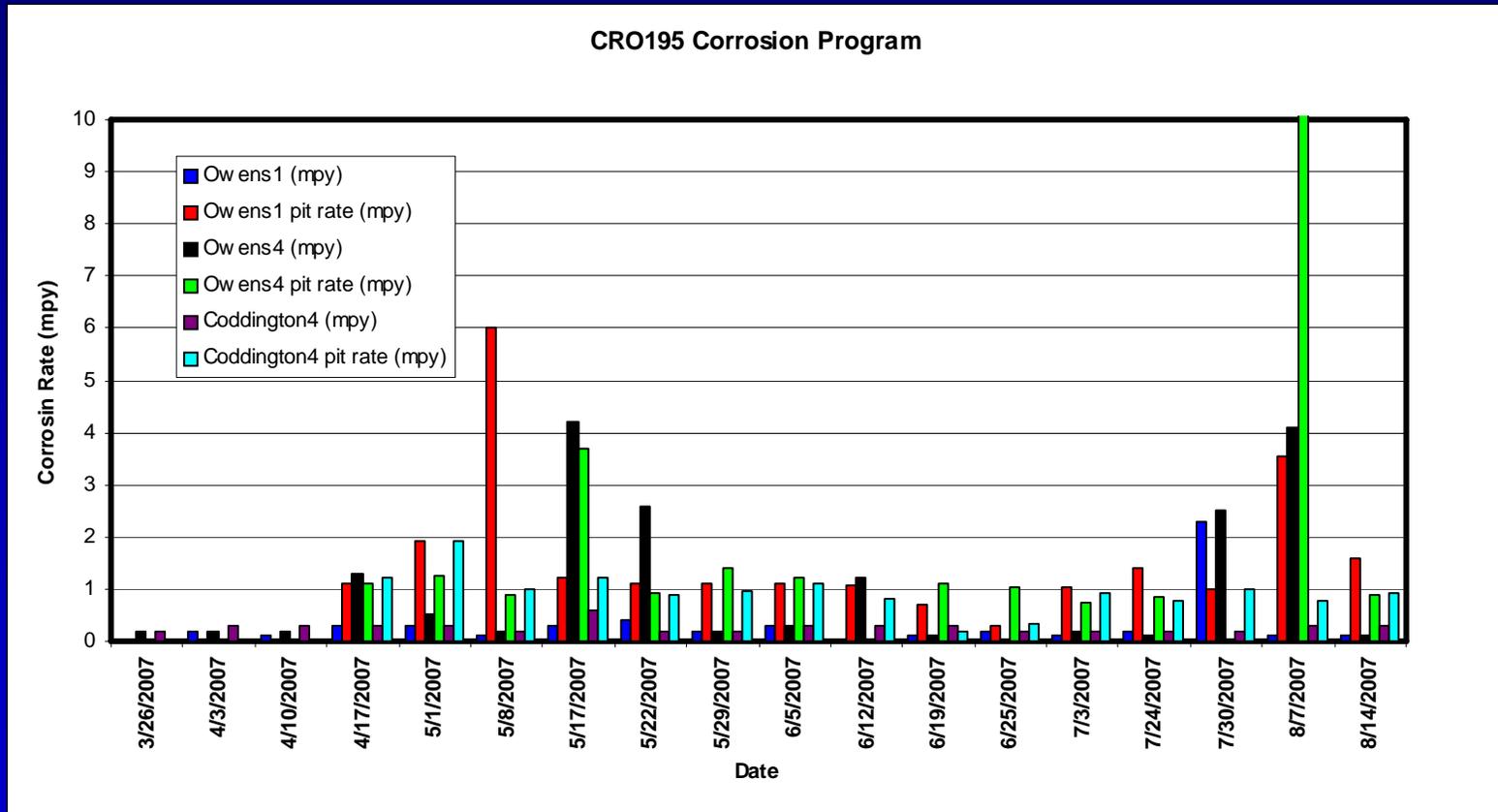
# Post-CO<sub>2</sub> Injection HNP Well Oil Rate Response



# Post-CO<sub>2</sub> Injection: HNP Well Casing Gas Rate



# Post-CO<sub>2</sub> Injection: Corrosion - No CO<sub>2</sub> Corrosion



# EOR I Summary: CO<sub>2</sub> Sequestered and EOR

- 43 tons CO<sub>2</sub> injected in 5 days
  - 33 tons of CO<sub>2</sub> produced
- Reduction of water production
  - Initially fell 33%
  - 2 months back to nearly pre-injection rates (94%)
- EOR 95 bbls oil (2 months)
  - Peak 8x base rate
  - Decrease quickly to stable near stable rate
- Quick-look Economics
  - 43 tons @ \$75/ton => \$3,225
  - 95 bbls @ \$50/bbl => \$4,750

# EOR II Screening

# EOR Pilot Selection Exhaustive Screening

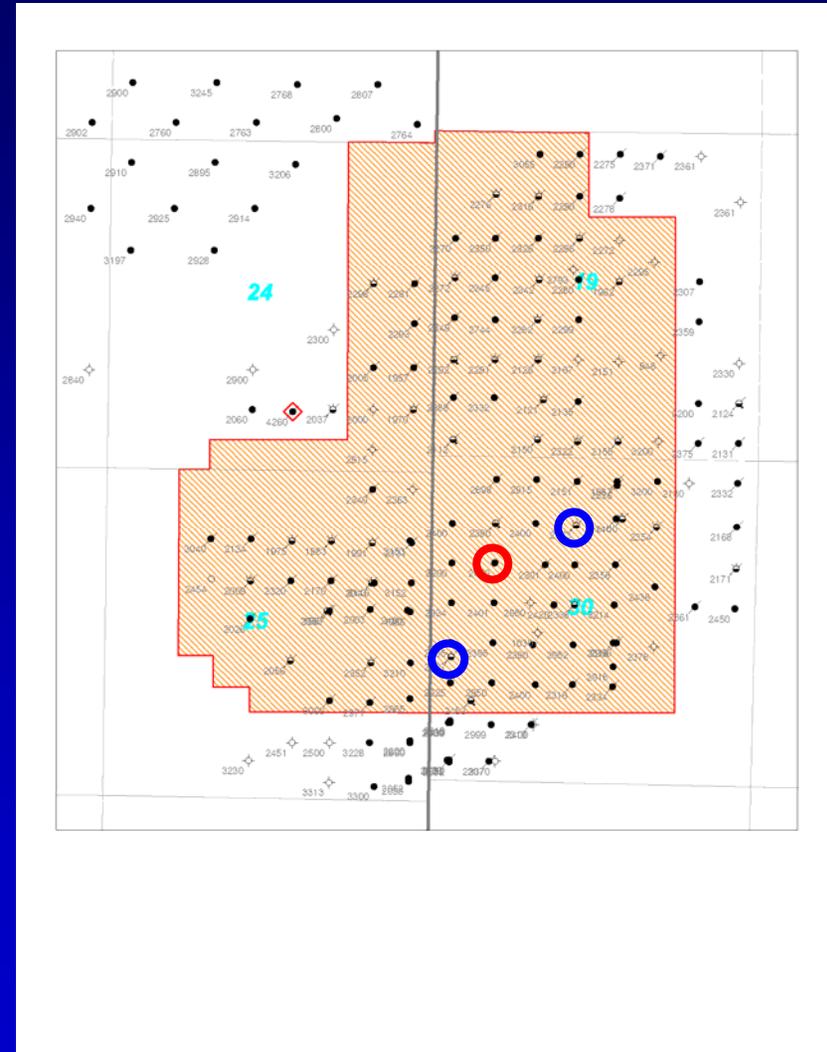
- Geologic Screening Criteria
- Mechanical Screening Criteria
- Logistical Screening Criteria

# Geologic Screening Criteria

- Prolific ILB geologic unit
- Single zone (Budgeted CO<sub>2</sub> and time)
- Data availability
  - Geologic
  - Well history

# Geological Site Selection Problems

- Low quality reservoir
- Limited reservoir size
- Commingled zones
- No or low-quality data
  - Logs, prod., inj., psi
  - No core or phi-K data
- Low pressure reservoirs
- High water cuts
- 5 spot pattern problems
  - Lack of producers
  - Unconventional pattern



# Mechanical Screening Criteria

- Wellbore integrity
- Casing size
- Completion type and vintage

# Mechanical Site Selection Problems

- Old...everything
- Holes in casing
- Communication behind pipe
- Fill, Formation damage, Failure
- Casing liner and size restrictions
  - Isolation problems
- Open hole completions, Multiple zone, No logs
- Incomplete, ambiguous well histories

# Logistical Screening Criteria

- Surface site availability
- CO<sub>2</sub> deliverable
- Area of review (injection permit)

# Logistical Site Selection Problems

- Access to wells, particularly injector
  - Equipment and MMV space, CO<sub>2</sub> Delivery space
  - Dry, not on flood plain
  - Surface owners
- Safety: e.g. proximity of wells to residence, major roads, domestic water wells
- Plugged well, Area Of Review Injection Permit complications

# EOR II Selection Issues for Loudon: Mechanical and Surface

- 4" liner inside 6" casing surface to above formations
- Proximity of wells to
  - flood plains
  - major roads
  - Homes
  - private ponds
- Must weigh risks and make decision or give up on Loudon

# EOR II Selection Issues for Loudon: Geologic and Reservoir Models

- Budgeted 2500 tons and 2-3 mos. injection
- 5 geologic and reservoir models developed for 5 sites.
  - Relatively low perm: no response at producers
  - Relatively thick zone: no response at producers
- Modeling obstacles
  - Low pressure CO<sub>2</sub> injection
  - Converting CO<sub>2</sub> to water injection (WAG)



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