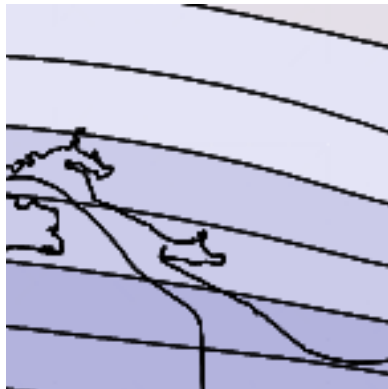




# SECARB's Mississippi Test Site: A Field Project Update

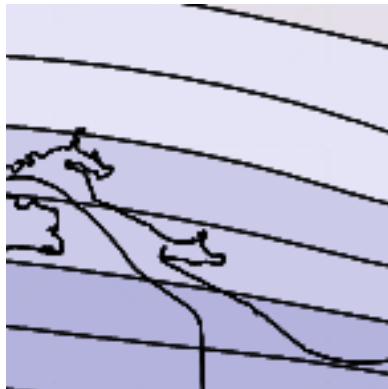


for:

**7<sup>th</sup> Carbon Capture & Sequestration Conference  
Pittsburgh, PA  
May 5-8, 2008**

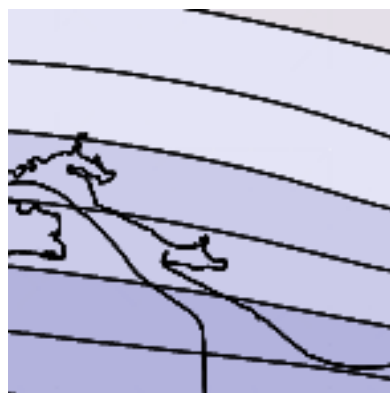
by:

**George J. Koperna Jr., Advanced Resources  
David Riestenberg, Advanced Resources  
Vello Kuuskraa, Advanced Resources  
Richard Esposito, Southern Company  
Richard Rhudy, EPRI**



# Outline for Presentation

1. Introduction
2. Well Drilling & Completion
3. Reservoir Characterization
4. CO2 Injection Operations
5. Monitoring and Verification
6. Project Schedule and Next Steps

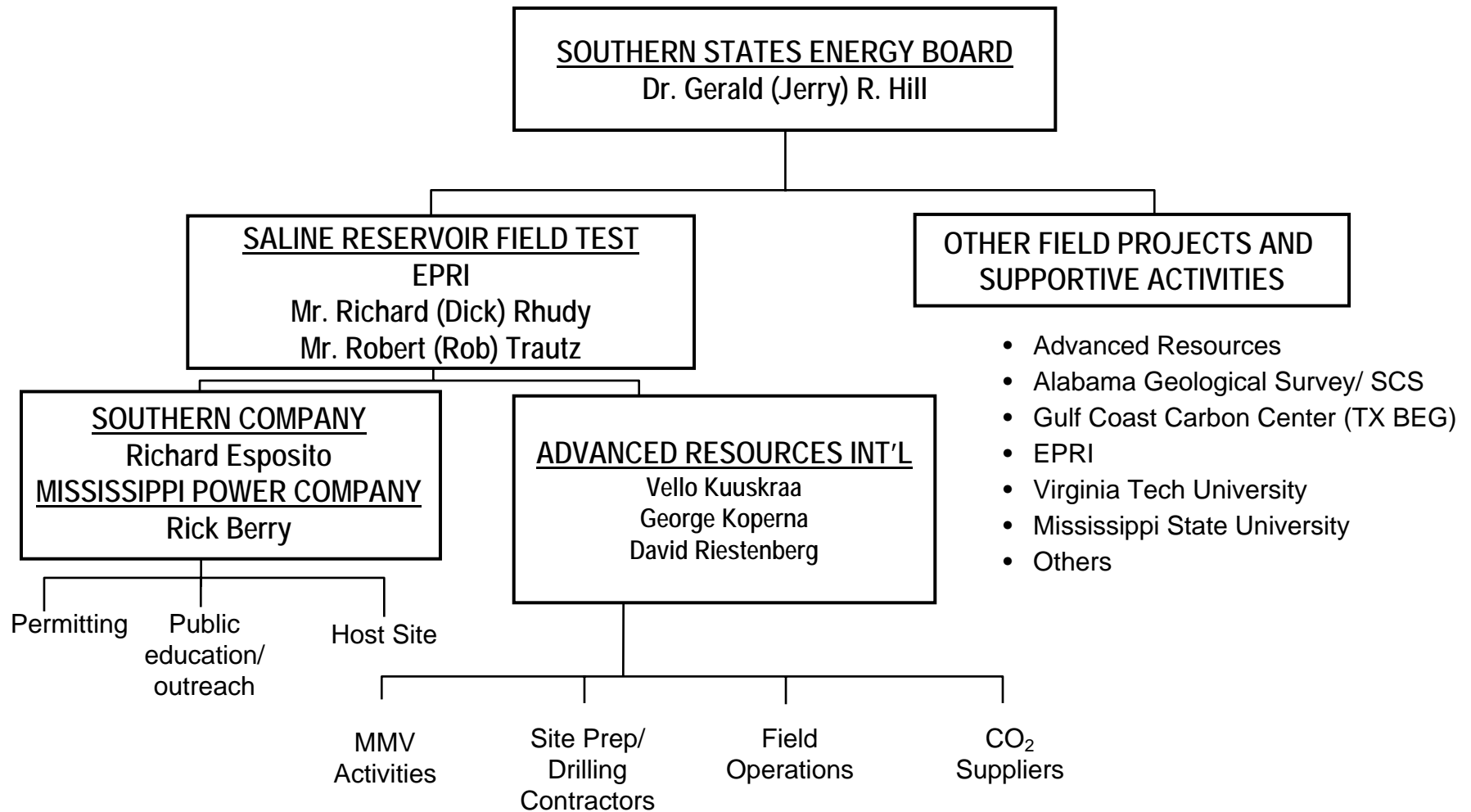


# 1. Introduction

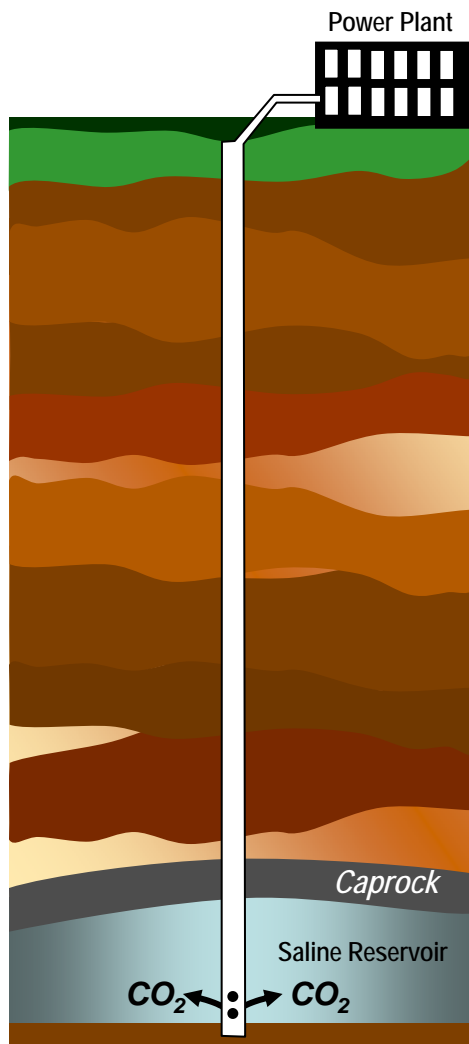
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# Key Organizations and Individuals

## Southeast Regional CO<sub>2</sub> Sequestration Partnership (SECARB)



# Mississippi Saline Reservoir CO<sub>2</sub> Injection Project



- **Purpose:** Locate and test suitable geological sequestration sites in proximity to large coal-fired power plants in the Southeast region
- **Initial Target:** Deep saline reservoirs along MS Gulf Coast with high potential CO<sub>2</sub> storage capacity
- **Objectives:**
  - Build geological and reservoir maps for test site
  - Conduct reservoir simulations to estimate injectivity, storage capacity, and long-term fate of injected CO<sub>2</sub>
  - Address state/local regulatory and permitting issues
  - Foster public education and outreach
  - Inject 3,000 tons of CO<sub>2</sub>
  - Conduct longer-term monitoring

# Victor J. Daniel Power Plant

High capacity CO<sub>2</sub> storage sites exist at Plant Daniel located in Jackson County, Mississippi.

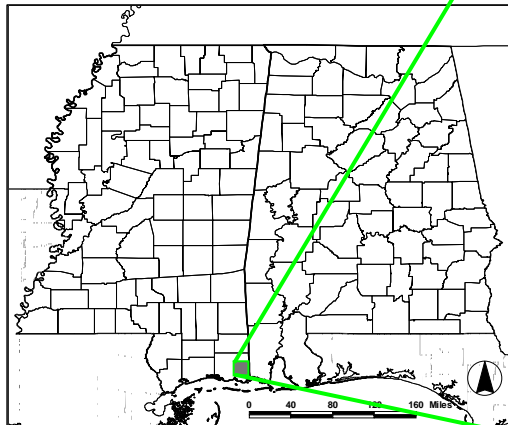


Image Source: Google Earth

# Saline Reservoir Units and Seals (SE Mississippi)

## Potential CO<sub>2</sub> Storage Units

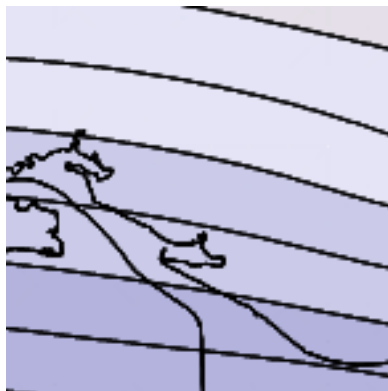
- Lower Tuscaloosa Massive Sand Unit (U. Cretaceous)
- Dantzler Formation (L. Cretaceous)

## Confining Units (Seals):

- Marine Tuscaloosa
- Austin Formation (Fm.)
- Selma Chalk/Navarro Fm.
- Midway Shale

System	Series	Stratigraphic Unit	Sub-Units	Hydrology
Tertiary	Miocene	Misc. Miocene Units	Pascagoula Fm.	Freshwater Aquifers
			Hattiesburg Fm.	
			Catahoula Fm.	
	Oligocene	Vicksburg		Saline Reservoir
			Red Bluff Fm.	Minor confining unit
	Eocene	Jackson		Saline Reservoir
		Claiborne		Saline Reservoir
		Wilcox		Saline Reservoir
	Paleocene	Midway Shale		Confining unit (Seal)
	Cretaceous	Upper	Selma Chalk	Navarro Fm.
Taylor Fm.				
Eutaw			Austin Fm.	Confining unit (Seal)
			Eagle Ford Fm.	Saline Reservoir ← CO <sub>2</sub>
Tuscaloosa Group			Upper Tusc.	Minor Reservoir
			Marine Tusc.	Confining unit (Seal)
Lower		Washita Fredricksburg	Lower Tusc.	Saline Reservoir ← CO <sub>2</sub>
			Dantzler Fm.	Saline Reservoir ← CO <sub>2</sub>
			"Limestone Unit"	

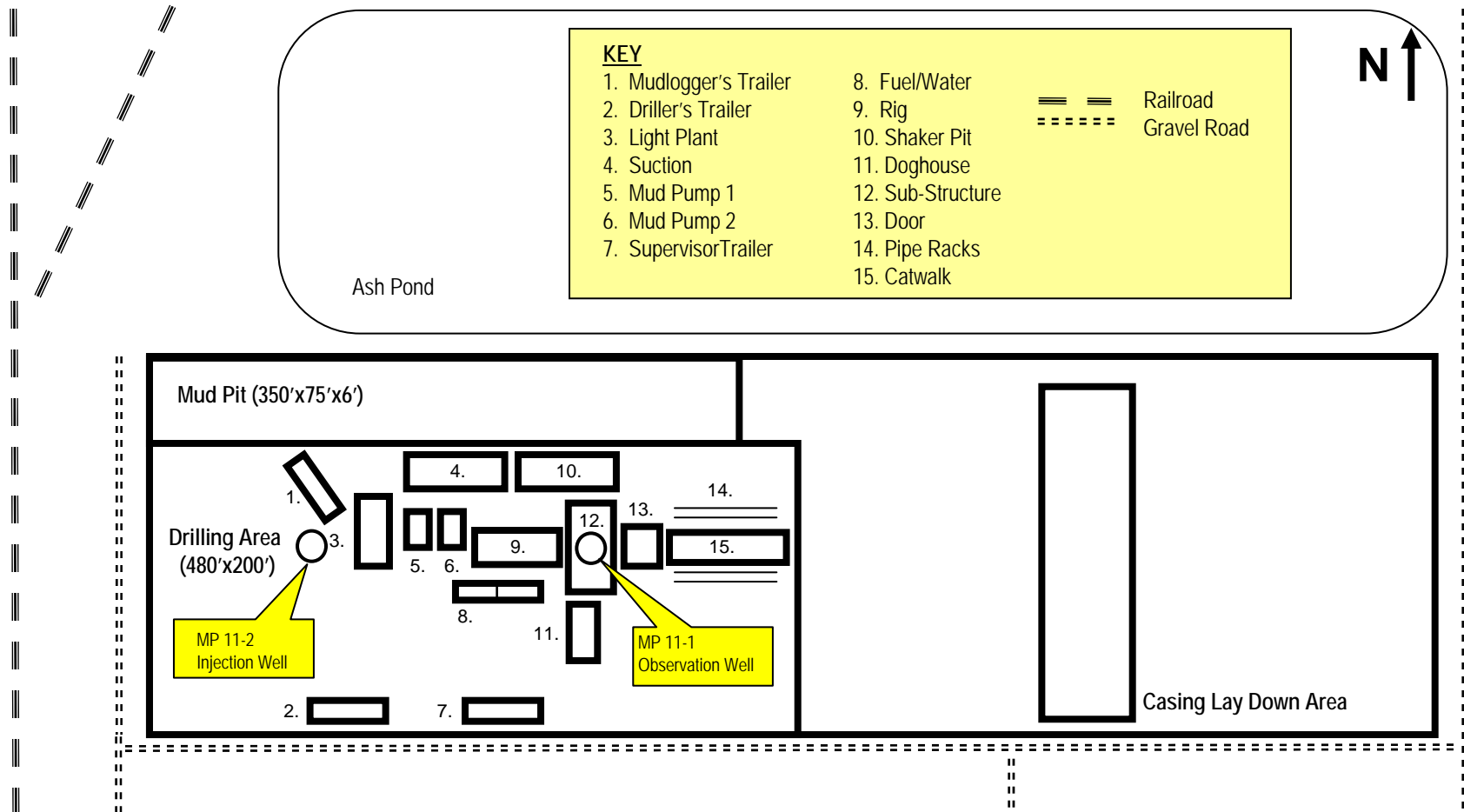
Injection Target



## 2. Well Drilling & Completion

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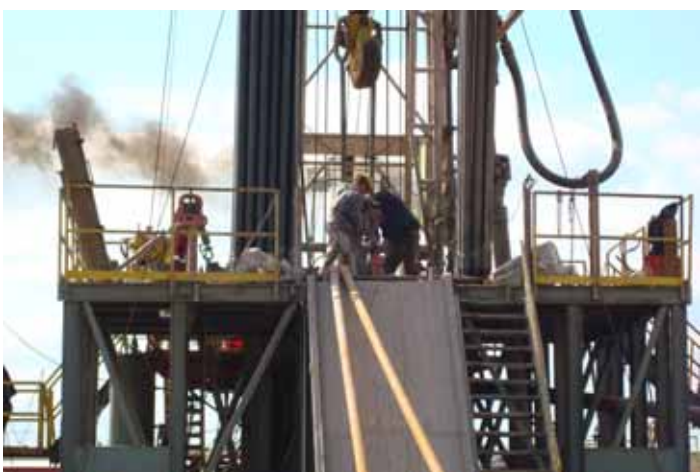
# Surface Location



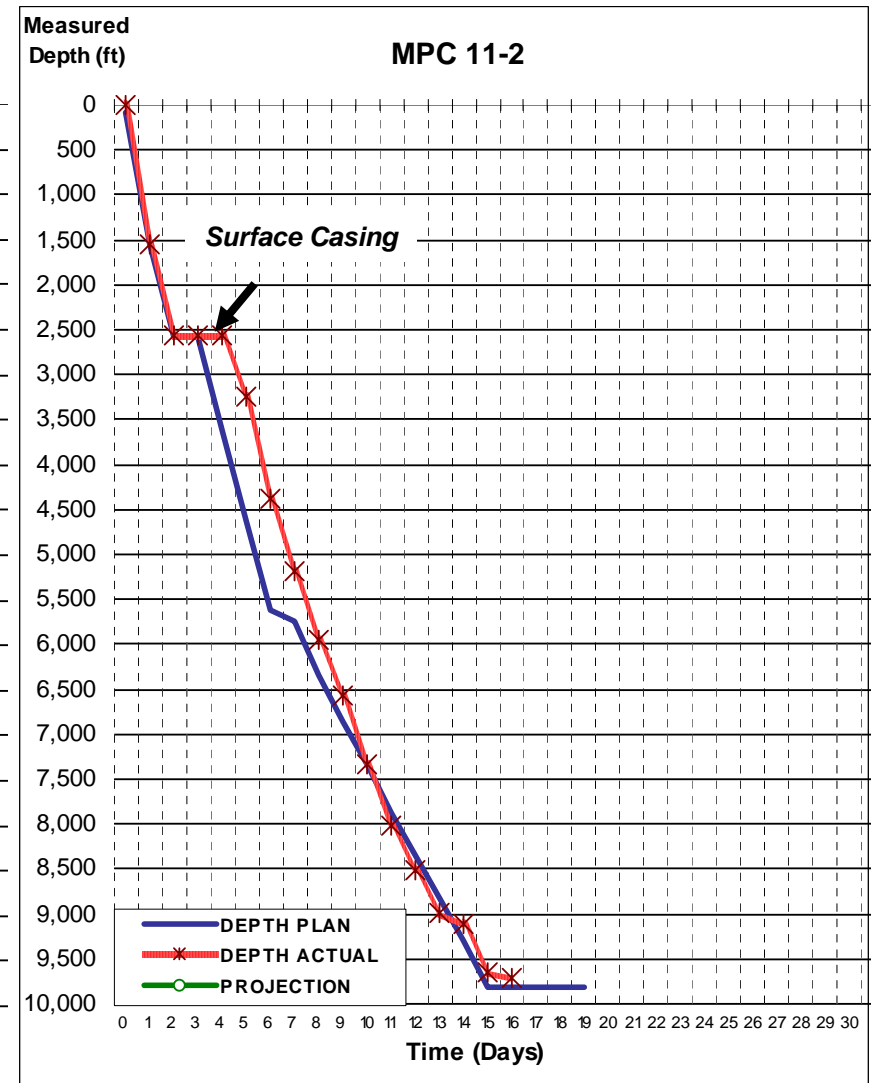
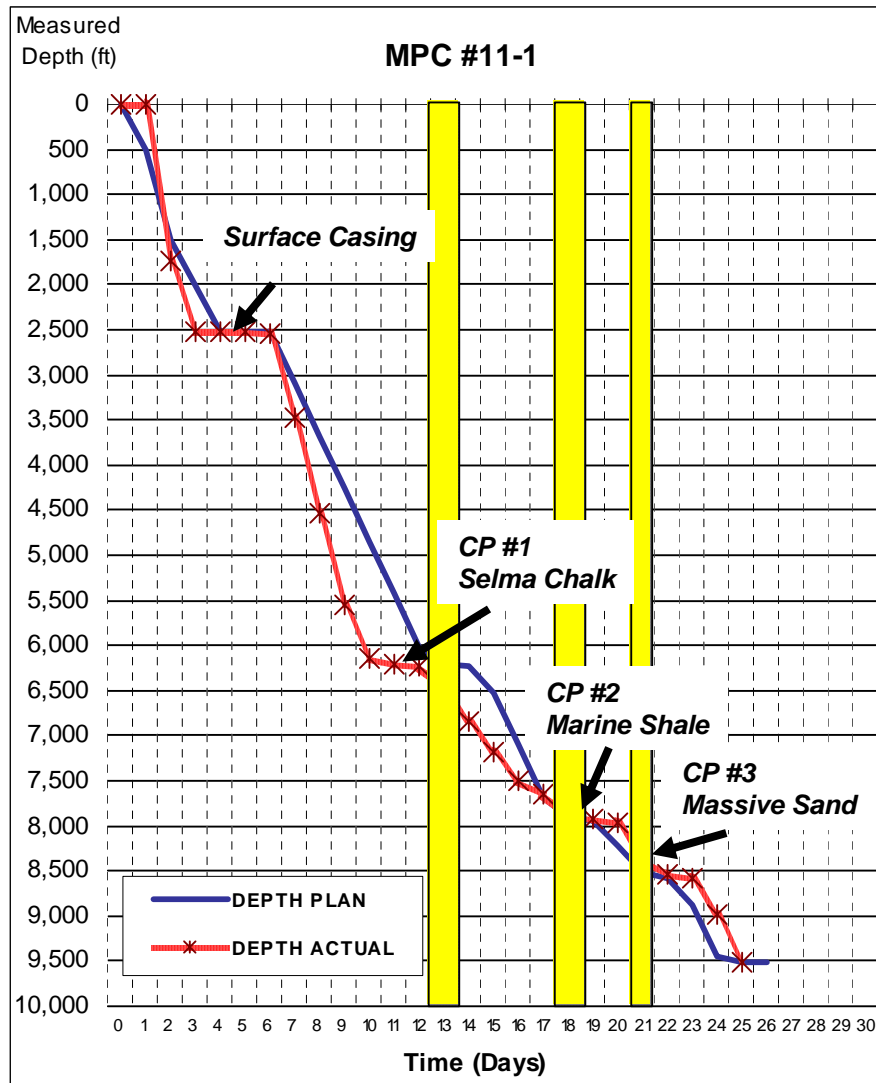
# Surface Location Preparation



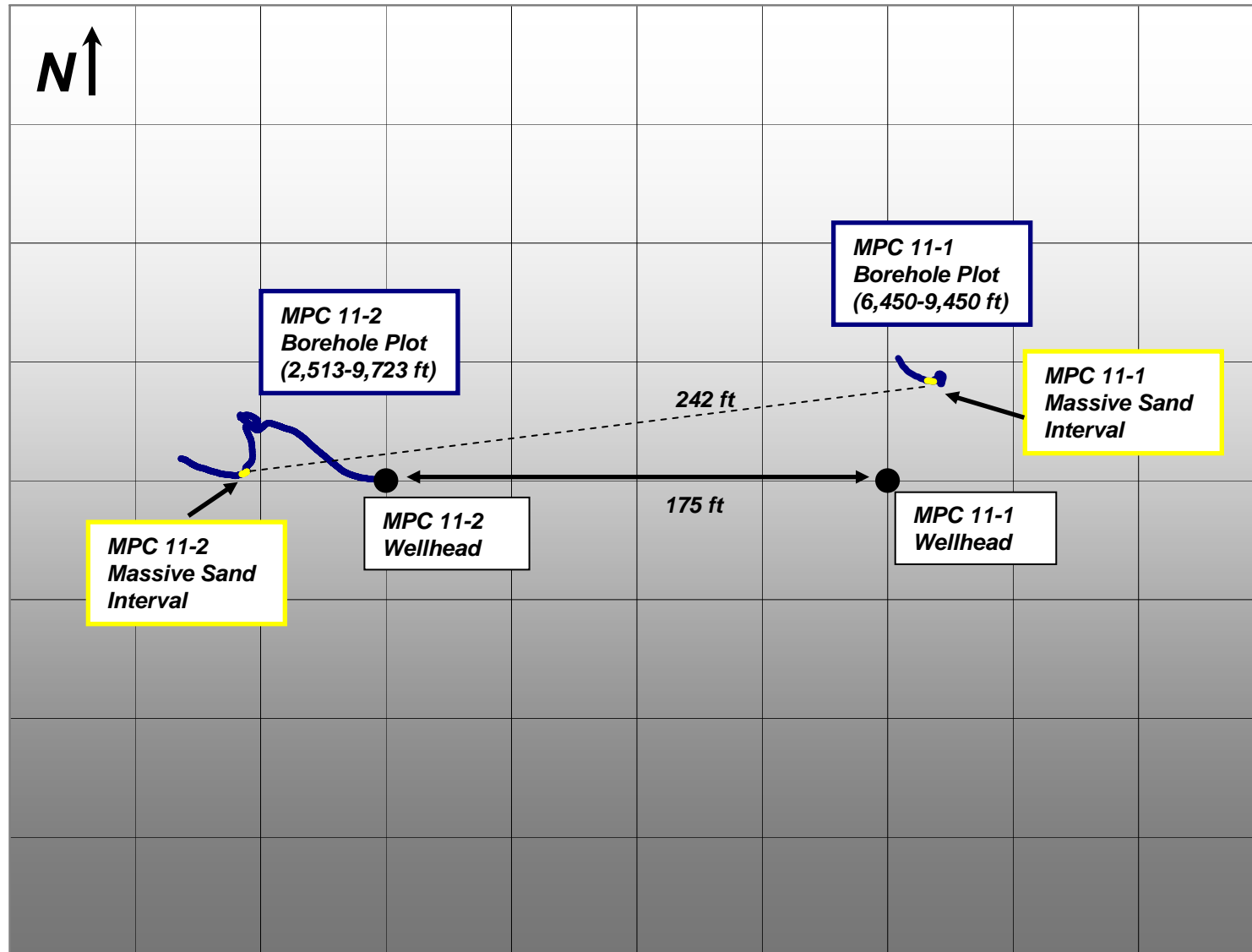
# Well Drilling and Completion



# Well Drilling and Completion

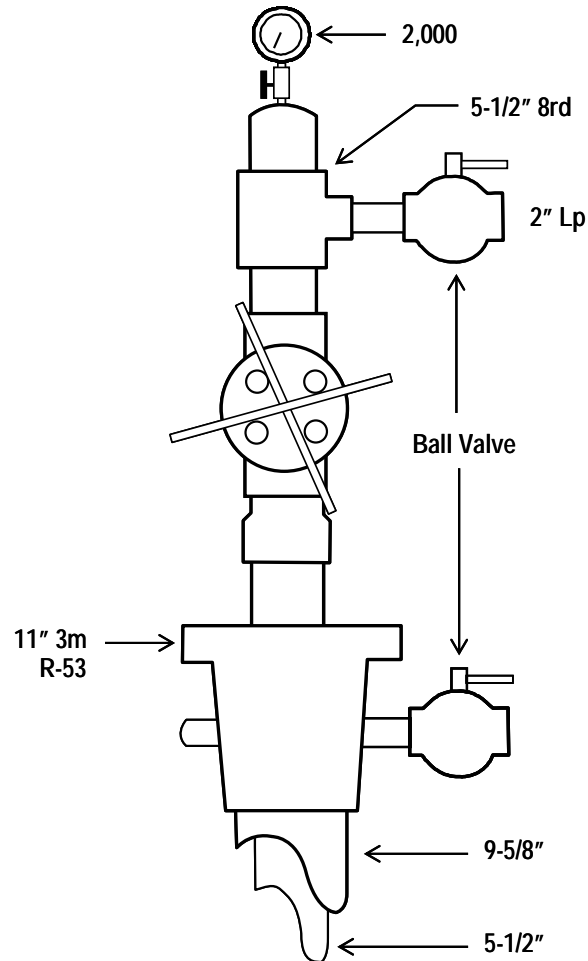


# Well Drilling and Completion



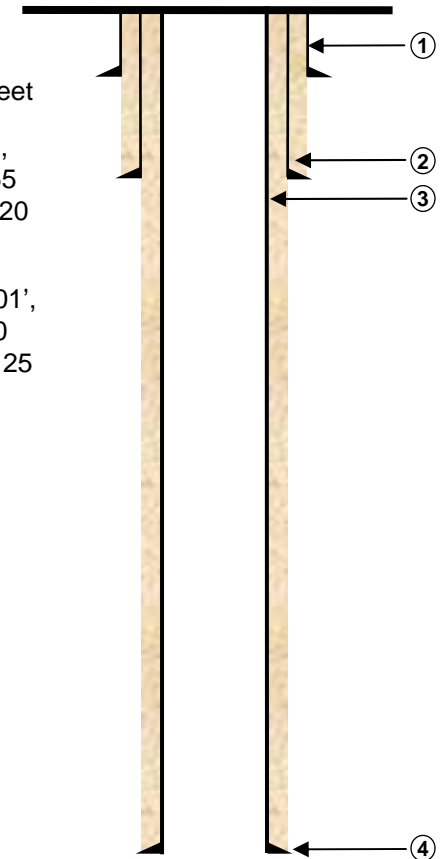
# Observation Wellhead and Observation Well Design

## WELLHEAD ASSEMBLY DETAIL



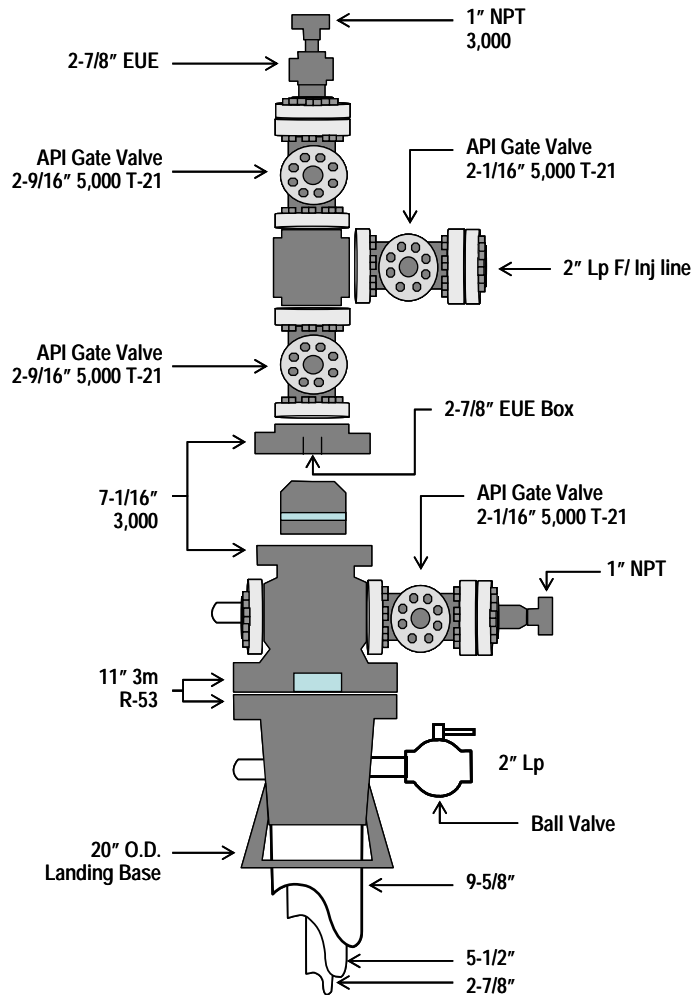
## COMPLETION DETAIL

1. ~16" Conductor Pipe set at 90 feet
2. 9-5/8" Surface Casing @ 2,526', set in 12-1/4" hole; 40.0 lb/ft J-55 STC; Cemented to surface w/ 420 sacks.
3. 5-1/2" Protection Casing @ 9,501', set in 7-7/8" hole; 20.0 lb/ft N-80 LTC; Cemented to 1,300' w/ 1,125 sacks.
4. Total Depth @ 9,500'



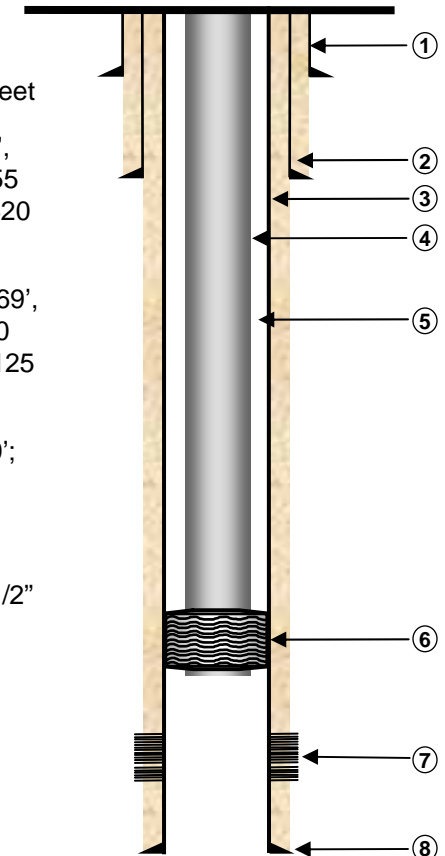
# Injection Wellhead and Injection Well Design

## WELLHEAD ASSEMBLY DETAIL



## COMPLETION DETAIL

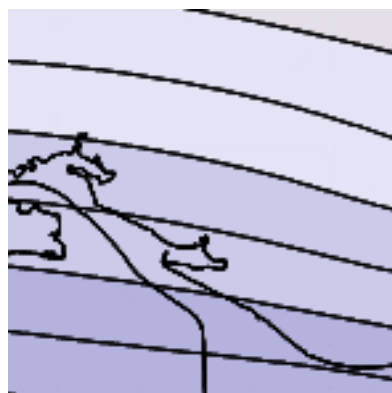
1. ~16" Conductor Pipe set at 90 feet
2. 9-5/8" Surface Casing @ 2,568', set in 12-1/4" hole; 40.0 lb/ft J-55 STC; Cemented to surface w/ 420 sacks.
3. 5-1/2" Protection Casing @ 9,669', set in 7-7/8" hole; 20.0 lb/ft N-80 LTC; Cemented to 1,100' w/ 1,125 sacks.
4. 2-7/8" Injection Tubing @ 8,500'; 6.5 lb/ft J-55 EUE 8rd.
5. Annular Fluid: TBD
6. Injection Packer @ ~8,500'; 5-1/2" x 2-7/8" retrievable production packer.
7. Perforations: TBD
8. Total Depth @ 9,668'



# Key Geologic Horizons

<i>Formation Tops</i>	<i>Depth Feet</i>	<i>Interval Thickness Feet</i>
<i>Bottom of Fresh Water (&lt;1,000 mg/l)</i>	<i>1,400</i>	<i>1,400</i>
<i>Bottom of Potable Water (&lt;10,000 mg/l)</i>	<i>2,200</i>	<i>800</i>
<i>Selma Chalk Group</i>	<i>5,910</i>	<i>1,240</i>
<i>Eutaw Group</i>	<i>-</i>	<i>280</i>
<i>Austin Chalk Formation</i>	<i>7,150</i>	<i>90</i>
<i>Eagle Ford Formation</i>	<i>7,240</i>	<i>190</i>
<i>Tuscaloosa Group</i>	<i>-</i>	<i>1,290</i>
<i>Upper Tuscaloosa Formation</i>	<i>7,430</i>	<i>240</i>
<i>Marine Tuscaloosa Formation</i>	<i>7,670</i>	<i>490</i>
<i>Lower Tuscaloosa Formation</i>	<i>-</i>	<i>560</i>
<i>Interbeds</i>	<i>8,160</i>	<i>350</i>
<i>Massive Sand Member</i>	<i>8,510</i>	<i>210</i>
<i>Lower Cretaceous Group</i>	<i>8,720</i>	<i>-</i>

Thicknesses taken from MPC 11-1



## 3. Reservoir Characterization

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# Observation Well: Reservoir Characterization

A variety of data gathering activities were performed in the observation well to characterize the subsurface, to assure the integrity of the completed well and to prepare for MMV:

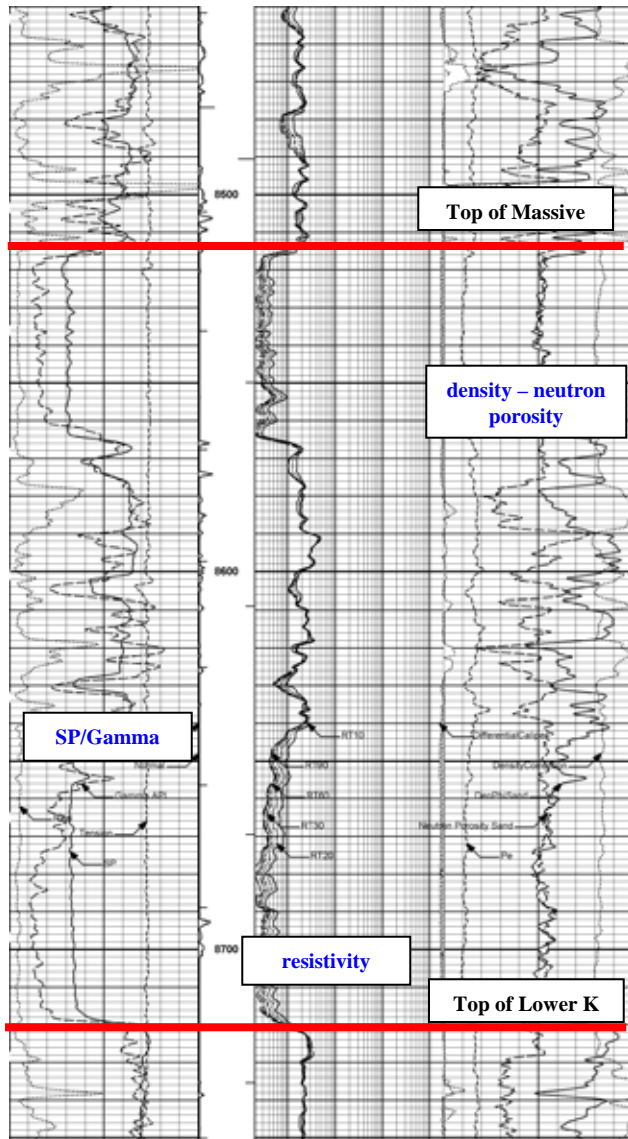
- Mud Logging from 6,000 ft to TD
- Nearly 120 feet of whole core from three formations:
  - Selma (30'/27'), Marine Shale (28'/26'), and Tuscaloosa Massive Sand (60'/58').
- Core analysis will include permeability (horizontal and vertical), porosity, capillary pressure, relative permeability and mineralogy.
- Wireline Logging included:
  - Halliburton's Triple Combo (gamma ray, resistivity, and porosity).
  - Cement Bond Log with Cast V Evaluation
  - Thermal Decay Log for baseline and time-lapse for gas saturation identification
- Vertical Seismic Profiling (VSP) was performed on April 30:
  - Confirm geologic description
  - Provide baseline for CO<sub>2</sub> plume monitoring (time-lapse)

# Injection Well: Reservoir Characterization

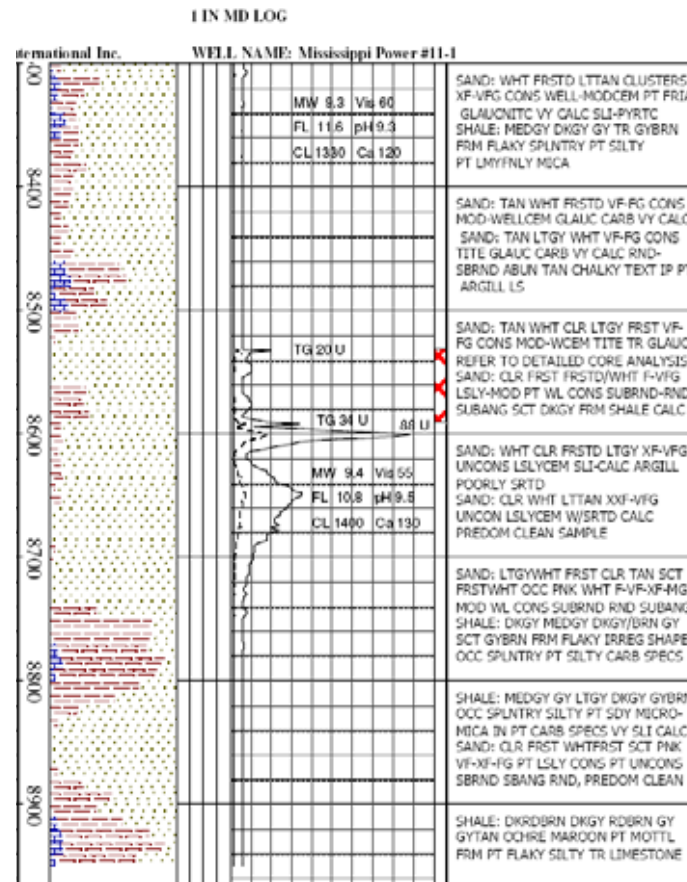
Additional geologic characterization and well integrity activities were conducted in the injection well:

- Wireline Logging included:
  - Schlumberger's Platform Express Log
  - Thermal Decay Log
  - Mechanical Properties Log
  - Combinable Magnetic Resonance
  - Elemental Capture Spectroscopy
  - Cement Bond Log with Cast V Evaluation
- Sidewall coring of the Marine Shale, Massive Sand and Washita-Fredericksburg formations
- Water sampling.
- 2-Day pressure transient testing scheduled for mid-June.
- Completion of the MIT in mid-June.

# Observation Well: Logs and Core



Open-Hole Logging of MPC 11-1

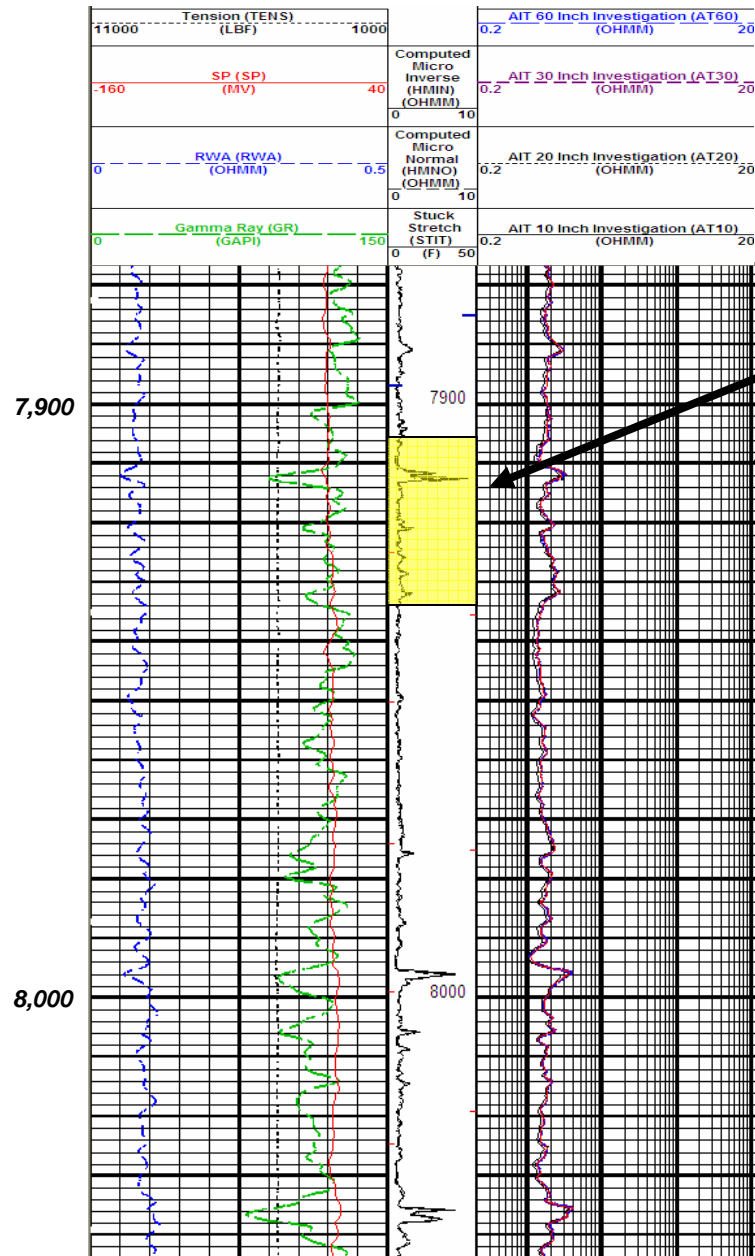


Marine Shale Whole Core MPC 11-1

Mud Log of the Lower Tuscaloosa Massive Sand, MPC 11-1

# Evaluating the Tuscaloosa Marine Shale Caprock

- 28 ft whole-core sample was taken from MPC 11-1 (~26' recovery)
- Six sidewall cores were taken in MPC 11-2
- Core analysis is currently underway, including permeability, porosity, capillary pressure



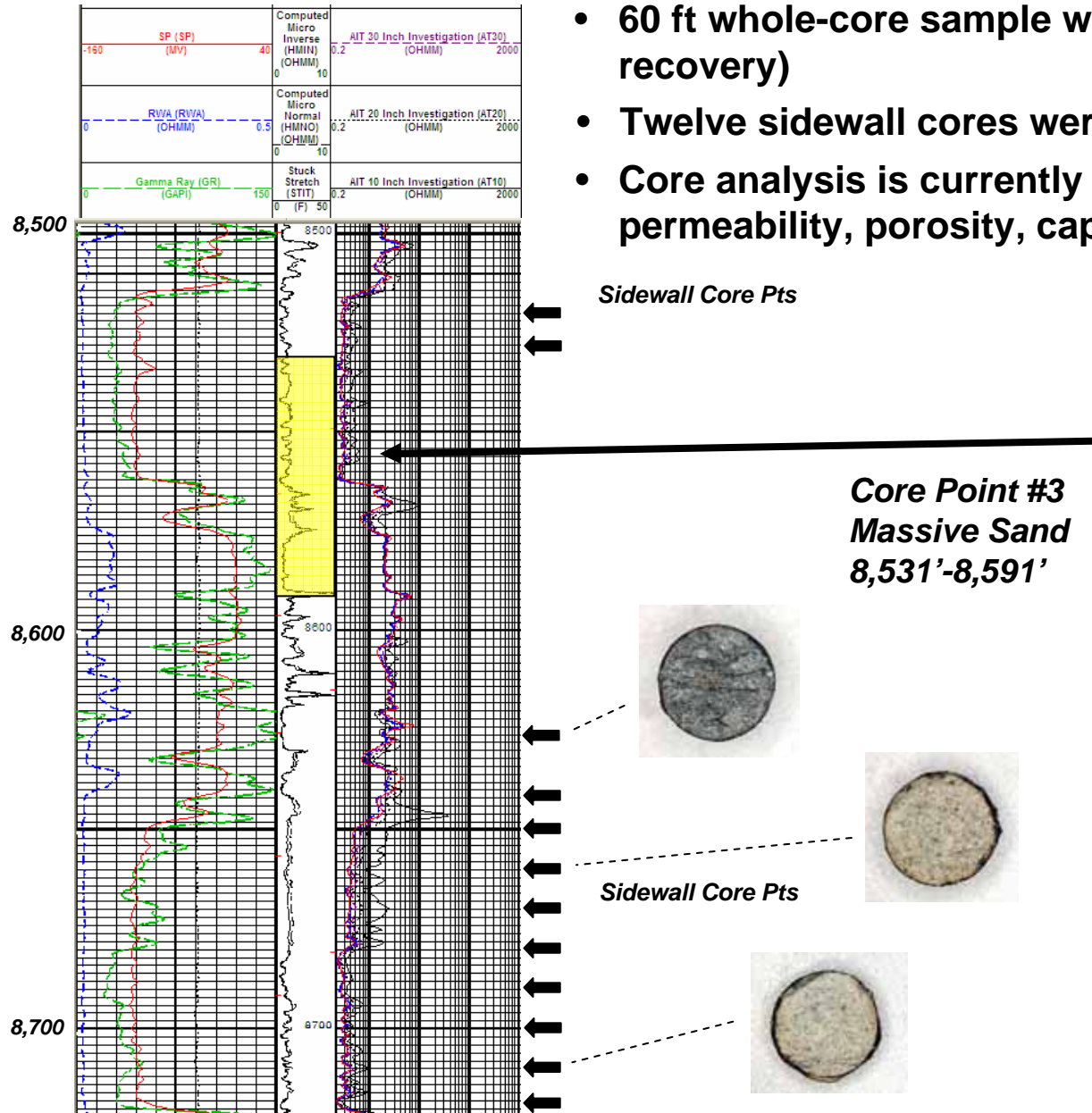
**Core Point #2  
Marine Tuscaloosa  
7,906'-7,934'**

**Sidewall Core Pts**



# Evaluating the Lower Tusc. Massive Sand Storage Formation

- 60 ft whole-core sample was taken from MPC 11-1 (~57' recovery)
- Twelve sidewall cores were taken in MPC 11-2
- Core analysis is currently underway, including permeability, porosity, capillary pressure



# Preliminary Massive Sand Core Analysis Results (Lower Tuscaloosa Massive Sand Storage Formation)

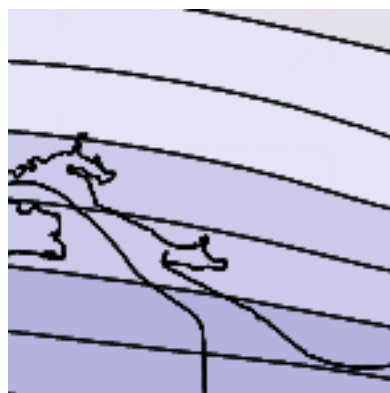
Core Number	Sample Number	Sample Depth, (ft)	Pemeability millidarcys,		Porosity, percent		Grain Density, gm/cc
			to Air	Klinkenberg	Ambient	2500 psi	
3	3-1	8531.45	1450.	1380.	22.7	22.4	2.65
3	3-5	8535.50	2390.	2300.	24.5	24.2	2.64
3	3-9	8539.50	1930.	1850.	24.1	23.8	2.65
3	3-13	8543.45	652.	614.	19.7	19.4	2.67
3	3-17	8547.50	1460.	1400.	23.8	23.5	2.65
3	3-21	8551.50	936.	888.	23.2	22.9	2.65
3	3-25	8555.50	848.	804.	22.8	22.5	2.66
3	3-29	8559.50	1030.	977.	24.4	24.1	2.65
3	3-33	8563.50	641.	603.	23.4	23.1	2.65
3	3-37	8567.50	3390.	3280.	25.3	25.0	2.65
3	3-41	8571.40	0.0082	0.0028	7.8	7.5	2.71
3	3-45	8575.50	7.16	5.63	17.9	17.6	2.68
3	3-49	8579.50		+	9.1		2.75
<b>Average values:</b>			<b>1230.</b>	<b>1180.</b>	<b>20.7</b>	<b>21.3</b>	<b>2.66</b>

+ Indicates the sample is unsuitable for this type of measurement

# Preliminary Sidewall Core Analysis Results

In. Rec.	Sample Depth Feet	Permeability mD	Porosity %
<b>Lower Tuscaloosa Marine Shale</b>			
0.0	7910.0		
1.7	7920.0	<0.1	8.2
1.4	7930.0	<0.1	9.2
1.4	7976.0	<0.1	8.8
0.0	7986.0		
1.5	7996.0	<0.1	8.3
<b>Lower Tuscaloosa Interbeds</b>			
0.9	8500.0	5.1	17.4
1.6	8510.0	<0.1	9.6
0.8	8520.0	420.0	20.3
0.9	8530.0	800.0	22.9
<b>Massive Sand Interlobe</b>			
1.0	8630.0	3.8	16.5
0.8	8642.0	9.5	18.6

In. Rec.	Sample Depth Feet	Permeability mD	Porosity %
<b>Massive Sand Lower Lobe</b>			
0.8	8650.0	450.0	23.2
1.1	8660.0	550.0	23.4
0.8	8670.0	300.0	22.5
1.1	8680.0	900.0	23.3
0.6	8690.0	980.0	24.0
0.6	8700.0	175.0	19.3
0.9	8710.0	660.0	22.9
1.0	8720.0	600.0	21.6
<b>Lower Cretaceous</b>			
0.9	8820.0	3.0	17.5
0.5	8830.0	56.0	20.0
1.5	8840.0	1000.0	23.1
1.0	8850.0	950.0	22.8
0.0	8860.0		
1.0	9010.0	525.0	22.4
1.0	9020.0	1050.0	22.1
1.1	9030.0	775.0	22.9
1.0	9040.0	580.0	23.1
1.2	9050.0	1050.0	24.4



## 4. CO2 Injection Operations

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# Surface Equipment

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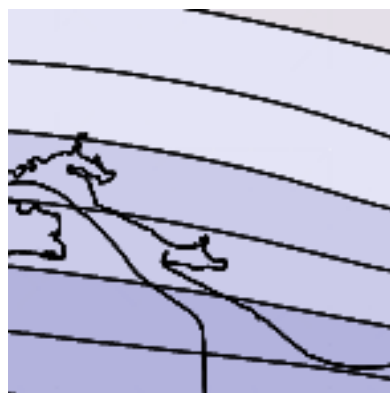
- After completion of the well, surface equipment will include the wellhead assembly and:
  - CO<sub>2</sub> storage tanks
  - In-line heater
  - CO<sub>2</sub> pump
  - Automated operations data collection system (pressures and rates)
- Advanced Resources is currently planning to begin CO<sub>2</sub> injection operations in October of 2008. This will allow adequate time to analyze the data collected and conduct detailed modeling studies incorporating the new newly collected reservoir data.

# CO<sub>2</sub> Supply and Injection

In October 2008, approximately 3,000 tons of CO<sub>2</sub> will be injected at a rate of 100 tons (1.72 MMcf) per day for 30 days.

- CO<sub>2</sub> supply will be from Denbury's CO<sub>2</sub> pipeline outlet in central Mississippi.
- A to be determined provider will deliver the CO<sub>2</sub> to the plant site; anticipate 4 to 6 trucks of liquid CO<sub>2</sub> per day.
- CO<sub>2</sub> will be stored on-site, heated and pumped into the formation.

After completion of CO<sub>2</sub> injection, a slug of N<sub>2</sub> may be used to drive the CO<sub>2</sub> into the formation.



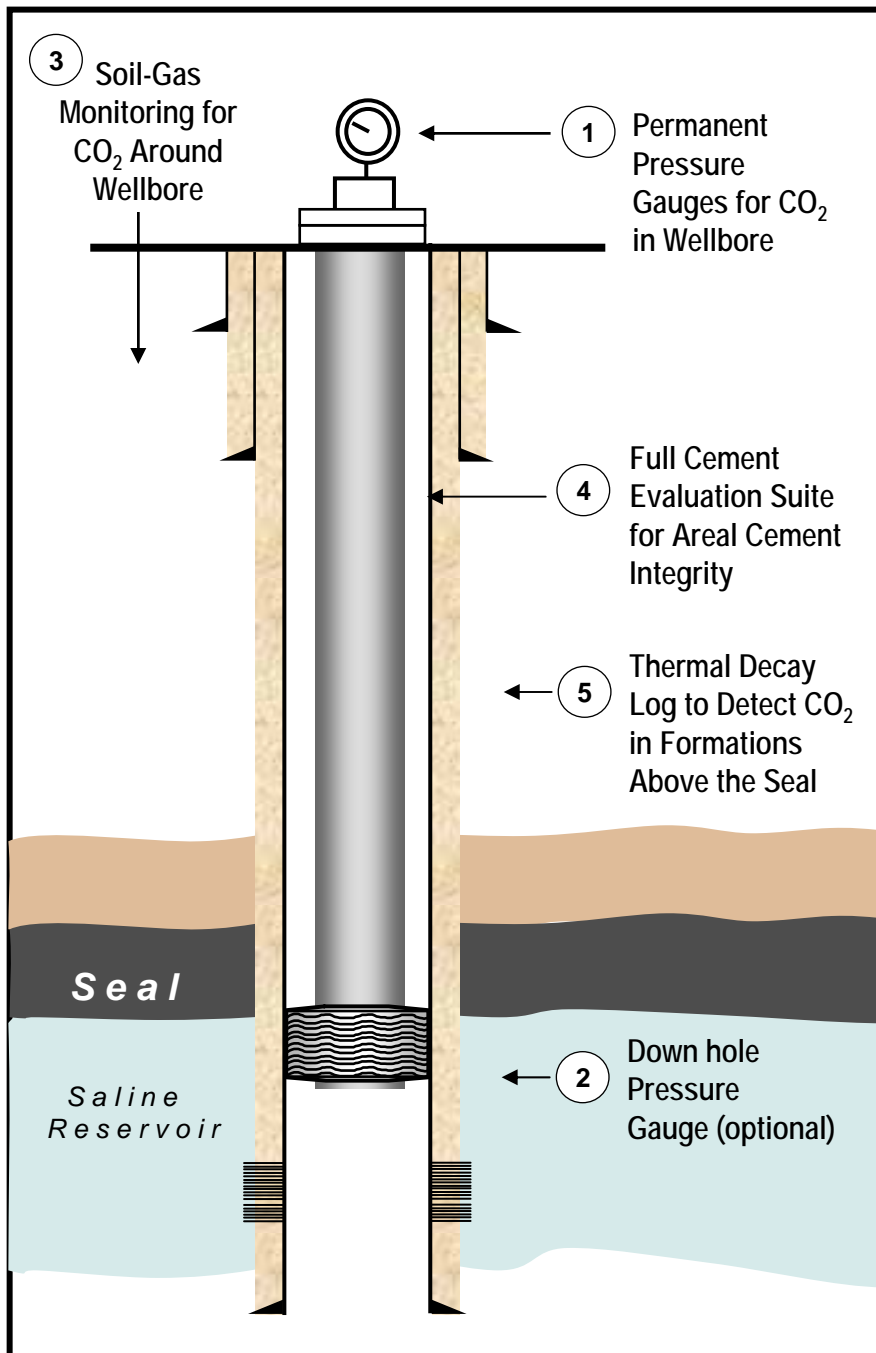
## 5. Monitoring, Measurement and Verification (MMV)

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# Well Integrity and Pressure Monitoring

The project will include a series of MMV activities to assure well integrity:

- To assure well integrity at the surface, we will: (1) install a pressure gauge on the wellhead to measure sustained casing pressure (CO<sub>2</sub> leakage in the well); (2) conduct continuous monitoring of annular and down hole pressure (optional); and, (3) conduct near-surface soil gas measurements.
- To assure downhole well integrity, we will: conduct (4) Cement bond evaluation both after cementing and after CO<sub>2</sub> injection; and, (5) run a series of Thermal Decay Logs to detect any CO<sub>2</sub> above the reservoir seal.



# CO<sub>2</sub> Plume Monitoring

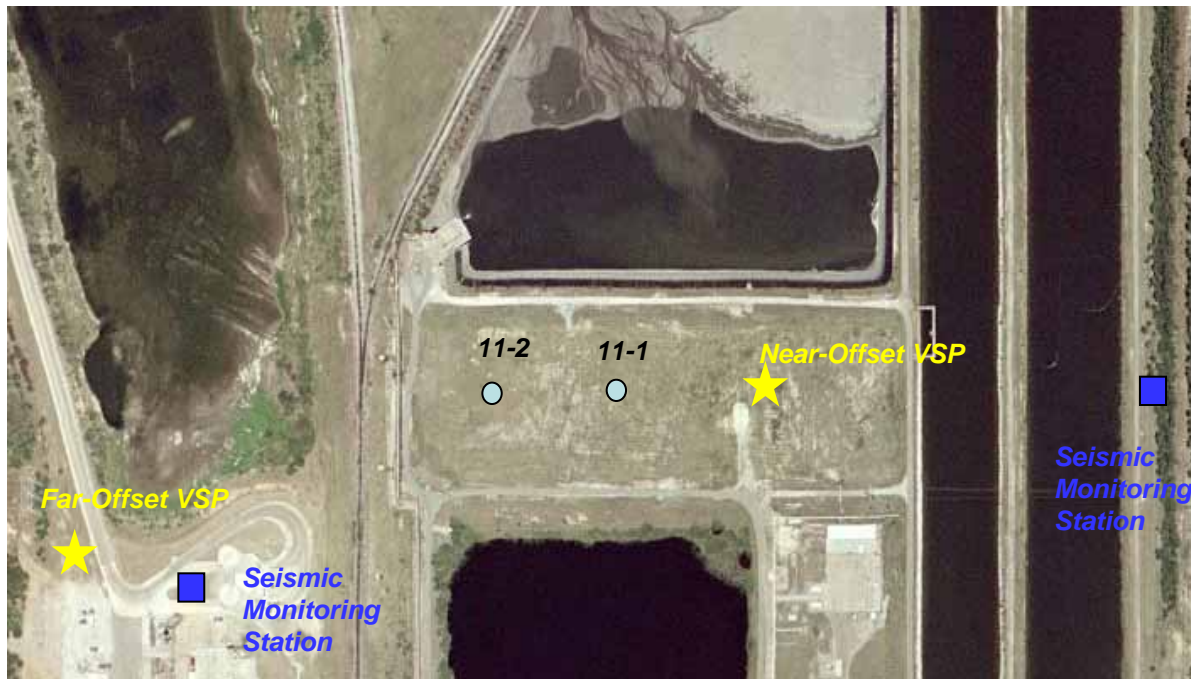
To monitor the flow and storage of CO<sub>2</sub> in the saline reservoir, we will use well logs, seismic and other tools:

- For monitoring the areal profile of the CO<sub>2</sub> plume, we will use time-lapse Vertical Seismic Profiles (VSP) before CO<sub>2</sub> injection and about 3 months after CO<sub>2</sub> injection.
- For monitoring the vertical profile of the CO<sub>2</sub> plume, we will use: (1) a time lapse series of thermal decay logs (in both wells) and (2) also use time-lapse VSP.



# Baseline VSP Deployment

- A baseline Vertical Seismic Profile (VSP) was collected in April
- A four-level geophone string was deployed in the observation well (11-1)
- Two seismic sources were utilized, at near and far offset locations
- Two locations were monitored by staff from Vibra-Tech for potentially damaging vibrations and noise







# Near-Surface Monitoring

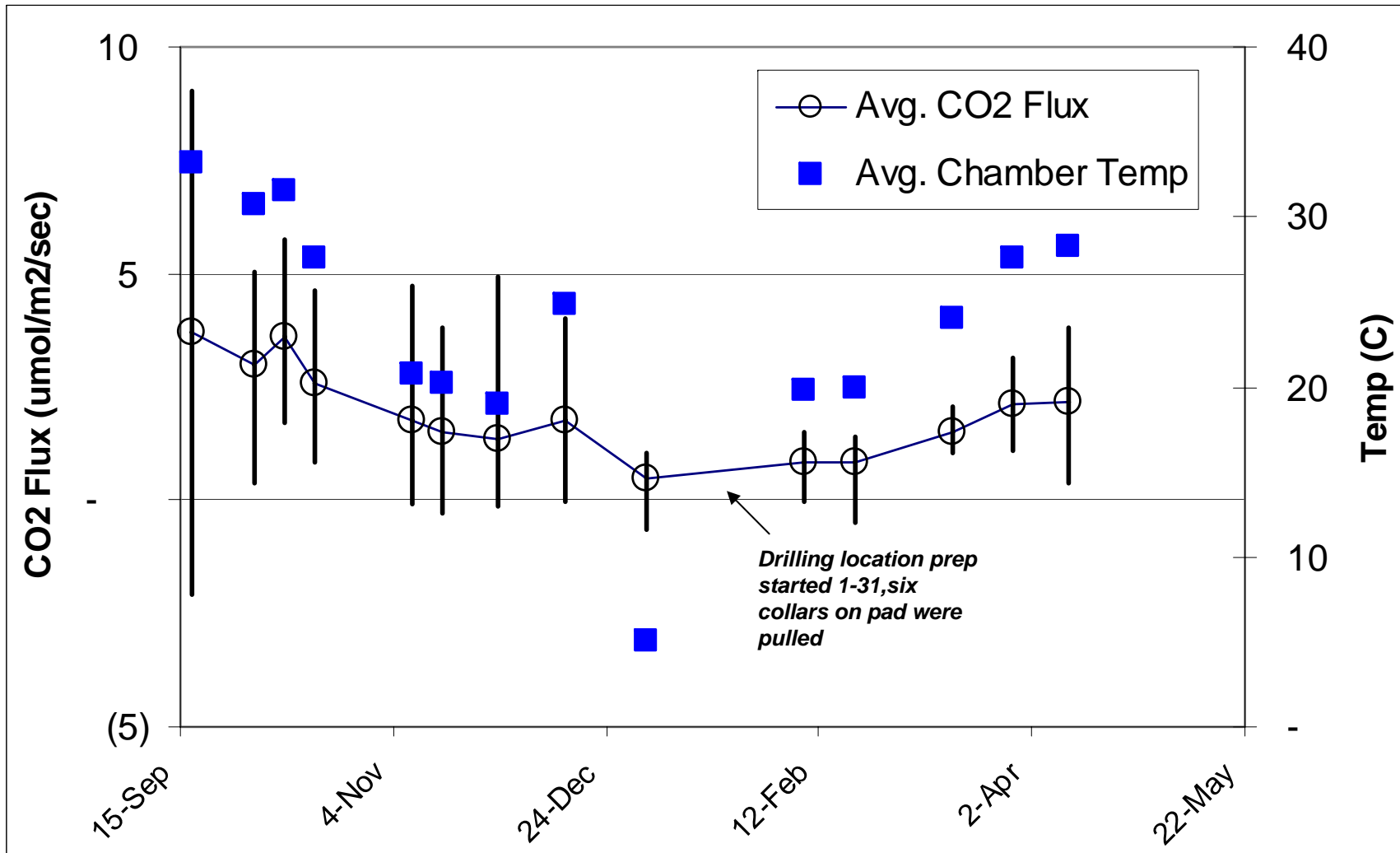
- **Soil Flux.** An automated real-time monitoring system will be used to determine surface soil CO<sub>2</sub> flux.
- **Tracer Injection with CO<sub>2</sub>.** Perfluorocarbon Tracers (PFT's) will be added at the wellhead and used to tag and track injected CO<sub>2</sub>. Surface sweep monitoring using Praxair's SeeperTrace™ sample collection will be performed.
- **CO<sub>2</sub> Isotopes.** Isotopic sampling of surface CO<sub>2</sub> will be conducted using shallow (1 meter) boreholes.
- **Water Sampling.** Shallow water wells will be sampled on a quarterly basis for pH, salinity, metals, alkalinity, conductivity and temperature.
- **Base-line Monitoring.** Monitoring will be performed before, during, and after injection CO<sub>2</sub> injection for all MMV protocols.

# Soil CO<sub>2</sub> Flux Monitoring Stations



-  Permanent soil monitoring stations
-  Near-well soil monitoring stations (will be affected by drilling/injection operations)
-  Soil monitoring stations within the drilling footprint (may be affected by drilling/injection operations)
-  Control soil monitoring stations

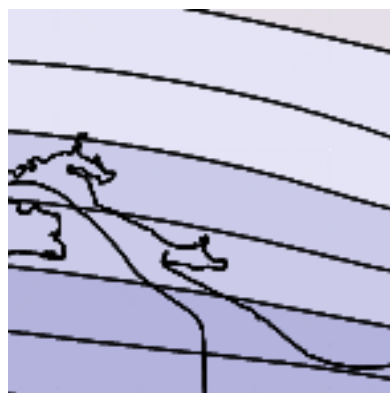
# Soil Flux Baseline Monitoring



# Deep Water Well Baseline Chemistry (Plant Daniel)

Analyte	Well #1	Well #2	Units
<b>Classical Chemistry Parameters</b>			
Bicarbonate Alkalinity	353	355	mg/L
Chloride	18	17	mg/L
Specific Conductance (EC)	651	657	umhos/cm
Silica (SiO <sub>2</sub> )	18.2	18.0	mg/L
Sulfate as SO <sub>4</sub>	4.07	2.80	mg/L
<b>Metals</b>			
Aluminum	0.050	ND	mg/L
Calcium	0.757	0.649	mg/L
Iron	ND	ND	mg/L
Magnesium	0.110	0.089	mg/L
Potassium	0.551	0.496	mg/L
Sodium	174	174	
<b>Field Test</b>			
pH	9.03	9.15	pH Units
Temperature	70.0	70.0	°F

ND = Not Detected



## 6. Project Schedule/Next Steps

# Proposed Project Schedule

	2005	2006	2007	2008	2009
<b>Task 1. PROJECT DEFINITION</b>					
<b>Task 2. PROJECT DESIGN</b> <ul style="list-style-type: none"> <li>• Test Site Plan</li> <li>• Establish MMV Protocols</li> <li>• Regulatory/Permitting</li> <li>• CO<sub>2</sub> Supply</li> </ul>		   			
<b>Task 3. IMPLEMENTATION</b> <ul style="list-style-type: none"> <li>• Observation Well Plan</li> <li>• MMV Baseline</li> <li>• Drill/Test Observation Well</li> </ul>			   		
<b>Task 4. OPERATIONS</b> <ul style="list-style-type: none"> <li>• Injection Well Site Plan</li> <li>• Drill/Equip Injection Well</li> <li>• Operations and MMV</li> <li>• Geologic/Reservoir Model</li> </ul>		 	  		
<b>Task 5. CLOSE /REPORT</b>					

▲ Key Decision Milestones

## Next Steps (2008)

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- Complete Core Analysis Laboratory Work (May)
- Complete VSP processing (May)
- Update Reservoir Modeling Work (May/June)
- Water Sampling, Pressure Transient Testing & MIT Testing in the Injection Well (June)
- Rig Up Injection Site and Test Equipment (late September)
- Begin Injection (October)
- Quick-look Report (October)
- Periodic Pulsed Neutron Logging (October)
- Revisit Reservoir Modeling Work (November/December)
- Time-lapse VSP (December)