

**WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP**  
[westcarb.org](http://westcarb.org)



# WESTCARB Annual Business Meeting

## WESTCARB Phase II Northern Arizona Saline Formation CO<sub>2</sub> Storage Pilot Test Overview

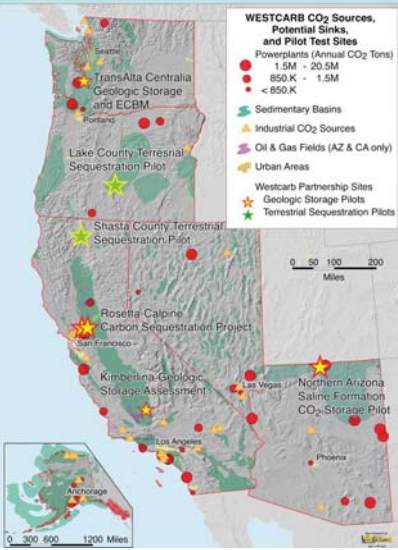
**Sally Benson**  
Lawrence Berkeley National Laboratory  
[smbenson@lbl.gov](mailto:smbenson@lbl.gov)

Phoenix, AZ  
November 8, 2006



## WESTCARB Northern Arizona Geologic Storage Pilot Test

- Large CO<sub>2</sub> sources in the region
  - 4 large coal-fired power plants
  - 20-30 Mt CO<sub>2</sub> per year
  - Additional capacity anticipated
- Focus on siting for future power plants



**WESTCARB CO<sub>2</sub> Sources, Potential Sinks, and Pilot Test Sites**

Powerplants (Annual CO<sub>2</sub> Tons)

- 1.5M - 20.5M
- 850 K - 1.5M
- < 850 K

Sedimentary Basins

Industrial CO<sub>2</sub> Sources

Oil & Gas Fields (AZ & CA only)

Urban Areas


Westcarb Partnership Sites

- Geologic Storage Pilots
- Terrestrial Sequestration Pilots

0 50 100 200 Miles

0 300 600 1200 Miles

**WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP**



## Phased Approach to the Pilot Test

- Phase I: Pre-pilot planning, geologic characterization and outreach
- Phase II: Characterization, detailed pilot project planning and permitting
- Phase III: CO<sub>2</sub> injection, monitoring and storage assessment

Storage  
Options

Site  
Assessment

Injection and  
Monitoring



## Schedule

		FY06		FY07		FY08		FY09	
Phase I									
Phase II									
Phase III									



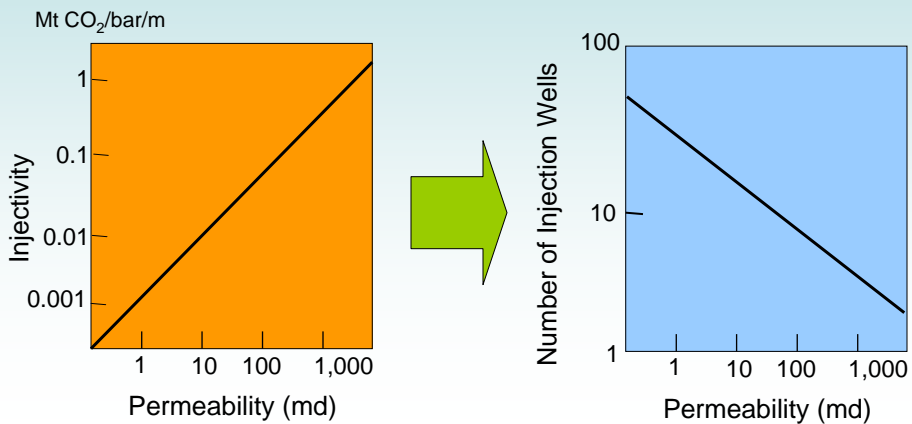
## Phase I: Siting Considerations

- Formation permeability
  - Effect on injectivity
  - Effect on capacity
- Depth of storage formation
  - Influence of storage depth on capacity
  - Influence of a deep water table on capacity

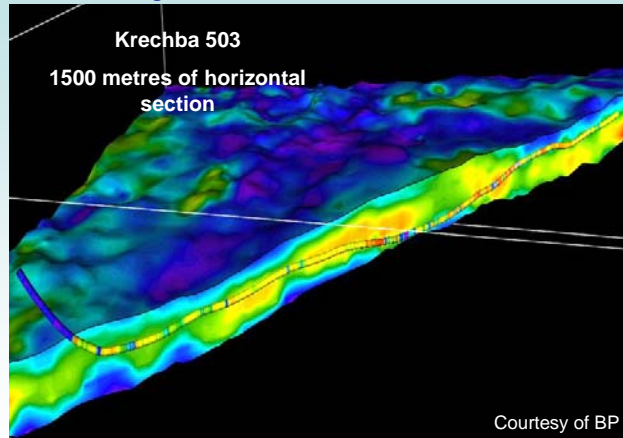


## Effect of Permeability on Injectivity: Lower Permeability Rocks Have Lower Injectivity

$$\text{Injectivity} = \text{Injection Rate} / \text{Pressure Buildup} / \text{Thickness}$$



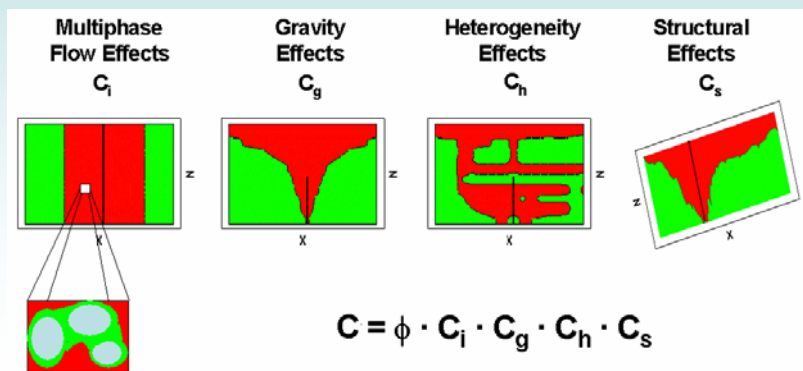
## Adequate Injectivity in Low Permeability Formations Can Be Obtained Using Horizontal Injection Wells



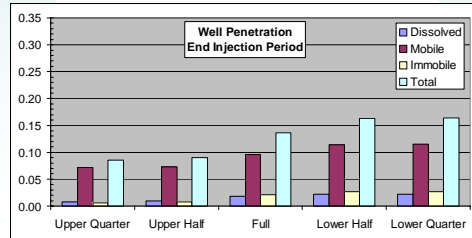
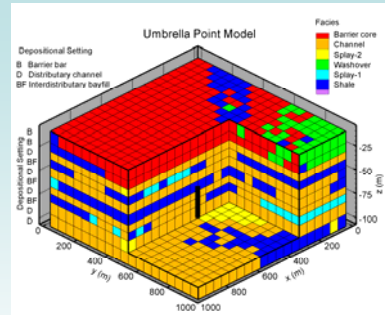
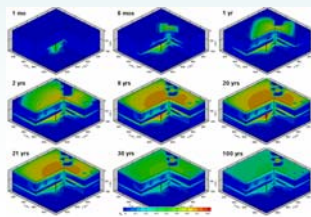
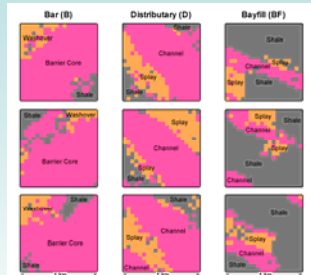
Horizontal Wells at the In Salah Field, Algeria Result in 10-fold Increase in Injectivity



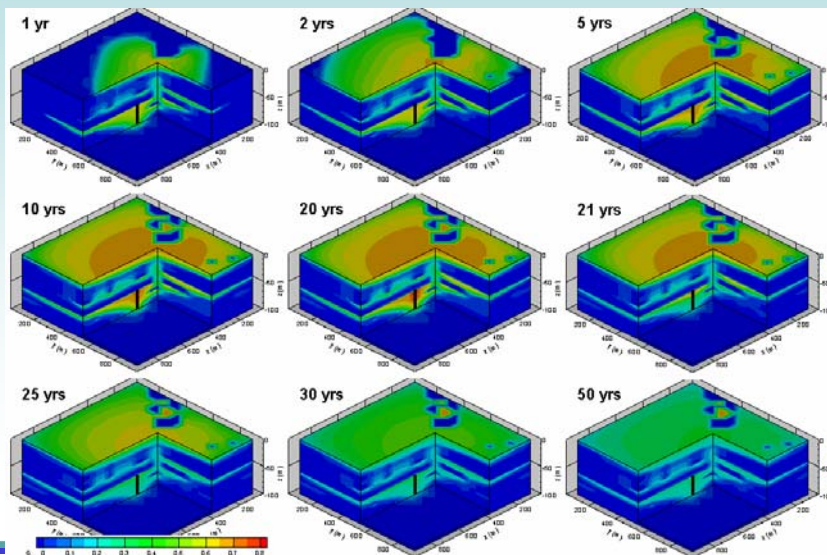
## Some Factors Controlling the Capacity of Storage Reservoirs

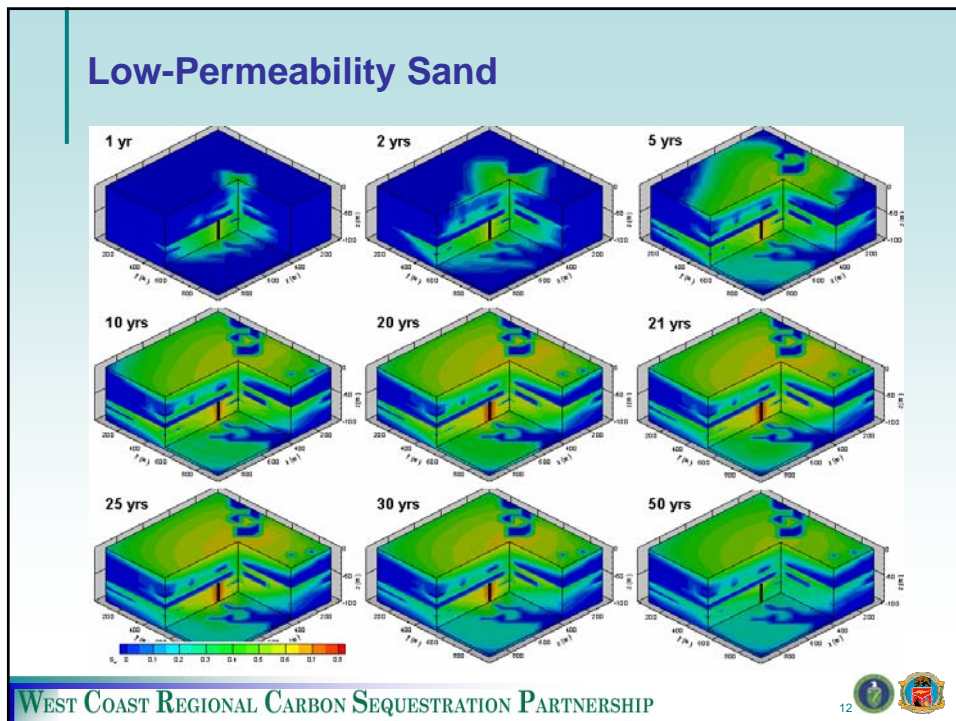
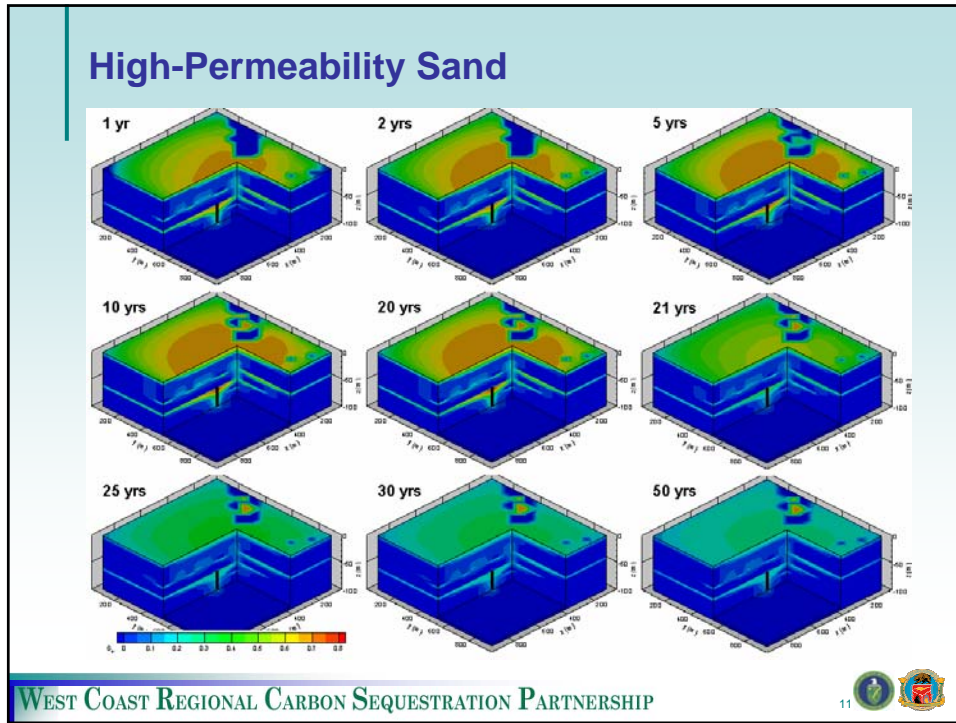


## Approach

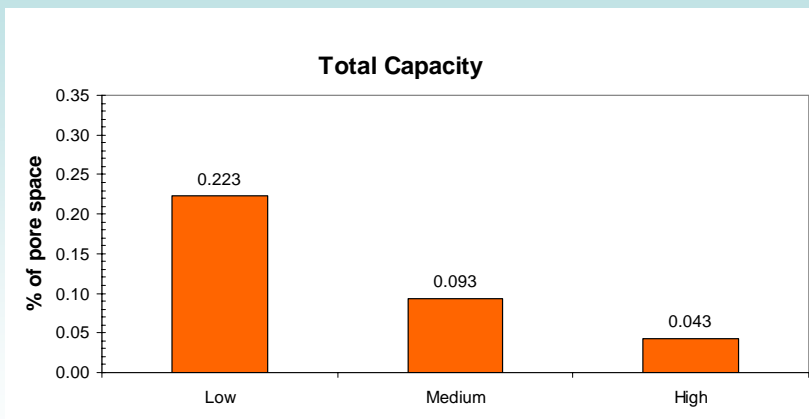


## Moderate Permeability



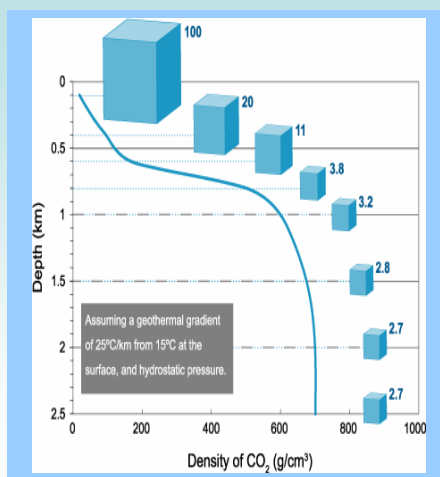


## Effect of Permeability on Storage Capacity



*Lower permeability rocks may have higher capacity*

## Effect of Storage Reservoir Depth on Capacity



*Storage capacity increases with depth because the density of CO<sub>2</sub> becomes greater.*

## Phase II: Detailed Site Characterization

- Drill a single well
  - Geologic logs
  - Geophysical logs
  - Short term permeability tests of promising injection zones
- Assess most promising options for CO<sub>2</sub> storage test
- Assess regional storage potential

```

            graph TD
            A[Flow Modeling] --> B[Geophysical Modeling]
            B --> C[Test Plan]
            B --> A
            
```

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP 15

## Phase III: CO<sub>2</sub> Injection, Monitoring and Storage Assessment


- CO<sub>2</sub> Injection
  - ~2,000 tonnes
  - Manufactured or natural source
- Seal integrity assessment
- Injectivity assessment
- Capacity assessment

The diagram shows a cross-section of the ground with an elevation scale from 5,000 feet to -5,000 feet. An injection well is shown extending from the surface down to approximately -3,500 feet. A CO<sub>2</sub> plume is depicted as a yellow area spreading from the wellhead. Three component seismic receivers are located at various depths around the well. A truck and a train are shown at the surface near the wellhead.

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP 16

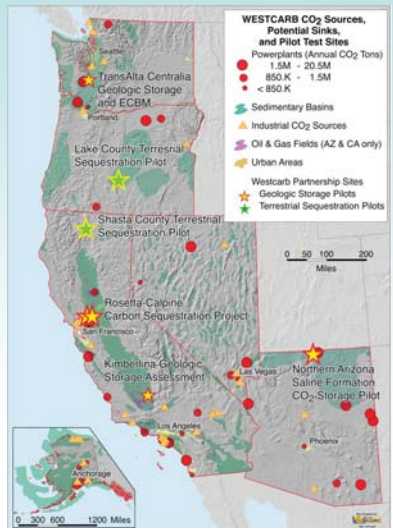
### Phase III: Monitoring

Measurement technique	Measurement parameters	Application
Fluid composition	CO <sub>2</sub> & natural gas composition Brine salinity, alkalinity, pH and composition	Predict solubility and mineral trapping Quantifying CO <sub>2</sub> -water-rock interactions
Subsurface pressure	Reservoir pressure Overlying reservoir pressure Annulus pressure Groundwater aquifer pressure	Control of formation pressure below fracture gradient Wellbore and injection tubing condition Leakage out of the storage formation
Well logs	Gamma, SP, resistivity Brine salinity Sonic velocity CO <sub>2</sub> saturation (RST)	Lithology Tracking CO <sub>2</sub> movement in and above storage formation Tracking migration of brine into shallow aquifers Calibrating seismic velocities for VSP surveys
Vertical seismic profiling	P and S wave velocity Reflection horizons Seismic amplitude attenuation	Detecting detailed distribution of CO <sub>2</sub> in the storage formation Detection leakage through faults and fractures
Cap rock integrity (if feasible)	Leakoff test, pressure drop across seal	Natural stress state, maximum injection pressure
CO <sub>2</sub> land surface flux monitoring using flux chambers and eddy covariance	CO <sub>2</sub> fluxes between the land surface and atmosphere	Detect, locate and quantify CO <sub>2</sub> releases
Soil gas sampling	Soil gas composition Isotopic analysis of CO <sub>2</sub>	Detect elevated levels of CO <sub>2</sub> Identify source of elevated soil gas CO <sub>2</sub>

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP 17 

### Benefits to the Region

- Large and growing CO<sub>2</sub> sources
- Favorable geology for geological storage
- Assessment of CO<sub>2</sub> storage potential
  - Seal integrity
  - Injectivity
  - Capacity



**WESTCARB CO<sub>2</sub> Sources, Potential Sinks, and Pilot Test Sites**  
Powerplants (Annual CO<sub>2</sub> Tons)  
1.5M - 20.5M  
850 K - 1.5M  
< 850 K  
Sedimentary Basins  
Industrial CO<sub>2</sub> Sources  
Oil & Gas Fields (AZ & CA only)  
Urban Areas  
Westcarb Partnership Sites  
Geologic Storage Pilots  
Terrestrial Sequestration Pilots

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP 18 