WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP
westcarb.org

Arizona Utilities CO_2 Storage Pilot

Regional Carbon Sequestration Partnerships Initiative Review Meeting

Pittsburgh, Pennsylvania
October 7, 2008

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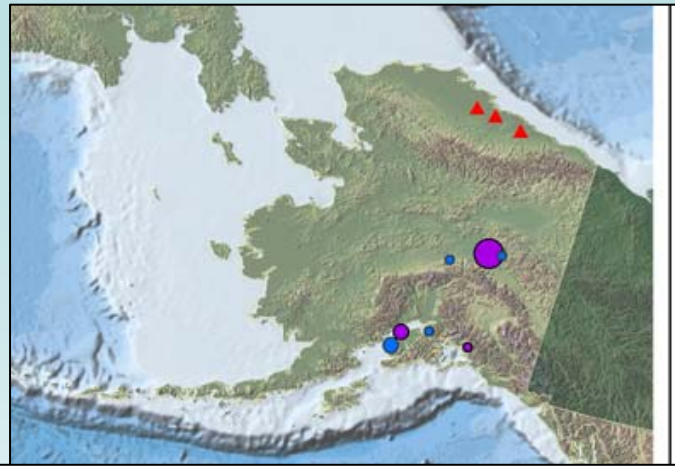
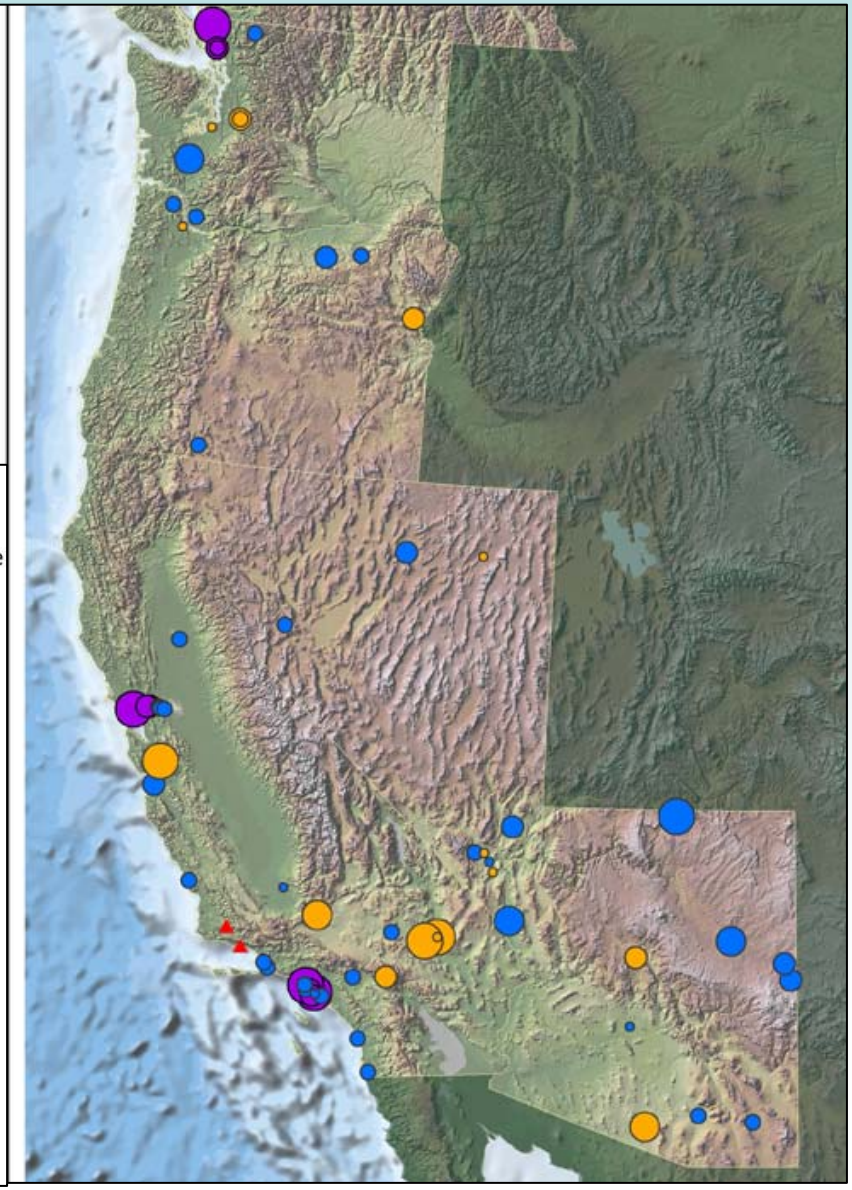
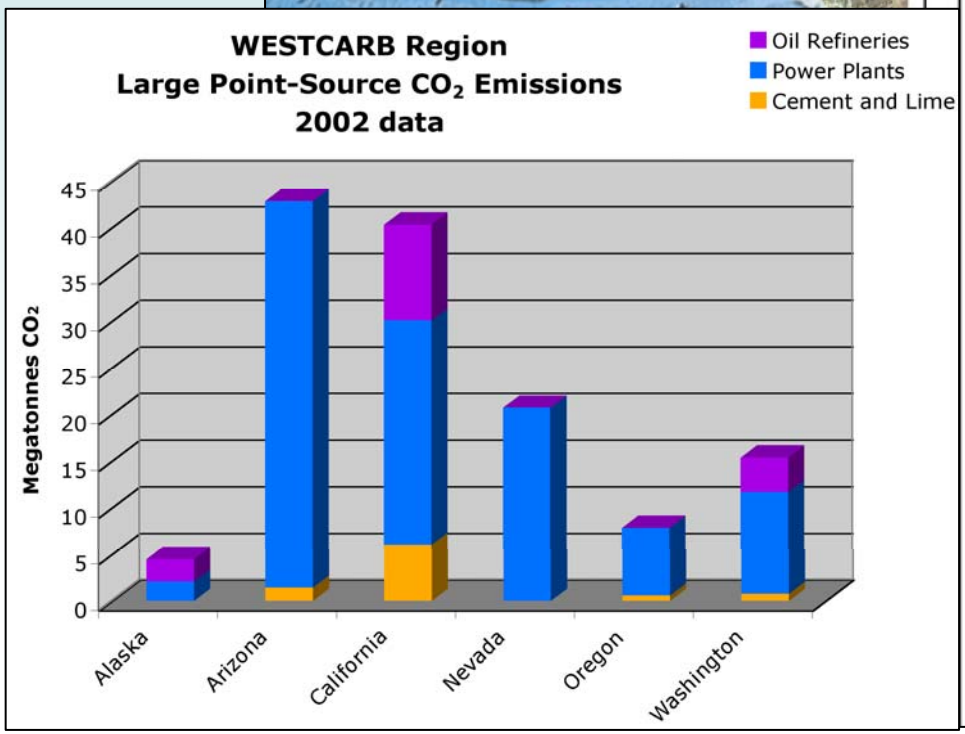
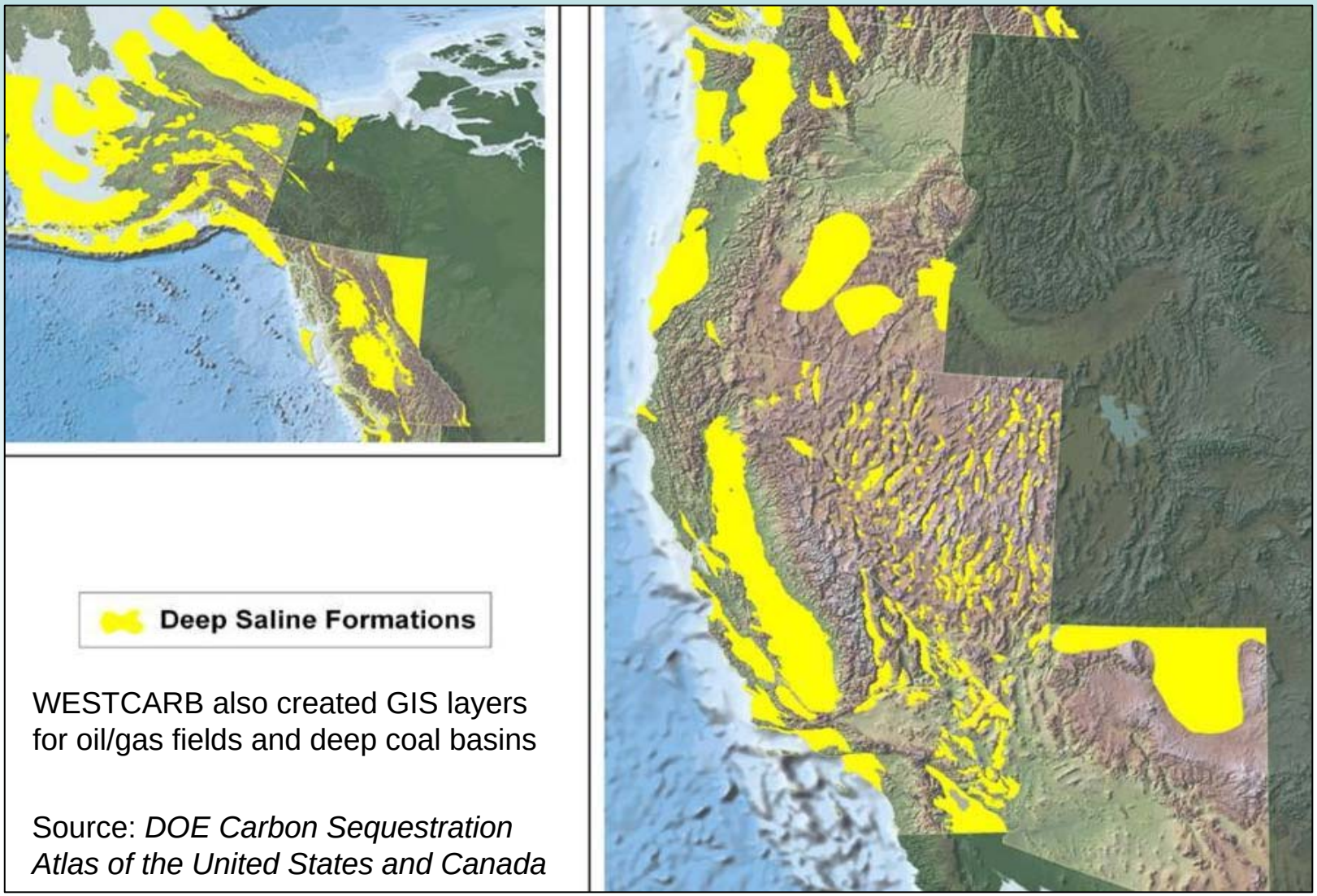
WESTCARB region has major CO_2 point sources







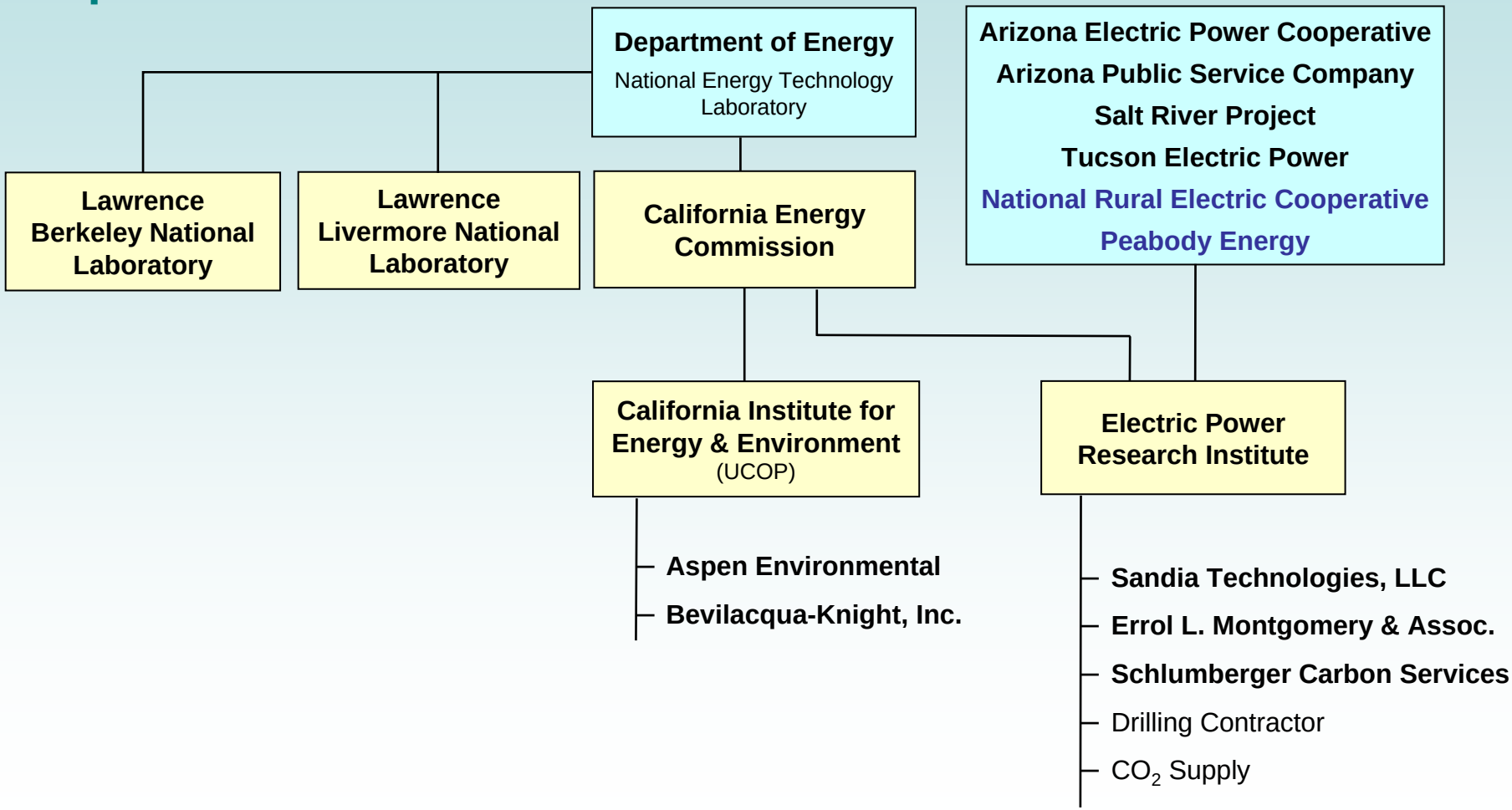
WESTCARB region has many deep saline formations – candidates for CO_2 storage



WESTCARB also created GIS layers for oil/gas fields and deep coal basins

Source: *DOE Carbon Sequestration Atlas of the United States and Canada*

Arizona Utilities CO_2 Storage Pilot Contracting and Funding Flow



Arizona Utilities CO_2 Storage Pilot project partners

- Arizona Public Service Company
- Salt River Project
- Tucson Electric Power
- Arizona Electric Power Cooperative
- National Rural Electric Cooperative Association
- Peabody Energy
- Electric Power Research Institute
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- California Energy Commission
- U.S. Department of Energy

EPRI - Site Selection and Project Support

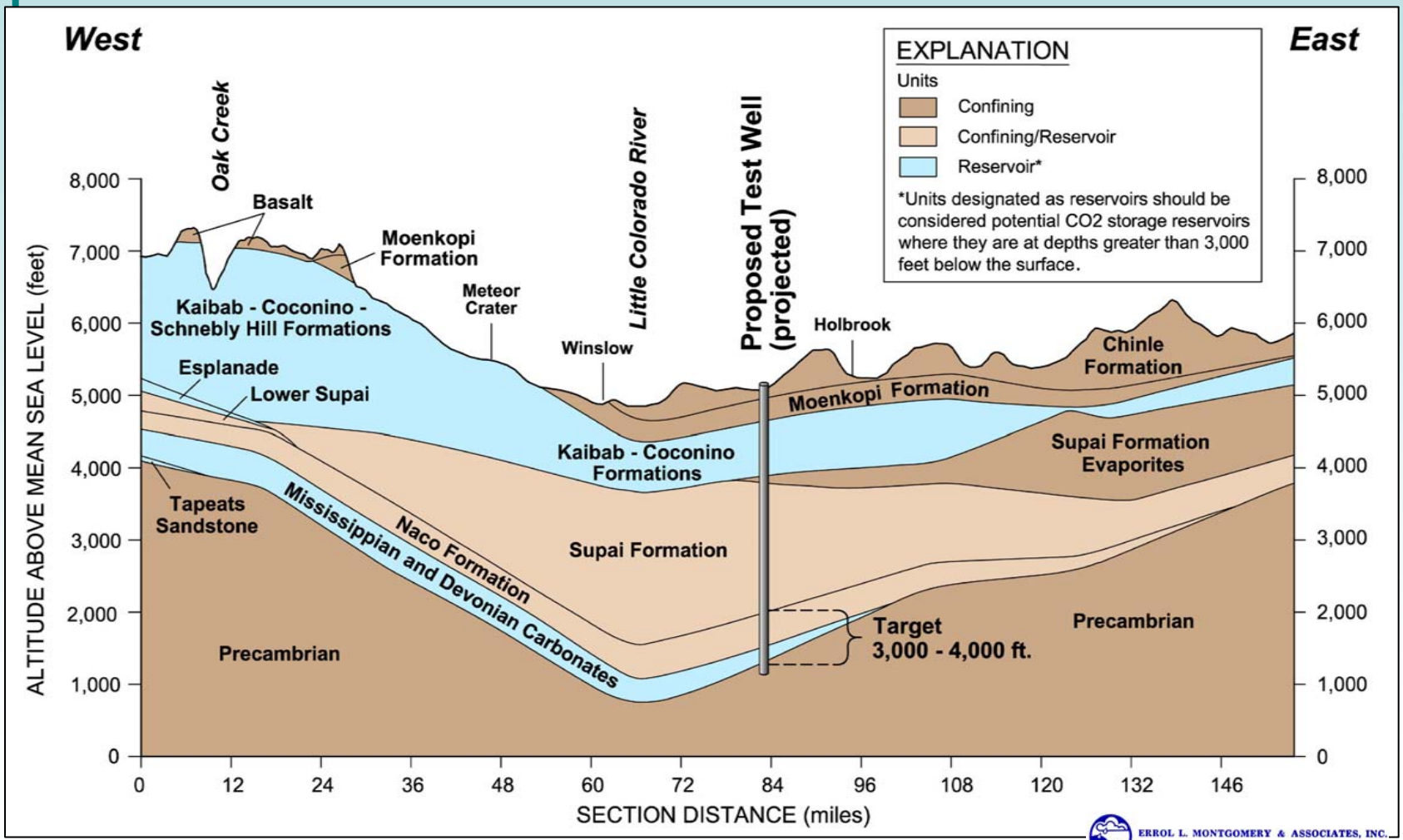
Storage potential of Arizona geologic provinces

- Significant capacity in Colorado Plateau Province
- Limited capacity in Basin and Range Province
- Minor capacity in Central Highlands Province

Project Site at Arizona Public Service Company Power Plant between Holbrook and Joseph City

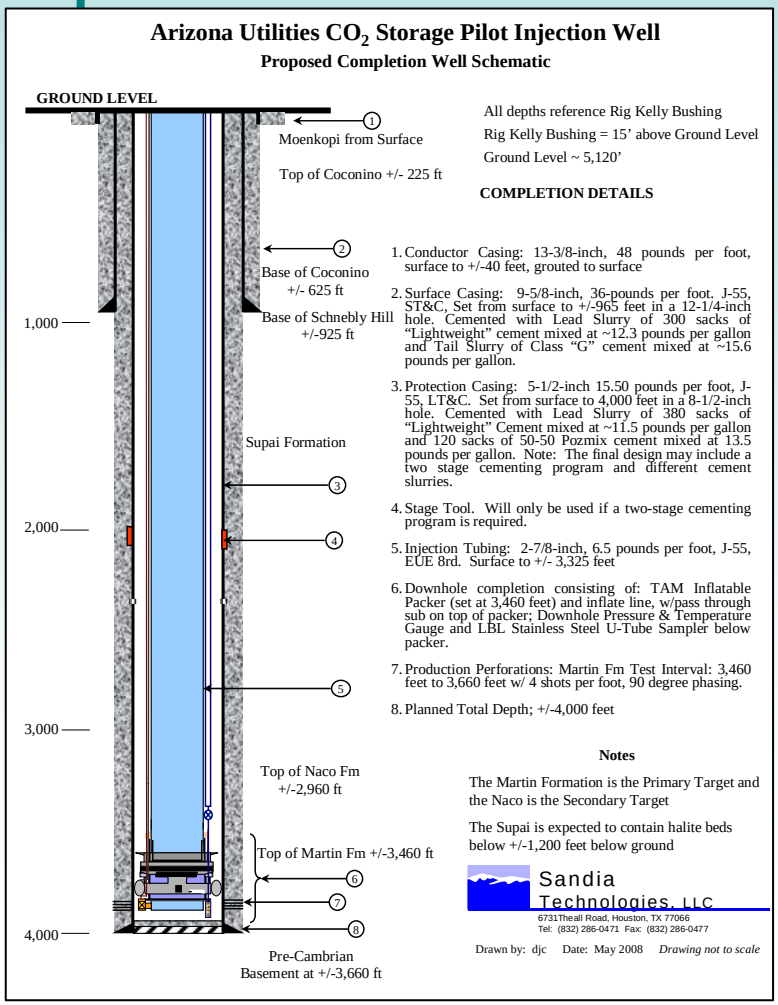
- Colorado Plateau location is scientifically interesting and has large CO_2 storage potential
- Potential high salinity, carbonate reservoir formation
- Thick, low permeability cap rock
- Cooperative project partner that owns surface and subsurface rights
- Near major highway, power line
- Controlled access to drill site

Geologic section in southern Colorado Plateau



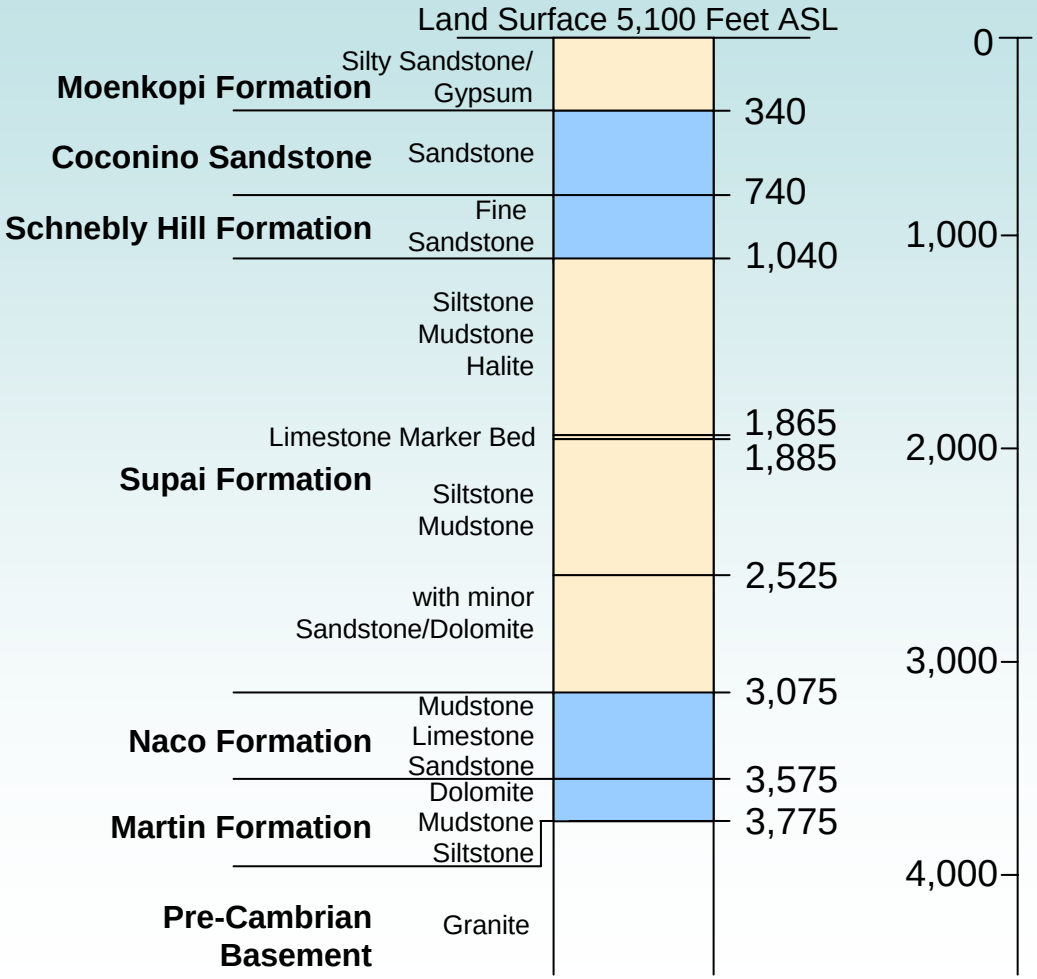
Vertical exaggeration 50:1

Exploratory well to confirm suitability of site



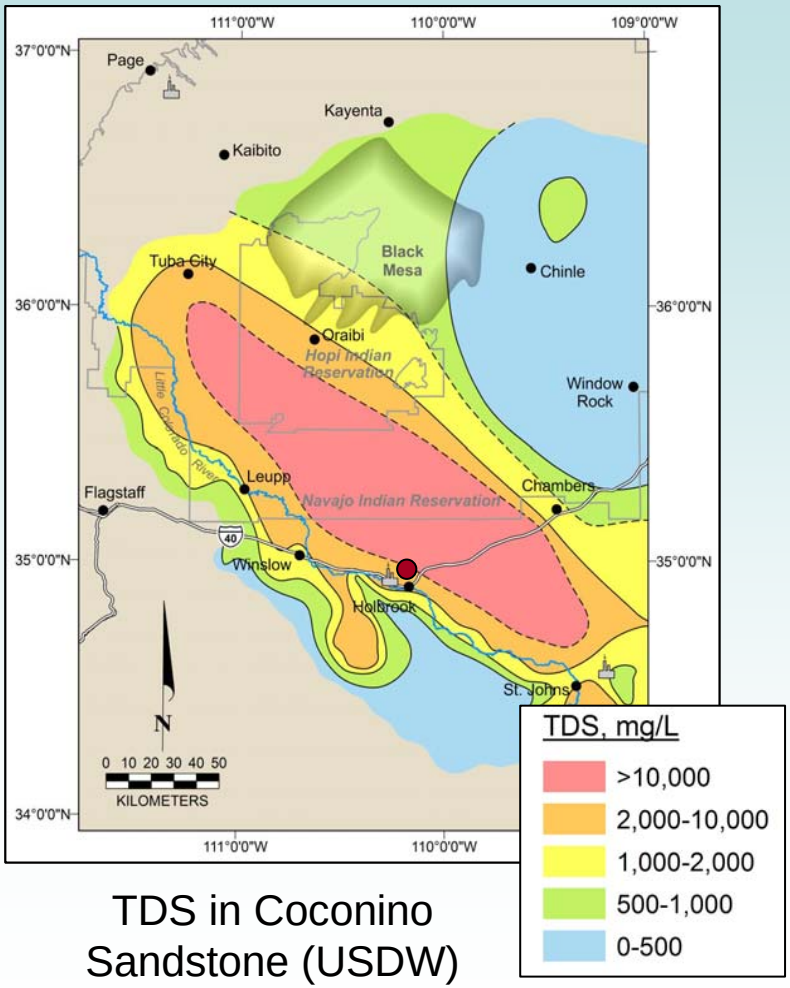
Source: Sandia Technologies, LLC

Geology at Project Site

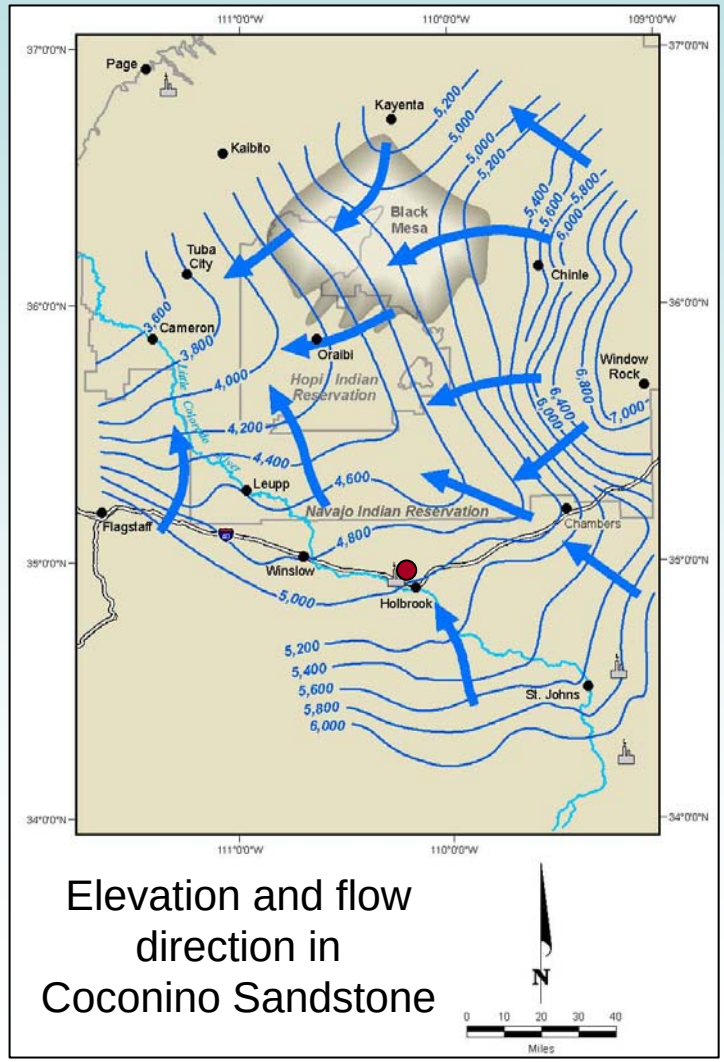


Source: Errol L. Montgomery & Associates

Evaluation of USDW above seal



TDS in Coconino Sandstone (USDW)



Elevation and flow direction in Coconino Sandstone

Source: Errol L. Montgomery & Associates

Scientific Objectives

- Determine injectivity and storage capacity of the reservoir
- Show that surface and borehole geophysical techniques can monitor the trapping of the injected CO_2 in the subsurface
- Assess and maintain caprock integrity
- Demonstrate safe storage of CO_2 in porous carbonate formations containing non-potable saline water beneath thick, low permeability seal
- Develop, calibrate, and validate multiphase flow models for CO_2 injection into saline formations typical of the Colorado Plateau in northeastern Arizona


Cholla Power Plant
fly ash pond

Test Plan

- Numerical simulation of CO_2 injection
- Drill and log a single well ~4,000 feet (1,200 m) deep near the APS Cholla Power Plant fly ash pond
- Ensure TDS of reservoir formation >10,000 mg/L
- Step-rate injection test to determine maximum safe injection pressure
- Short huff-puff test with a few tons of CO2 to estimate residual saturation, and test water-CO_2 interaction (using tracers)
- Inject 2,000 tons of commercial-grade CO_2
- Sample fluids and tracers with U-tube system; chemical analysis
- Pre- and post-CO_2 injection monitoring
  - Reservoir Saturation Tool (RST) logs
  - Distributed Thermal Perturbation Sensor (DTPS) logs
  - Vertical seismic profile (VSP) surveys
- Release pressure in well and flow back fluids (water, CO_2, phase-partitioning tracers); analyze interactions

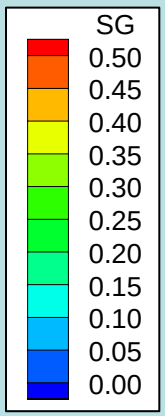
TOUGH2* simulation of CO_2 injection

Uniform high permeability

$k_h = k_v = 100$ mD

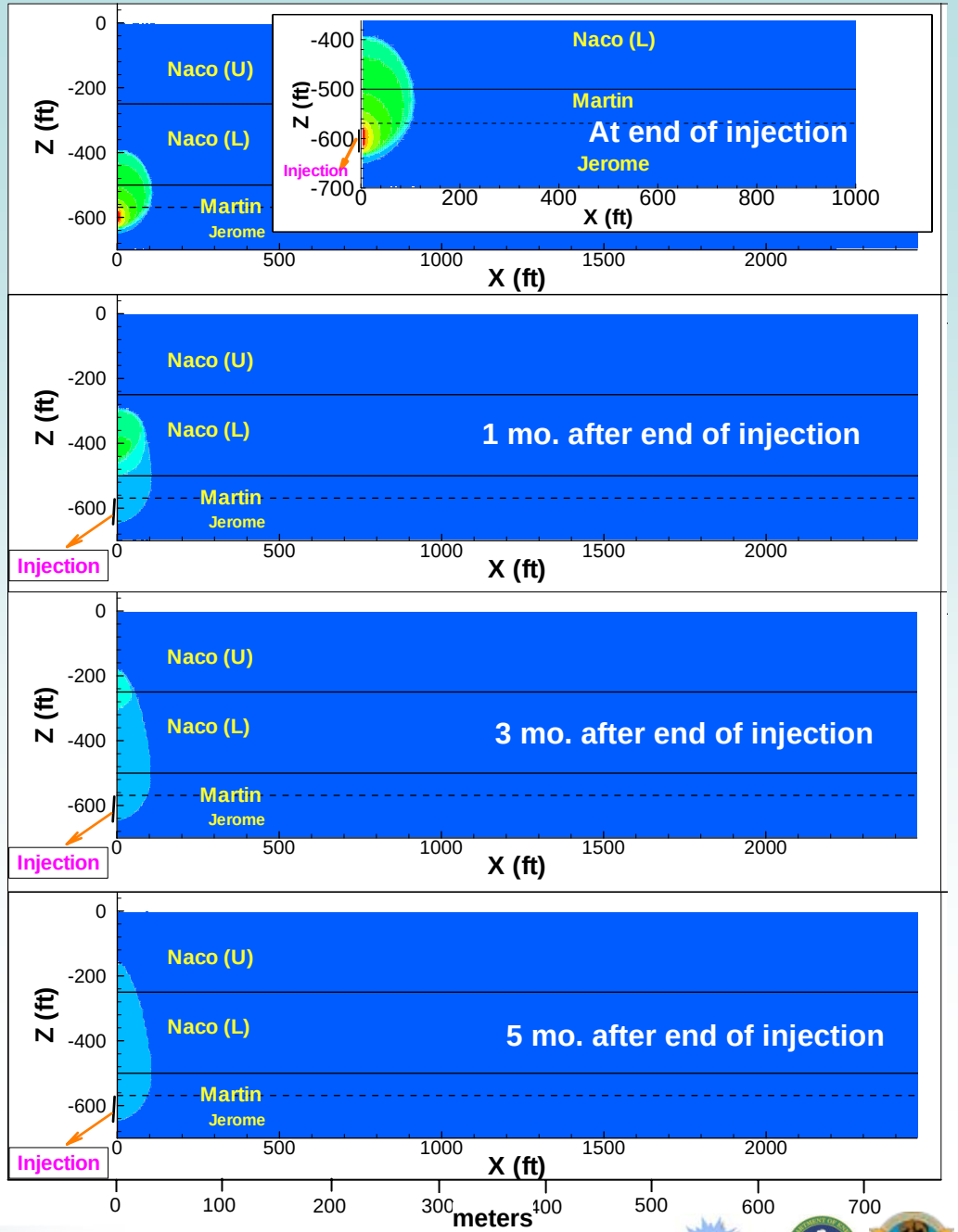
2,000 tonnes injected over 30 days (0.8 kg/s) into Jerome Member of Martin Formation

- Depth = 1,100 m (3,700 feet)
- P = 10.3 MPa (1,500 psi) [hydrostatic]
- T = 54°C (129°F) [normal gradient]
- Porosity = 10%
- Residual saturation, S_{gr} = 5%



Gas saturation
Fraction of pore space filled by supercritical CO_2

* Transport Of Unsaturated Groundwater and Heat

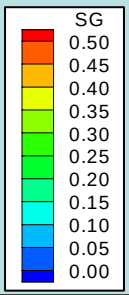


TOUGH2 simulation of CO_2 injection

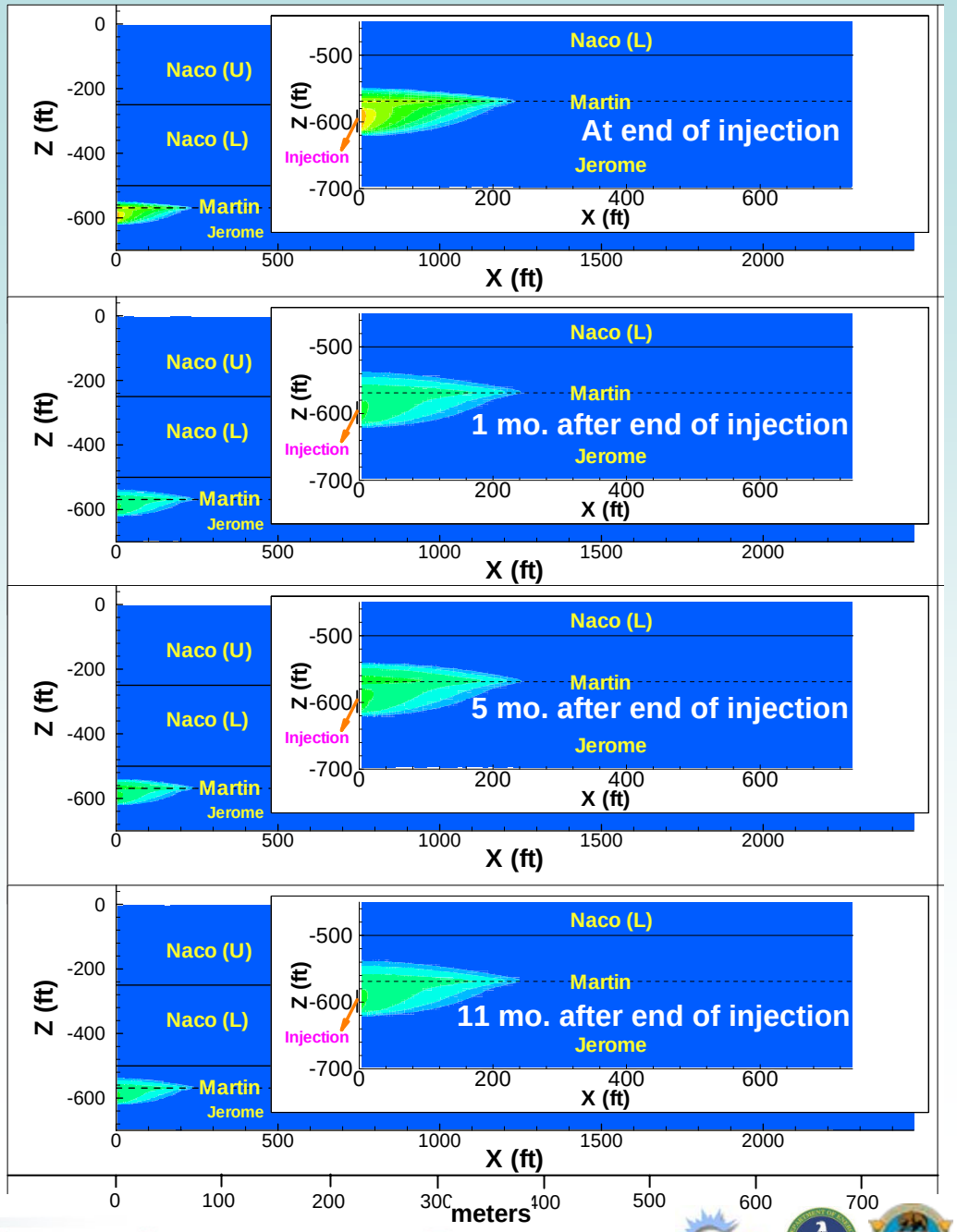
High horizontal permeability
Low vertical permeability

Formation	Thickness	k_h (mD)	k_v (mD)
Upper Naco	76 m (250 ft)	10	1
Lower Naco	76 m (250 ft)	100	3
Upper Martin	21 m (69 ft)	100	3
Jerome	40 m (131 ft)	700	20

- 2,000 tonnes injected over 30 days (0.8 kg/s) into Jerome Member of Martin Formation
- Depth = 1,100 m (3,700 feet)
- P = 10.3 MPa (1500 psi) [hydrostatic]
- T = 54°C (129°F) [normal gradient]
- Porosity = 10%
- Hysteretic effects included:
  - Residual saturation for drainage, S_{gr} = 0%
  - Residual saturation for imbibition, S_{gr} = 25%



Gas saturation
Fraction of pore space filled by supercritical CO_2



TOUGH2 simulation of pressure during CO_2 injection

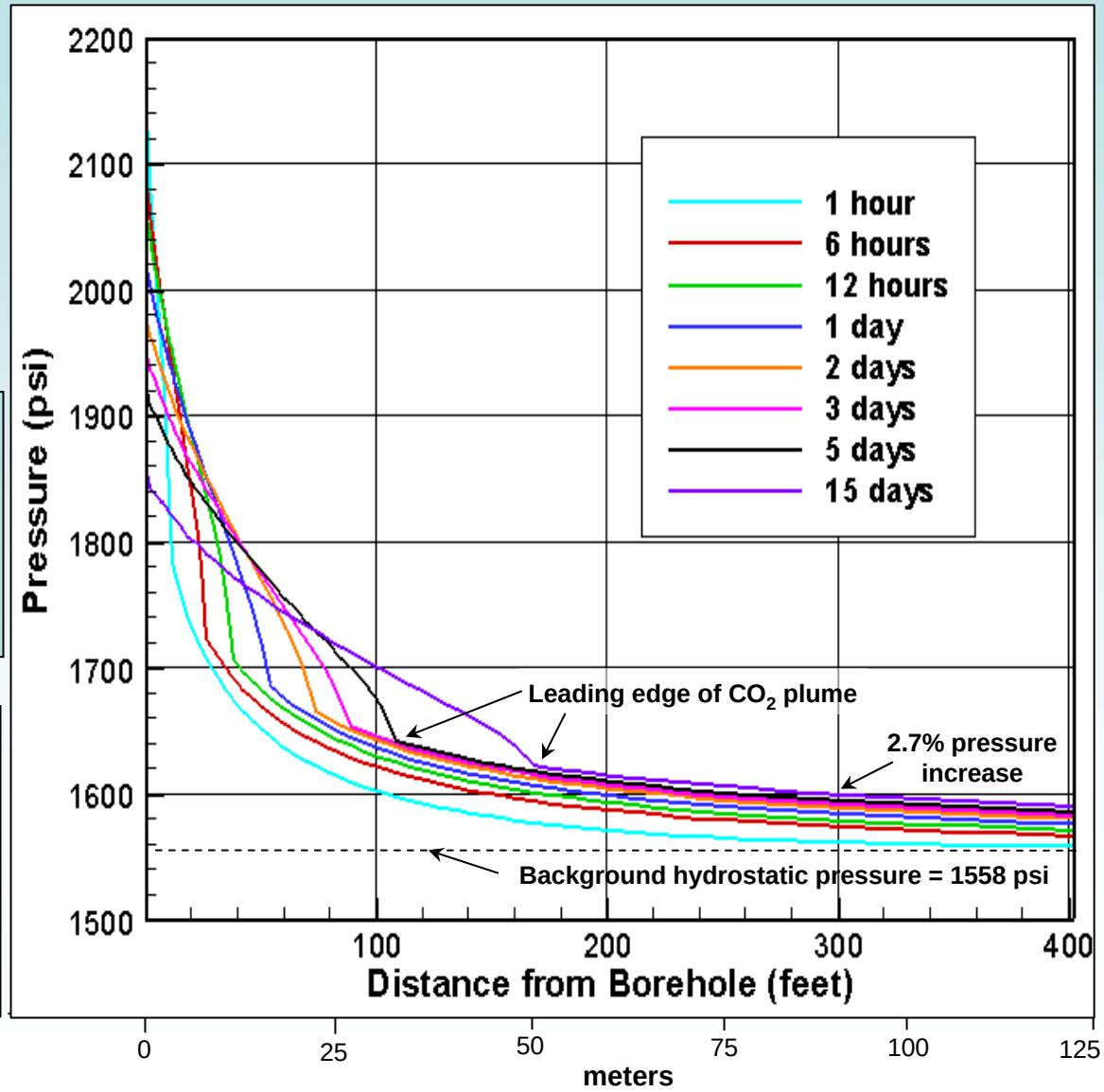
Pressure in reservoir formation at injection depth

High horizontal permeability

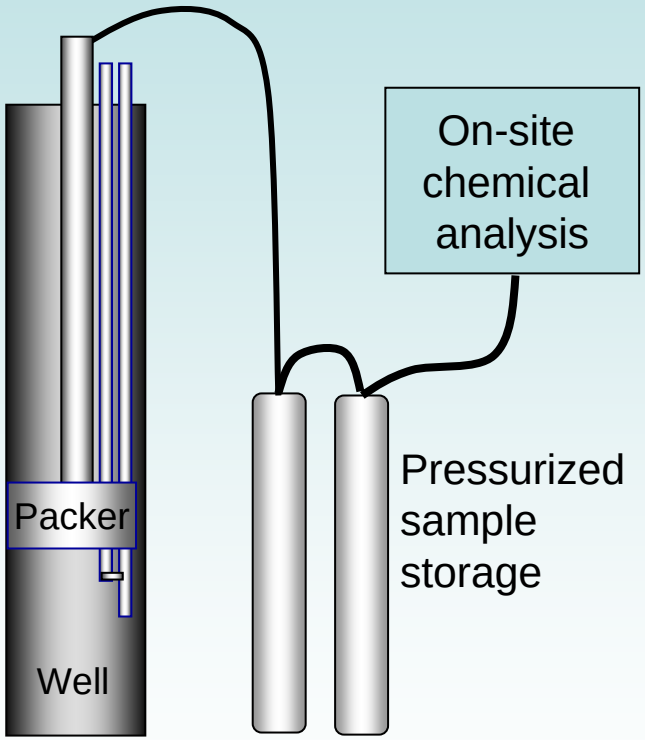
Formation	Thickness	k_h (mD)	k_v (mD)
Upper Naco	76 m (250 ft)	10	1
Lower Naco	76 m (250 ft)	100	3
Upper Martin	21 m (69 ft)	100	3
Jerome	40 m (131 ft)	700	20

2,000 tonnes injected over 15 days (1.6 kg/s)
into Jerome Member of Martin Formation

- Depth = 1,100 m (3,700 feet)
- P = 10.4 MPa (1558 psi) [hydrostatic]
- T = 54°C (129°F) [normal gradient]
- Porosity = 10%
- Residual saturation for drainage, S_{gr} = 0%



U-Tube System – continuous water, CO_2, and tracer samples at reservoir pressure

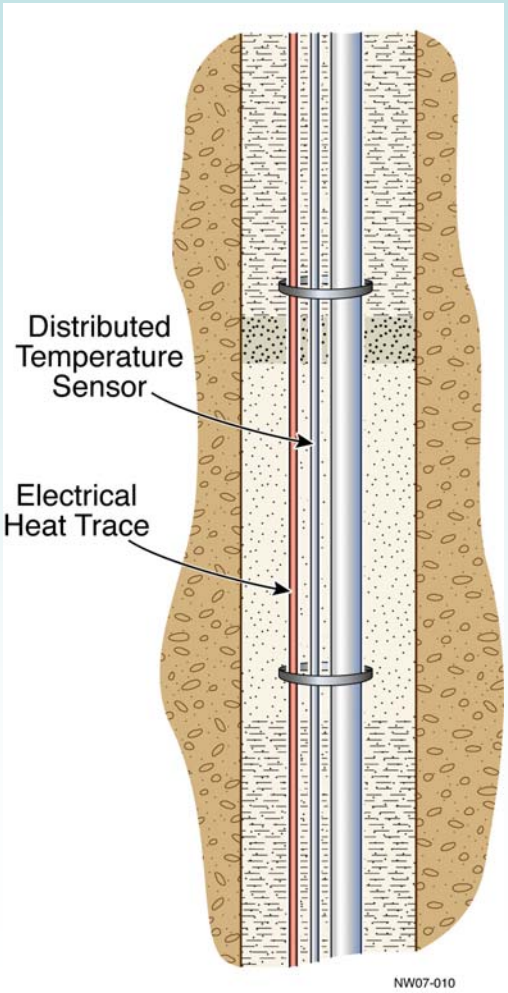


U-tube and check valve strapped to production tubing

Frio Brine CO_2 Pilot, Texas

Source: Barry Freifeld, LBNL

Distributed Thermal Perturbation Sensor (DTPS) for tracking CO_2 migration in the subsurface



Thermal conductivity measurements during and after CO_2 injection to monitor the distribution of CO_2 near the well

- The DTPS consists of a borehole-length electrical resistance heater and fiber optic distributed temperature sensor
- Constant heating is applied along the borehole, then is turned off. The temperature sensor measures the decay
- The low thermal conductivity of CO_2 versus water allows for estimates of CO_2 saturation
- The DTPS has been successfully tested at the CO_2SINK project in Germany

Source: Barry Freifeld, LBNL

Permitting

- DOE Environmental Questionnaire/NEPA – Approved by DOE
- US EPA Region 9, UIC permit application – Submitted for Class V Experimental Well
- Aquifer Protection Program permit, Arizona Department of Environmental Quality – Application submitted
- Drilling permit, Arizona Oil & Gas Conservation Commission – to be submitted

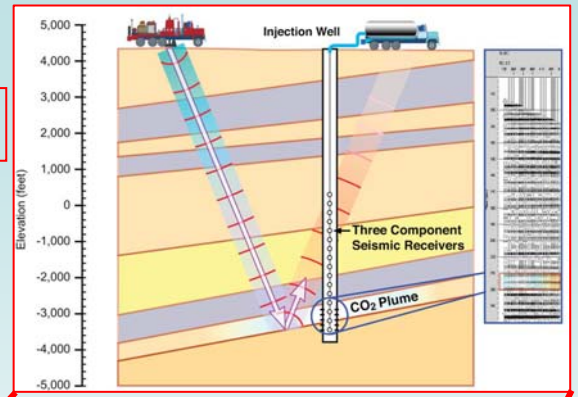
ADEQ Aquifer Protection Program (APP) Permit

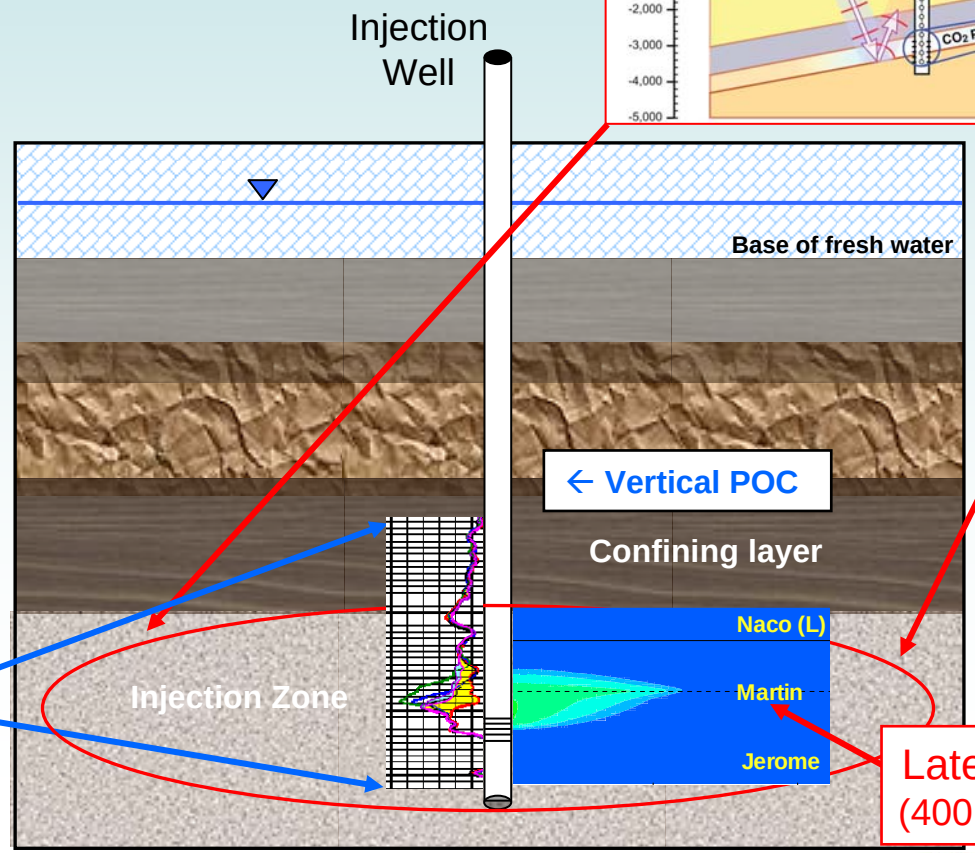
- All aquifers are designated as Drinking Water Aquifers
- Aquifer – a geologic unit with sufficient permeable to produce 5 gallons of water per day
- Water quality is not specified in law or regulation (no TDS limit)
- Use Best Available Demonstrated Control Technology (BADCT)
- Point of Compliance is the location down-dip where water quality returns to background level

Proposed APP Permit Conditions
Point of Compliance: 400 ft (122 m) up dip from well

Model predictions form basis of Point of Compliance (POC)

- **Verification:**
  - **Lateral POC determined by VSP**
  - **Vertical POC determined by RST well logs**
  - **Injection zone monitoring of pressure & temperature**



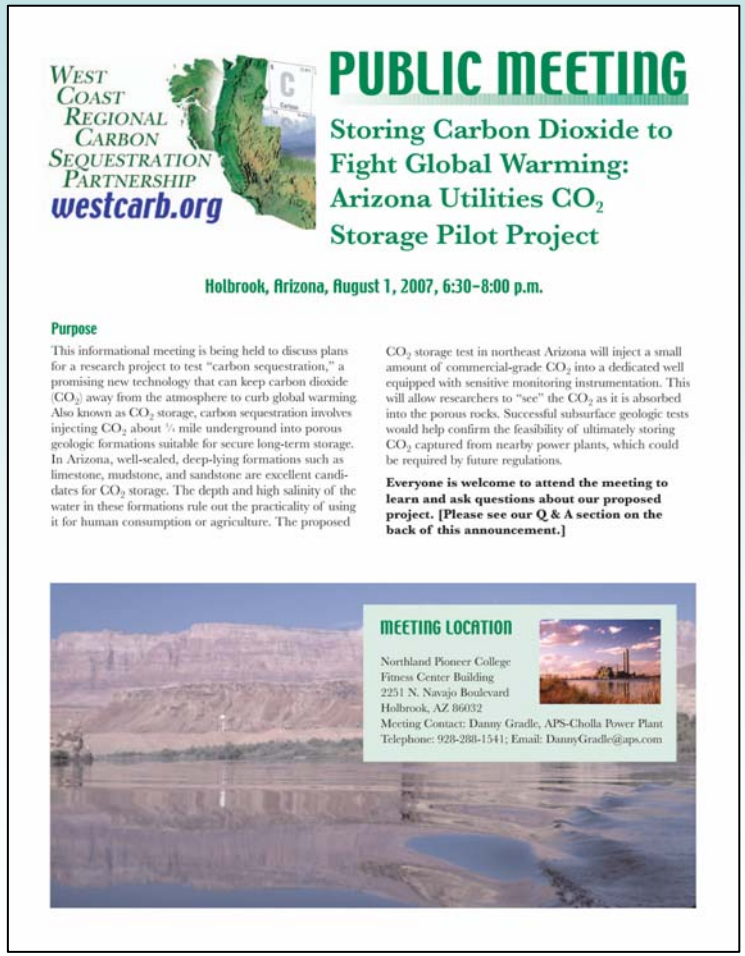


Arizona Utilities CO_2 Pilot Summary
WESTCARB has …

- Completed a hydrogeologic study
- Selected a site for the AZ pilot test
- Added new industry partners
- Characterized the hydrogeology
- Modeled CO_2 plume size and formation pressure
- Received NEPA approval from DOE
- Submitted APP and UIC permit applications
- Engaged in public outreach to the community through public meetings

…and will begin

- Drilling and testing in January 2009



West Coast Regional Carbon Sequestration Partnership
westcarb.org

PUBLIC MEETING

Storing Carbon Dioxide to Fight Global Warming: Arizona Utilities CO_2 Storage Pilot Project

Holbrook, Arizona, August 1, 2007, 6:30–8:00 p.m.

Purpose

This informational meeting is being held to discuss plans for a research project to test "carbon sequestration," a promising new technology that can keep carbon dioxide (CO_2) away from the atmosphere to curb global warming. Also known as CO_2 storage, carbon sequestration involves injecting CO_2 about ½ mile underground into porous geologic formations suitable for secure long-term storage. In Arizona, well-sealed, deep-lying formations such as limestone, mudstone, and sandstone are excellent candidates for CO_2 storage. The depth and high salinity of the water in these formations rule out the practicality of using it for human consumption or agriculture. The proposed CO_2 storage test in northeast Arizona will inject a small amount of commercial-grade CO_2 into a dedicated well equipped with sensitive monitoring instrumentation. This will allow researchers to "see" the CO_2 as it is absorbed into the porous rocks. Successful subsurface geologic tests would help confirm the feasibility of ultimately storing CO_2 captured from nearby power plants, which could be required by future regulations.

Everyone is welcome to attend the meeting to learn and ask questions about our proposed project. [Please see our Q & A section on the back of this announcement.]

MEETING LOCATION

Northland Pioneer College
Fitness Center Building
2251 N. Navajo Boulevard
Holbrook, AZ 86032
Meeting Contact: Danny Gradle, APS-Cholla Power Plant
Telephone: 928-288-1541; Email: DannyGradle@aps.com