Northern California CO_2 Storage Pilot

Regional Carbon Sequestration Partnerships Initiative Review Meeting

Pittsburgh, Pennsylvania
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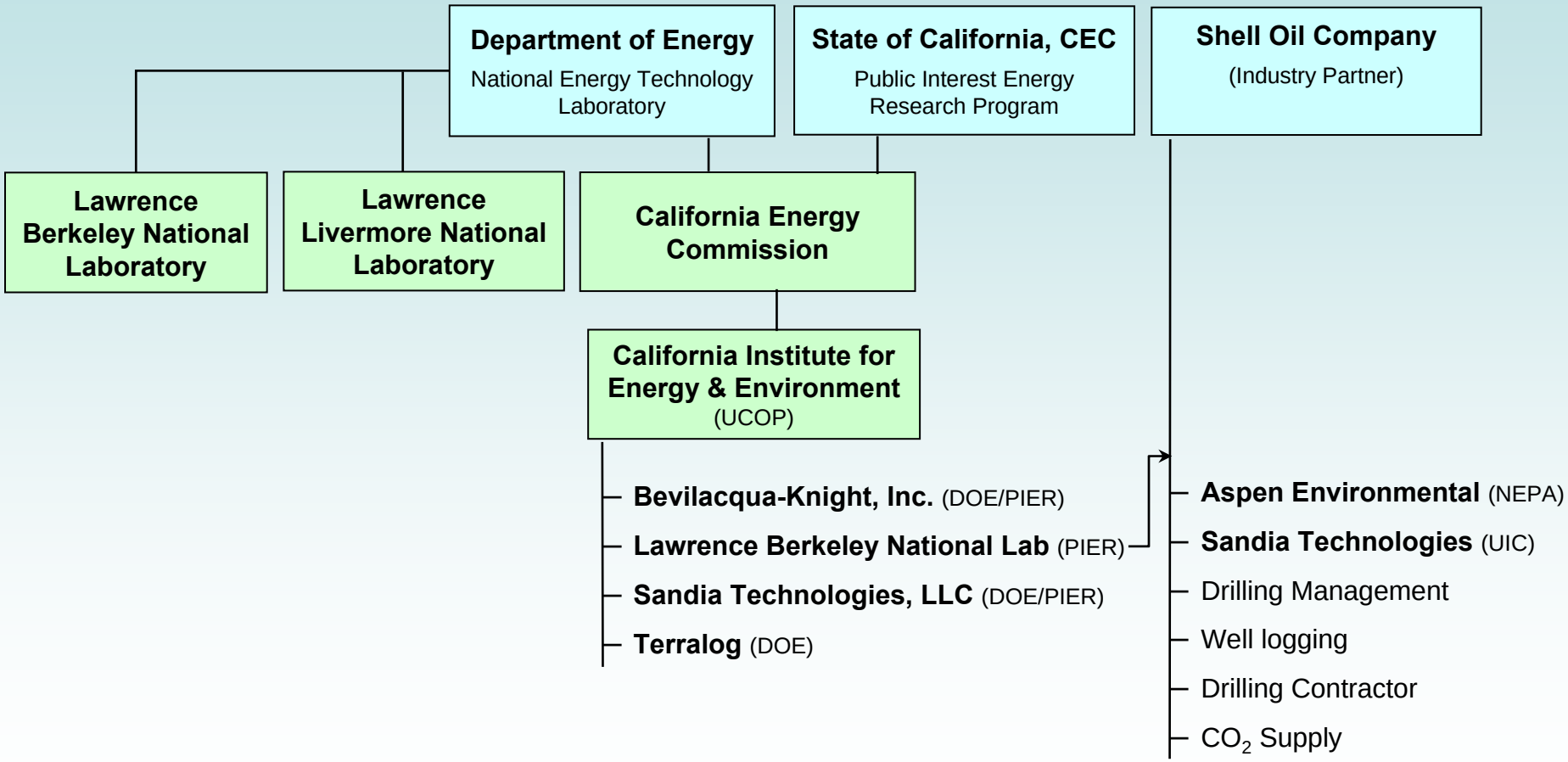
Industry Partner: Shell Oil Company

A welcome industry partner

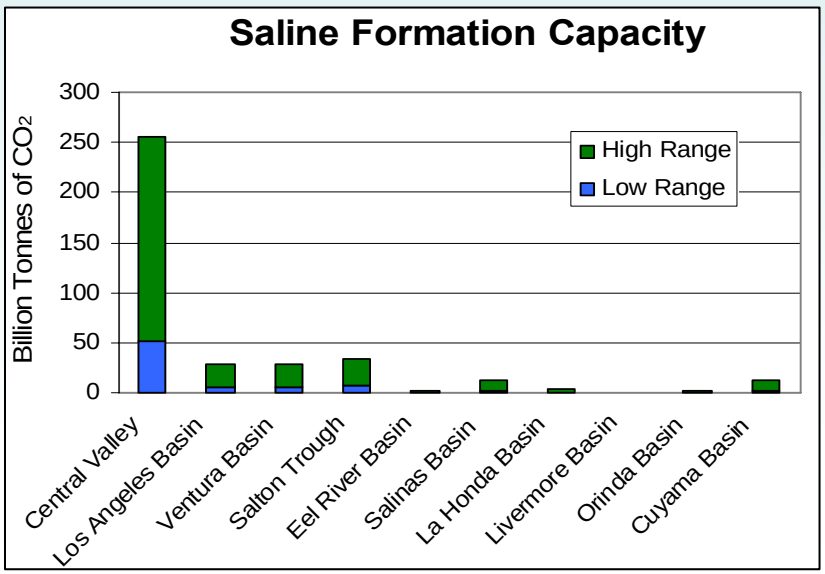
- Committed to reducing global CO_2 emissions
- Extensive technical expertise in:
  - Geologic evaluation
  - Well log analysis
  - Porosity and permeability evaluation
  - Geophysics
  - Deep well drilling
  - CO_2 injection

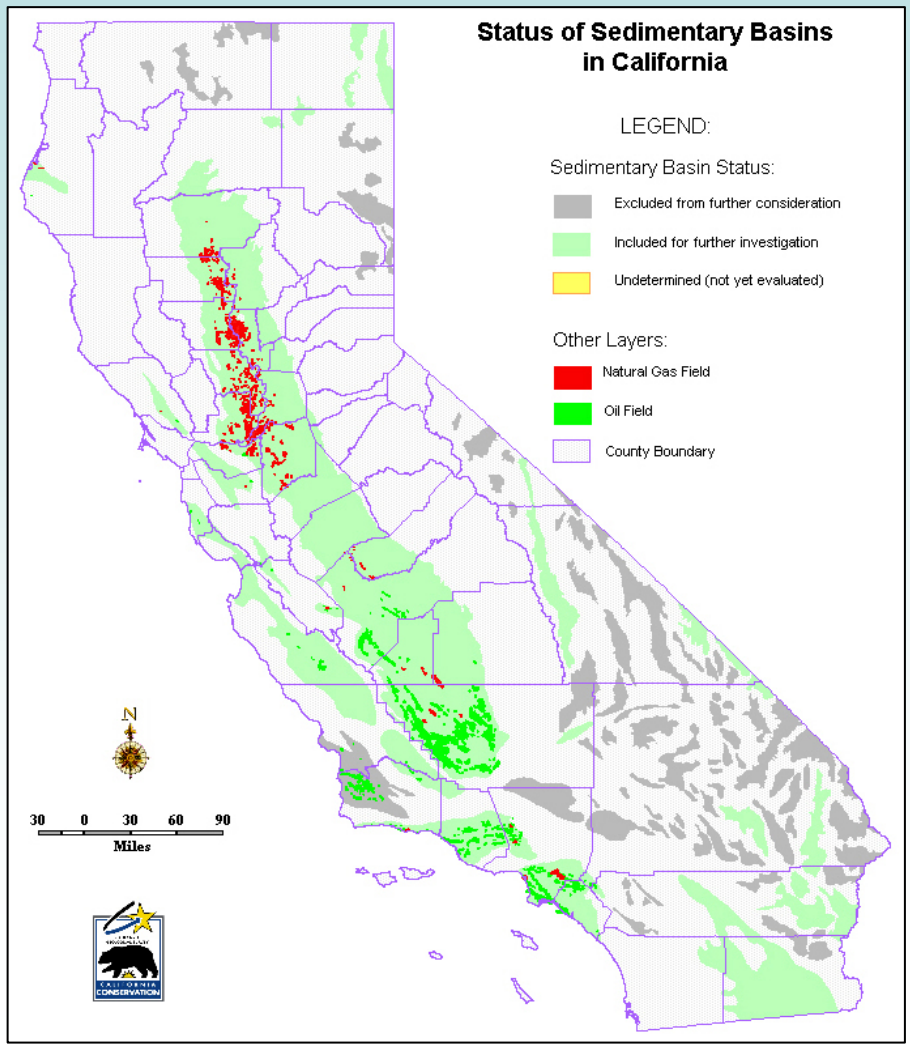
Northern California CO_2 Storage Pilot Contracting and Funding Flow



WESTCARB Phase I – Preliminary estimate of CO_2 storage capacity in California

- Oil reservoirs – 121 fields
  - 3.4 billion tonnes
- Gas reservoirs – 128 fields
  - 1.8 billion tonnes
- Saline formations – 27 basins
  - 75-300 billion tonnes

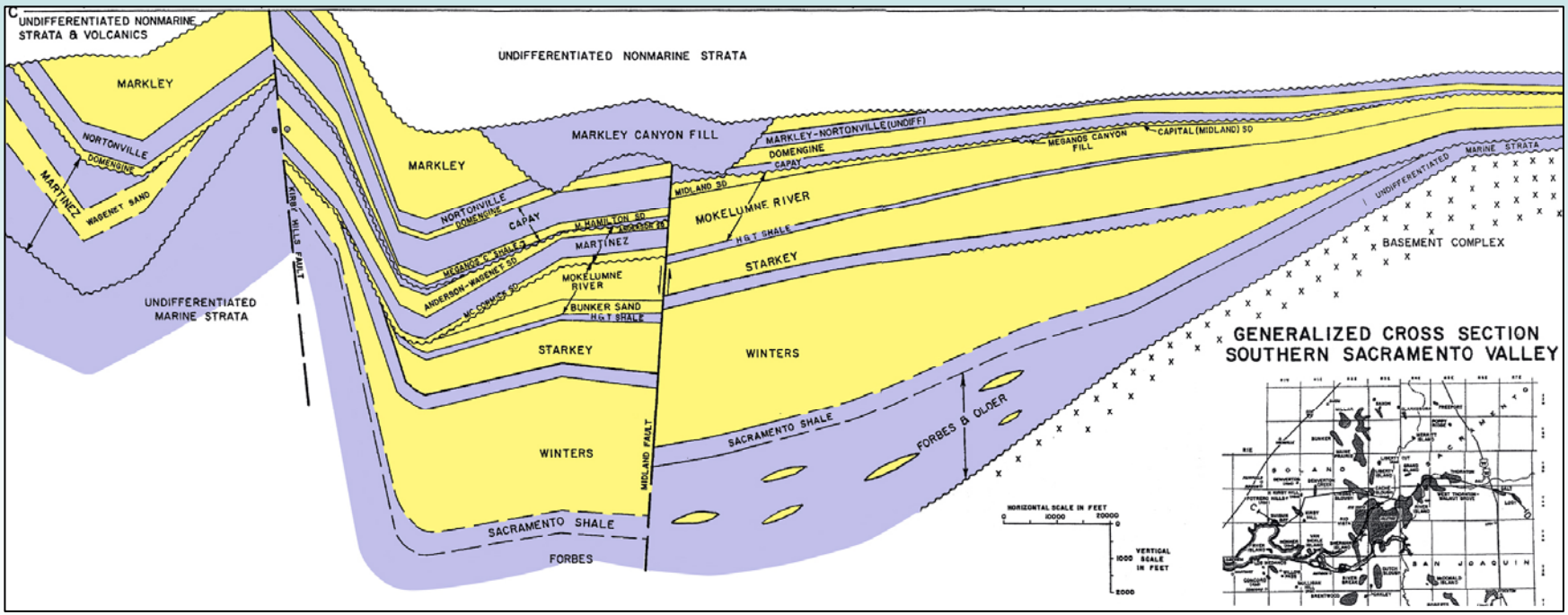




Sacramento Valley geologic cross-section

Numerous stacked sandstone (yellow) and shale (purple) formations

W



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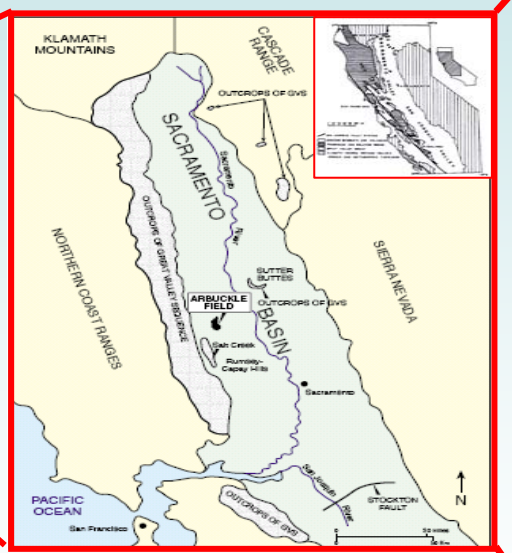
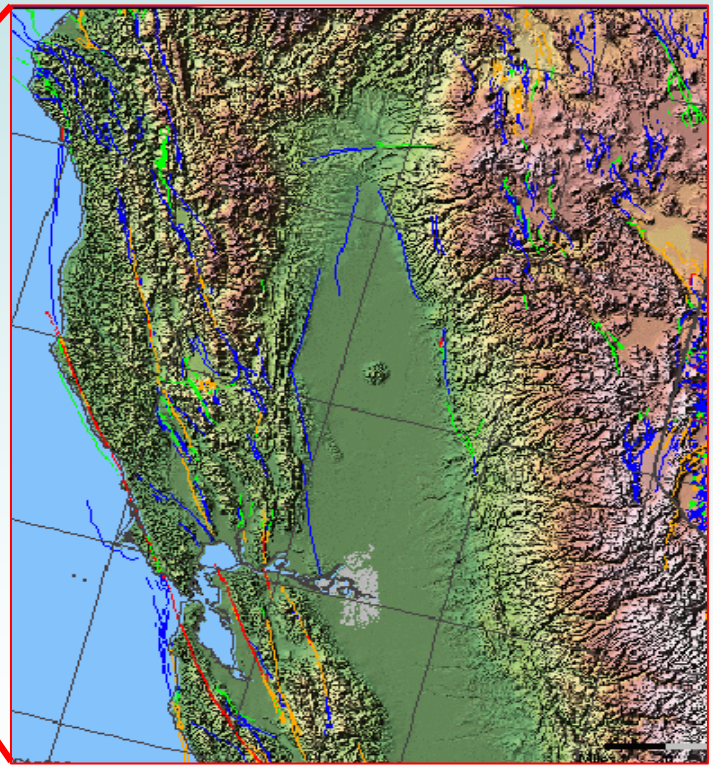
Source: California Geological Survey

Western Sacramento Valley Location

Viable Pilot Test Site

- Capacity to trap CO_2 is adequate for planned volume
- Leak potential is low due to scarcity of faults and old wells; thick, multiple shale seals
- Terrain and land ownership appears to be favorable





Uncertain issues to be determined

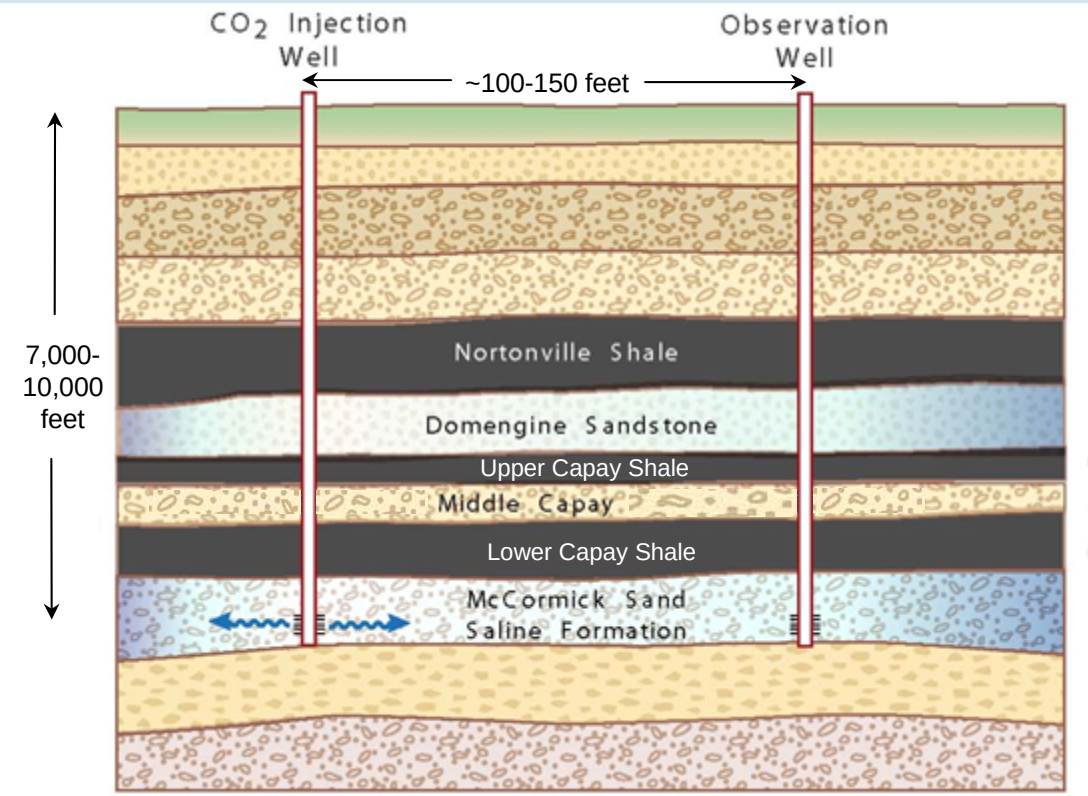
- Salinity possibly ~10,000 ppm in shallower sandstones
- Permeability uncertainty at injection depth – axis of syncline is very deep
- Sand continuity in the syncline is unknown

Source: Shell

Northern California CO_2 Storage Pilot

Site Geologic Attributes

- Multiple seals
- High permeability saline reservoir



Representative cross-section

Field Operations

- Drill two wells penetrating reservoir
- Inject 2,000 tonnes of CO_2 into a saline formation
- Assess injectivity and storage capacity
- Monitor subsurface CO_2 movement
- Test for leakage

Pilot Objectives

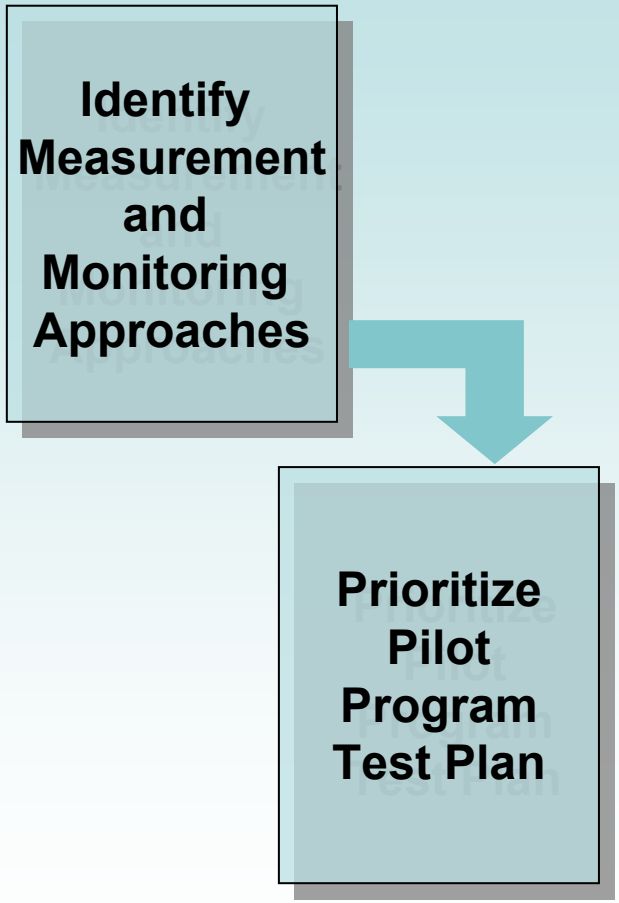
Identify Pilot Test Objectives

Rank Objectives
- Scientific
- Public
- Industry
- Likelihood of Success

- Determine the injectivity of the reservoir
- Estimate the storage capacity of the reservoir
- Model and monitor the trapping of the injected CO_2
- Assess and maintain seal integrity
- Demonstrate safe storage of CO_2 in a saline sandstone beneath a shale seal in northern California
- Develop, calibrate, and validate multiphase flow models for CO_2 injection in the Sacramento Valley

Pilot Project Test Plan

- Model CO_2 injection and CO_2 movement
- Assess injectivity and injection pressure with step-rate injection test
- Assess storage capacity
- Use tracers to assess supercritical and dissolved phases of CO_2
- Monitor subsurface CO_2 movement using time-lapse VSP and cross-well seismic
- Run Reservoir Saturation Tool (RST) logs to monitor near wellbore
- Use a Distributed Thermal Perturbation Sensor to monitor CO_2 near wells
- Monitor CO_2 at surface near wells
- Validate models

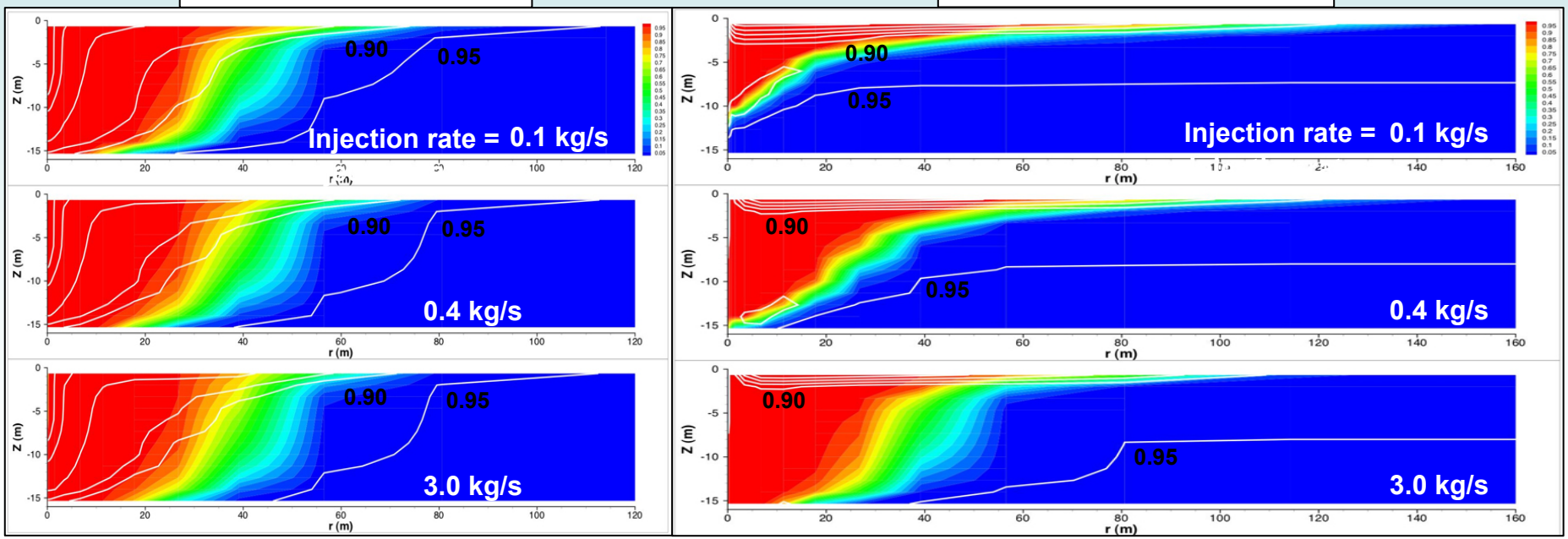


TOUGH2* simulation of CO_2 injection into saline reservoir

- CO_2 plume 1 year after injection of 2,000 tonnes
- High residual water saturation: S_W = 95%, S_G = 5%
- Supercritical CO_2 is buoyant; displaces water
- Sensitive to injection rate only at high permeability

Permeability = 50 mD

Permeability = 1,000 mD



Color contours: Weight % CO_2 in supercritical (gaseous) phase. White contours: Water saturation ($1 - S_g$).

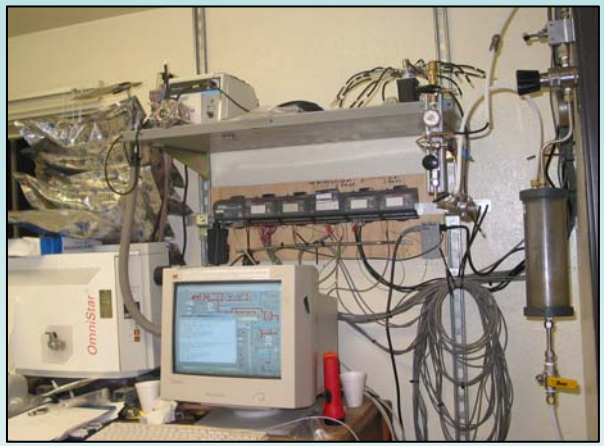
* Transport Of Unsaturated Groundwater and Heat

Source: C. Doughty, LBNL

U-Tube System for fluid and tracer sampling

pH, Ec, temperature monitors

Pressure control valves



Control room

Sample collection chambers

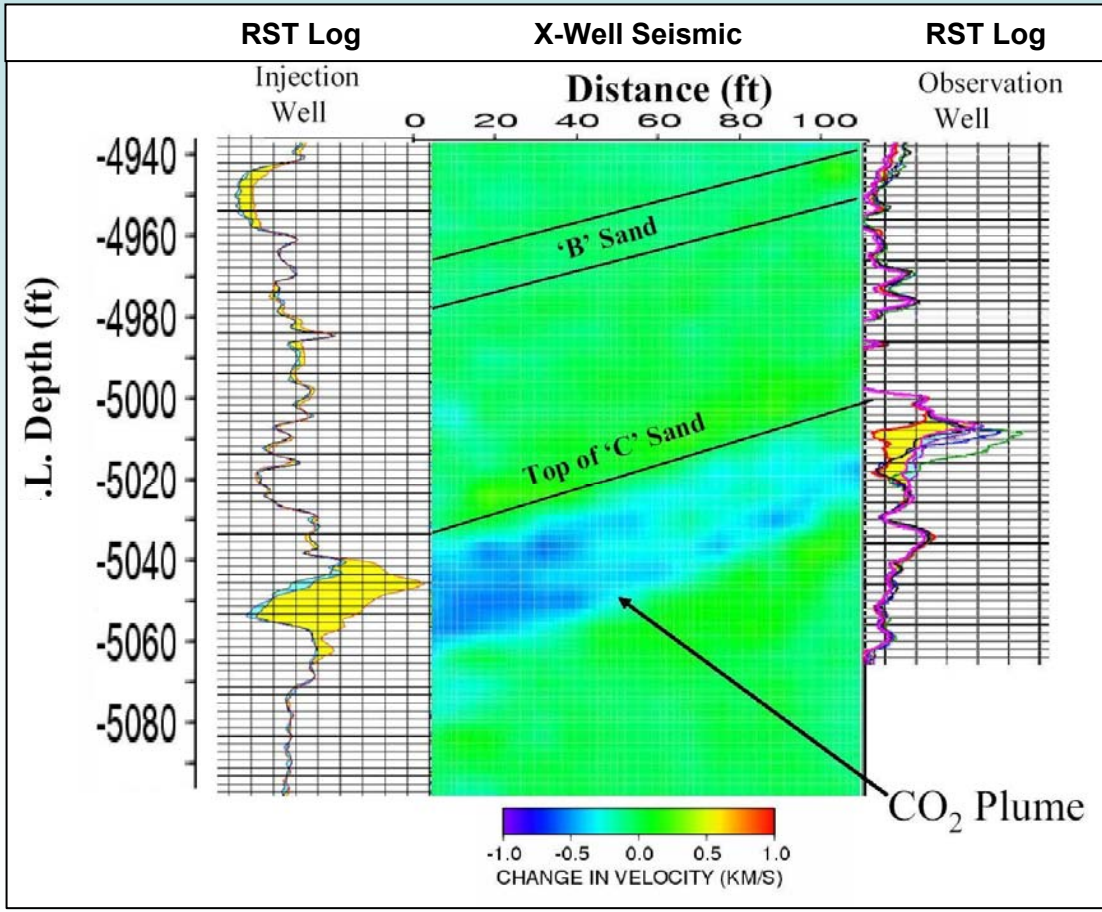
U-tube and check valve strapped to production tubing

Source: B. Freifeld, LBNL

Monitoring the CO_2

- Seismic imaging
  - Time lapse VSP
  - Time lapse crosswell
  - Controlled-Source Active Seismic Monitoring (CASSM)
  - Correlate seismic with fluid and tracer samples obtained with U-tube
- Time lapse Reservoir Saturation Tool (RST)* log

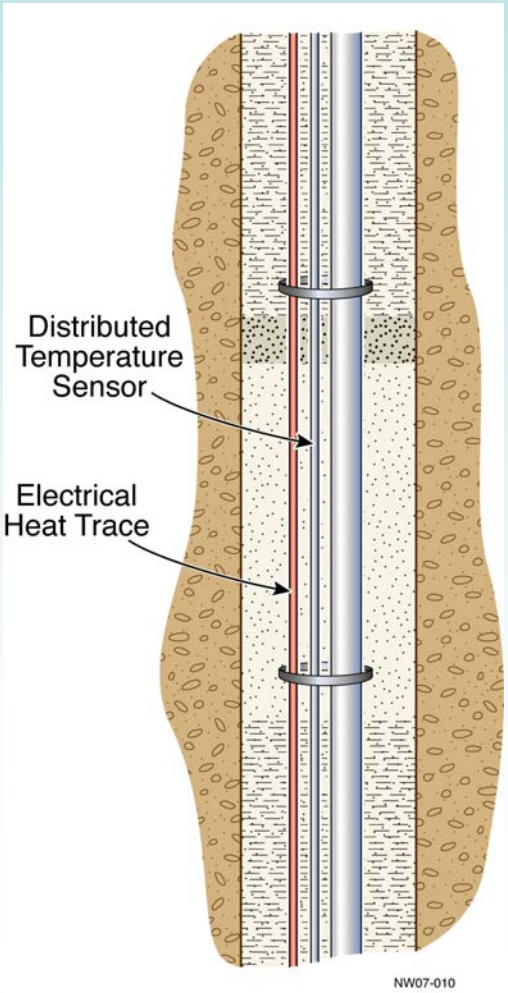
* Schlumberger tool that measures thermal neutron absorption to infer water saturation, and C/O ratio with an induced gamma ray spectrometer.



Frio Brine CO_2 Pilot, Texas

Source: T. Daley, LBNL

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



Thermal conductivity measurements during and after CO_2 injection 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

Regulatory Agencies & Permits

- Underground Injection Control (UIC) permit: US EPA, Region 9 – Class V, Experimental
- Drilling permit: County agency

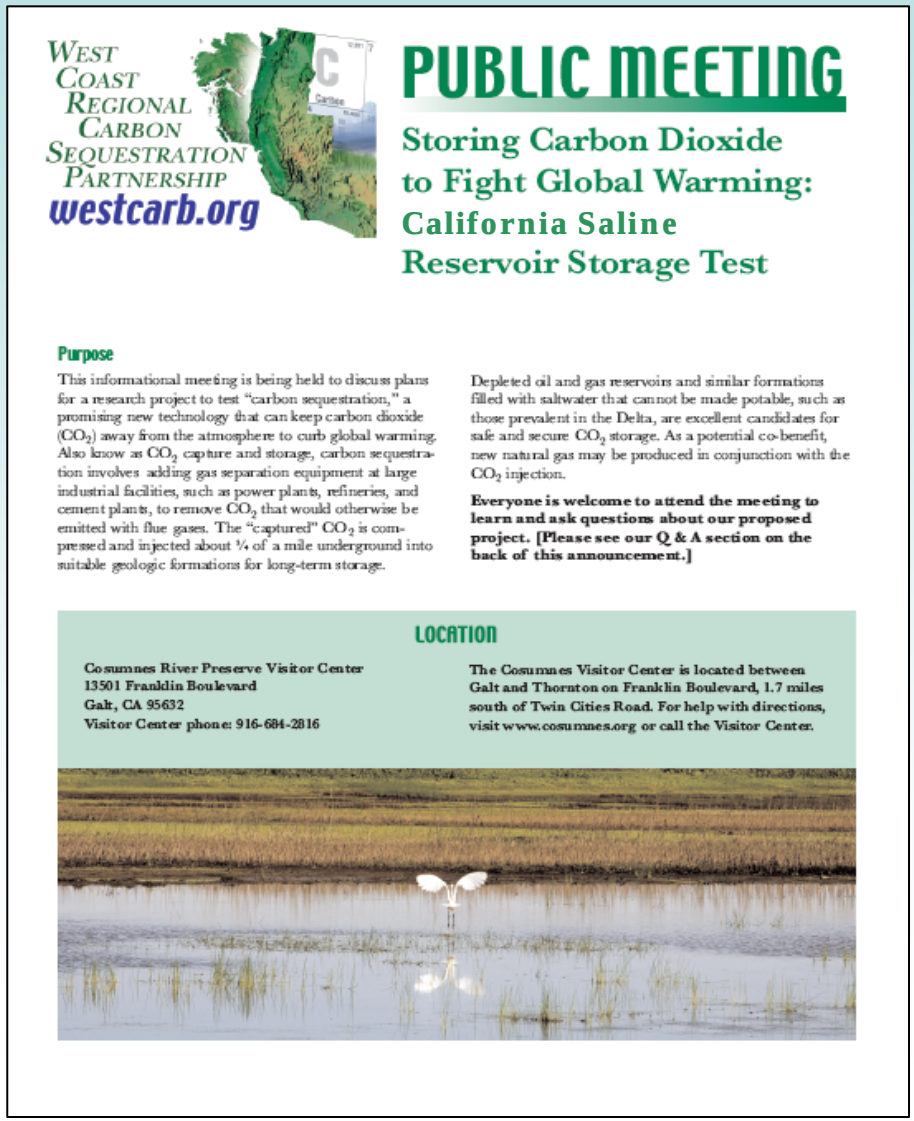
  (CA Department of Oil, Gas and Geothermal Resources if in oil/gas field)
- NEPA: DOE Environmental Questionnaire
- CEQA: Lead state or local agency; CEC approval

Agreements & Contracts

- Surface owner
- Adjacent surface owners for VSP source points
- Mineral rights owner
- Mineral rights leaseholder
- Pore space owner (not decided in California)
- Agreement with project partner – site access, liability, IP
- Contracts with subcontractors and suppliers

Public Outreach

- Inform state and local agencies and political leaders
- Press releases
- State-wide and local information
- Public meetings
- Input on test plans and monitoring



WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP
westcarb.org

PUBLIC MEETING

Storing Carbon Dioxide to Fight Global Warming: California Saline Reservoir Storage Test

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 know as CO_2 capture and storage, carbon sequestration involves adding gas separation equipment at large industrial facilities, such as power plants, refineries, and cement plants, to remove CO_2 that would otherwise be emitted with flue gases. The "captured" CO_2 is compressed and injected about ¼ of a mile underground into suitable geologic formations for long-term storage.

Depleted oil and gas reservoirs and similar formations filled with saltwater that cannot be made potable, such as those prevalent in the Delta, are excellent candidates for safe and secure CO_2 storage. As a potential co-benefit, new natural gas may be produced in conjunction with the CO_2 injection.

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.]

LOCATION

Cosumnes River Preserve Visitor Center
13501 Franklin Boulevard
Galt, CA 95632
Visitor Center phone: 916-684-2816

The Cosumnes Visitor Center is located between Galt and Thornton on Franklin Boulevard, 1.7 miles south of Twin Cities Road. For help with directions, visit www.cosumnes.org or call the Visitor Center.