Application of Site Assessment Methodology for Geologic Storage of CO_2: A Case Study of the Southern San Joaquin Valley, California

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Abstract

Rigorous site assessment methodologies are key to development of planning and permitting frameworks for commercial CO_2 storage projects. While several methods have been proposed, there is still no consensus on best approaches. A Westcarb case study was used to test and develop site assessment methodologies for geologic CO_2 storage sites. The study area is in the southern San Joaquin Valley, California, surrounding the Kimberlina power generation facility. The area includes saline aquifers, depleted oil and gas reservoirs, and operational oil fields where there is opportunity for combined carbon sequestration-EOR.

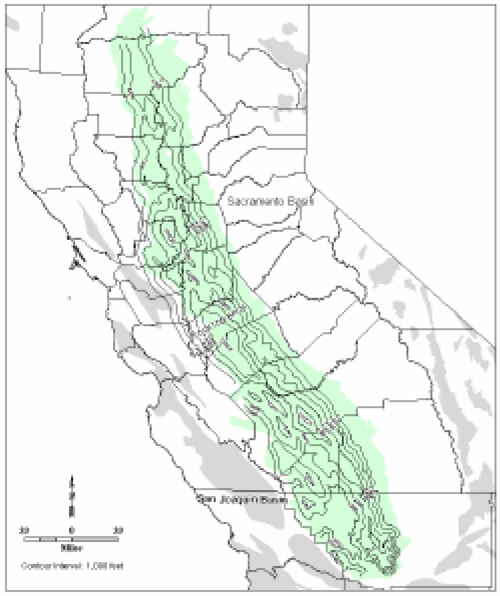
Methodologies must fulfill needs for:

- Regional screening to assess potential storage capacity near CO_2 sources;
- Down-selection to a subset of sites that meet project-specific metrics;
- Detailed economic and environmental risk assessments for individual site-specific projects.

As a part of this work, we developed a list of data needed for site assessments, technologies that can be used to obtain such data, approaches to use when available data are limited, and frameworks for integrating and evaluating available data. It is important to note that site assessments must be robust enough to assure that a site meets and maintains a project's economic and environmental objectives, including injectivity, capacity, and long-term storage integrity, throughout the project's life cycle. In this context, the time scales of concern for geologic storage are unprecedented for engineered projects. Ultimately, site assessment methodologies must provide a consistent and complete framework from which regulators and operators can develop site selection and assessment protocols.

Westcarb Phase II Context

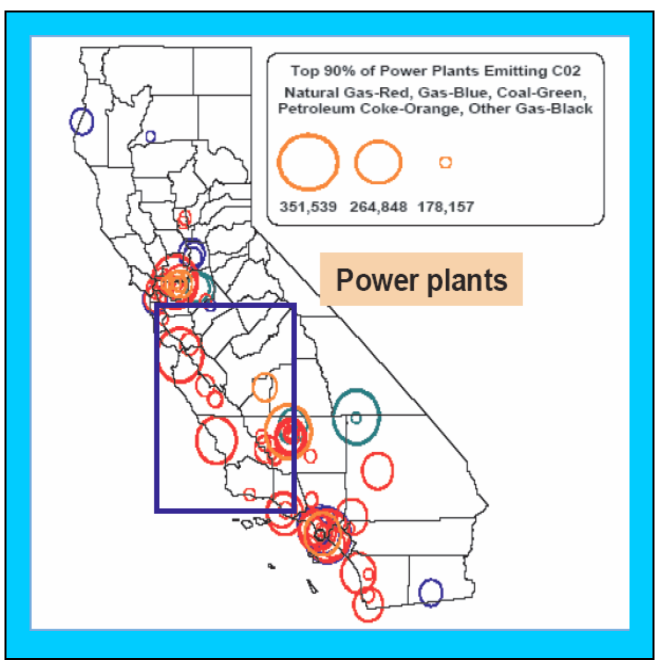
Task 4.2 of Westcarb Phase II specifies that the Kimberlina area be assessed with respect to the potential for saline and oil field storage. The deliverable from this task is a report on CO_2 storage options and capacity in the Southern San Joaquin Valley. This task builds on Phase I work done by the California Geological Survey for Westcarb that made preliminary estimates of statewide storage capacity. For this task, we needed to develop a general methodology for assessing specific sites and that could capture elements of geologic uncertainty that contribute to overall project risk.



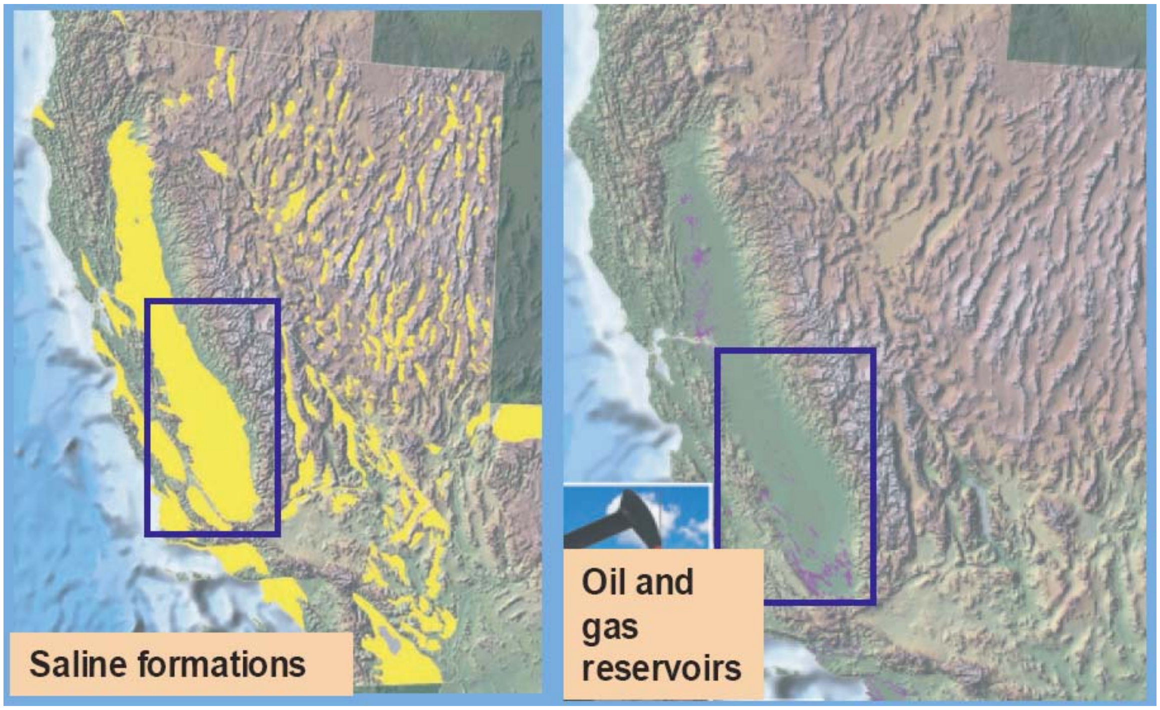
Gross sandstone isopach map for Sacramento-San Joaquin basin. From "An Overview of Geologic Carbon Sequestration Potential in California" California Geological Survey Special Report 183. Westcarb Topical Report, 2005. http://www.westcarb.org/partners/data/CA_geologic-seq-potential.pdf

High Storage Potential and Numerous CO_2 Sources Characterize California's Southern San Joaquin Valley

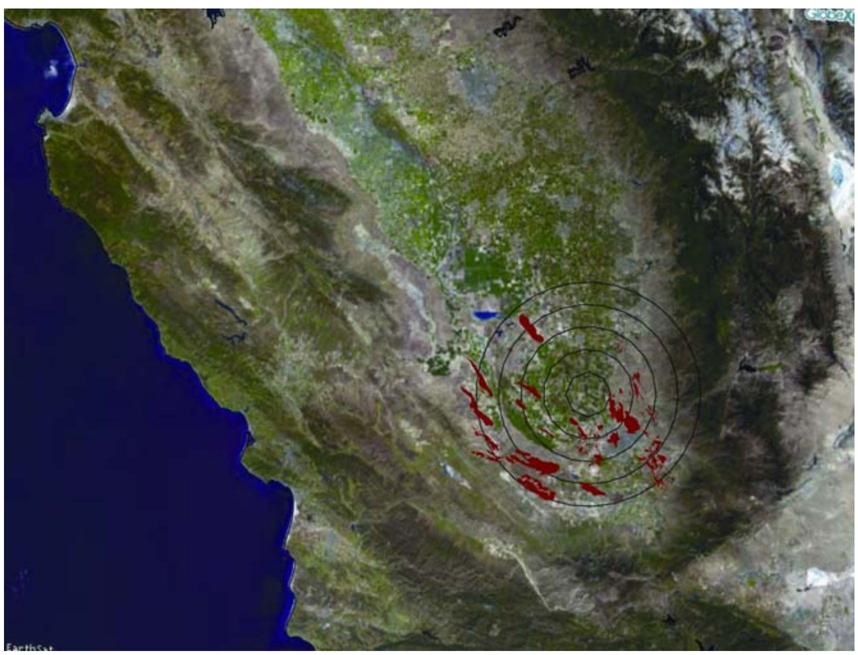
Reservoir targets include depleted oil and gas fields and saline units. There are also EOR opportunities. CO_2 sources in the region include power plants of various sizes. The San Joaquin Valley also is close to large sources, including cement plants and refineries, located along California's coast.



From: http://www.westcarb.org/partners/data/CECPlantMap.pdf



Figures from "Carbon Sequestration Atlas of the United States and Canada", DOE 2007



The target area for our detailed case study is a 50-km radius around the Kimberlina power plant (bulls-eye on map above).

Detailed Case Study of Kimberlina Area Captures Key Issues and Challenges For Site Assessment

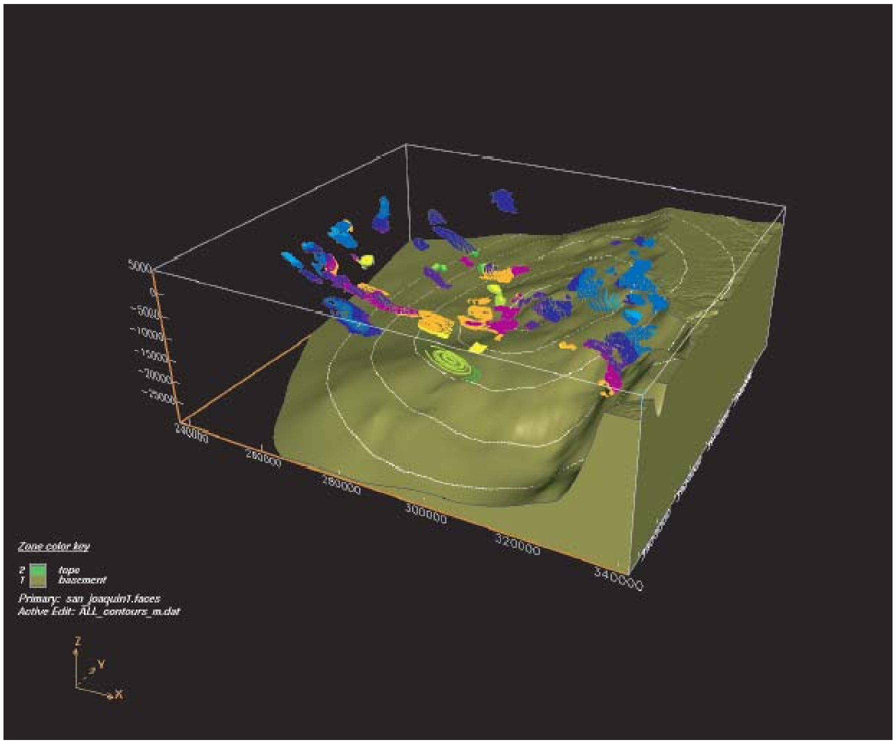
Assessing data availability, spatial coverage, and quality is the first key step to performing a site assessment. Ideally, data are non-proprietary or public. For the San Joaquin Valley, data sources include the USGS, CA Geological Survey, and CA Division of Oil and Gas. 2-D seismic is available over much of the study area.

There is a good well spatial coverage and documentation via digital and raster well files with:

- formation picks
- range of well-log types
- some lithology, porosity and permeability information.

But data density is very uneven within the basin.

Well locations near Kimberlina power plant



3-D model of basement surface. The overlying data represent structural tops of reservoir zones in selected oil fields. Colors show depth distribution (light blue, shallowest; green, deepest). These are the data-rich areas from which the regional picture must be constructed.

Data Were Used To Construct a Layered Geomodel Framework

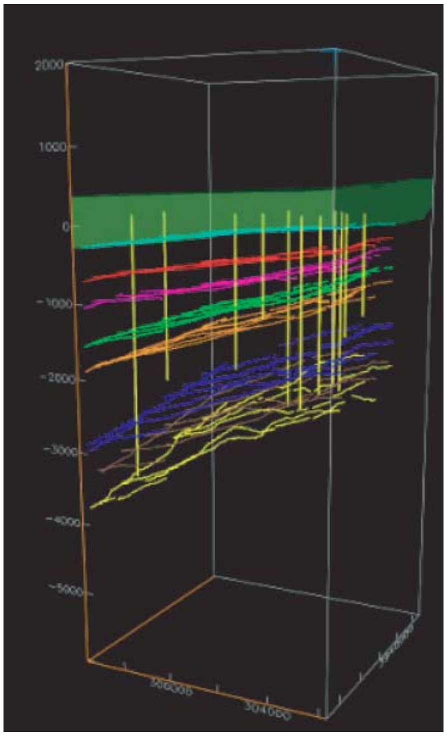
Data were imported into EarthVision® to construct a geomodel of the target strata. Miss-ties in picks were readily evident and easily fixed. To align disparate datasets, a reference well had to be identified based on greatest depth coverage and data quality.

Once a consistent geomodel was developed, lithologic and porosity/permeability information was used to target potential formations. In this study, the Vedder Sandstone appears to be one of the best candidates:

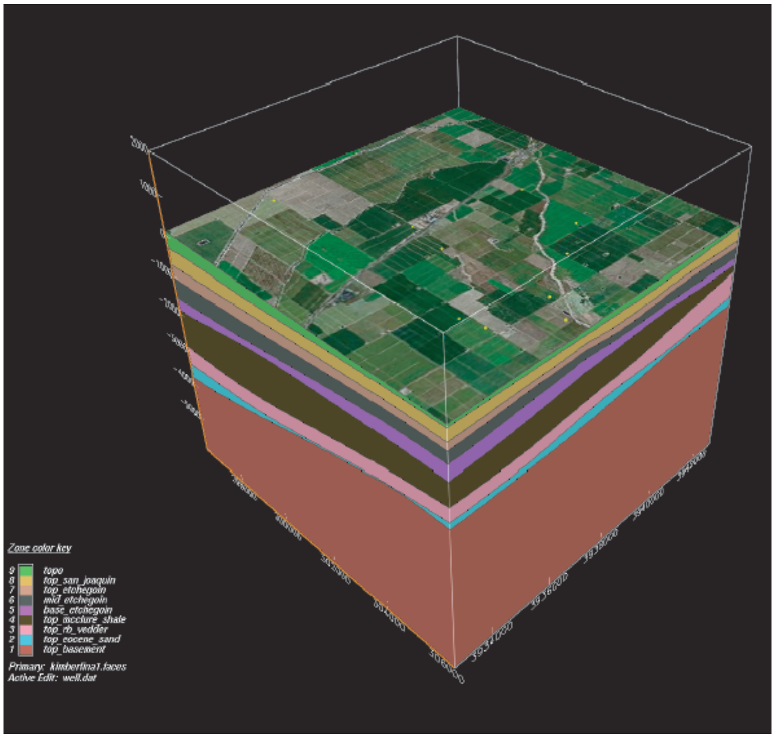
- Thick, continuous unit at depth
- High porosity and permeability
- Potentially good injectivity and capacity

Geomodel Yields Capacity Estimates and Risk From Geologic Uncertainty

Through gridding of intervals that include candidate units, storage volumes can be precisely quantified. Combined with lithologic, facies, and porosity/permeability information, estimates are made of storage capacity via physical and chemical (dissolved, mineral) mechanisms. Addition of geostatistical methods will provide ways to estimate project risks deriving from geologic uncertainty due to data or knowledge gaps, and also will allow quantitative comparison of results from this method and other approaches.



Geomodel view showing tops of main units along seismic lines and wells (vertical yellow lines).



Geomodel view showing main units. The Vedder Sandstone is the pink layer.

Acknowledgments

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Appendix A:
Methodology For Calculating Storage Capacity In Saline Aquifers

Several discrete steps are needed to adequately characterize the potential CO_2 storage of a site, formation, region, or basin. These steps combine to form a methodology that can be applied to siliciclastic and carbonate saline formations provided that CO_2 will be supercritical. The critical issue is to render and propagate uncertainties through the calculation in ways that are transparent, accurate, and quickly improved as new data are gathered.

Pore Volume Determination

To calculate pore volumes requires integration of rock thickness (h) and areal extent (A) to get the rock volume. This is then multiplied by fractional porosity (ϕ) and "net pay" meaning the fraction of the rock unit which is sufficiently permeable to accept fluids like CO_2.

$$V = h*A*\phi*N$$

A perfect calculation would have perfect knowledge of this information over the area of interest. Since real cases often lack data, the thickness, area, porosity, and net pay can be represented as ranges or (given sufficient information) probability density functions (PDFs). Ranges and probability distributions can be drawn from the local data set, adjacent data sets, gridded interpolations, and geological analogs. In many cases, homogeneous distributions (rectangular PDFs) can be applied initially until better data are available (e.g., Gaussian, bimodal PDFs). These distributions can vary either randomly or according to the PDFs through a Monte-Carlo calculation, averaged over thousands of renderings.

Process Mechanism Calculation

The actual volume of CO_2 stored is a function of the mechanism or process that traps CO_2 underground. For most saline aquifers, three trapping mechanisms are important over short time scales:

- *Physical trapping*, in which the pore can be nearly filled provided there is an impermeable seal overlying the target formation;
- *Residual phase trapping*, in which the capillary forces within the pore trap CO_2 as a non-wetting phase (small bubble);
- *Dissolution trapping*, in which the CO_2 dissolves into the brine at a given rate up to saturation.

There are many published data sets on analog scenarios from hydrological and hydrocarbon studies that can parameterize all three storage mechanisms. In addition, knowledge of reservoir temperature and pressure is important to calculate supercritical CO_2 density, in order to translate volumes into CO_2 mass. These data can be used to provide estimates before injection, and can be validated after injection using conventional tools.

Preliminary Calculations at the Kimberlina Site

In the case of the area assessed under Westcarb's Kimberlina prospect, an area of 10 km by 10 km served as the preliminary study area. Three formations (Stevens Sandstone, Oclese Formation., Vedder Sandstone) were gridded in EarthVision using interpolation and linear extrapolation from existing wells to provide thickness. Density was calculated across the range of reservoir pressures and temperatures for the study area. Within those grids, these values were used to make the calculations. In all cases, conservative assessments of parameters were selected.

- Porosity varied uniformly between 0.15 and 0.30, reflecting published values, special core analyses, and interpretation of conventional petrophysical logs.
- Net pay was conservatively assessed at 0.65.
- Physical trapping pore volume assumed that 90% of the pore was filled with CO_2 and that only 50% of the available rock volume held CO_2.
- Residual phase trapping volume was conservatively assumed to be 8% (most sandstone systems range from 5-25%) and that only 50% of the available formation held CO_2
- Dissolved trapping volume was chosen to be 5% (most systems range from 3-6%)

These assumptions for a single calculation yielded the following results for the 10 km by 10 km study area:

- If all CO_2 were trapped by physical trapping only, the capacity of the three most accessible formations is 2800 million tons.
- If the CO_2 were trapped by a combination of residual and dissolution trapping, the capacity for the same three units is 800 million tons.

It should be stressed that these are likely to prove quite conservative. In the current research plan, a full Monte Carlo calculation will be completed for the larger study area.

Risked Volumes

In a full calculation, the uncertainties of the parameters are propagated through Monte Carlo method. In addition, the capacities are multiplied by a risk coefficient that represents the chance of success. In a situation where there is 100% certainty that the prospect will succeed, then the risked volume is equal to the process calculations. In most cases, however, there is some uncertainty about the potential effectiveness of the prospect. There are conventional, formal mechanisms to assess these risks given a range of scenarios of interest, usually resulting in a smaller probability. The Kimberlina preliminary calculation was NOT a risked volume.