


WESTCARB Phase I Results Review

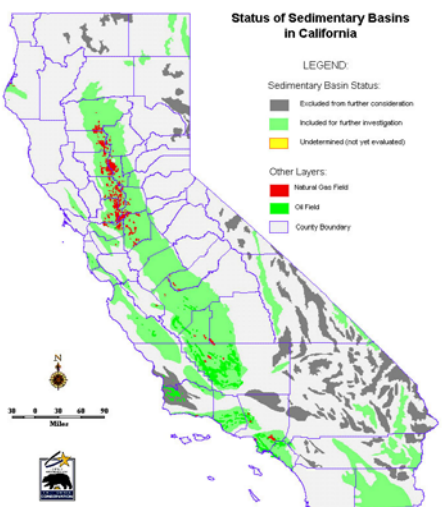
California CO₂ Storage Capacity Estimation

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California Has Significant Storage Opportunities in Oil and Gas Reservoirs and Saline Formations



**Status of Sedimentary Basins
in California**



LEGEND

Sedimentary Basin Status:

- Excluded from further consideration
- Included for further investigation
- Undetermined (not yet evaluated)

Other Layers:

- Natural Gas Field
- Oil Field
- County Boundary



Outline

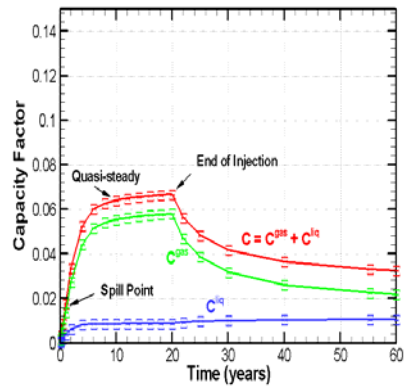
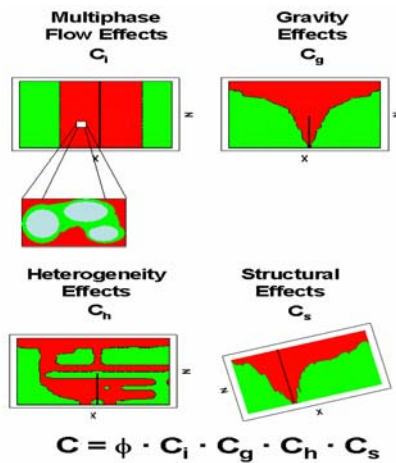
- Methods and uncertainties for calculating capacity
- Capacity estimates for California
 - Oil
 - Gas
 - Saline formations
- Next steps



WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP 3



Many Factors Affect Capacity Calculations

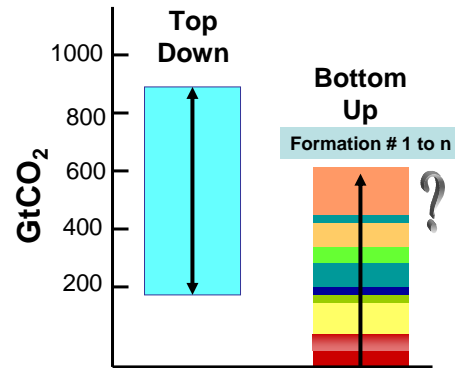


WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP 4



Storage Capacity Assessment Methodology

- No generally accepted methods
- Top down vs. bottom up
- WESTCARB capacity estimates use elements of both approaches



Screening Criteria for Oil and Gas Fields

- Oil and gas fields >3000 ft deep
- CO₂-EOR potential
 - API gravity more than 25° were classified as fields with miscible CO₂-EOR potential
 - API gravity between 17.5° and 25° were classified as fields with immiscible CO₂-EOR potential
 - API gravity less than 17.5° for storage only



Capacity Estimation: Oil and Gas Fields

$$Q_{CO_2} = (V_{Uoil} + V_{Ugas}) * \rho_{CO_2} / 1,000$$

$$V_{Uoil} = V_{oil(st)} * B_o$$

$$V_{Ugas} = V_{gas(st)} * B_g$$

- Q_{CO_2} = CO₂ storage capacity (MtCO₂)
 V_{Uoil} = Underground volume of oil produced (M m³)
 V_{Ugas} = Underground volume of gas produced (M m³)
 ρ_{CO_2} = CO₂ density at the reservoir pressure
 $V_{oil(st)}$ = Volume of oil at standard conditions (M m³) = 1.2
 $V_{gas(st)}$ = Volume of gas at standard conditions (M m³)
 B_o = Oil formation volume factor (FVF)
 B_g = Gas formation volume factor = 1/(4.8*P+93.1)
P = Reservoir pressure in MPa



Oil and Gas Field GIS Layer Is Attributed by Field Tables

Field Code:	VE024
Field:	Honor Rancho Oil
Discovery Well Operator:	The Texas Co.
Discovery Well:	Honor Rancho A (NCT-1) 1
Section:	6
Township:	4N
Range:	16W
Meridian:	SB
Discovery Date:	8/1/1950
Deepest Well Operator:	Southern California Gas Co.
Deepest Well:	Wayside Unit 28
Section:	7
Township:	4N
Range:	16W
Meridian:	SB
Depth (ft.):	11,747
Field Area (ac.):	450
Cum. Oil Prod. (MBO):	31,098
Cum. Gas Prod. (MMCF):	52,992
Base Fresh Water (ft.):	1,150



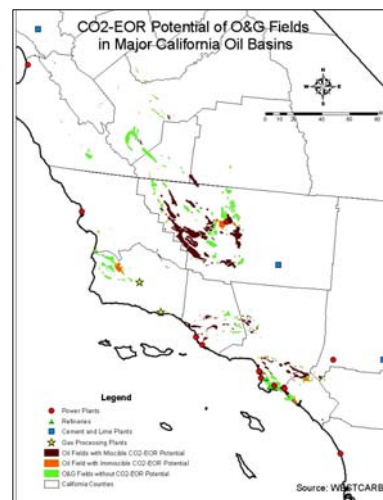
Zone Table Provides Detailed Data for Each Field

Field Code:	VE024	Perm. (md):	
Zone:	Modelo	Perm. Range Min. (md):	20
Fin. (Wayside Mbr.):		Perm. Range Max. (md):	179
Age:	U.	Pressure (lb. ft):	
Miocene		Pressure Range Min. (lb. ft):	2,962
Oil or Gas (O/G):	O	Pressure Range Max. (lb. ft):	4,500
Date of Discovery:		Temperature (°F):	190
12/1/1950		Temperature Range Min. (°F):	
Zone Status (P/A/SI):		Temperature Range Max. (°F):	
P		Salinity (ppm NaCl):	
API Gravity:		Salinity Range Min. (ppm NaCl):	11,200
API Range Min.:	35	Salinity Range Max. (ppm NaCl):	24,800
API Range Max.:	39	TDS (ppm):	20,200
GOR:		TDS Range Min. (ppm):	
GOR Range Min.:	550	TDS Range Max. (ppm):	
GOR Range Max.:	1,250	Seal:	Modelo Fin.
Sp. Gravity:		Seal Thickness (ft.):	
Sp. Gravity Range Min.:	0.470	Seal Thickness Range Min. (ft.):	5
Sp. Gravity Range Max.:	0.765	Seal Thickness Range Max. (ft.):	50
BTU:	1,066	Trap Type:	
BTU Range Min.:		Stratigraphic	
BTU Range Max.:		Fault Intensity:	L Gas
Cum. Oil (MBO):	29,094	ERP 1:	
Cum. Gas (MMCF):	47,601	Injection	
No Pool Breakdown:		ERP 1 Start:	1954
Depth (ft):		ERP 1 Stop:	1956
Depth Range Min. (ft):	6,481	ERP 2:	
Depth Range Max. (ft):	10,000	Waterflood	
Thickness (ft):		ERP 2 Start:	1959
Thickness Range Min. (ft):	94	ERP 2 Stop:	1966
Thickness Range Max. (ft):	310	ERP 3:	
Producing Area (ac.):	400	Waterflood	
Porosity (%):		ERP 3 Start:	1972
Porosity Range Min. (%):	7	ERP 3 Stop:	1975
Porosity Range Max. (%):	26		



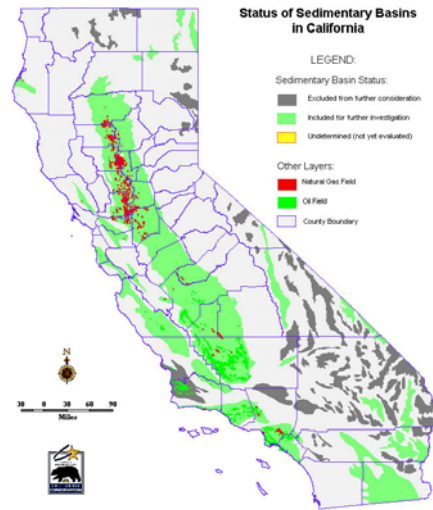
Significant Opportunities for EOR and EGR

- 121 fields met depth and miscible EOR criteria
 - 3.4 Gt CO₂ storage capacity for EOR fields
 - 3.8 Gt CO₂ storage capacity for all oil fields
 - Other studies suggest 5.4 billion barrels oil technically recoverable (ARI, 2004)
- 128 gas fields met depth criteria
 - 1.8 Gt CO₂ storage capacity

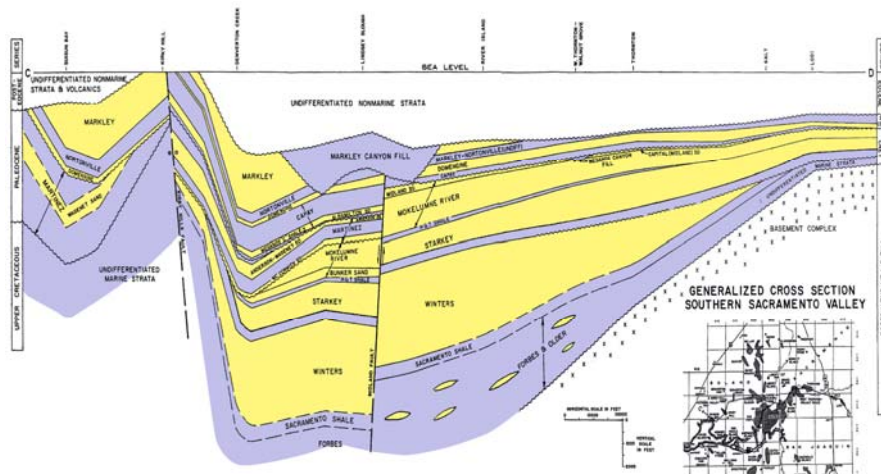


Saline Formation Capacity Assessment: Preliminary Screening Eliminated 74 of 101 Basins in California

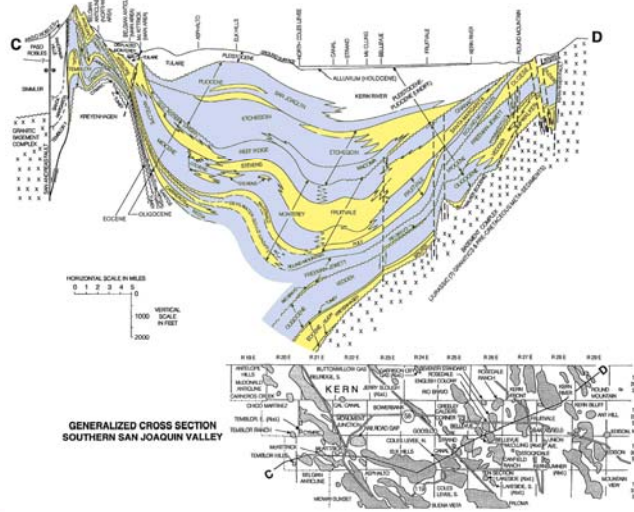
- Screening criteria
 - Depth (<1000m)
 - Presence of porous and permeable sediments
 - Presence of seals
 - Restricted access (parks, Indian lands, military installations)
- Data from literature and well logs



Generalized Cross-Section of Southern Sacramento Basin

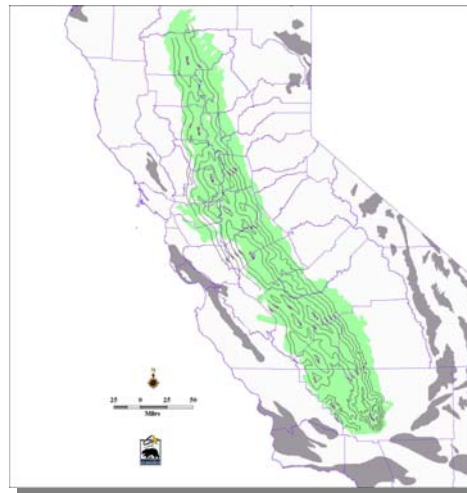


Generalized Cross-Section of Southern San Joaquin Basin



Sand Isopach Map Provides Basis for Estimate of Capacity

- Sand thickness calculated for interval from 2625 ft (800m) to 10,000 ft
- Sequence stratigraphy not taken into account
- Sand thickness in excess of 4000 ft found in several areas



Volumetric Estimates Made for 10 Largest Basins

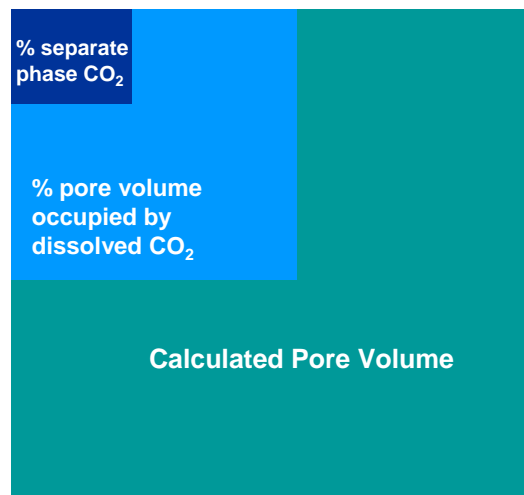
Table 1. Data used for calculation of pore volume of California basins

Volumetric Data for California Basins				
	Area	Estimated Average	Estimated Average	Pore Volume
	(sq. miles)+	Thickness (ft.)*	Porosity**	(cu. meters)
Sacramento-San Joaquin basins	18,550	2,000	0.25	7,321,941,287,906
Salton Trough	2,559	2,000	0.24	969,669,749,085
Ventura Basin	1,450	3,000	0.24	824,162,447,932
Los Angeles Basin	1,341	3,000	0.25	793,966,841,004
Cuyama Basin	582	3,000	0.27	372,151,974,334
Salinas Basin	1,343	1,250	0.28	371,070,458,478
La Honda Basin	268	1,500	0.25	79,337,477,028
Eel River Basin	175	1,500	0.26	53,878,435,892
Orinda Basin	296	600	0.23	32,246,539,917
Livermore Basin	144	800	0.23	20,916,674,541

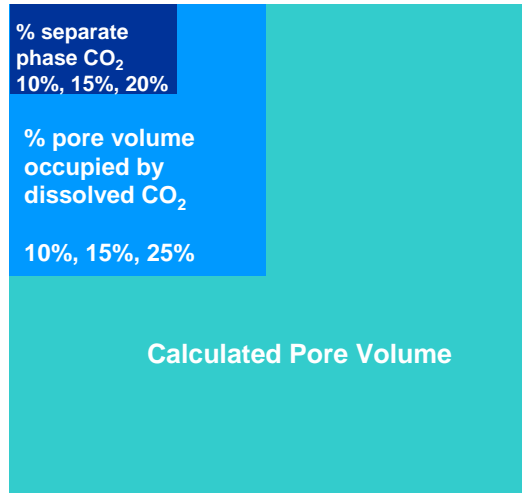
+Area of basin at depths greater than 2,625 ft. (800 m)
*Average sands (isopachs) thickness for depth window 2,625 ft (800 m)– 10,000 ft
**Approx. average porosity for all zones in isopachs window



Capacity Estimation for Saline Formations

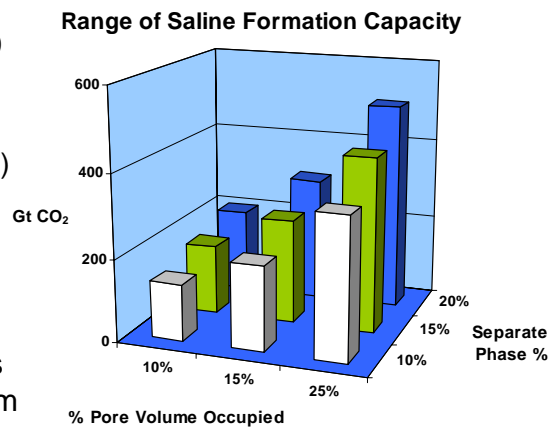


Capacity Estimation for Saline Formations



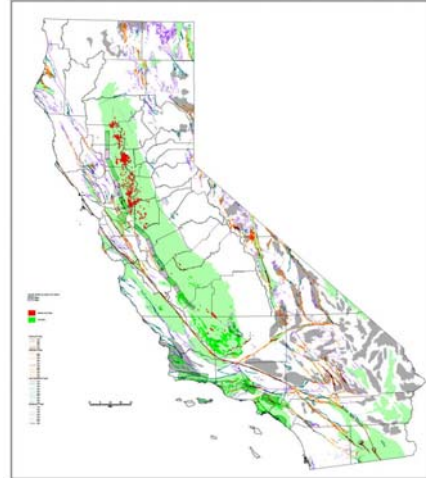
CO₂ Storage Capacity of 10 Largest Basins Is Immense

- Assume
 - Density (ρ_{CO_2}) = 600 kg/m³
 - Solubility = 1.5 mole % (20,000 ppm TDS)
- Range from 140 to 500 GtCO₂
- Low end of range > 1000 years of today's annual emissions from point sources in CA



Low Occurrence of Quaternary Faulting in Many Basins

- Hydrocarbons have remained trapped in faulted basins
- In Central Valley faulting is absent except at southern end; deep thrust faulting along western margin



Summary

- Regional scale assessment yields huge potential CO₂ storage capacity in California sedimentary basins
- Over half of the capacity is in the Central Valley
- Large numbers of oil and gas fields with EOR/EGR potential
- Low occurrence of active faulting in several basins, including Central Valley
- More detailed characterization at formation level needed for site-specific project planning

