

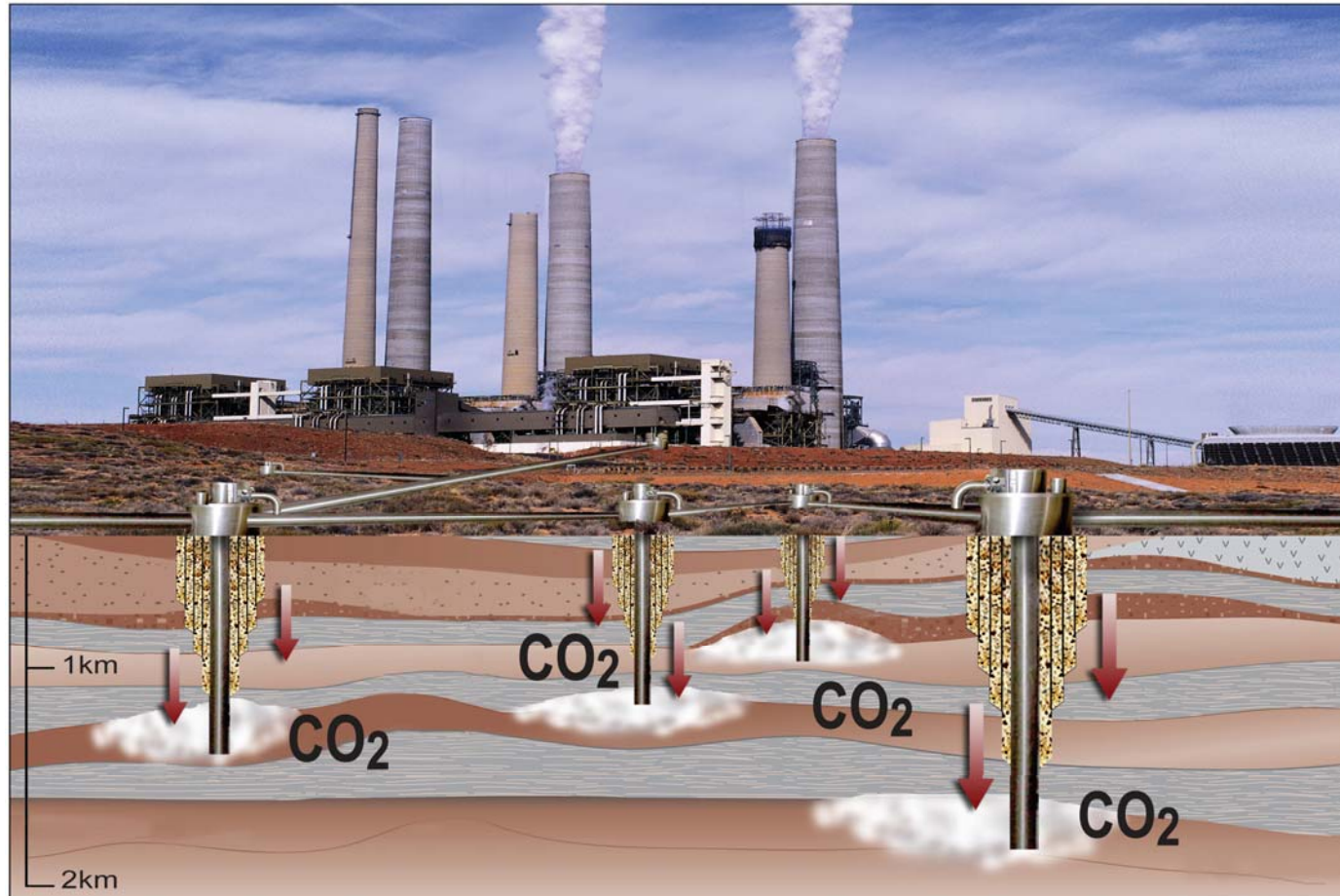


Gasification Technology Conference
San Francisco, CA
October 16, 2007

Geological Storage Capacity in the United States

Professor Sally M. Benson
Energy Resources Engineering Department
Executive Director, Global Climate and Energy Project
Stanford University

Carbon Dioxide Capture and Geologic Storage



Capture



Compression



Pipeline
Transport



Underground
Injection



Topics



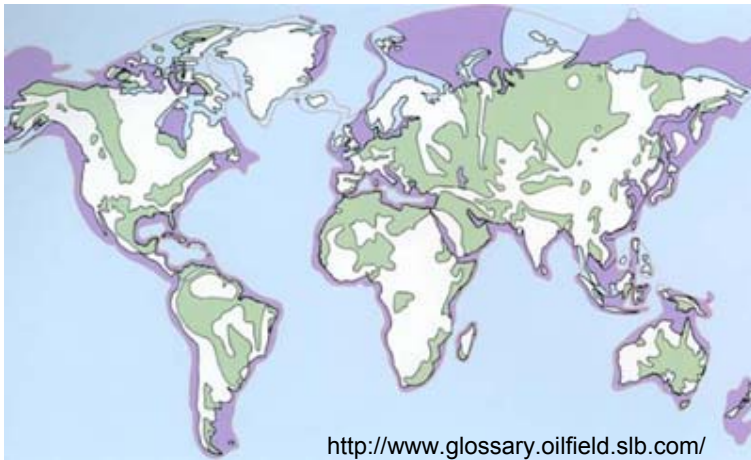
- What formations are suitable for storage?
- Where are they located?
- How much storage capacity is there?
- Conclusions



What Types of Rock Formations are Suitable for Geological Storage?

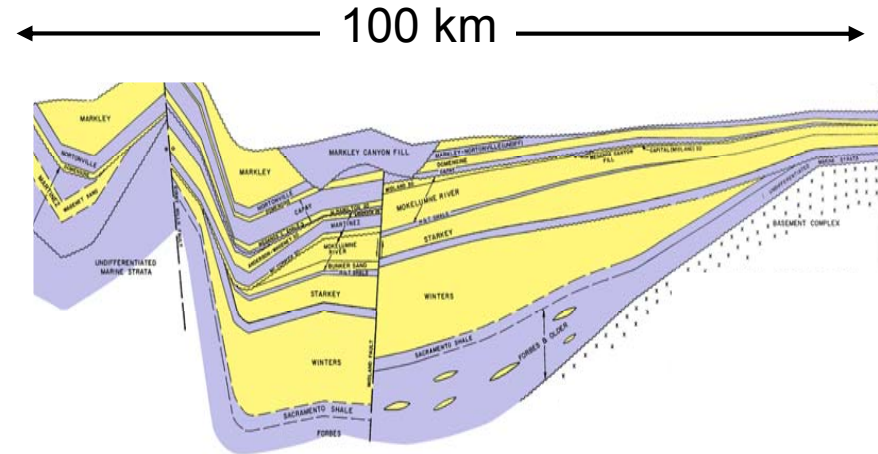


Rocks in deep sedimentary basins are suitable for CO₂ storage.



<http://www.glossary.oilfield.slb.com/>

Map showing world-wide sedimentary basins



Northern California Sedimentary Basin

Specific formation types

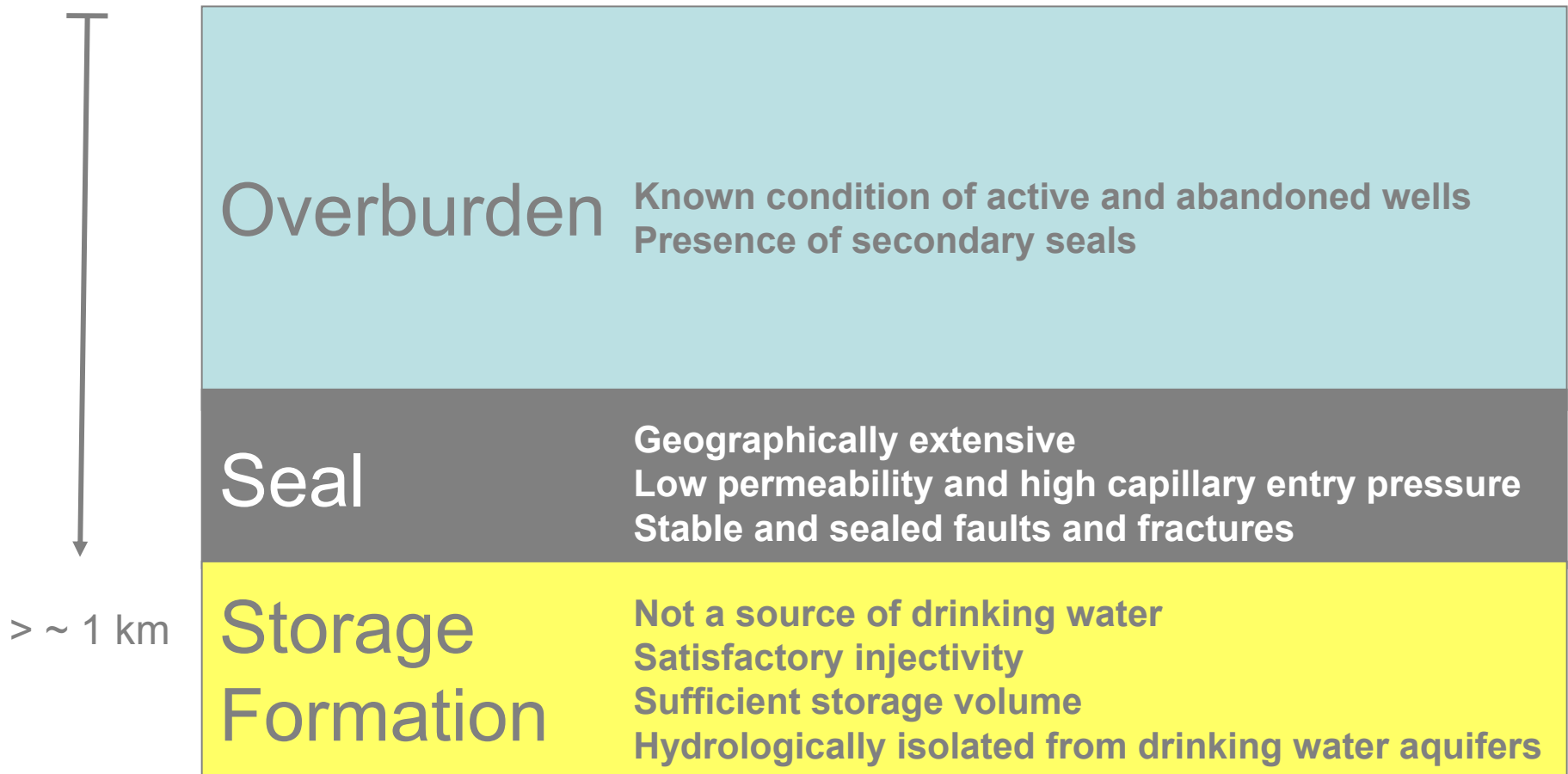
- Oil reservoirs
- Gas reservoirs
- Saline aquifers
- Deep unminable coal beds

What about CO₂ storage in basalt?

This is an unproven technology that is the subject of ongoing research.



Some Attributes of Effective Storage Sites

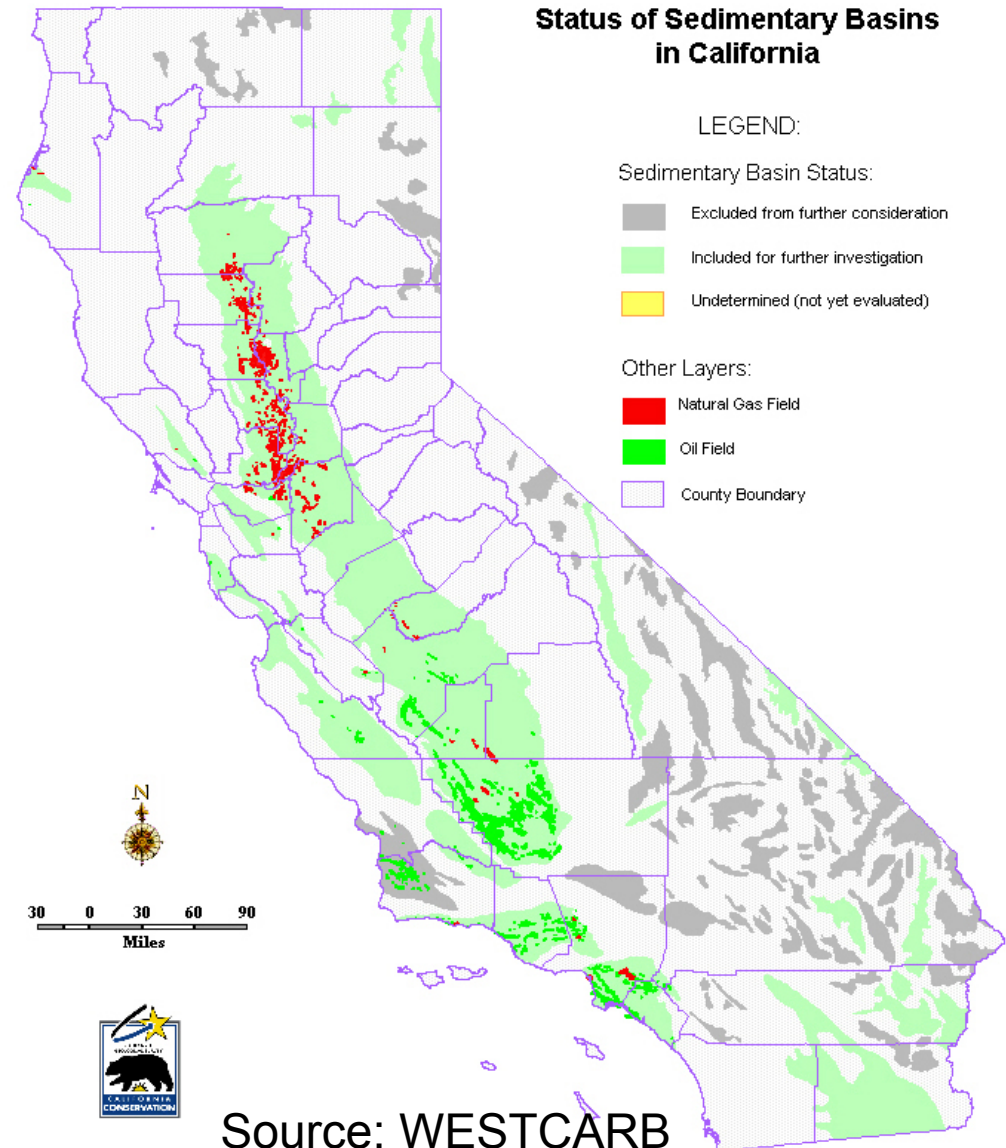




Capacity Assessment: California



- Screening criteria
 - depth (<800m),
 - presence of porous, permeable sediments,
 - presence of seals,
 - restricted access (parks, Indian lands, military installations)
- Data from literature and well logs



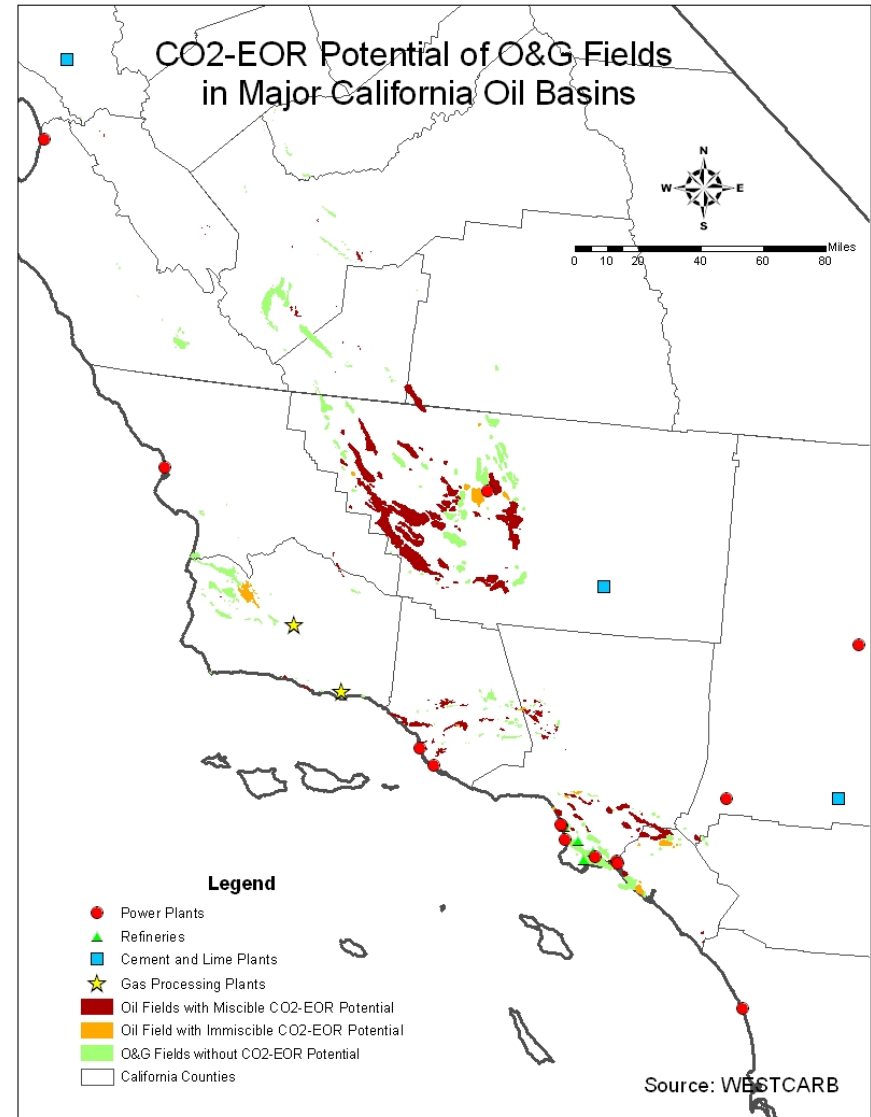
Source: WESTCARB



Oil and Gas Field Capacity Assessment



- 121 fields met depth and miscible EOR criteria
 - 3.4 Gt CO₂ storage capacity, using production as a basis
 - Other studies suggest 5.4 billion barrels oil technically recoverable
- 128 gas fields met depth criteria
 - 1.8 Gt CO₂ storage capacity

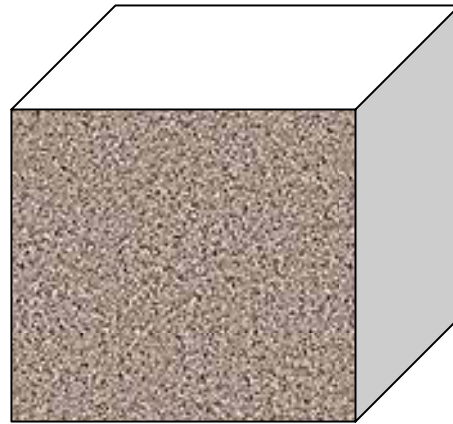




Saline Aquifer Capacity Assessment

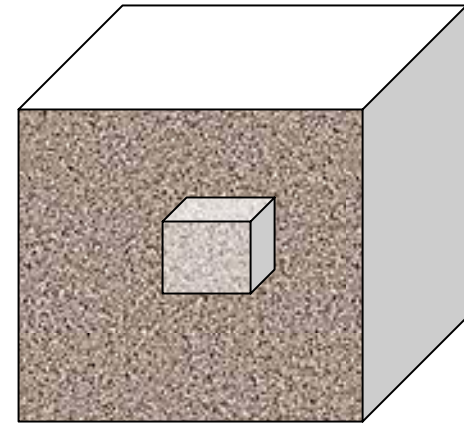


Storage Capacity =



Size of the "Box"

x



Fraction of the
Pore Space
Filled with CO₂



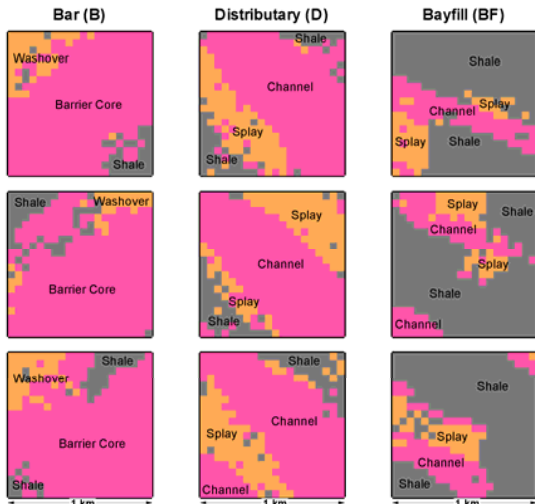
Saline Aquifer Capacity Assessment



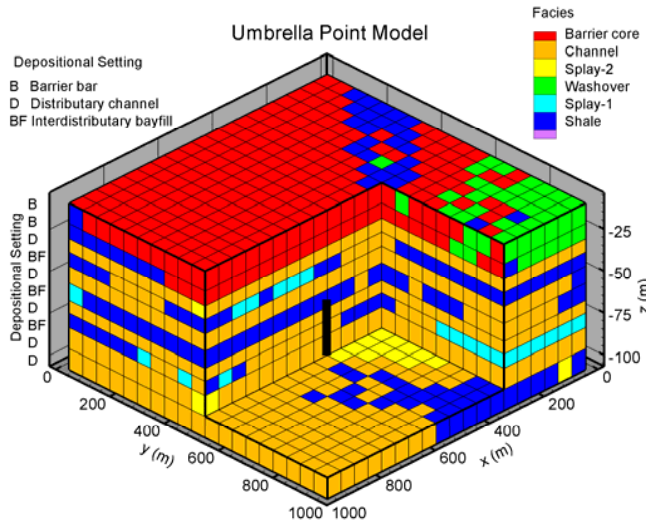
Basin	Area (> 800 m deep) (sq. miles.)	Average Thickness (ft.)	Average Porosity	Total estimated Pore Volume (cu. ft.)	Total estimated Pore Volume (cu. meters)
Sacramento-San Joaquin basins	18,550	2,000	0.25	258,572,160,000,000	7,321,941,287,906
Los Angeles Basin	1,341	3,000	0.25	28,038,700,800,000	793,966,841,004
Ventura Basin	1,450	3,000	0.24	29,105,049,600,000	824,162,447,932
Salton Trough	2,559	2,000	0.24	34,243,596,288,000	969,669,749,085
Eel River Basin	175	1,500	0.26	1,902,700,800,000	53,878,435,892
Salinas Basin	1,343	1,250	0.28	13,104,241,920,000	371,070,458,478
La Honda Basin	268	1,500	0.25	2,801,779,200,000	79,337,477,028
Livermore Basin	144	800	0.23	738,666,086,400	20,916,674,541
Orinda Basin	296	600	0.23	1,138,776,883,200	32,246,539,917
Cuyama Basin	582	3,000	0.27	13,142,435,328,000	372,151,974,334



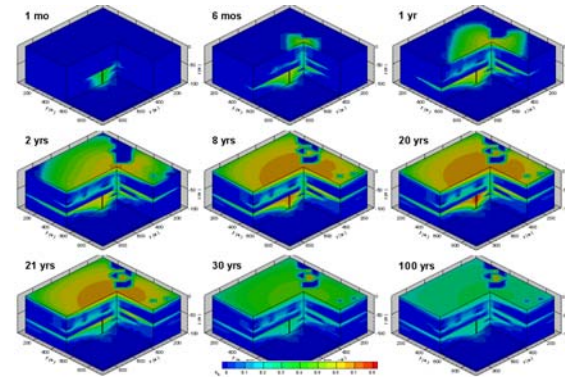
Approach for Assessing Capacity in Saline Aquifers



Geology

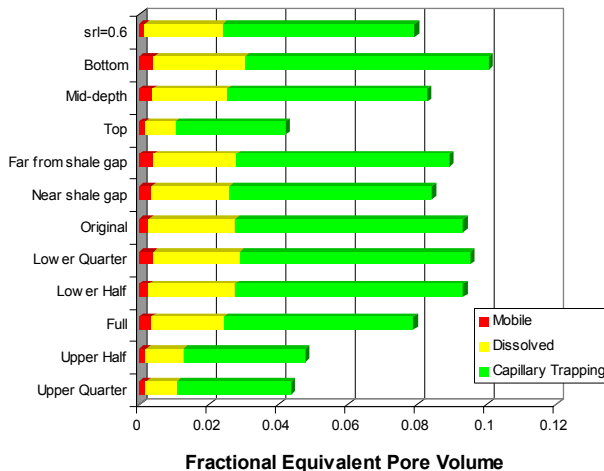


Models



Simulations

Statistics



“Rules of Thumb”

CO₂ Storage Capacity = 1 to 4% Total Pore Volume¹

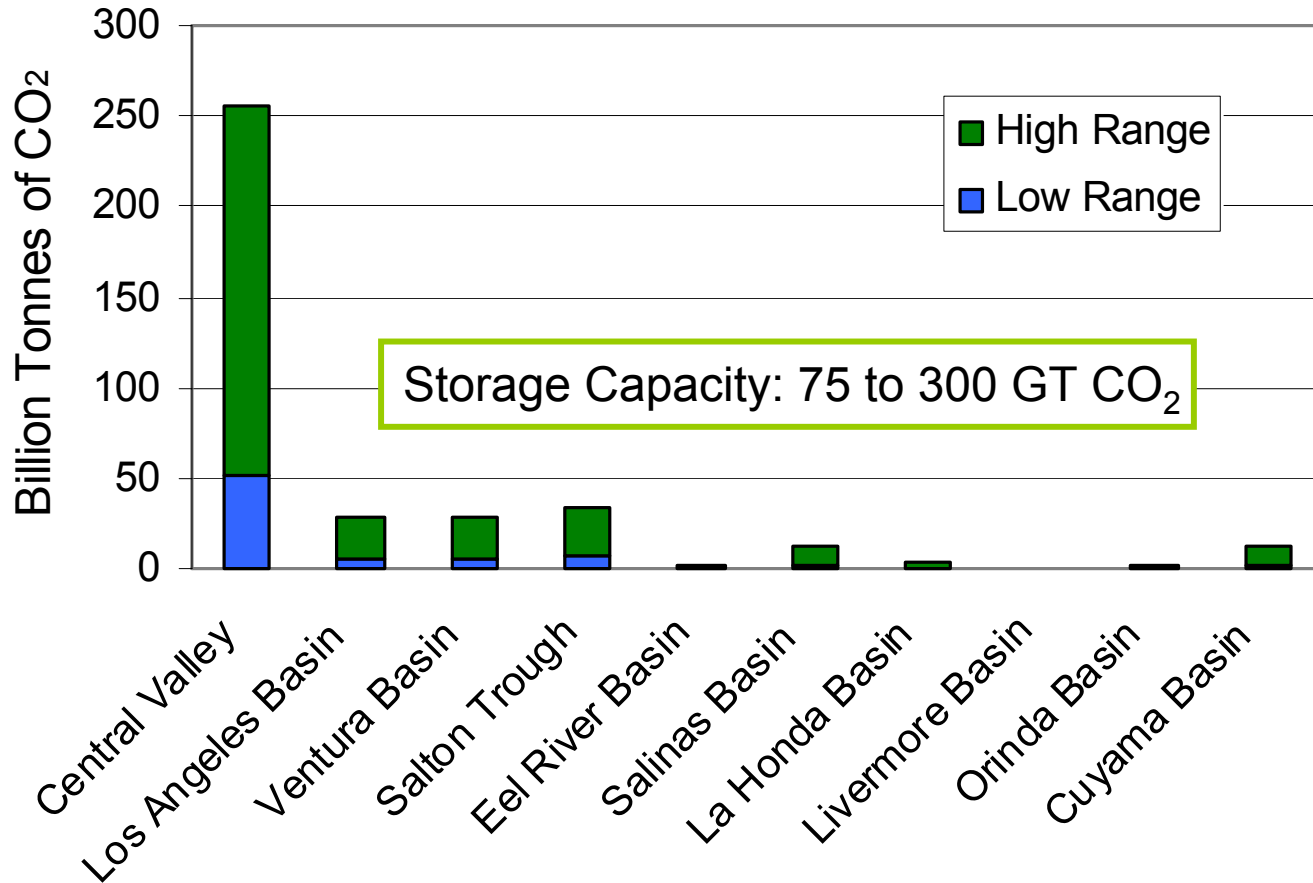
¹Values used in the First North American Carbon Sequestration Atlas, 2006



CO₂ Storage Capacity in California



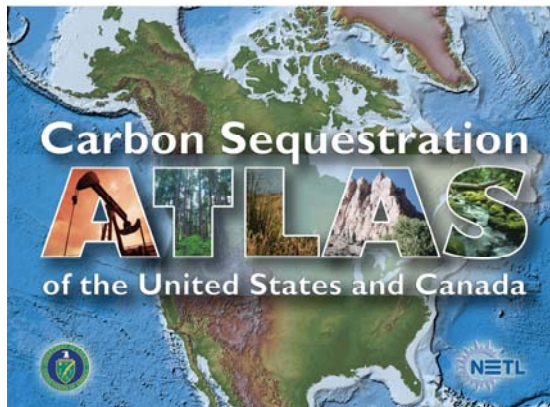
Saline Formation Capacity





Location of Storage Sites I

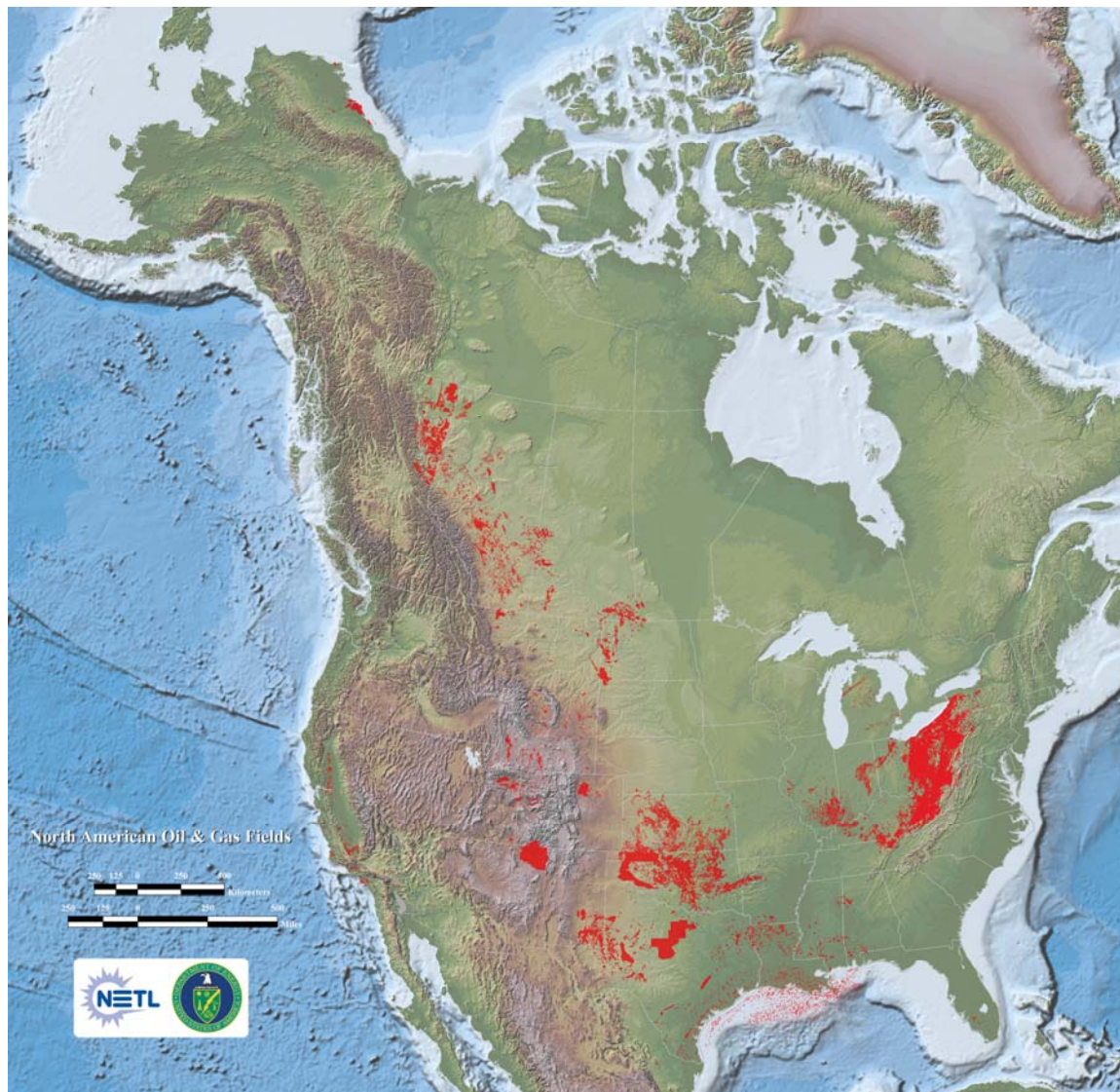
North America: Oil and Gas Fields



First North American Carbon Sequestration Atlas, 2006

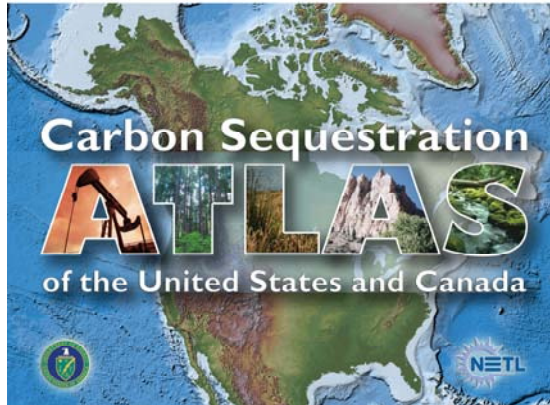
CO₂ Storage Capacity (Billion Metric Tons)

Big Sky	0.8
MGSC	0.4
MRCSP	2.5
PCOR	19.6
SECARB	32.4
SOUTHWEST	21.4
WESTCARB	5.3
TOTAL	82.4





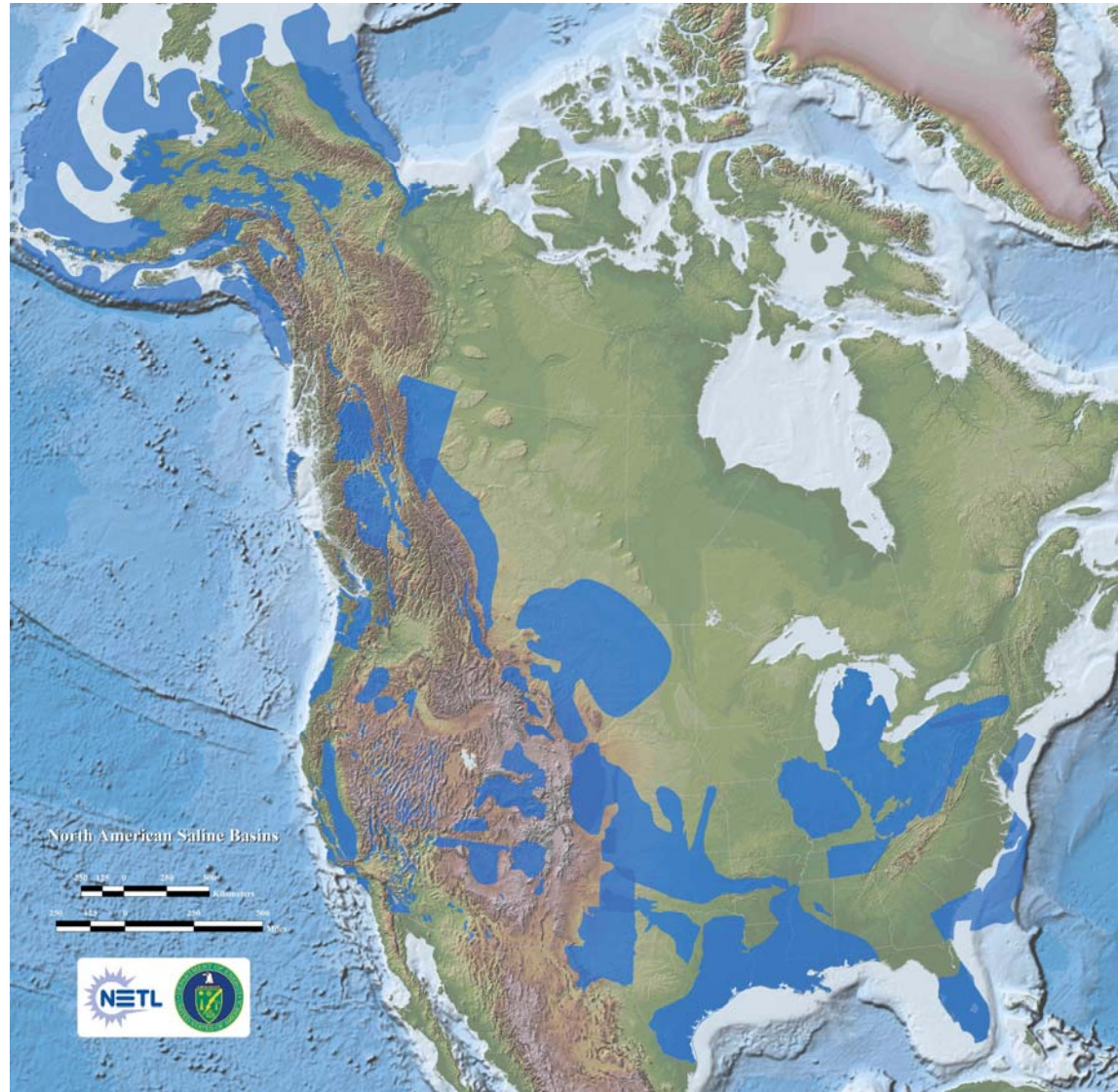
Location of Storage Sites in North America: Saline Aquifers



First North American Carbon Sequestration Atlas, 2006

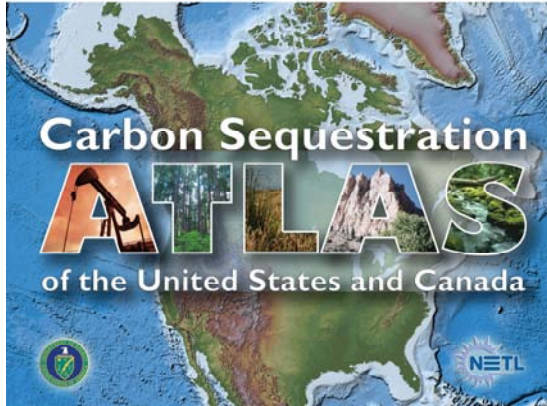
CO₂ Storage Capacity (Billion Metric Tons)

Big Sky	271	1,085
MGSC	29	115
MRCSP	47	189
PCOR	97	97
SECARB	360	1,440
SOUTHWEST	18	64
WESTCARB	97	288
TOTAL	919	3,378





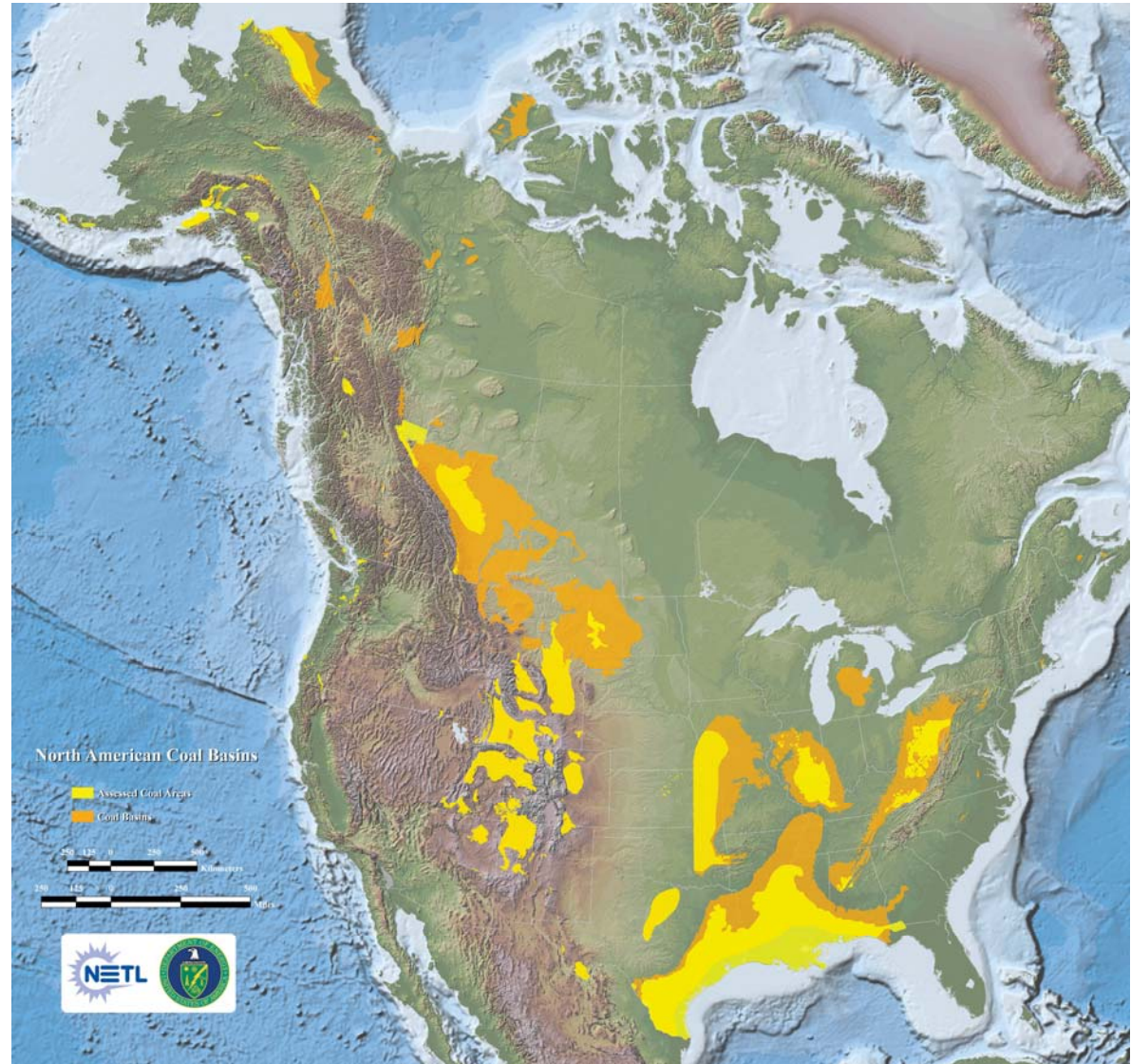
Location of Storage Sites in North America: Coal



First North American Carbon Sequestration Atlas, 2006

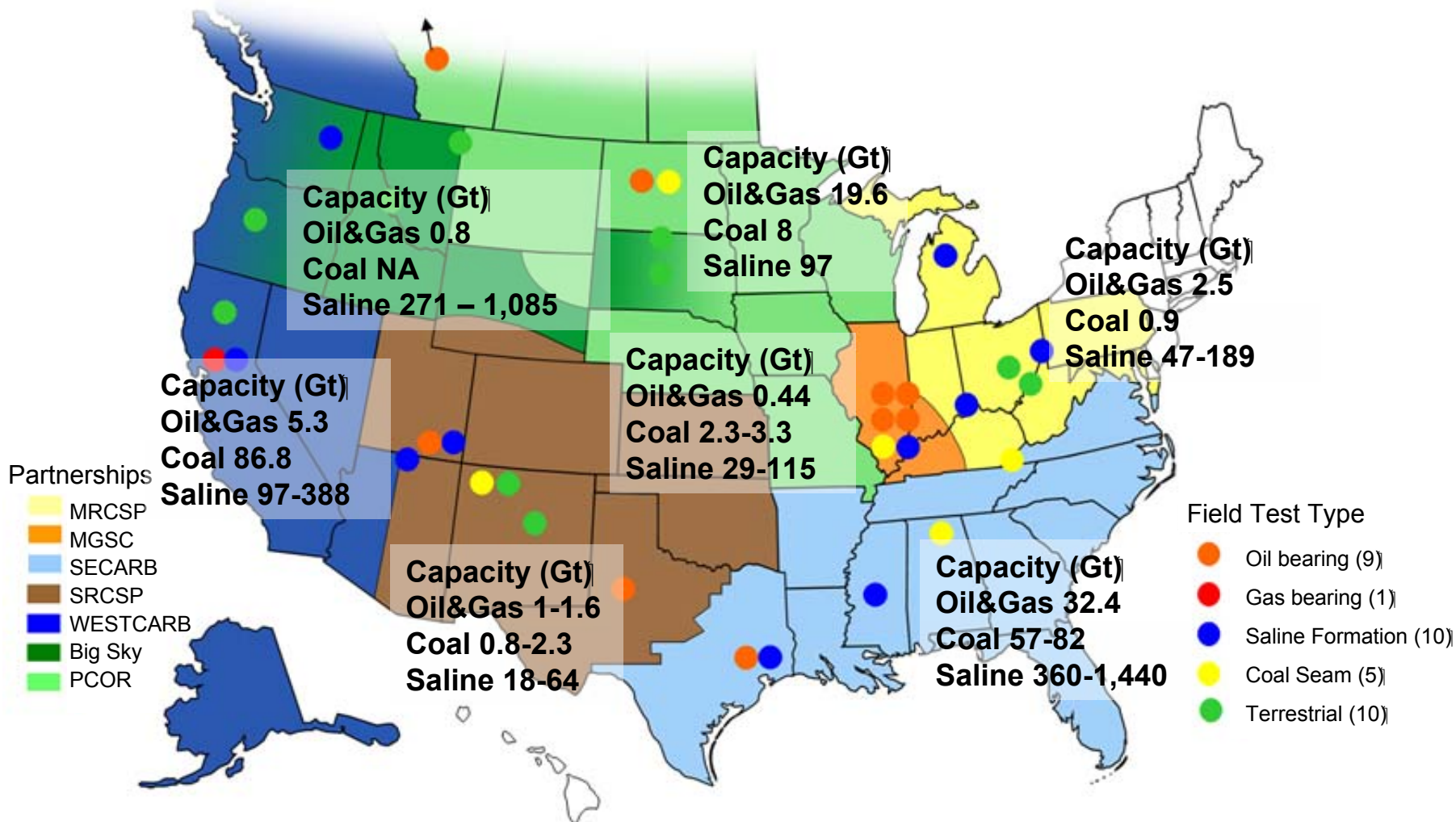
CO₂ Storage Capacity (Billion Metric Tons)

Big Sky	NA	NA
MGSC	2.3	3.3
MRCSP	0.7	1.0
PCOR	8.0	8.0
SECARB	57	82
SOUTHWEST	0.9	2.3
WESTCARB	87	87
TOTAL	156	183





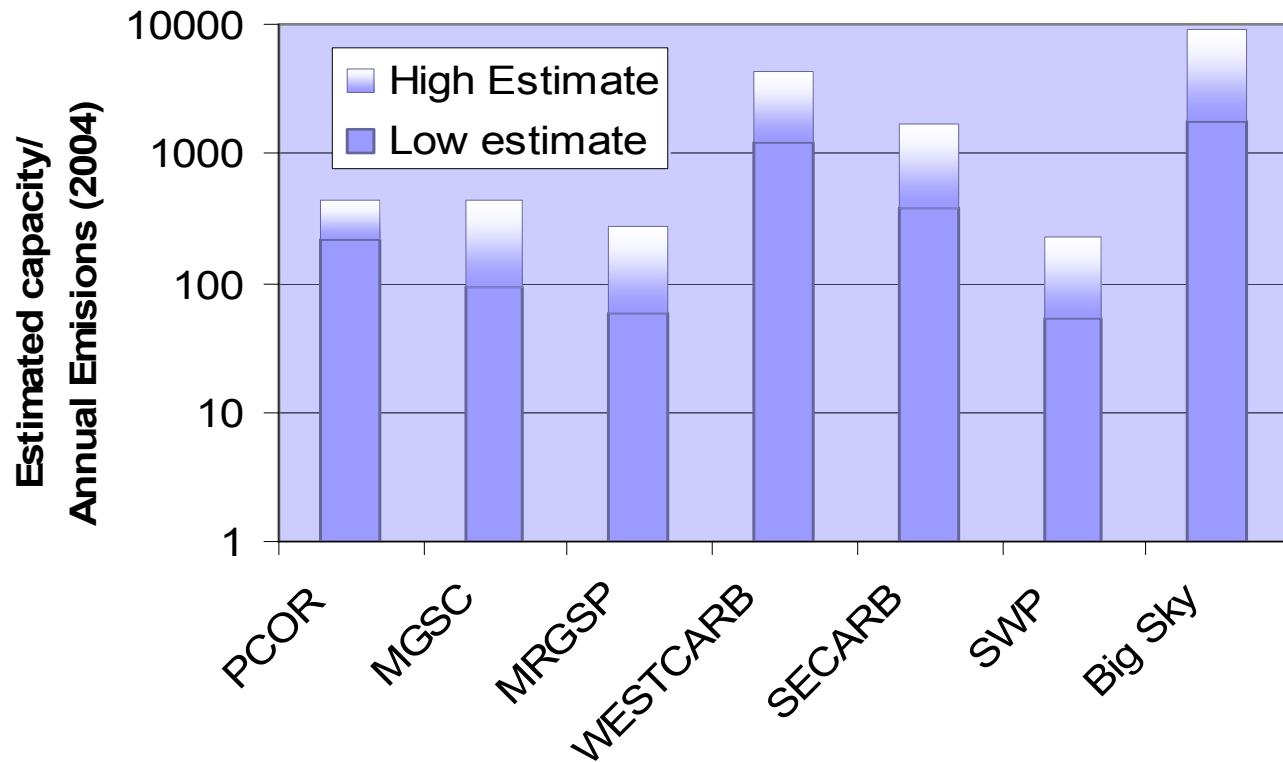
Storage Capacity* and Validation Test Sites for Phase II



* Tentative, subject to revision as new information is available (From Dawn DEEL, USDOE)



Capacity Varies Widely by Region



Theoretical capacity estimates range from 50 to over 1,000 times annual emissions (from stationary sources), depending on location.



Summary



- U.S. CO₂ Storage Capacity Range: 1,160 to 3,550 billion metric tons
 - > 200 times total annual CO₂ emissions
- Potential storage capacity
 - Saline Aquifers >> Coal > Oil and Gas
- Reliability of estimates
 - Oil and Gas >> Saline aquifers > Coal
- Highly uneven distribution of capacity
- Much more work is needed to increase confidence in theoretical and practical storage capacity estimates
- U.S. DOE is working on an update to the National Carbon Sequestration Atlas