FE0001922

Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage
August 21-23, 2012

Presentation Outline

1. **Benefit to the Program**
2. **Goals & Objectives (SOPO)**
3. **Project Background & Motivation**
4. **Accomplishments to Date**
5. **Summary**
6. **Project Sponsors & Participants**

Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

1. Benefit to the Program

This project is contributing to the understanding of injectivity, containment mechanisms, rate of dissolution and mineralization, and storage capacity of the Wilmington Graben and associated analog basins. The benefit of this research is that it will broaden the experimental knowledge base of best practices for site characterization and approving storage site selection with the ultimate goal of developing practical guidelines for future commercially developed CO_2 storage sites. This effort contributes to the Carbon Storage Program's effort of conducting field tests to support the development of Best Practices for site selection, characterization, and operations.

2. Goals & Objectives (a. SOPO Statement)

The overall objective of this collaborative research project led by Terralog Technologies is to fully characterize Pliocene and Miocene sediments in the Wilmington Graben, offshore Los Angeles, for high volume CO_2 storage.

These sediments are suspected to span more than 5000 feet of vertical interval, with an estimated capacity to store more than 50 million tons of CO_2.

2. Goals & Objectives (b. SOPO Specifics)

1) Detailed log evaluation of existing exploration wells in the area
2) Improved evaluation and interpretation of existing 2D and 3D seismic data
3) Acquisition and interpretation of additional 2D seismic lines
4) Drilling and coring three new evaluation wells into the Graben (Pliocene and Miocene) and/or on the landward side of the THUMS-HB fault
5) Development of 3D geologic models, geomechanical models, and CO_2 injection and migration models for the region
6) Analysis of industrial sources (top 20 in the LA Basin)
7) Transport Infrastructure Study: engineering study of existing and new pipeline systems to transport CO_2 from significant local sources to sequestration sites
8) Risk analysis

3. Project Background & Motivation

The Los Angeles Basin presents a unique combination of great need and great opportunity for large scale geologic storage of CO_2.

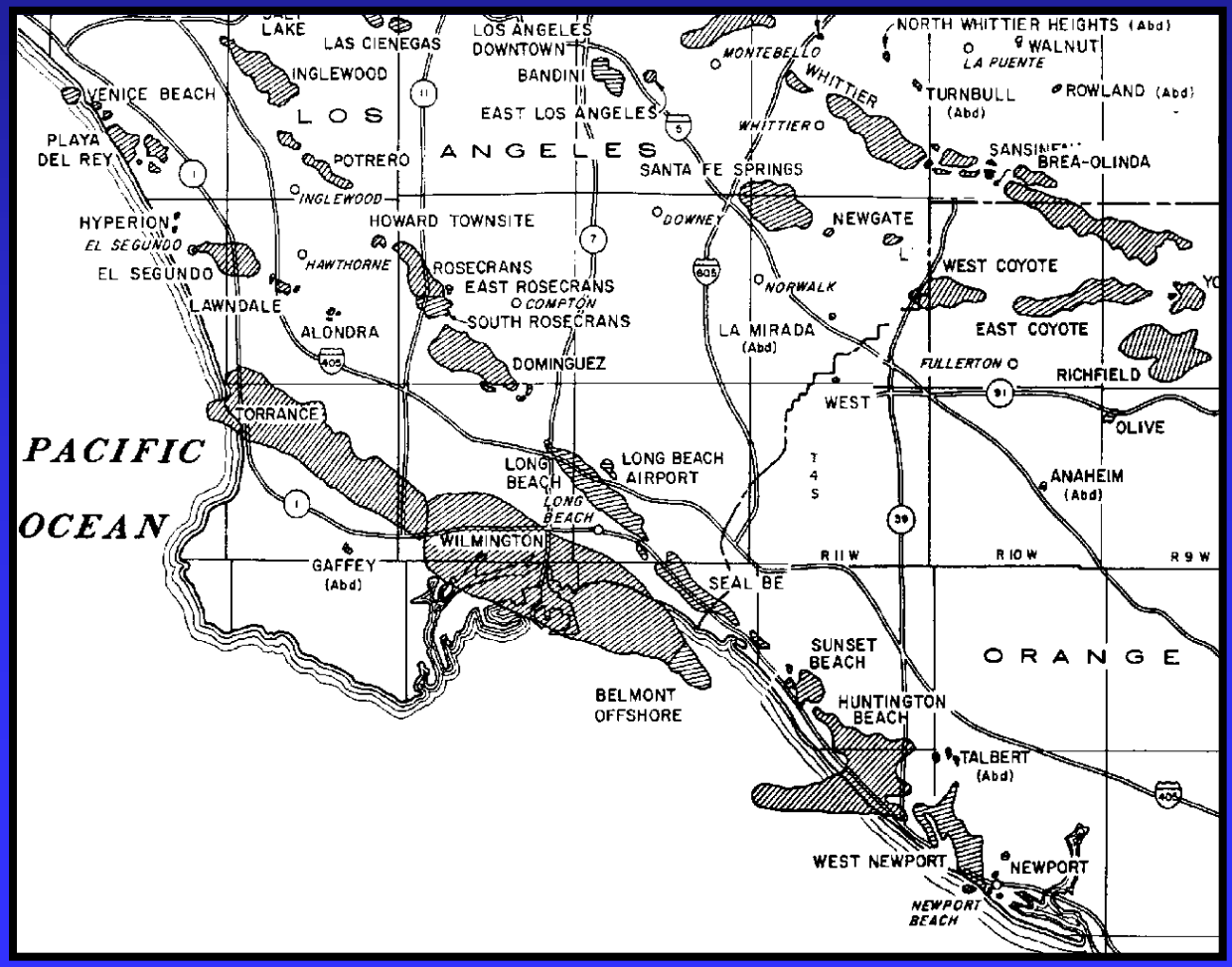
In part due to its significant population, and in part due to its historical and geologic setting as one of the most prolific oil and gas producing basins in the United States, the region is home to more than a dozen major power plants and oil refineries which produce more than 5 million metric tons of fossil fuel related CO_2 emissions each year.

3. Project Background & Motivation

Pliocene and Miocene sediments in the Los Angeles Basin (massive interbedded sand and shale sequences) are known to provide excellent and secure traps for oil and gas.

The area contains several billion-barrel oil and gas fields, including the giant Wilmington Field in Long Beach (more than two billion barrels produced to date).

These formations have been used by Southern California Gas Company for very large scale underground storage of natural gas at half a dozen locations throughout the Los Angeles basin for more than fifty years, demonstrating both the storage potential and security of these formations for CO_2 sequestration if properly characterized and selected.

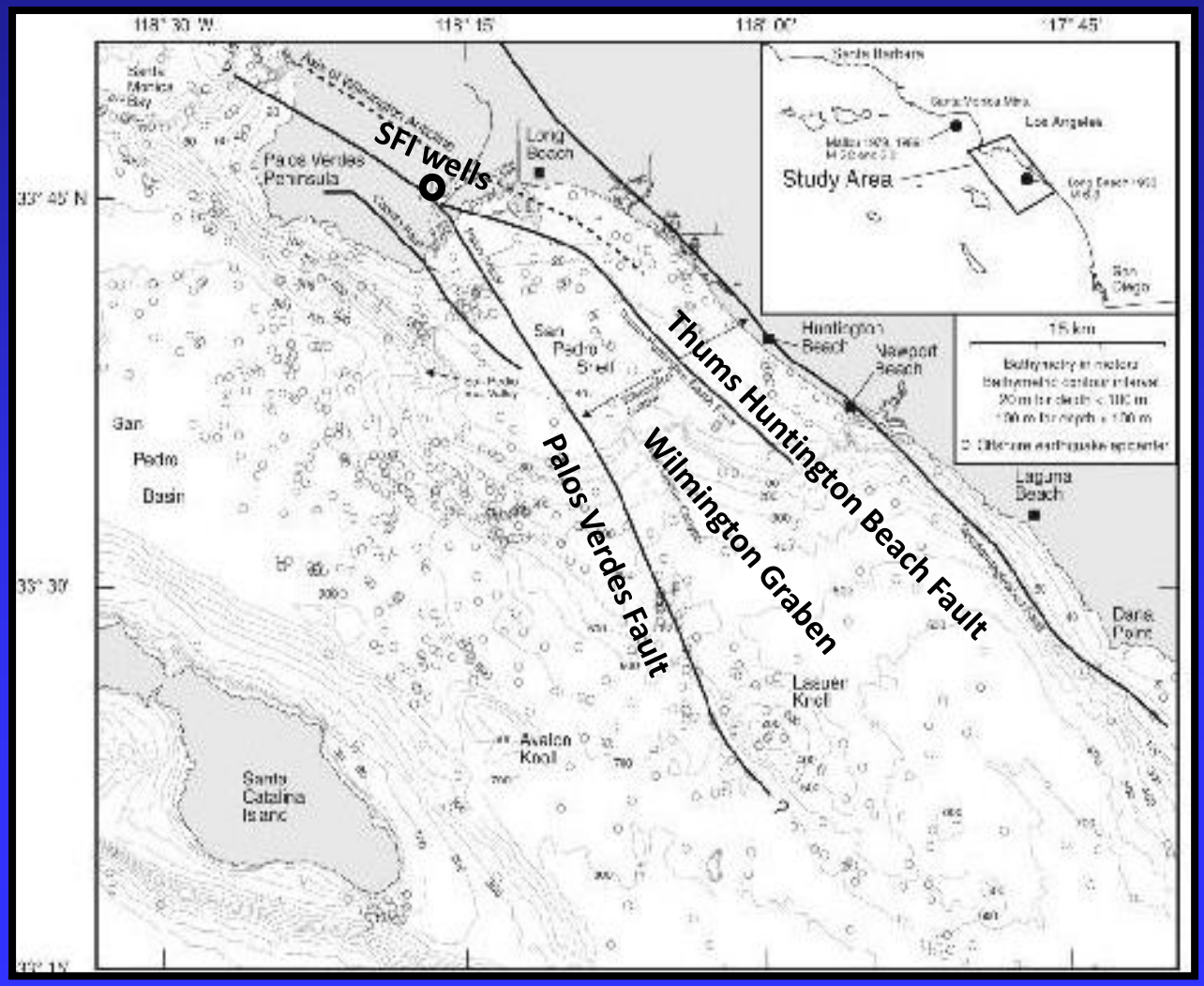


3. Project Background & Motivation

Given the current population density (and complex land ownership), it is impractical to site a large scale CO_2 storage project onshore beneath the City.

More than 3000 feet thickness of these same Pliocene and Miocene formations are present in the large Wilmington Graben directly offshore the Los Angeles and Long Beach Harbor area, at appropriate depth for ^c sequestration (about 3000 to 7000 ft).

This zone is easily accessible yet geologically isolated from the nearby Wilmington Oilfield and onshore area, reducing communication risk and public risk.



4. Accomplishments to Date

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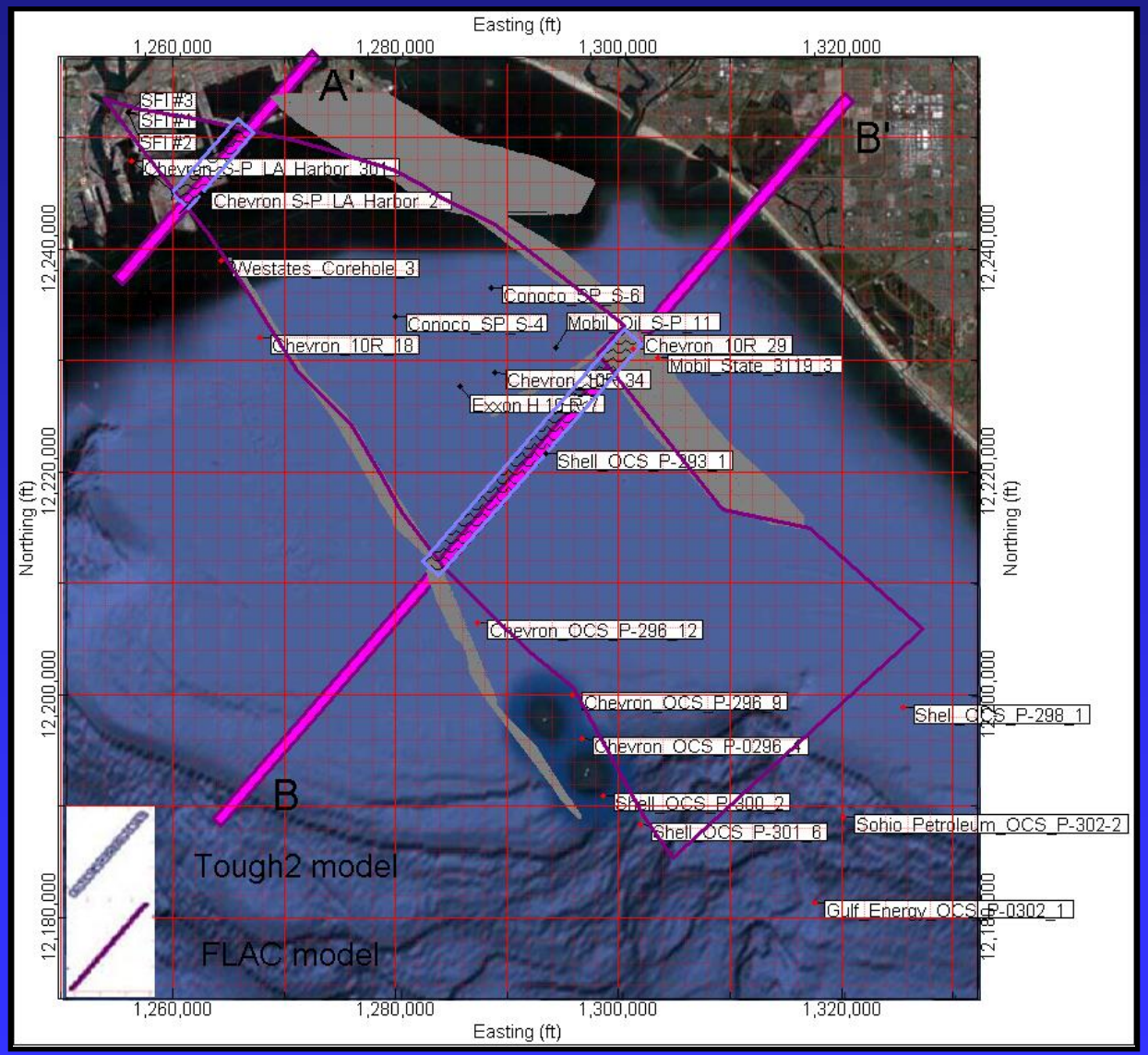
Exploration Wells in Wilmington Graben



Wells Reviewed for Lithology and Stratigraphy

API_no	Operator	Lease	Well_no	Td	Latitude	Longitude
State						
23700493	Exxon Mobil Corp		H 10 R-7	6643	33.67754	-118.16522
23720208	Conoco Inc.		SP S-4	4775	33.69454	-118.18442
23720211	Conoco Inc.		SP S-6	5025	33.70187	-118.1562
25920074	Chevron U.S.A. Inc.		10R-34	6976	33.68089	-118.15494
23705997	Chevron U.S.A. Inc.	S-P La Harbor	2	9936	33.72407	-118.24223
25900361	Mobil Oil Corp.		SP-11	8423	33.68704	-118.13692
Federal						
4312200100000	GULF OIL CORP	OCS P-0302	1	6660	33.5512	-118.0601
4312200240000	SOHIO PETROLEUM CO	OCS-P-0302	2	7100	33.5724	-118.0516
4312200110000	SHELL OIL CO	OCS-P-0298	1	7200	33.5995	-118.0345
4312200080000	SHELL OIL CO	OCS-P-0293	1	6805	33.6611	-118.1405
4312200190000	CHEVRON U S A INC	OCS-P-0296	12	10973	33.6192	-118.1603
4312200180100	CHEVRON U S A INC	OCS P-0296	9	8400	33.6018	-118.1322
4312200060200	CHEVRON U S A INC	OCS-P-0296	4	5336	33.5908	-118.1289
4312200130100	SHELL OIL CO	OCS-P-0300	2	4988	33.577	-118.1225
4312200160000	SHELL OIL CO	OCS P-0301	6	5244	33.5698	-118.1114
SFI						
n/a (EPA Permit)	City of LA		SFI#1	5499	33.74388	-118.26497
n/a (EPA Permit)	City of LA		SFI#2	5426	33.74385	-118.26502
n/a (EPA Permit)	City of LA		SFI#3	5448	33.74399	-118.26466

4. Accomplishments to Date

1) Detailed log evaluation of existing exploration wells in the area
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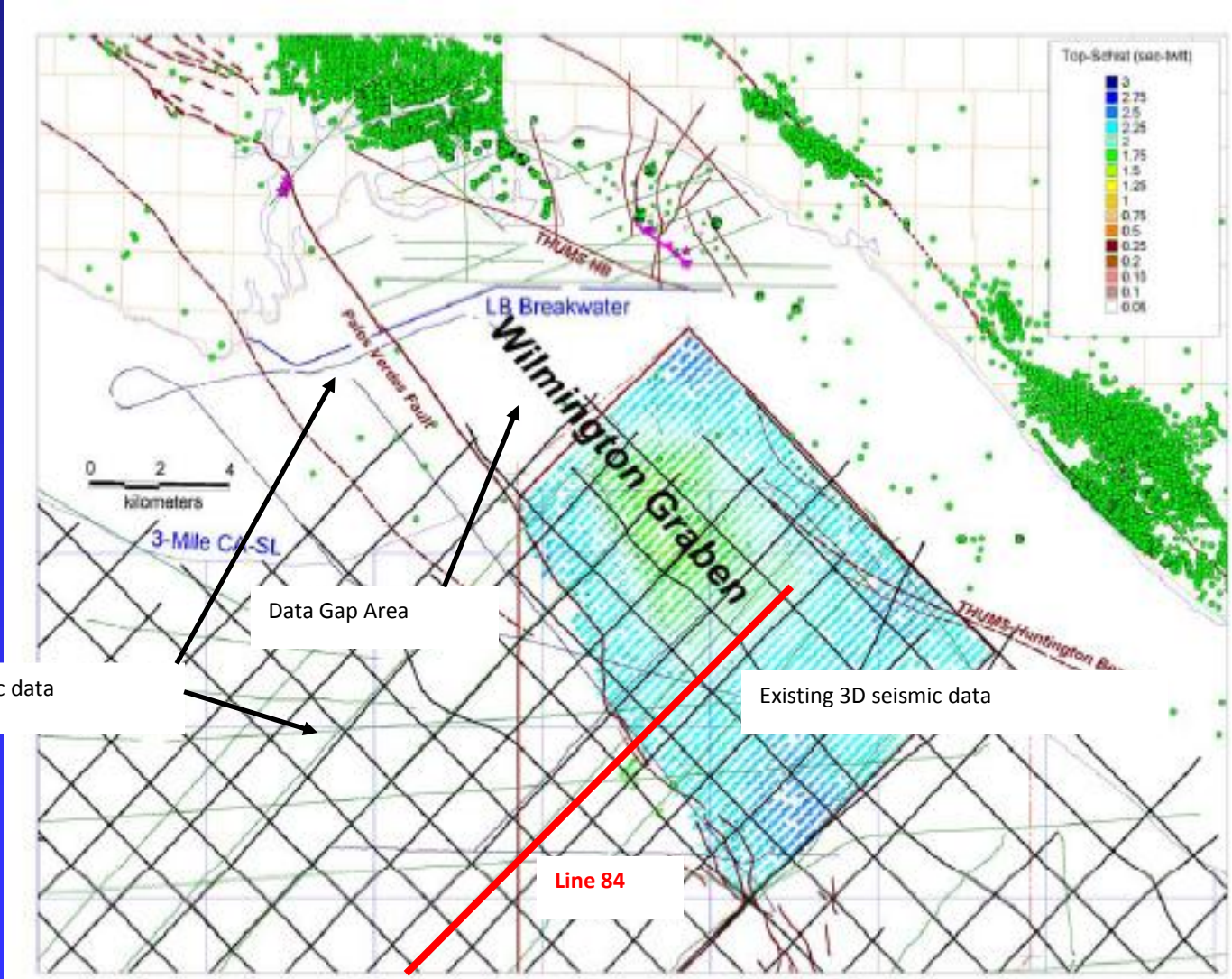

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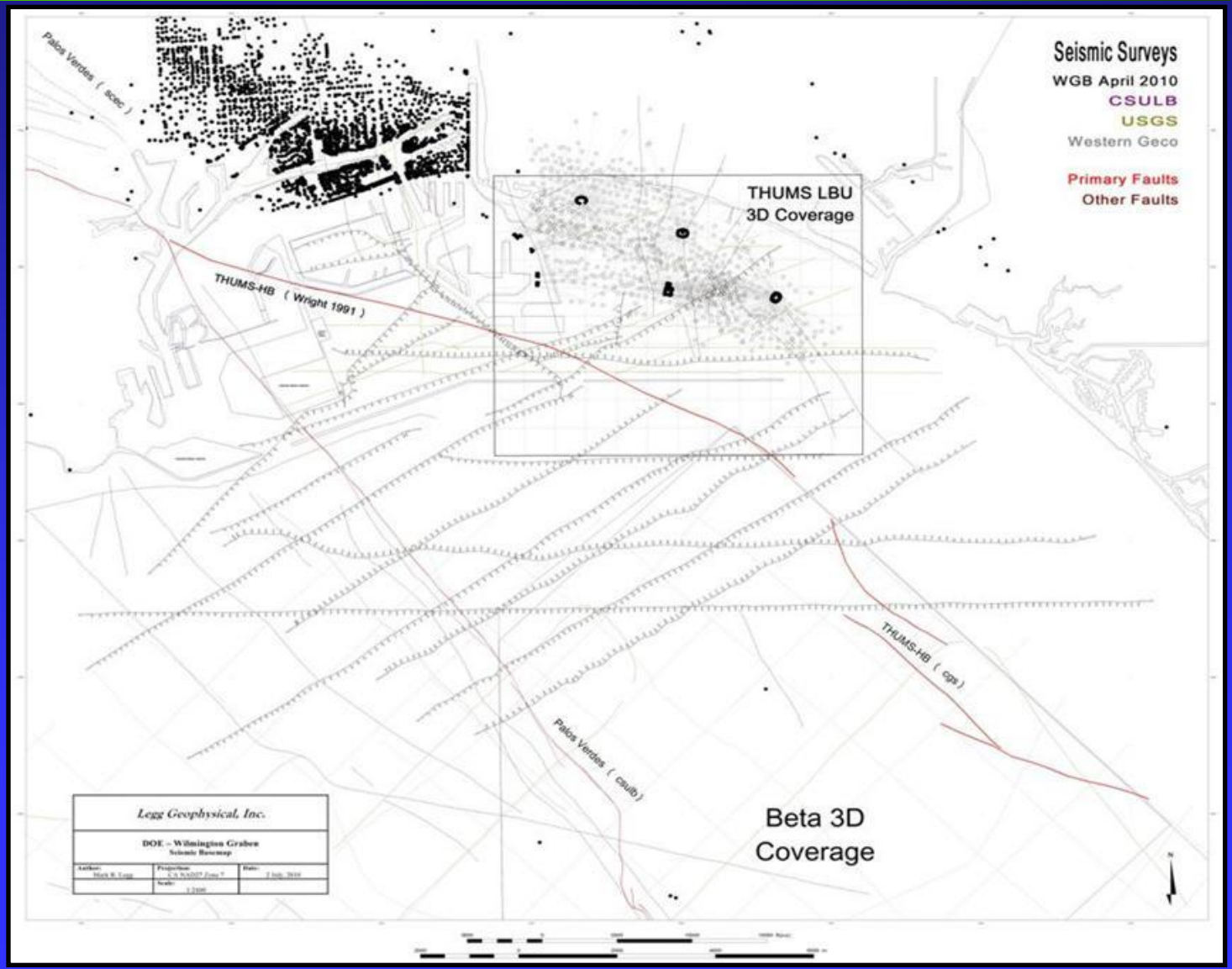
Shot Point Map for 175km of new seismic lines



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California State University, Long Beach Provided the Boat and Seismic Equipment

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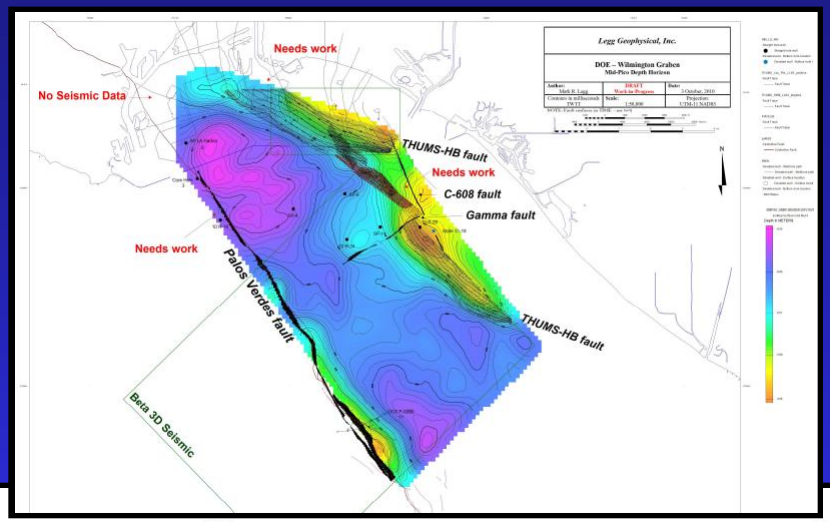

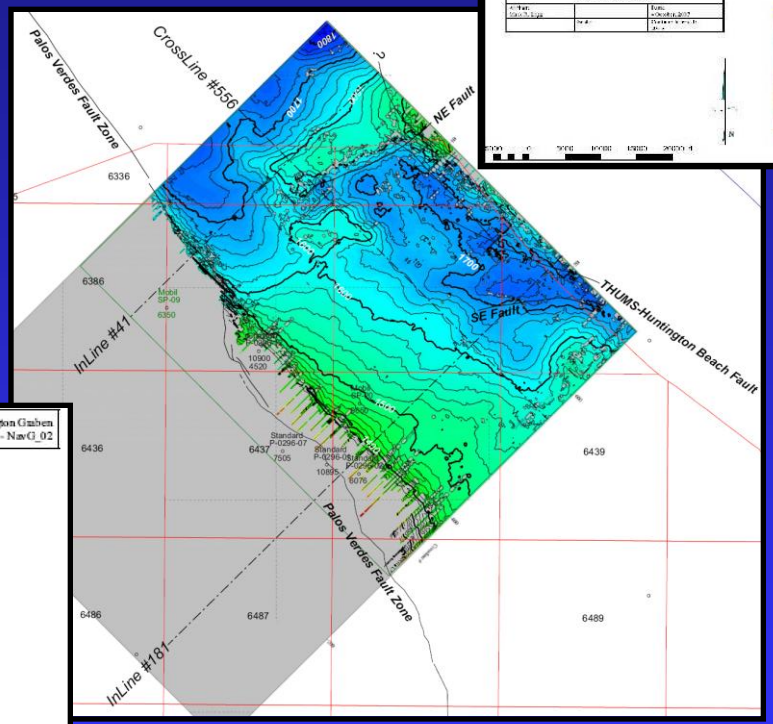

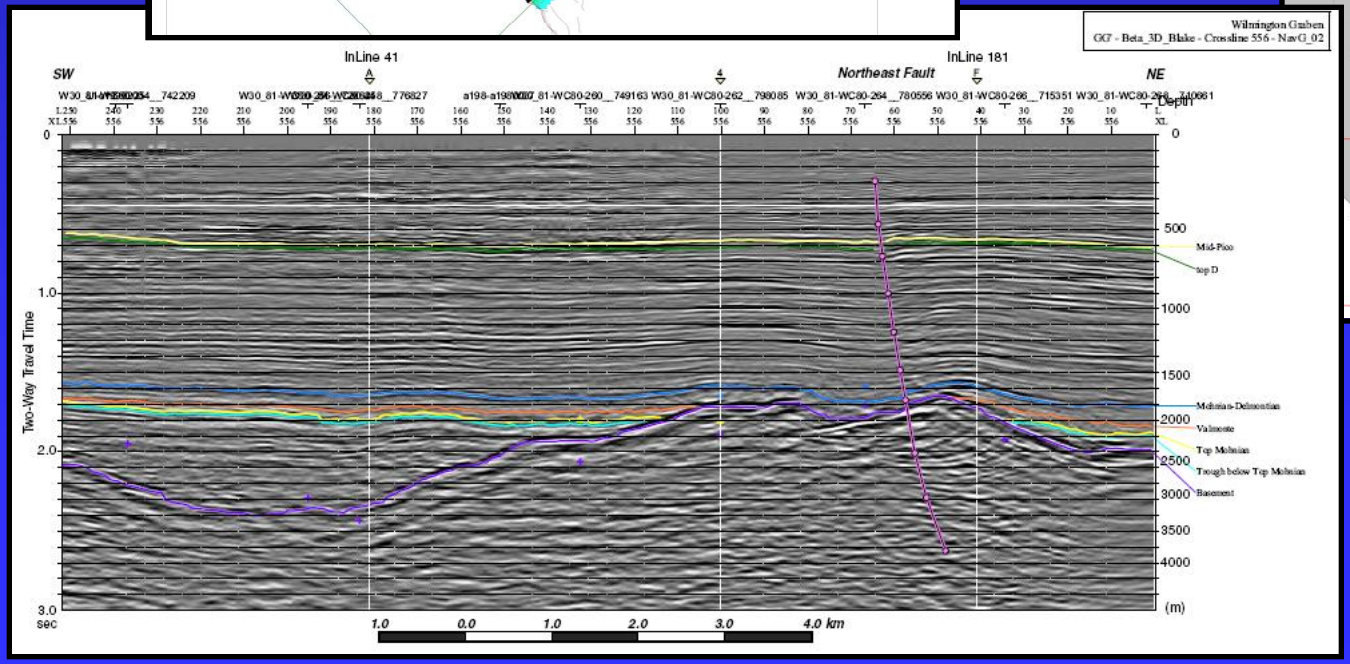

Structural & Statigraphic Seismic Interpretations

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DOE#1 Well Schematic

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Terminal Island Facility

DOE#1 (aka SFI # 3)

Section 8 - T5S - R13W

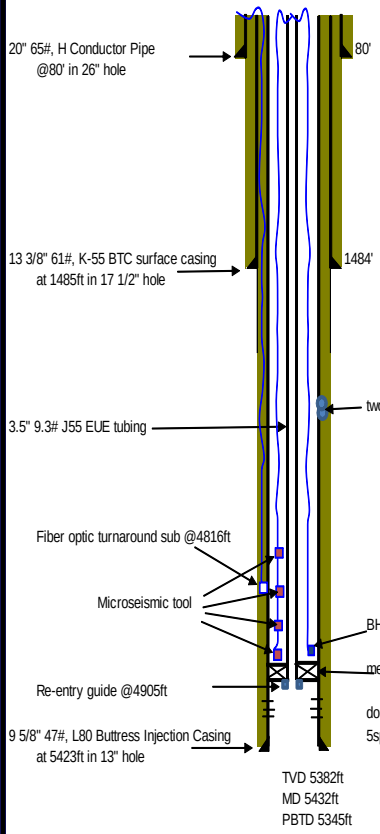
Slurry Injector

Deviated Well — KOP 1600ft, build angle 1degree/100ft

	Surface:	Bottom:
Lat: (NAD83)	33.74399	33.74405
Long: (NAD83)	-118.26465	-118.26281

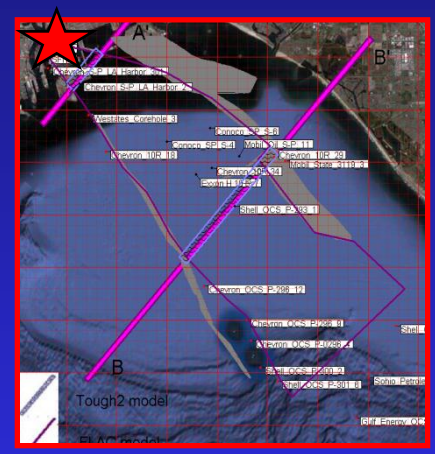
KB (above sea level) 30ft

GL (above sea level) 10ft



MD	TVD (from deviation survey)
1604	1604
2076	2075
2554	2550
3002	2990
3512	3492
3956	3930
4399	4367
4872	4833
5430	5382

Microseismic Sensor	TVDss
1	-4215.1
2	-4264.4
3	-4313.6
4	-4362.9
5	-4412.2
6	-4461.5
7	-4510.8
8	-4560.0
9	-4609.1
10	-4658.3
11	-4707.5
12	-4756.7



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DOE#1 Well Sidewall Cores

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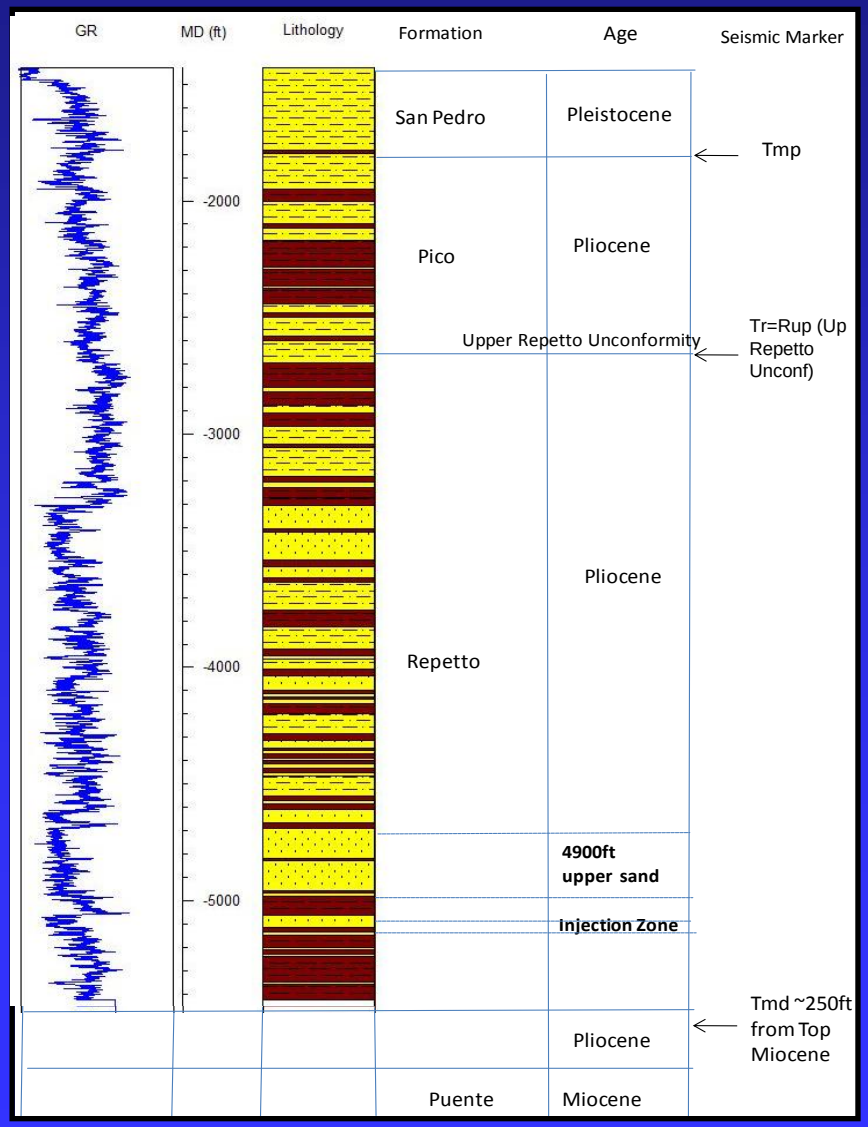
DOE#1 Well Stratigraphic Column



- Correlated with SFI#1 and SFI#2 wells
- Well TD in Pliocene based on micropaleontology correlation from SFI#2 well
- Pliocene gross sand thickness – 3000-3500ft

Reservoir Properties from 29 SWC's and 9.5' of Conventional Core

Zones	Porosity (%)	Permeability (md)
Shale between 4465-4570ft	28 to 29	2 to 4
Sand at 4640ft	32	371
Shale above 4900ft sand	27	<1
4900ft sand @ 4690-4975ft	24 to 30	51 to 187
Shale above Injection Zone	28 to 29	<1 to 2
Injection Zone (5055-5115ft)	26 to 31	50 to 353
Sand at 5351ft	29	135
Conventional Core shale (5431-5439.5ft)	23 to 24	<1

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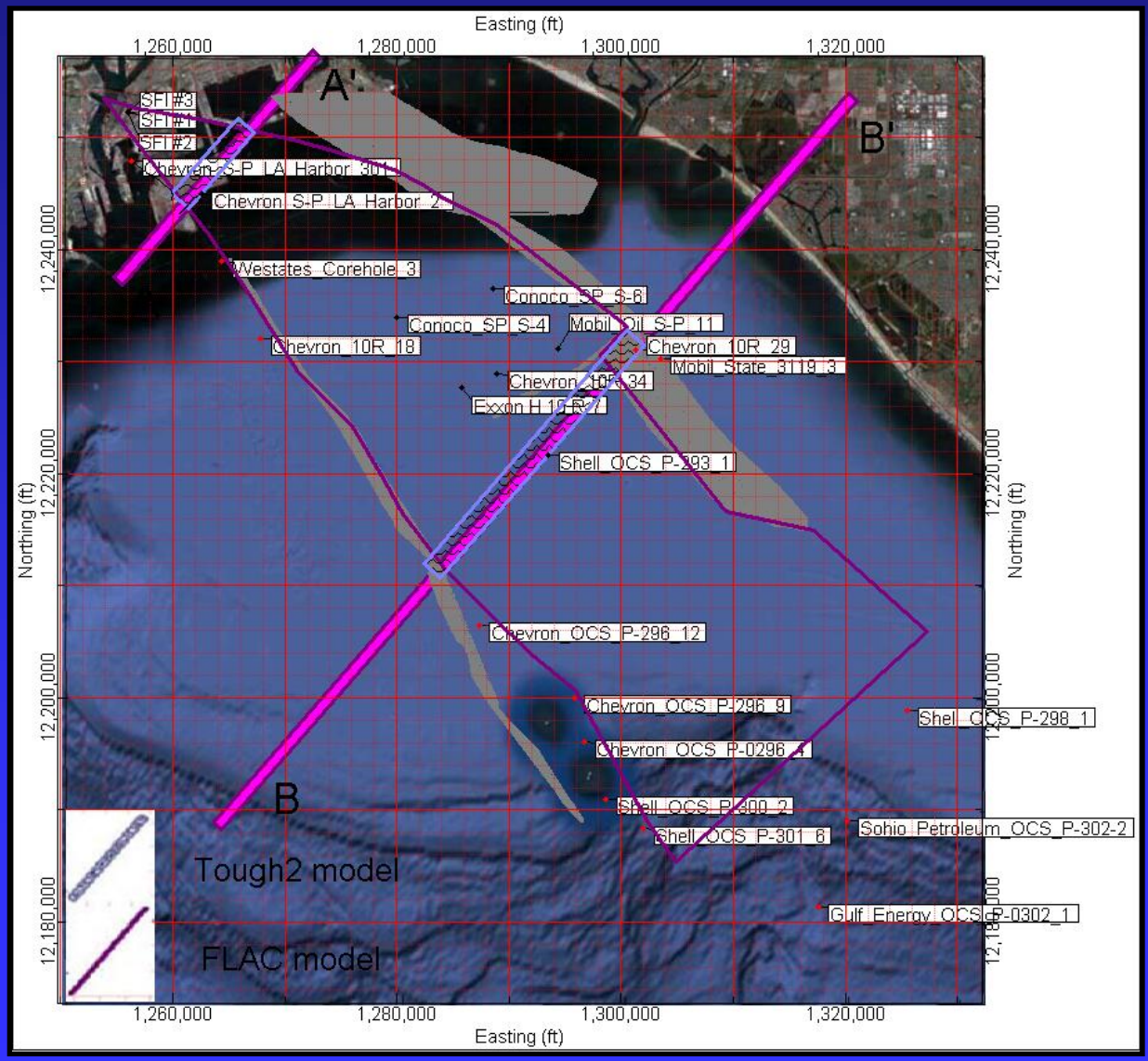
Location Map for Models



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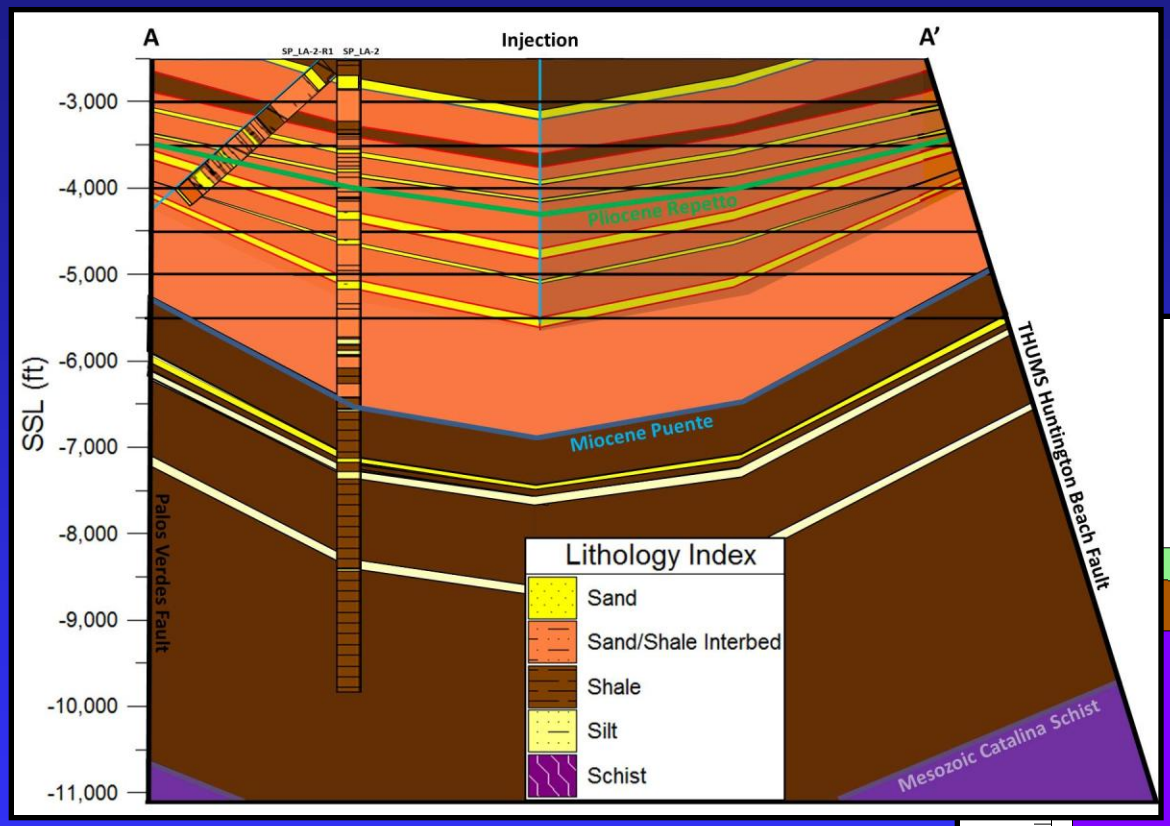

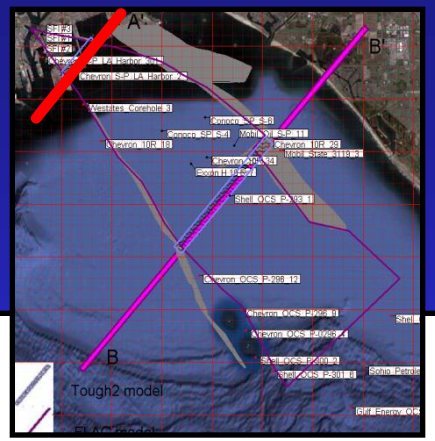

Cross Section AA' – Lithology & Stratigraphy

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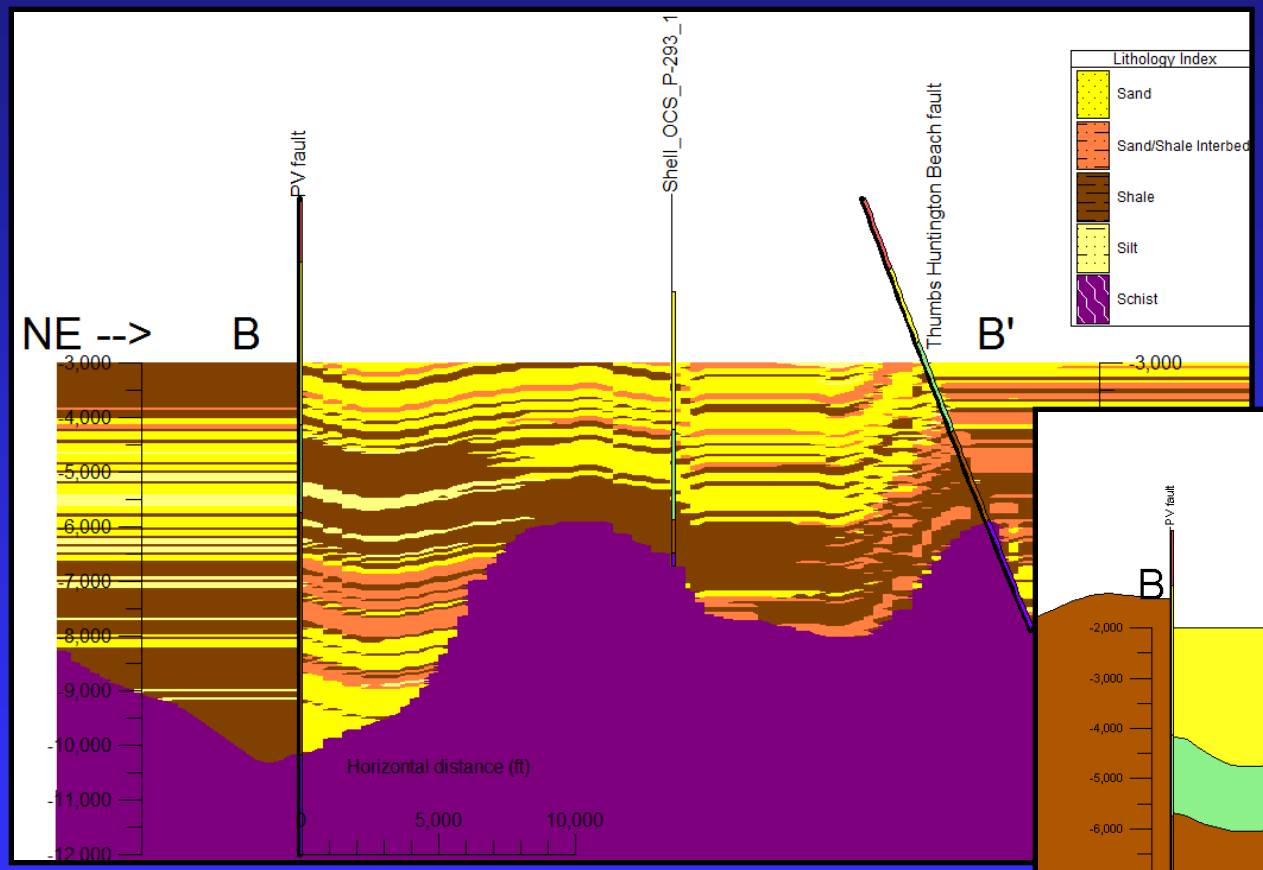

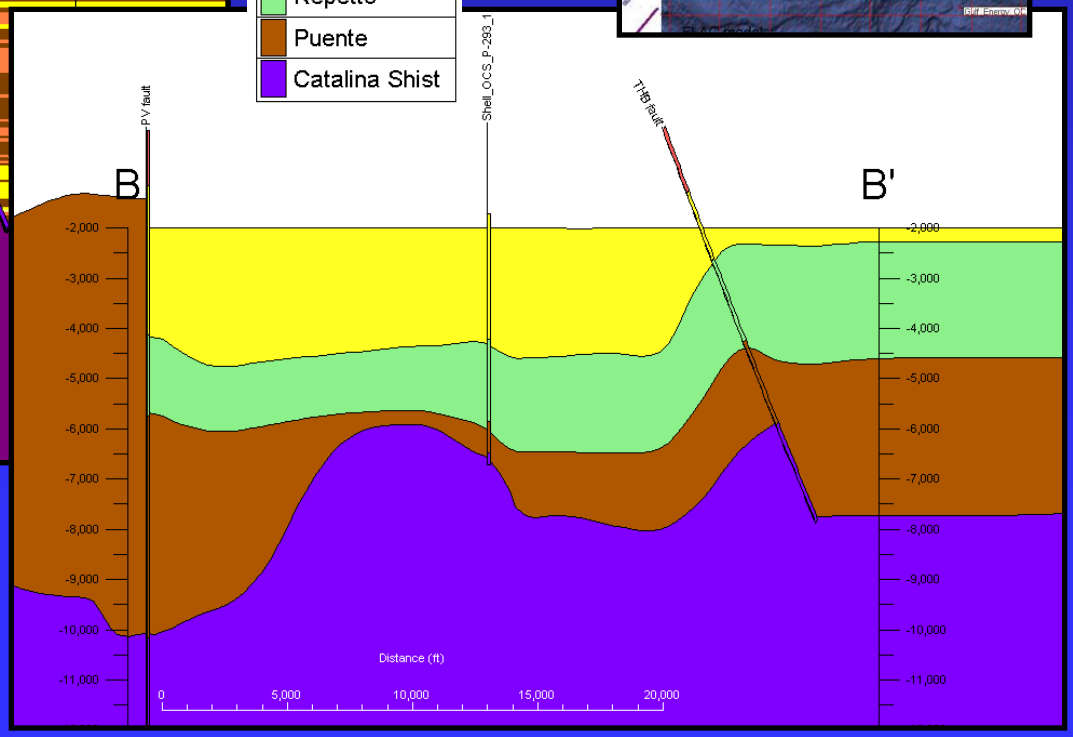

Cross Section BB' (2XVE) – Lithology & Stratigraphy

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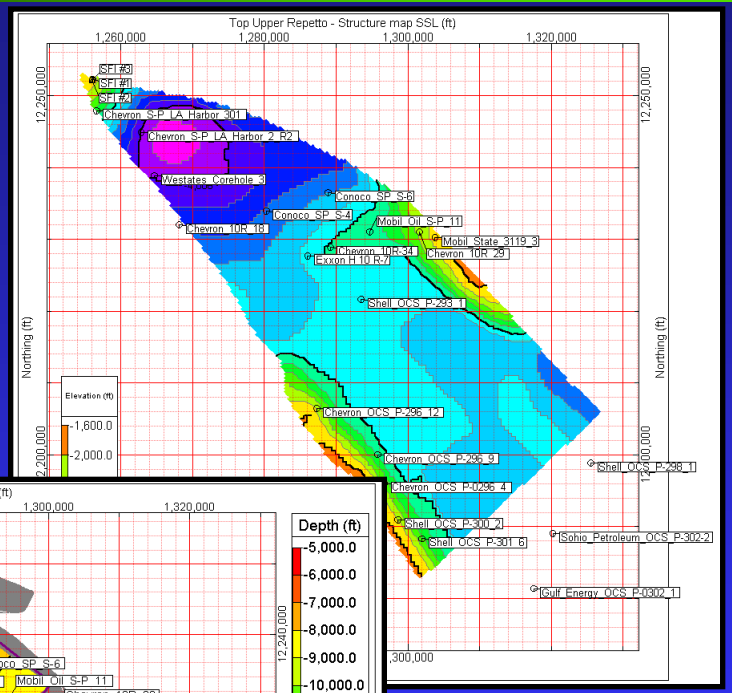

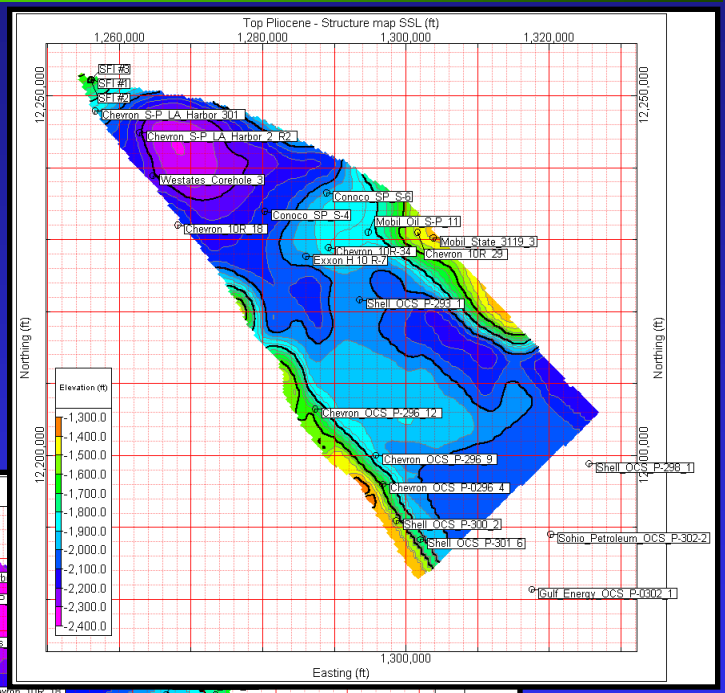

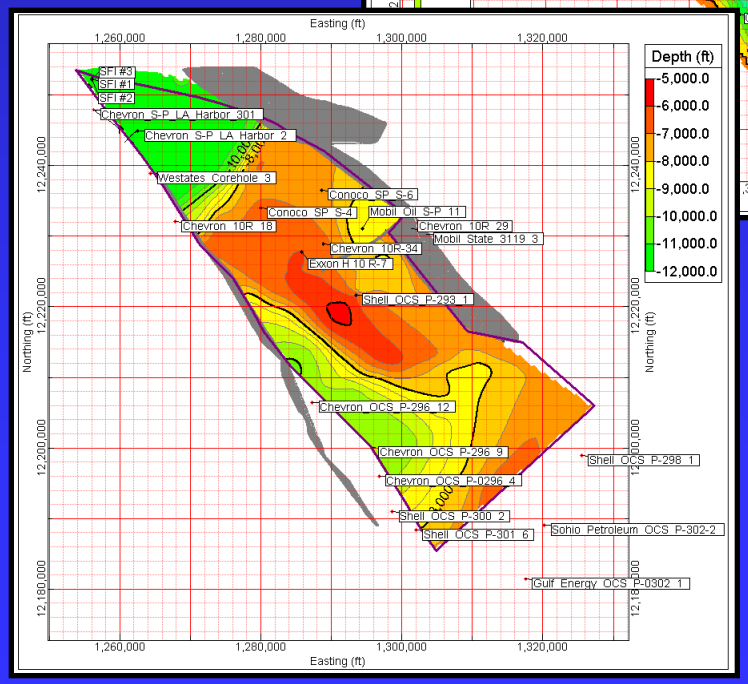

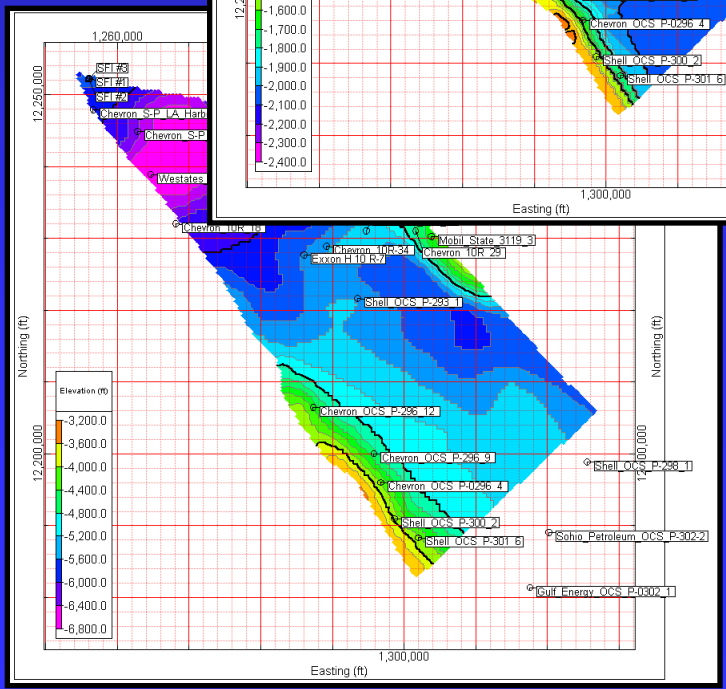

Structure Maps for 4 Stratigraphic Units Below 2000' SSL

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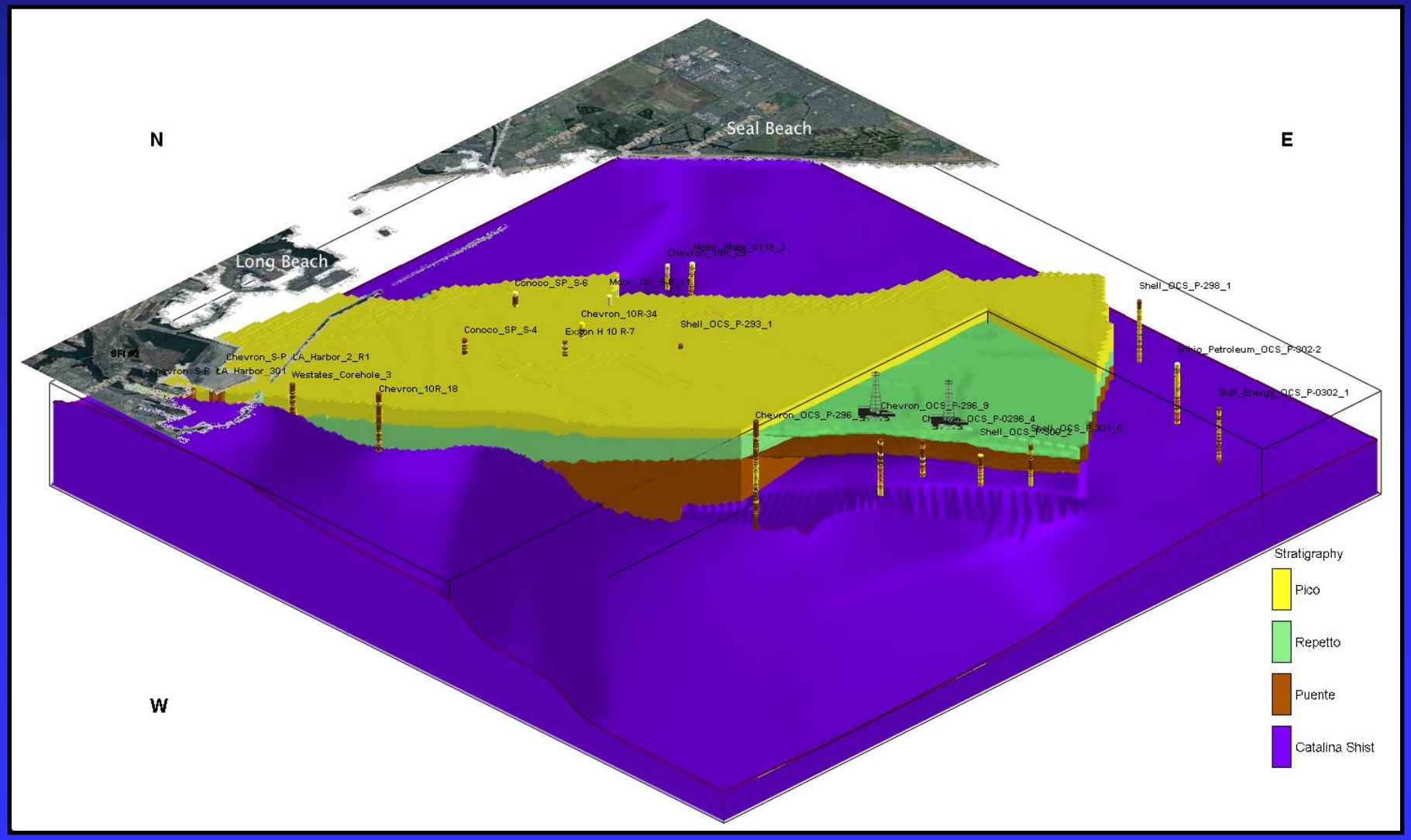
3D Stratigraphic Representation of Wilmington Graben Project Area Below 2000' SSL



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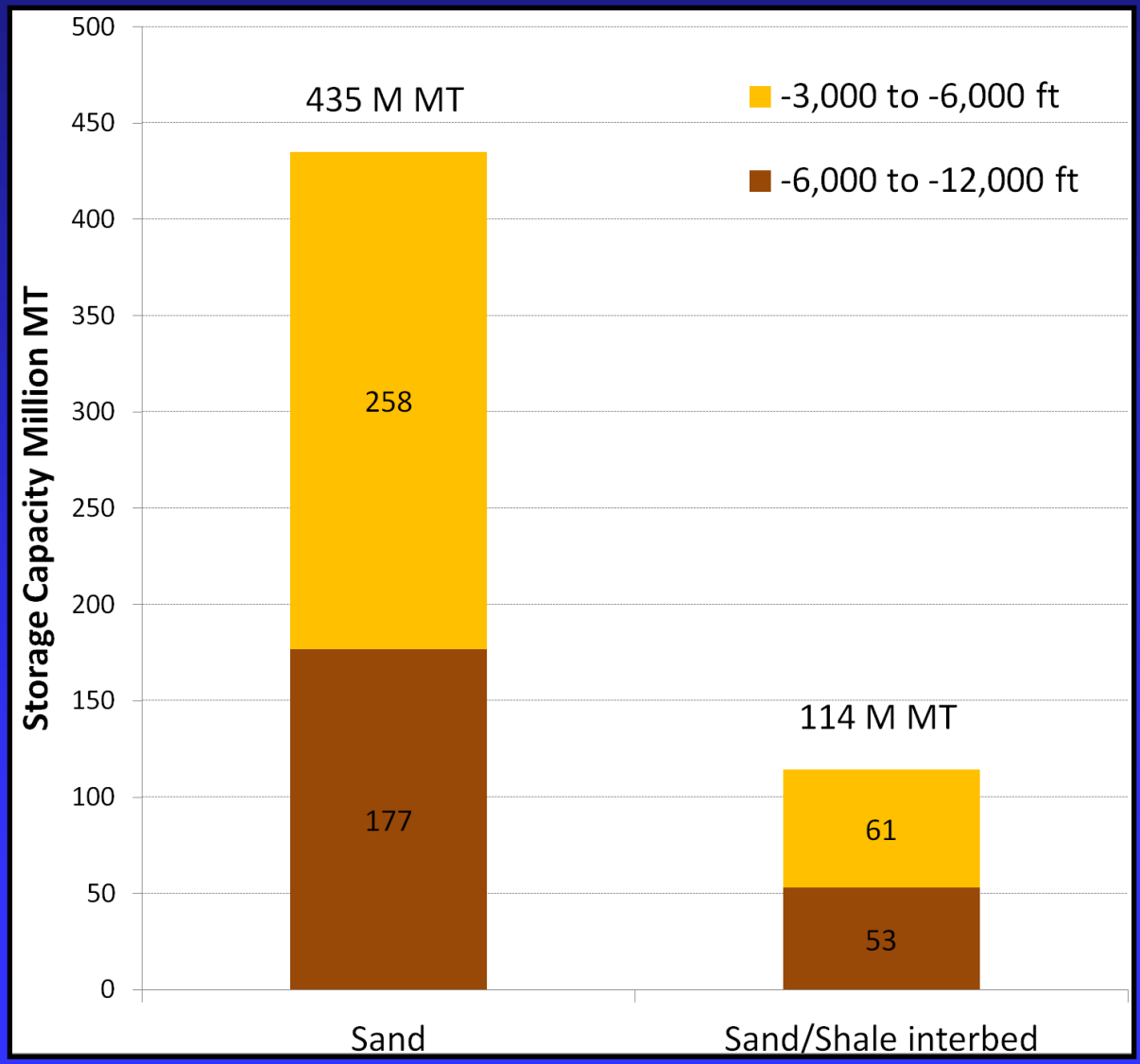
Estimated Storage Capacity



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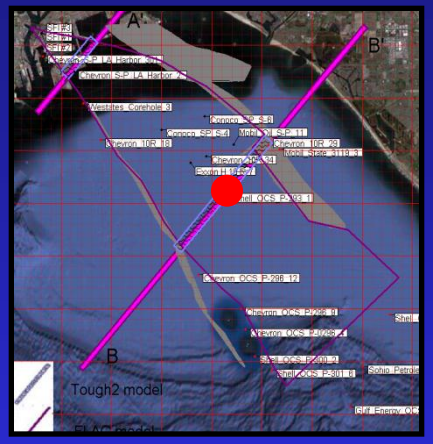
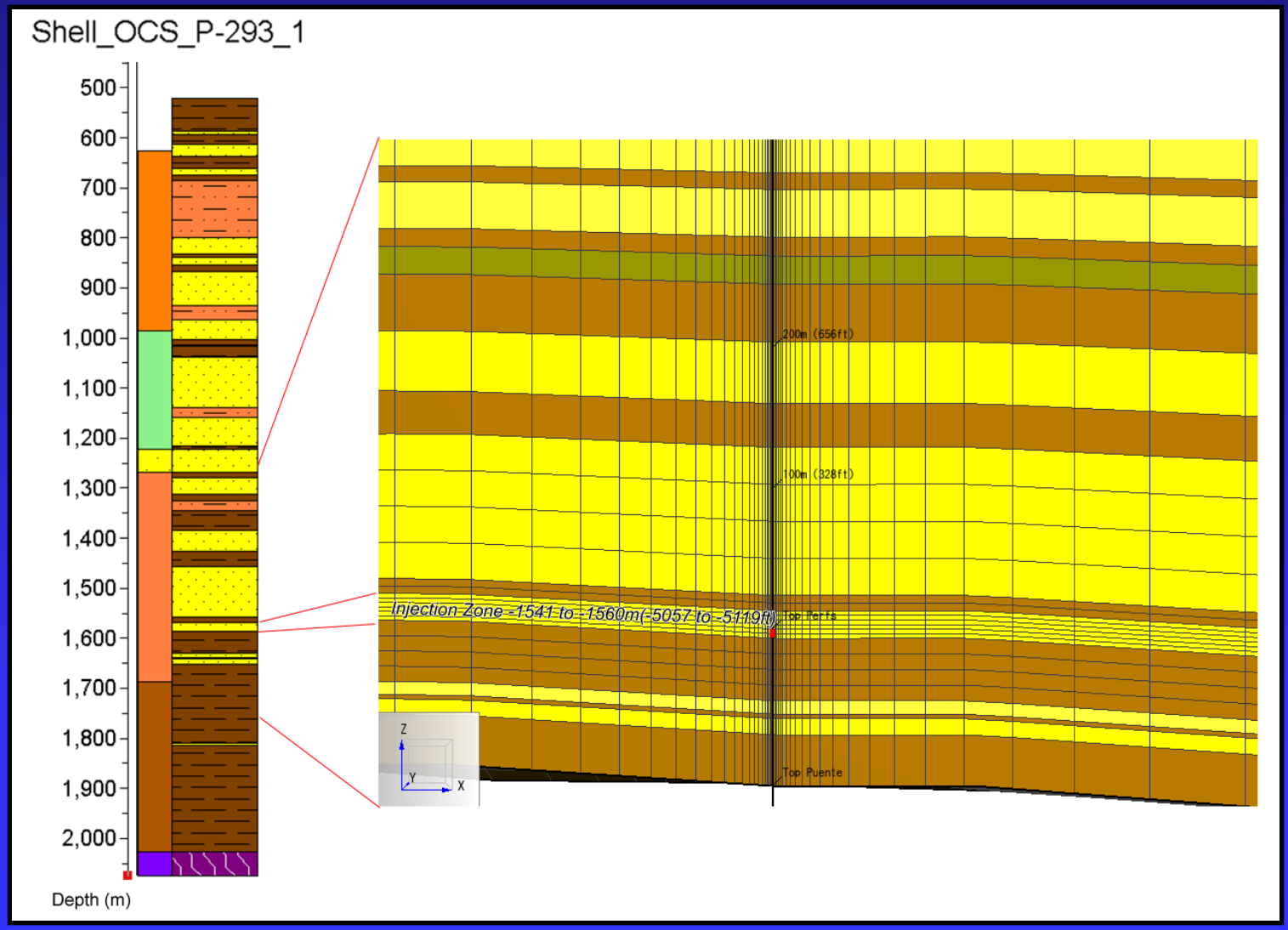
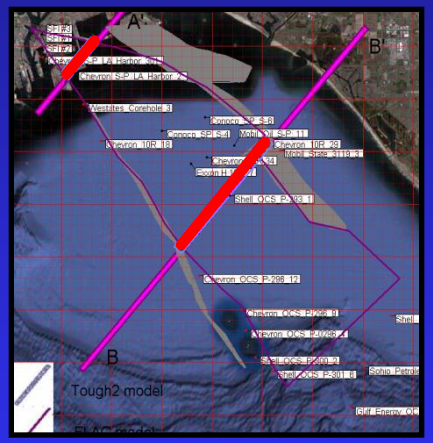
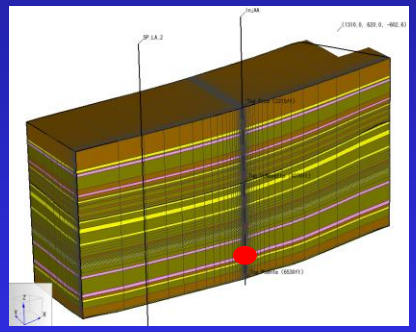


TOUGH2 Injection Well Grid based on Lithology from Shell_OCS_P-293_1

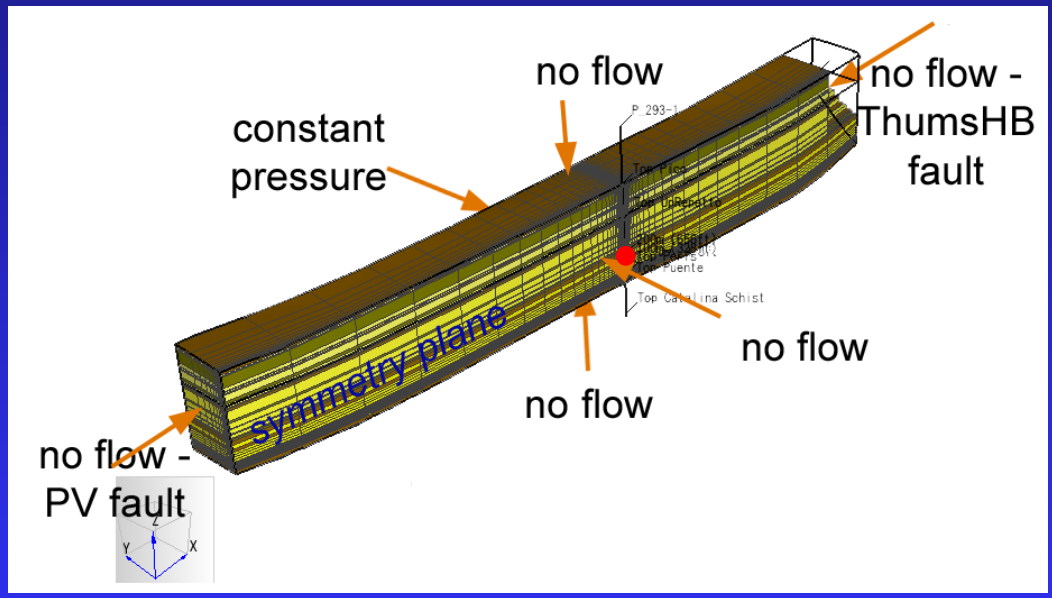


Gas Migration Models – Concept (not to scale)





AA



BB

# of cells	60,000	68,000
SW-NE x SE-NW	2,600 x 620 m (8,500 x 2,000 ft)	7,830 x 620 m (26,000 x 2,000 ft)
Model interval	-600 to -2,000 m (-1970 to -6560 ft)	-465 to -1720 m (-1525 to -5643 ft)
Injection interval	-1570 to -1600 m (-5150 to 5250 ft)	-1535 to -1555 m (-5036 to -5100 ft)

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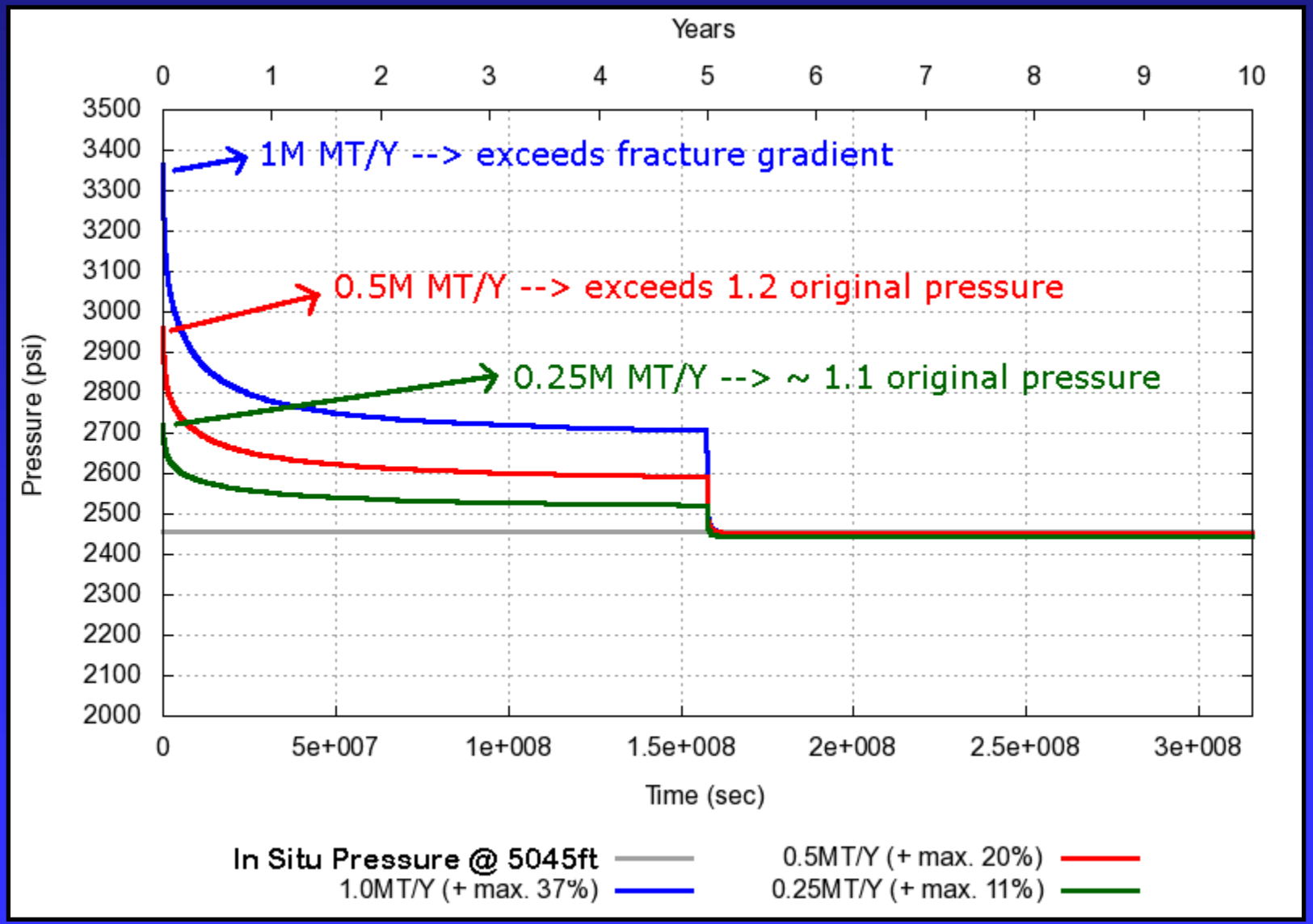
Injection for 5 years at BB' -

Pressure at Injection Cell for 1M MT/Yr, 0.5M MT/Yr & 0.25M MT/Yr



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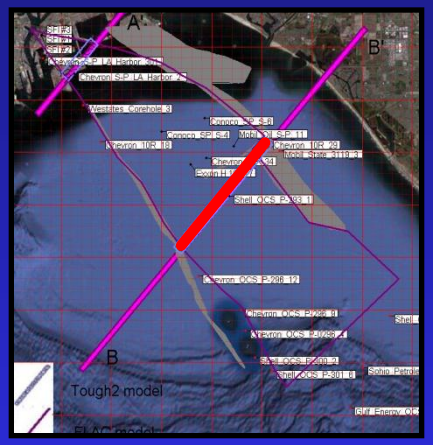
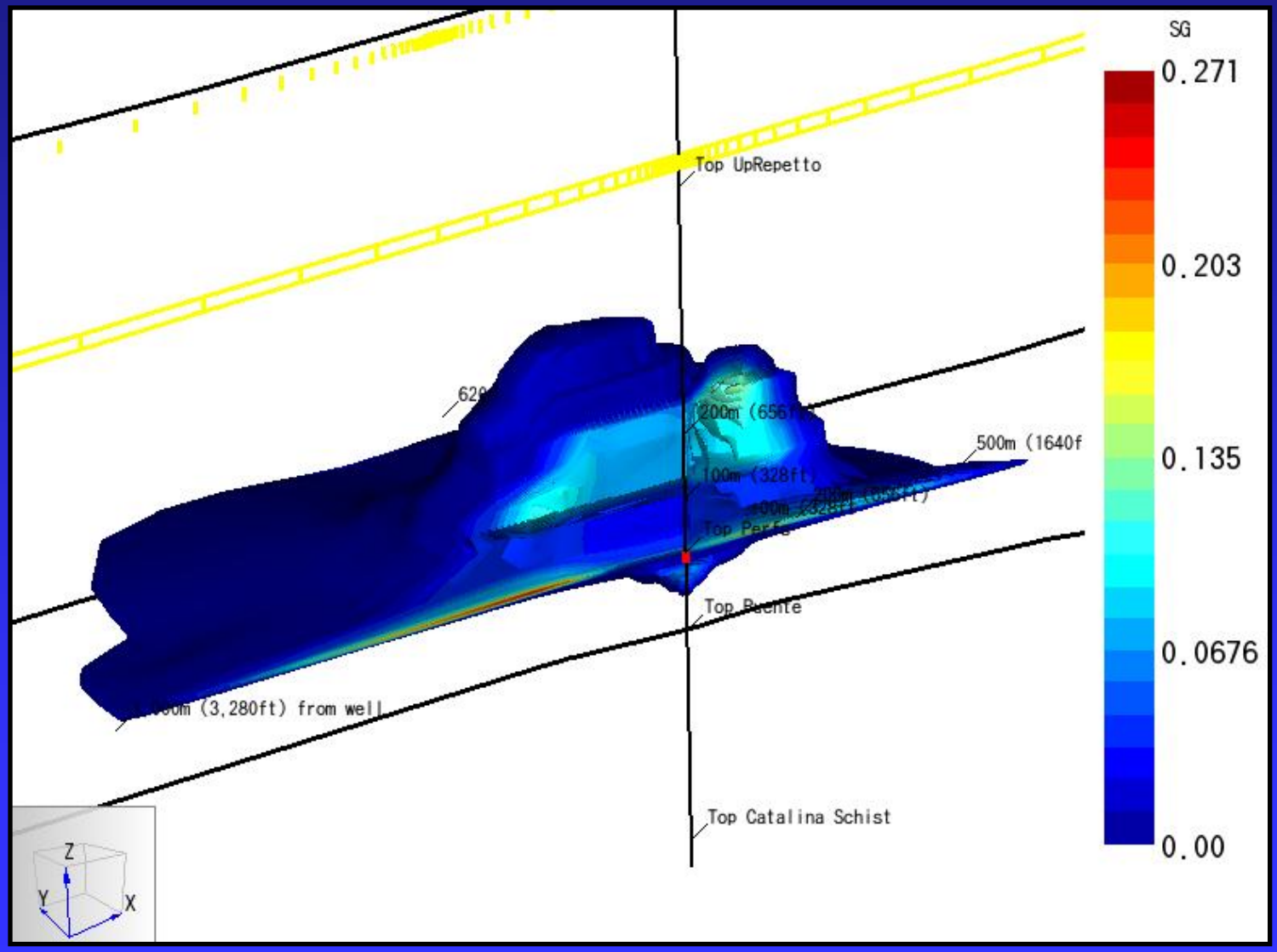


Gas plume after 55 years –

B-B', looking due North



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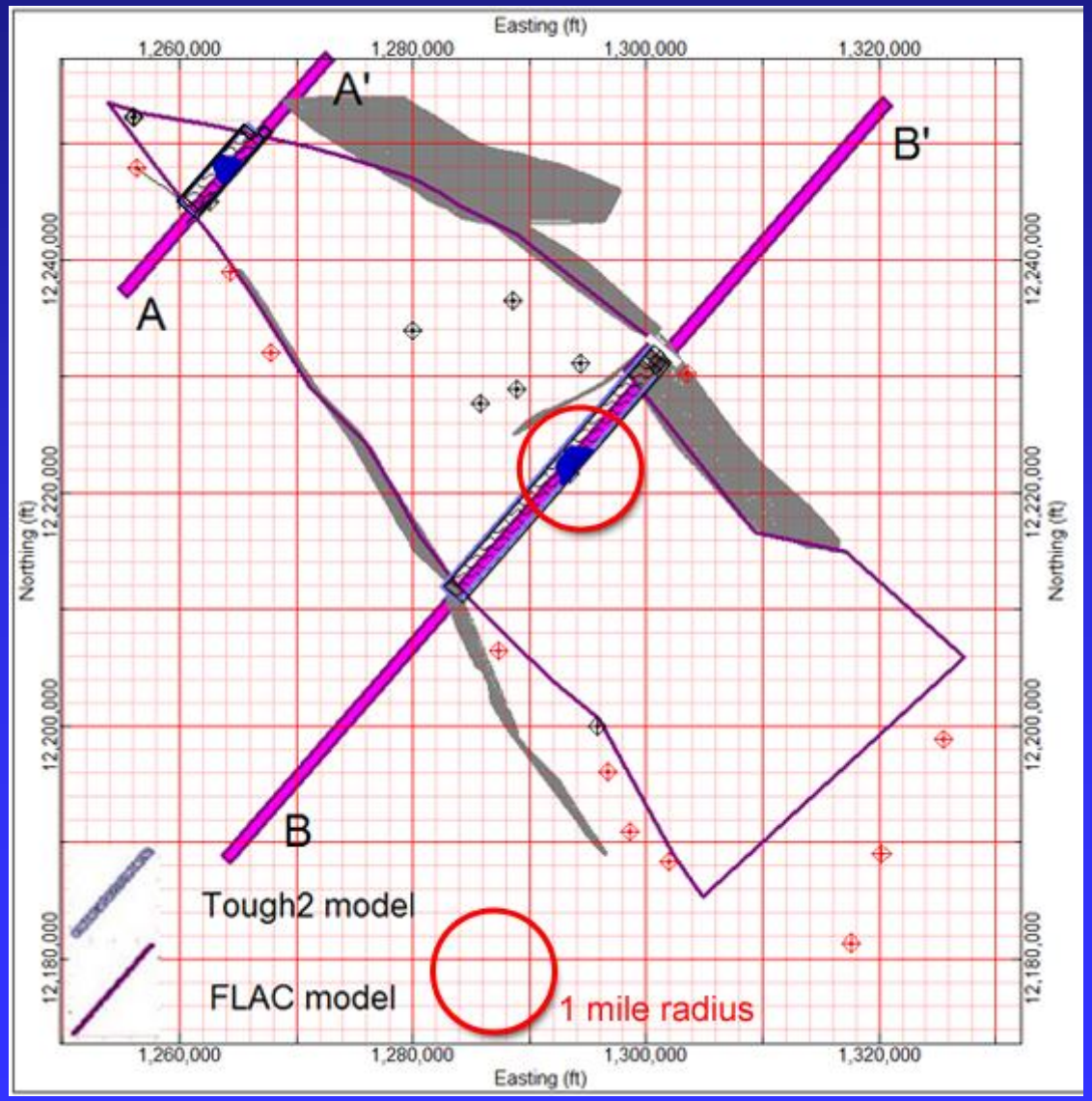
Gas Migration Modeling Conclusions Thus Far:

- max. 250,000 MT/Y per well
- min. distance between wells: 1 mile



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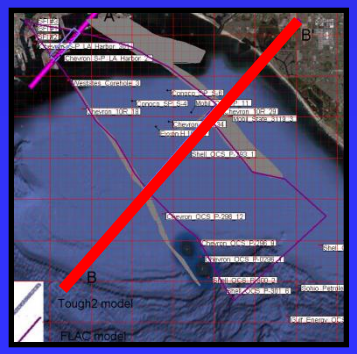
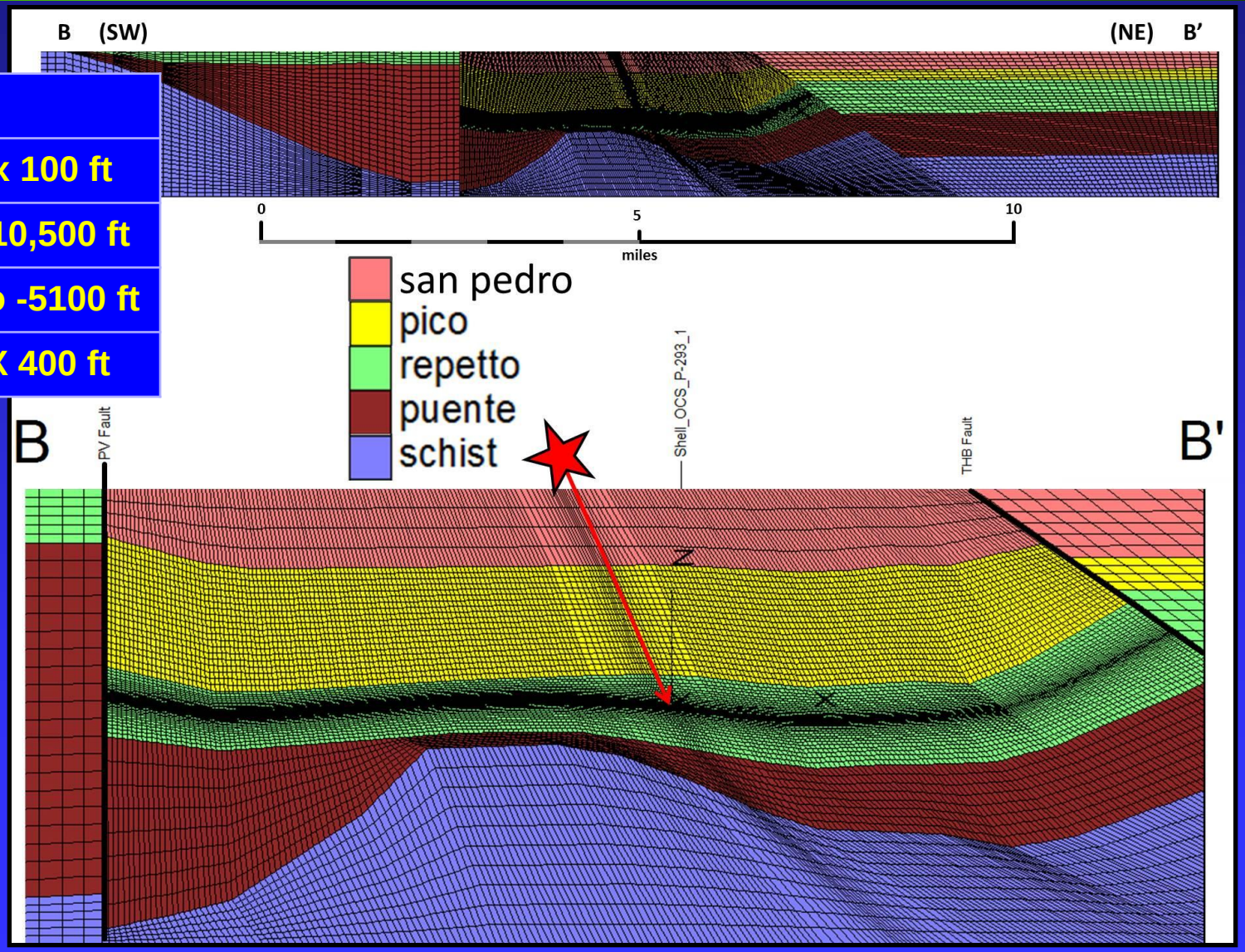
# of cells	30,000
SW-NE x SE-NW	86,000 x 100 ft
Model interval	-75 to -10,500 ft
Injection interval	-5036 to -5100 ft
Max Cell Size	600 ft X 400 ft

Cross Section BB' FLAC3D Model





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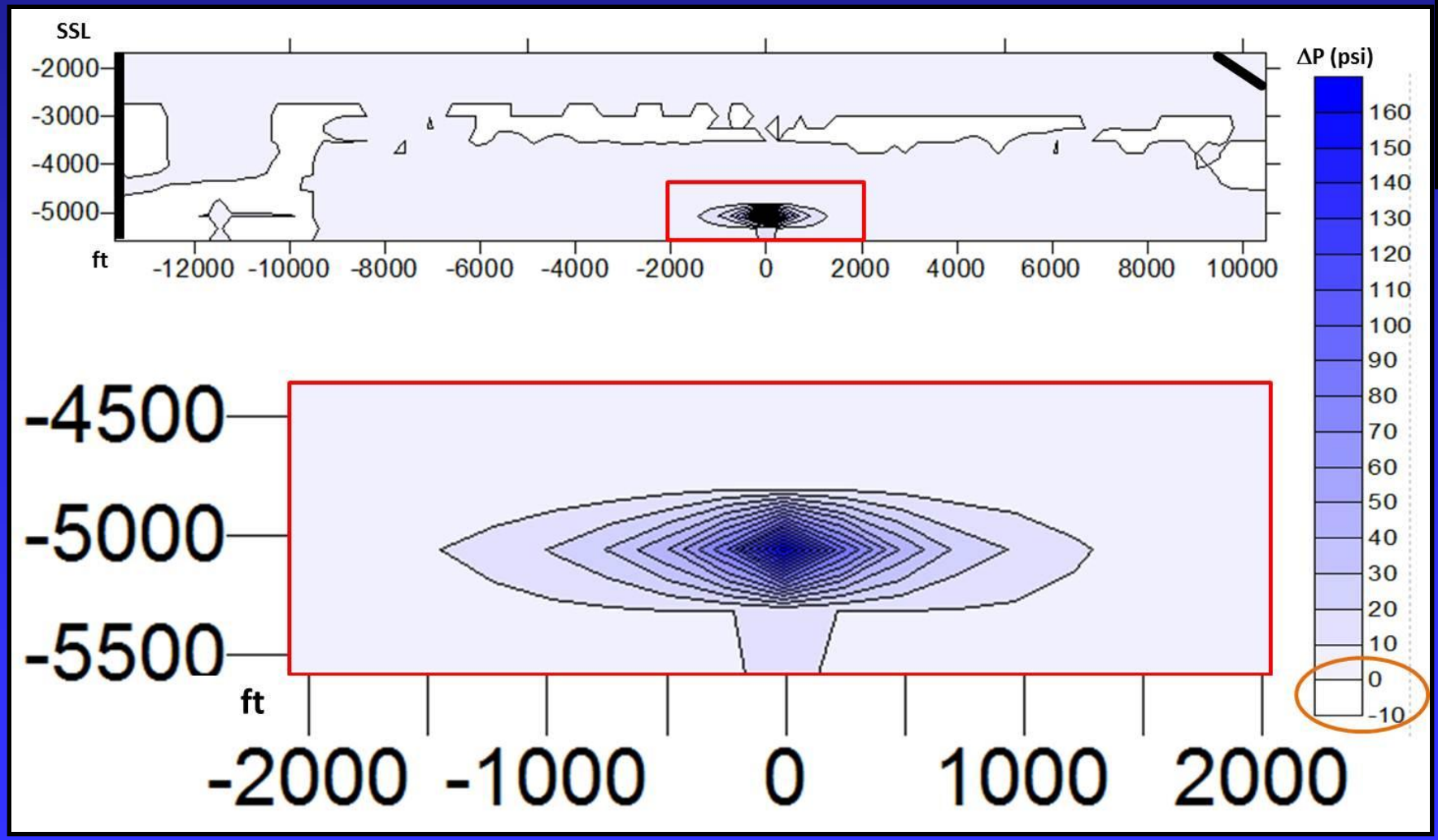
Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

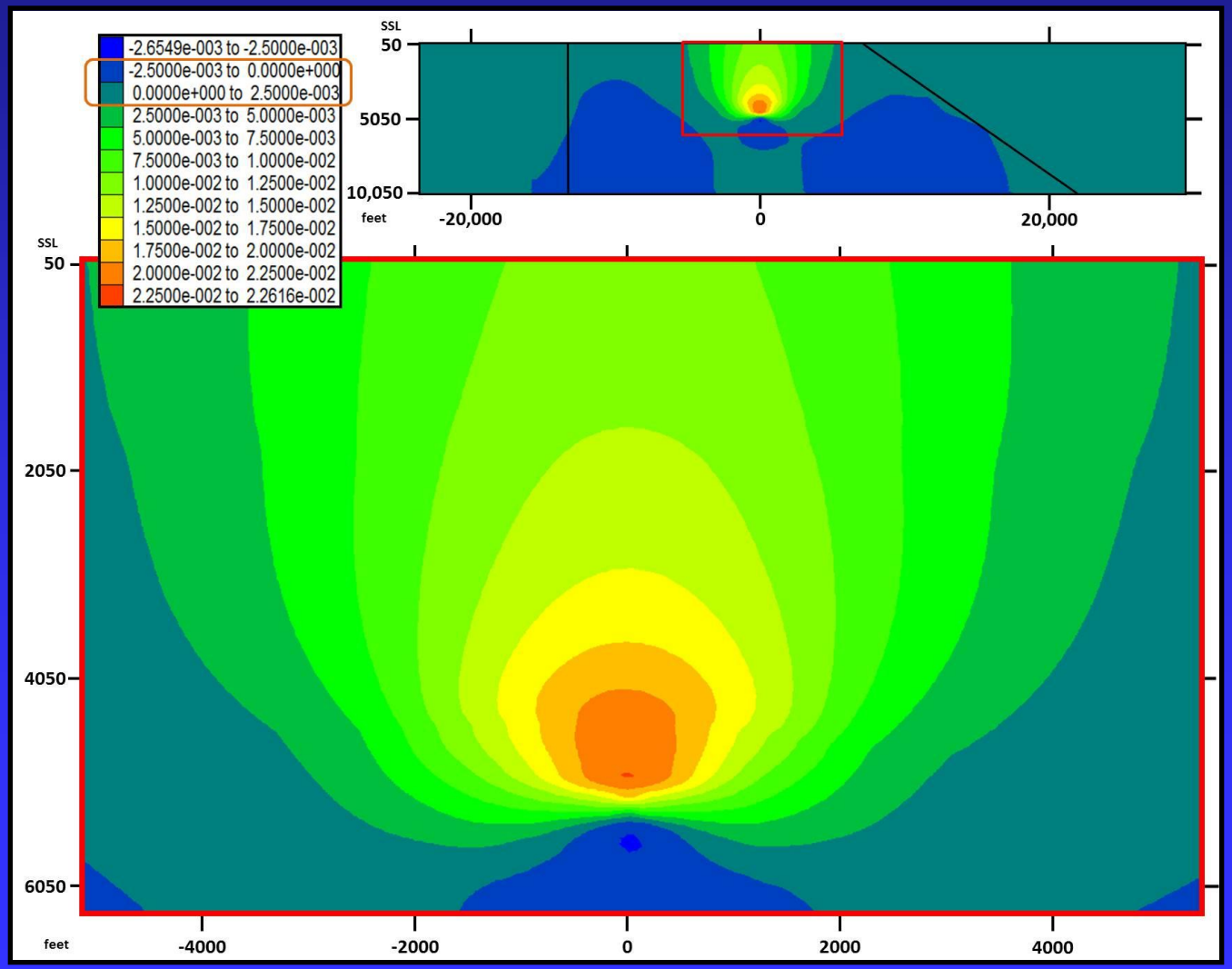
Input Pressures Based on TOUGH2 Output



Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Contour Plot of Induced Vertical Displacement

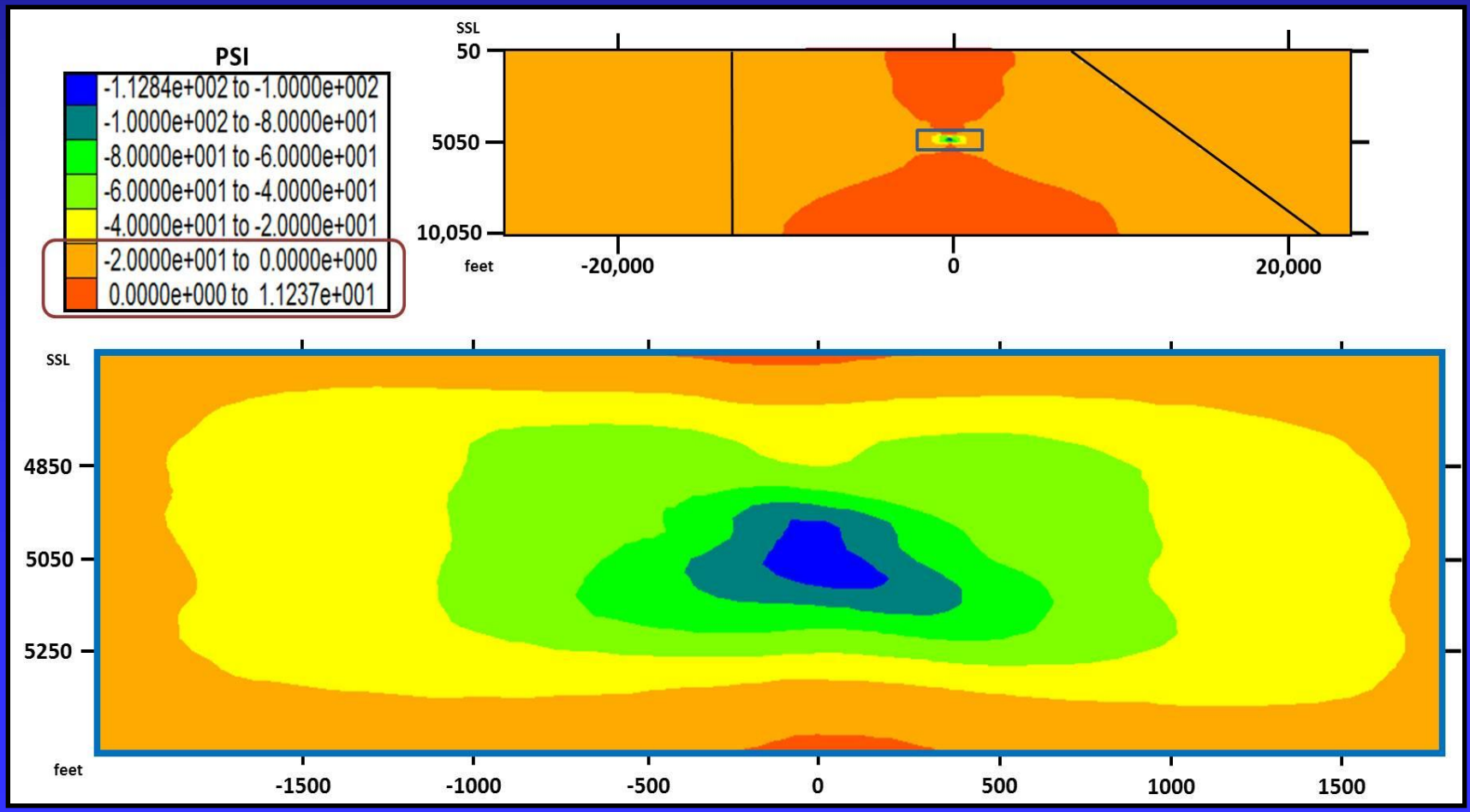
- Virtually 0 Throughout Most of Graben
- 0.025” Below Injection
- Greatest About 0.27” Just Above Injection
- Maybe As Much As 0.18” Uplift at the Seafloor



Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Contour Plot of Induced Horizontal Stress (sxx)

- Virtually 0 Throughout Graben



- Except In Few Thousand of Feet Around Injection
- Greatest About 112 psi Of Compression At Injection
- Less Than 60 psi a Few Hundred of Feet From Injection

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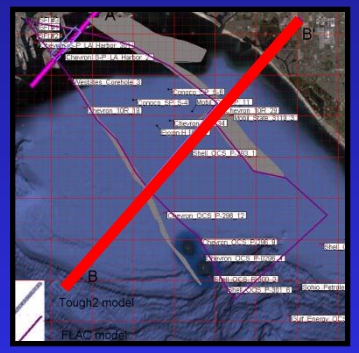
Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Contour Plot of Induced Shear Stress (sxz)

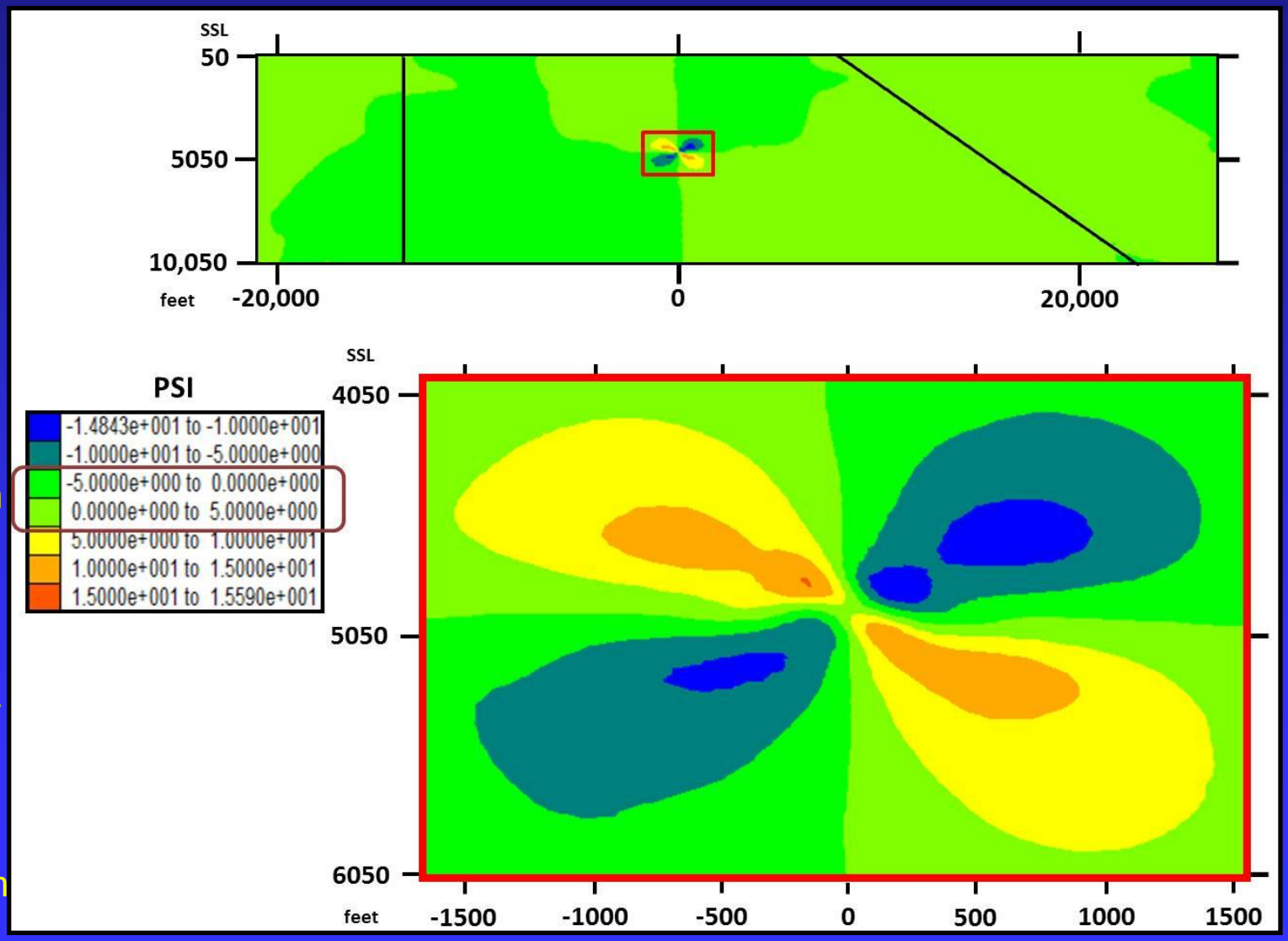


-Virtually 0 Throughout Graben

-Except In Few Thousand of Feet Around Injection

-Greatest Is Under 20 psi Near Injection

-Less Than 10 psi a Few Hundred of Feet From Injection



4. Accomplishments to Date

1) Detailed log evaluation of existing exploration wells in the area
2) Improved evaluation and interpretation of existing 2D and 3D seismic data
3) Acquisition and interpretation of additional 2D seismic lines
4) Drilling and coring three new evaluation wells into the Graben (Pliocene and Miocene) and/or on the landward side of the THUMS-HB fault
5) Development of 3D geologic models, geomechanical models, and CO_2 injection and migration models for the region
6) **Analysis of industrial sources (top 20 in the LA Basin)**
7) Transport Infrastructure Study: engineering study of existing and new pipeline systems to transport CO_2 from significant local sources to sequestration sites
8) Risk analysis

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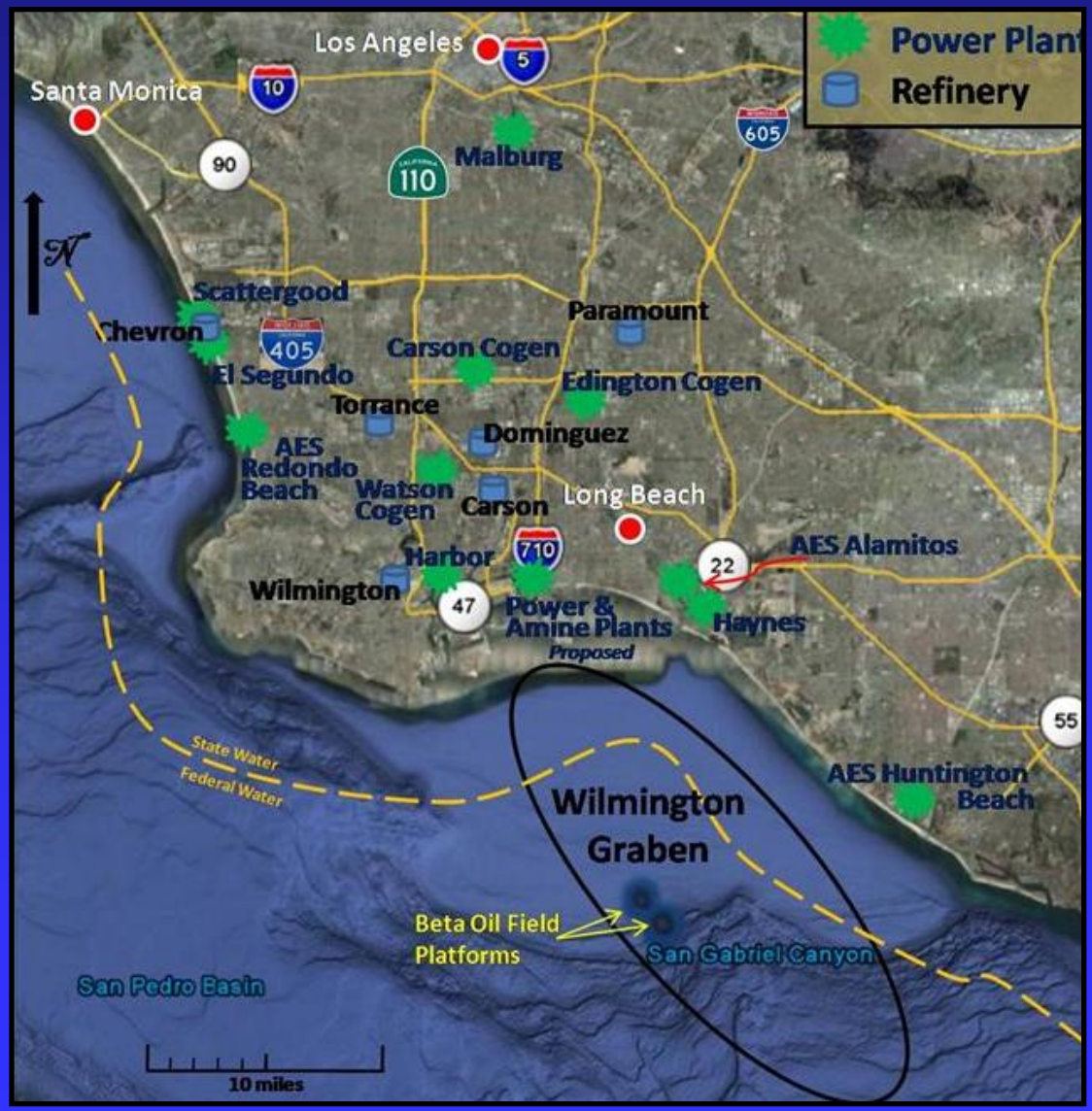
Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

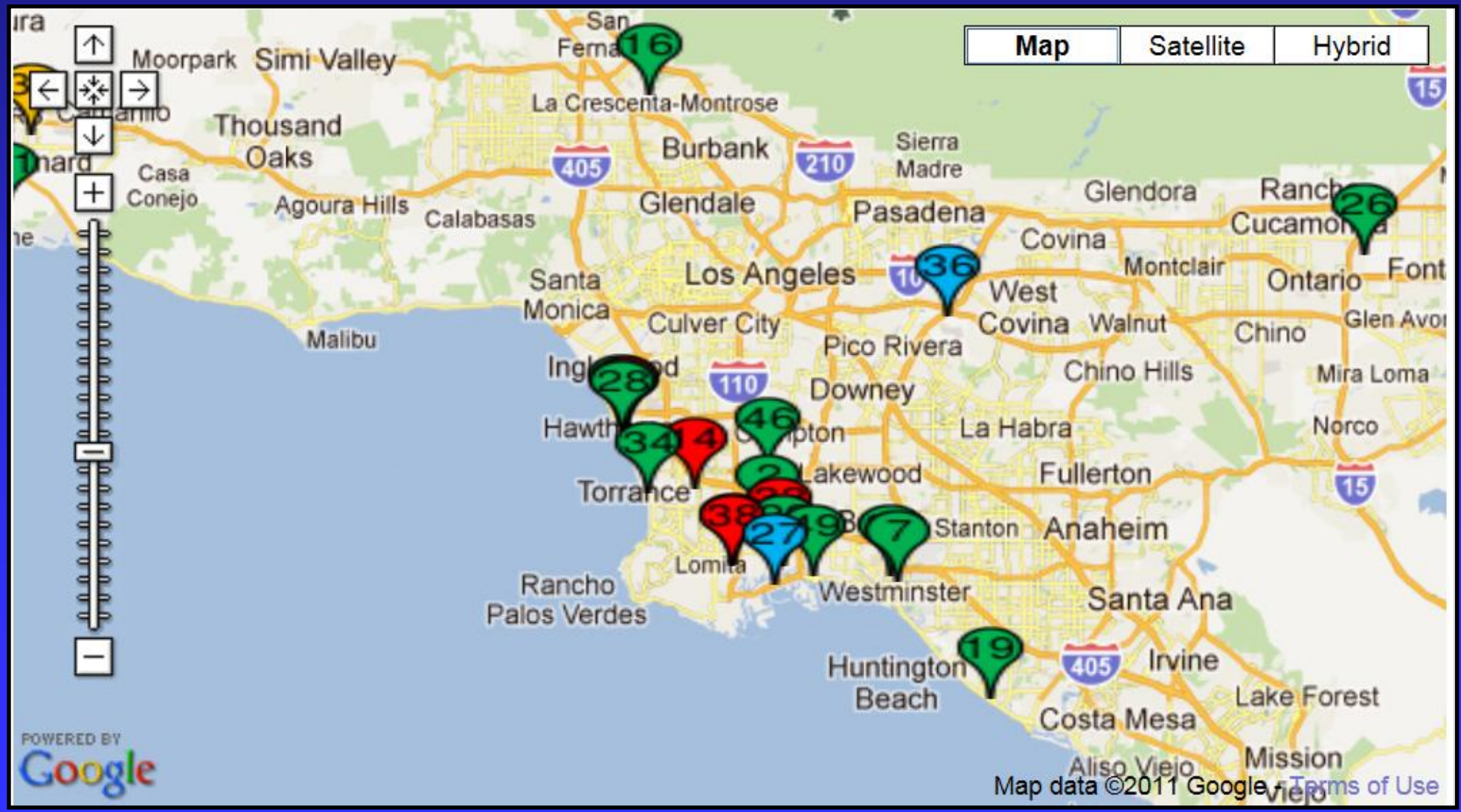
Industrial CO_2 Sources in LA Basin



Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

www.socalcarb.org

SoCalCarb Atlas Page for Industrial CO_2 Sources in LA Basin



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8) Risk analysis

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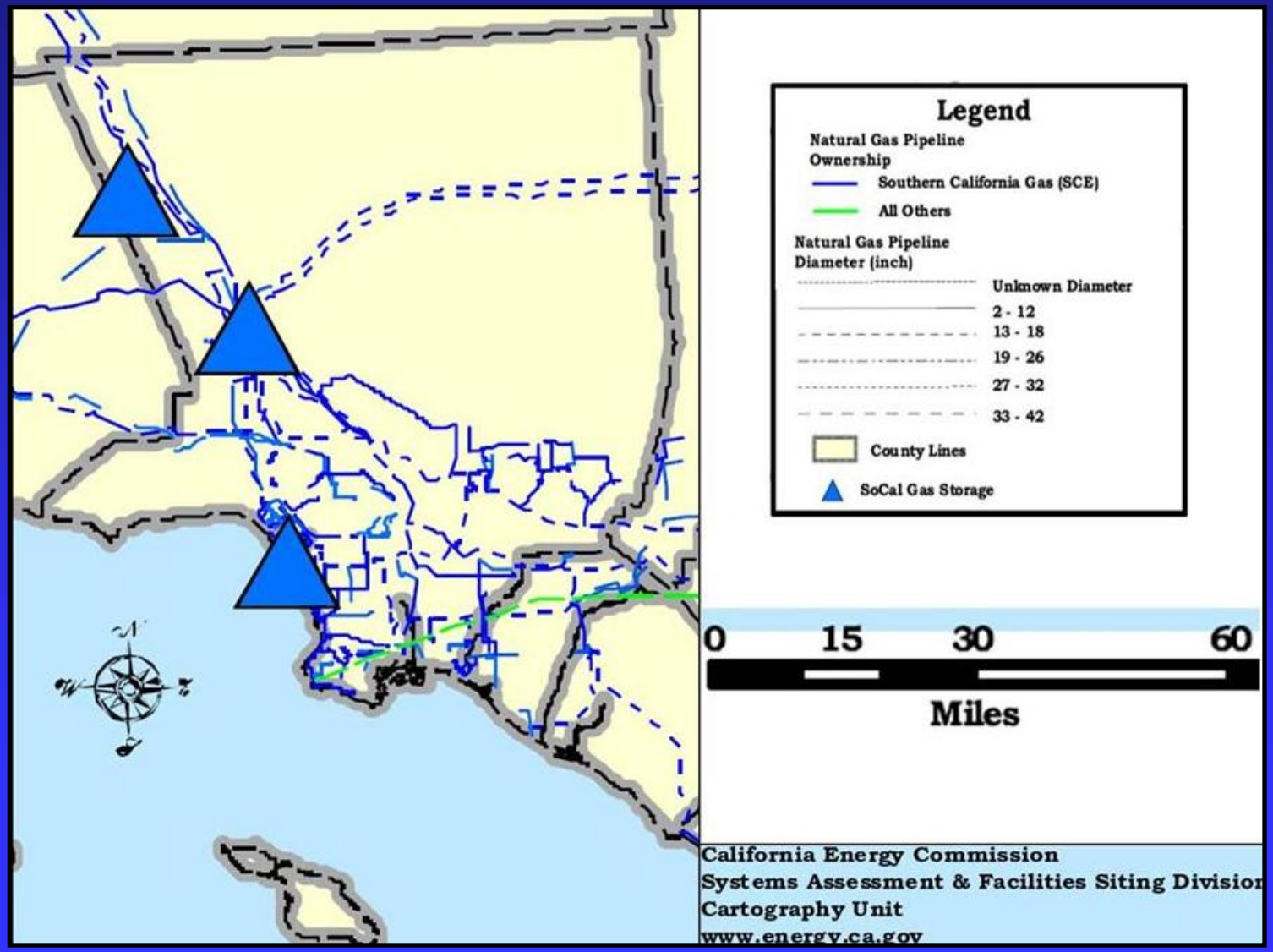
Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Existing Oil & Gas Pipelines and Active Storage



SoCalCarb Atlas Page for Potential Pipelines for CO_2 Transport

4. Accomplishments to Date

1) Detailed log evaluation of existing exploration wells in the area
2) Improved evaluation and interpretation of existing 2D and 3D seismic data
3) Acquisition and interpretation of additional 2D seismic lines
4) Drilling and coring three new evaluation wells into the Graben (Pliocene and Miocene) and/or on the landward side of the THUMS-HB fault
5) Development of 3D geologic models, geomechanical models, and CO_2 injection and migration models for the region
6) Analysis of industrial sources (top 20 in the LA Basin)
7) Transport Infrastructure Study: engineering study of existing and new pipeline systems to transport CO_2 from significant local sources to sequestration sites
8) **Risk analysis**

Risk Assessment and Documentation Includes:

- Lateral Migration to Offset Wells
- Injection Well Failure and Transmission (e.g., corrupted cement)
- CO_2 Migration to Sea Floor
- Induced Seismicity
- Natural seismicity (historical impact on O&G and gas storage operations in LA Basin);
- Caprock Integrity

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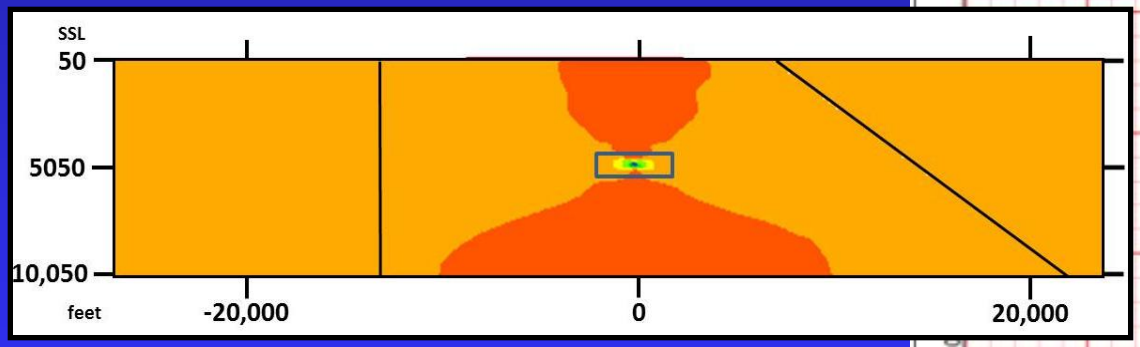
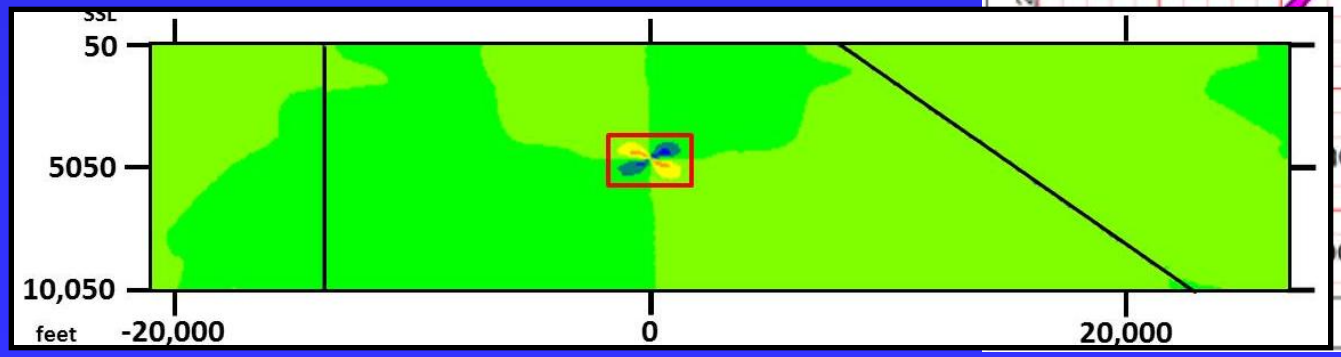
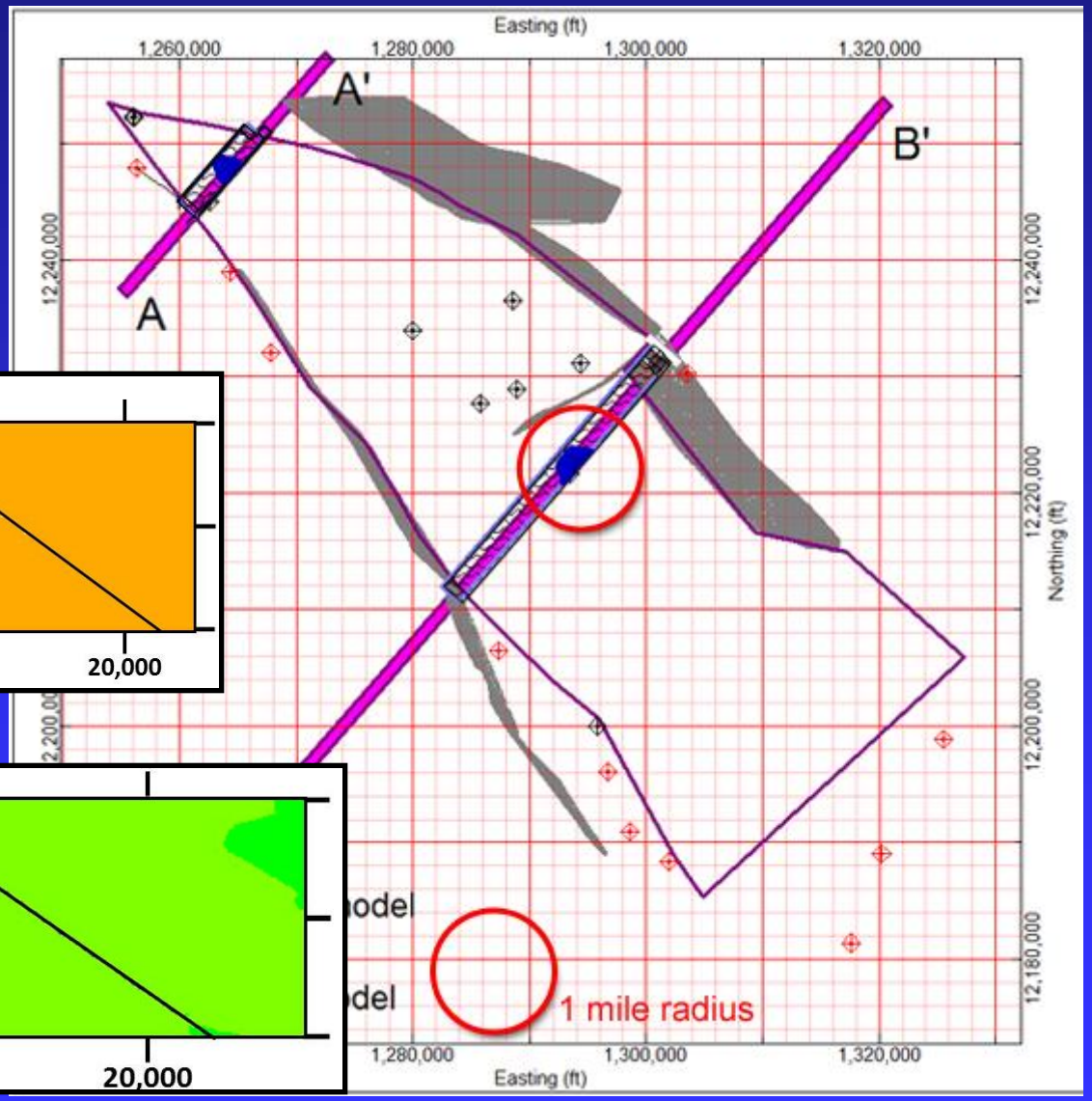
Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Low Risks:

- Lateral Migration to Offset Wells
- Induced Seismicity







5. Summary – Key Accomplishments & Findings

- Acquired 175km of new seismic lines…Interpreted all, old & new
- Drilled 1st characterization well into Pliocene
- Rock properties collected for Pliocene formation
- Reviewed all exploratory wells and built 3D Geologic Model
- Preliminary storage estimates >100MT
- Completed CO_2 migration modeling (TOUGH2) and geomechanical modeling (FLAC3D)
- Source, sink and pipeline interactive maps available online
- Offset wells and Induced Seismicity may pose little risk for unintended CO_2 escape

5. Summary – Future Plans

- **Explore all options to obtain drilling well permits for 2 characterization wells (especially for Miocene characterization)**
- **Update all models w/ this new well data**
- **Complete engineering study of LA Basin transportation systems**
- **Complete Risk characterization and documentation**

6. Project Sponsors and Participants:

DOE NETL

California Energy Commission

City of Los Angeles, Department of Public Works

Southern California Gas Company (transport infrastructure)

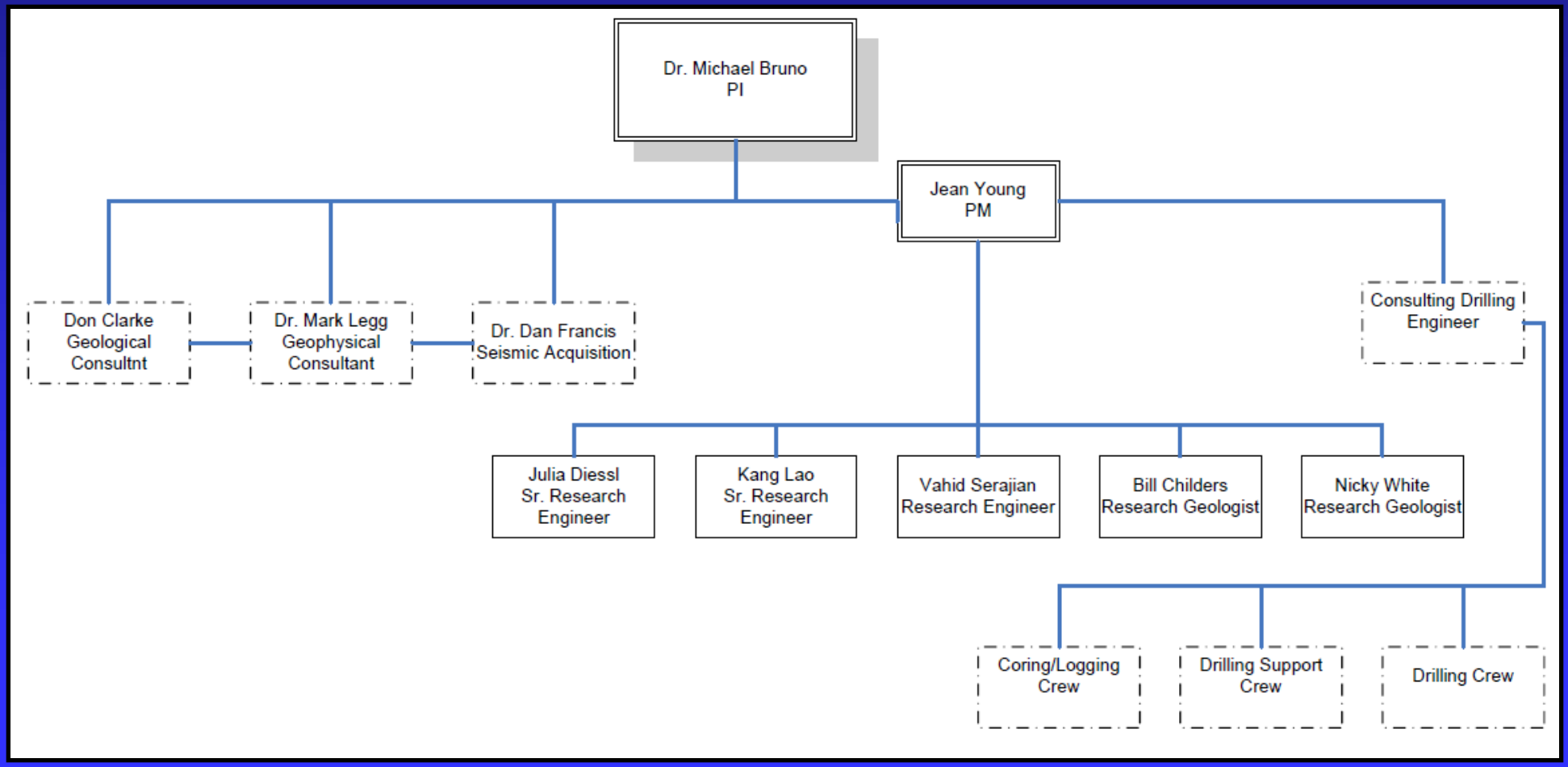
Cal State Long Beach, Dr. Dan Francis (seismic acquisition)

Legg Geophysics (seismic interpretation)

USGS, Dr. Dan Ponti (cores and samples repository)

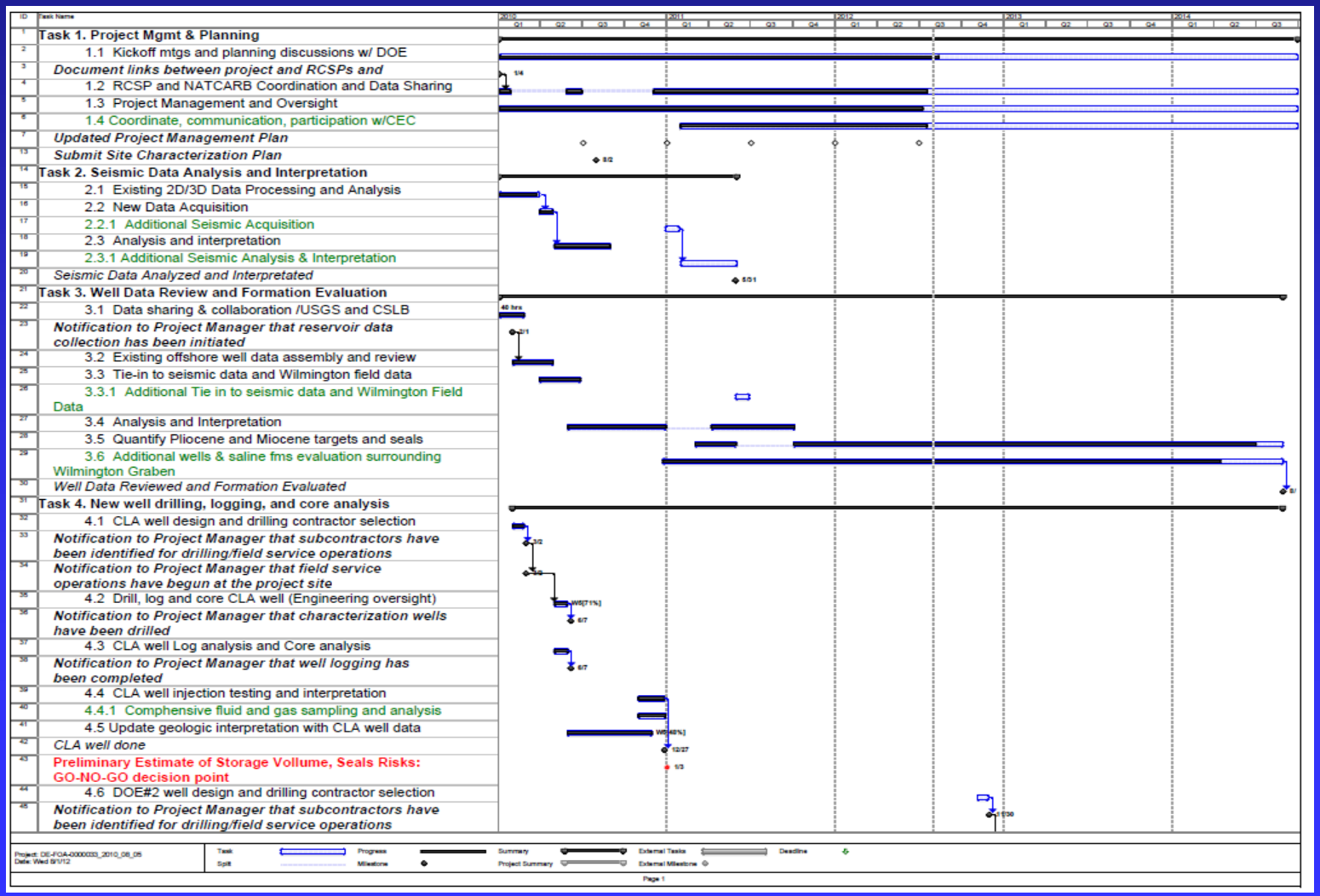
Terralog Technologies USA (geology, geomechanics, reservoir eng)

Appendix A: Project Organization Chart



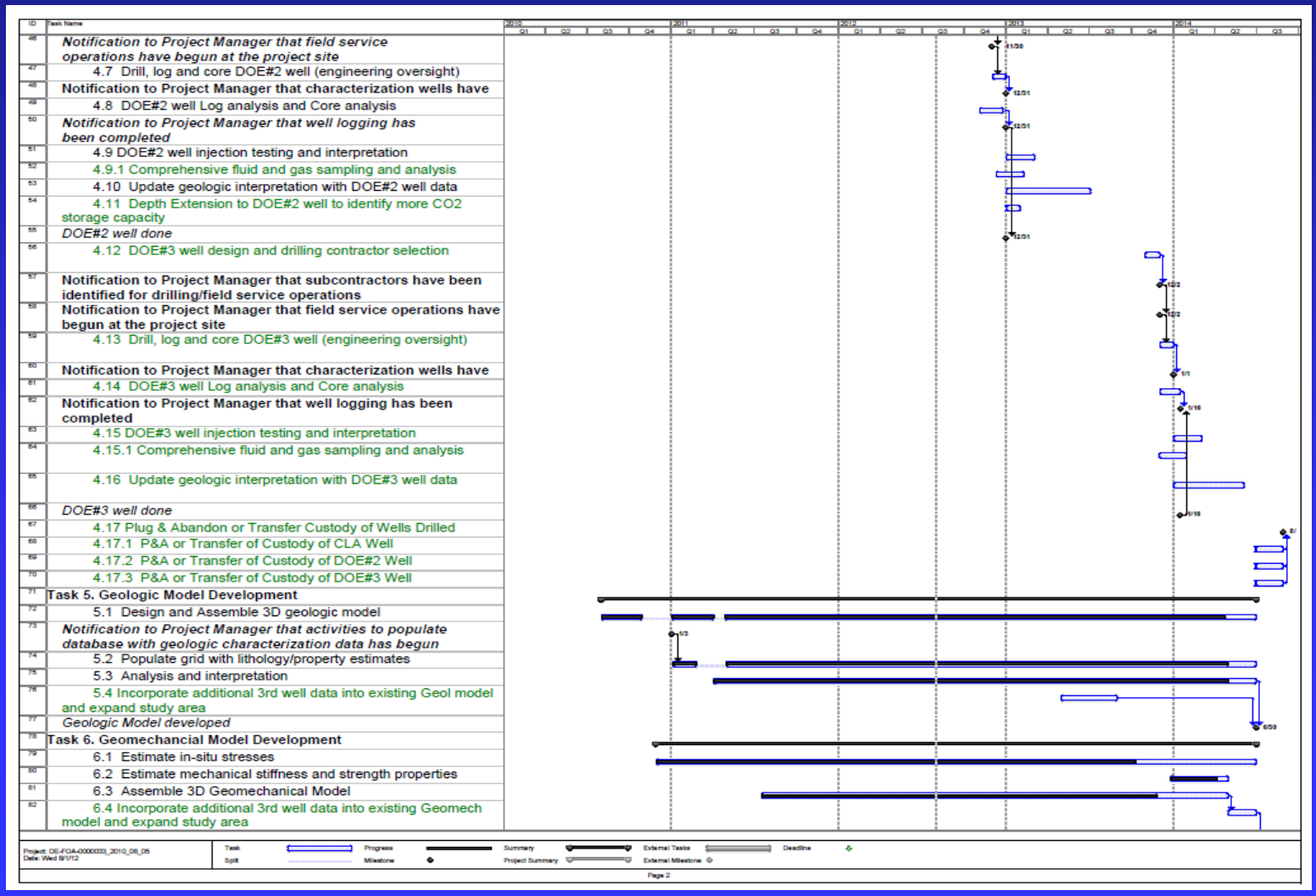
Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Appendix B1: Gantt Chart



Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

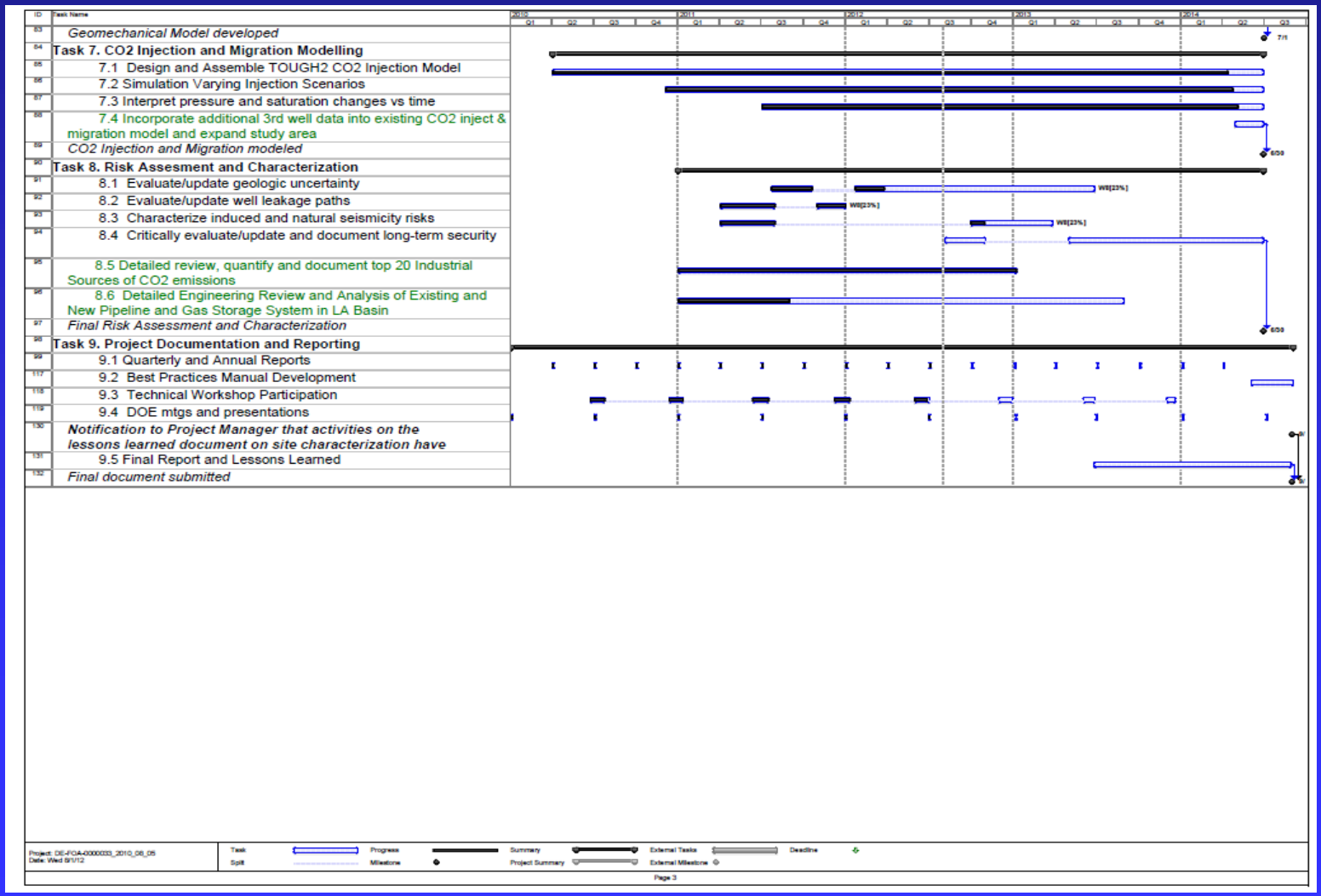
Appendix B2: Gantt Chart



ID	Task Name
46	*Notification to Project Manager that field service operations have begun at the project site*
47	4.7 Drill, log and core DOE#2 well (engineering oversight)
48	**Notification to Project Manager that characterization wells have**
49	4.8 DOE#2 well Log analysis and Core analysis
50	*Notification to Project Manager that well logging has been completed*
51	4.9 DOE#2 well injection testing and interpretation
52	4.9.1 Comprehensive fluid and gas sampling and analysis
53	4.10 Update geologic interpretation with DOE#2 well data
54	4.11 Depth Extension to DOE#2 well to identify more CO2 storage capacity
55	*DOE#2 well done*
56	4.12 DOE#3 well design and drilling contractor selection
57	**Notification to Project Manager that subcontractors have been identified for drilling/field service operations**
58	**Notification to Project Manager that field service operations have begun at the project site**
59	4.13 Drill, log and core DOE#3 well (engineering oversight)
60	**Notification to Project Manager that characterization wells have**
61	4.14 DOE#3 well Log analysis and Core analysis
62	**Notification to Project Manager that well logging has been completed**
63	4.15 DOE#3 well injection testing and interpretation
64	4.15.1 Comprehensive fluid and gas sampling and analysis
65	4.16 Update geologic interpretation with DOE#3 well data
66	*DOE#3 well done*
67	4.17 Plug & Abandon or Transfer Custody of Wells Drilled
68	4.17.1 P&A or Transfer of Custody of CLA Well
69	4.17.2 P&A or Transfer of Custody of DOE#2 Well
70	4.17.3 P&A or Transfer of Custody of DOE#3 Well
71	**Task 5. Geologic Model Development**
72	5.1 Design and Assemble 3D geologic model
73	*Notification to Project Manager that activities to populate database with geologic characterization data has begun*
74	5.2 Populate grid with lithology/property estimates
75	5.3 Analysis and interpretation
76	5.4 Incorporate additional 3rd well data into existing Geol model and expand study area
77	*Geologic Model developed*
78	**Task 6. Geomechancial Model Development**
79	6.1 Estimate in-situ stresses
80	6.2 Estimate mechanical stiffness and strength properties
81	6.3 Assemble 3D Geomechanical Model
82	6.4 Incorporate additional 3rd well data into existing Geomech model and expand study area

Characterization of Wilmington Graben, Offshore Los Angeles, for Large Scale Geologic Storage of CO_2

Appendix B3: Gantt Chart



ID	Task Name
83	*Geomechanical Model developed*
84	**Task 7. CO2 Injection and Migration Modelling**
85	7.1 Design and Assemble TOUGH2 CO2 Injection Model
86	7.2 Simulation Varying Injection Scenarios
87	7.3 Interpret pressure and saturation changes vs time
88	7.4 Incorporate additional 3rd well data into existing CO2 inject & migration model and expand study area
89	*CO2 Injection and Migration modeled*
90	**Task 8. Risk Assesment and Characterization**
91	8.1 Evaluate/update geologic uncertainty
92	8.2 Evaluate/update well leakage paths
93	8.3 Characterize induced and natural seismicity risks
94	8.4 Critically evaluate/update and document long-term security
95	8.5 Detailed review, quantify and document top 20 Industrial Sources of CO2 emissions
96	8.6 Detailed Engineering Review and Analysis of Existing and New Pipeline and Gas Storage System in LA Basin
97	*Final Risk Assessment and Characterization*
98	**Task 9. Project Documentation and Reporting**
99	9.1 Quarterly and Annual Reports
117	9.2 Best Practices Manual Development
118	9.3 Technical Workshop Participation
119	9.4 DOE mtgs and presentations
130	*Notification to Project Manager that activities on the lessons learned document on site characterization have*
131	9.5 Final Report and Lessons Learned
132	*Final document submitted*