(ARRA Site Characterization) – Geologic Characterization of the Triassic Newark Basin of Southeastern New York and Northern New Jersey

(DE-FE0002352)

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Developing the Technologies and
Infrastructure for CCS
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- **Key Project Team Members:**

  Sandia Technologies, LLC; Conrad Geoscience/PVE-Scheffler, New York State Museum, Lamont Doherty Earth Observatory, Rutgers University, Schlumberger, Lawrence Berkeley National Laboratory

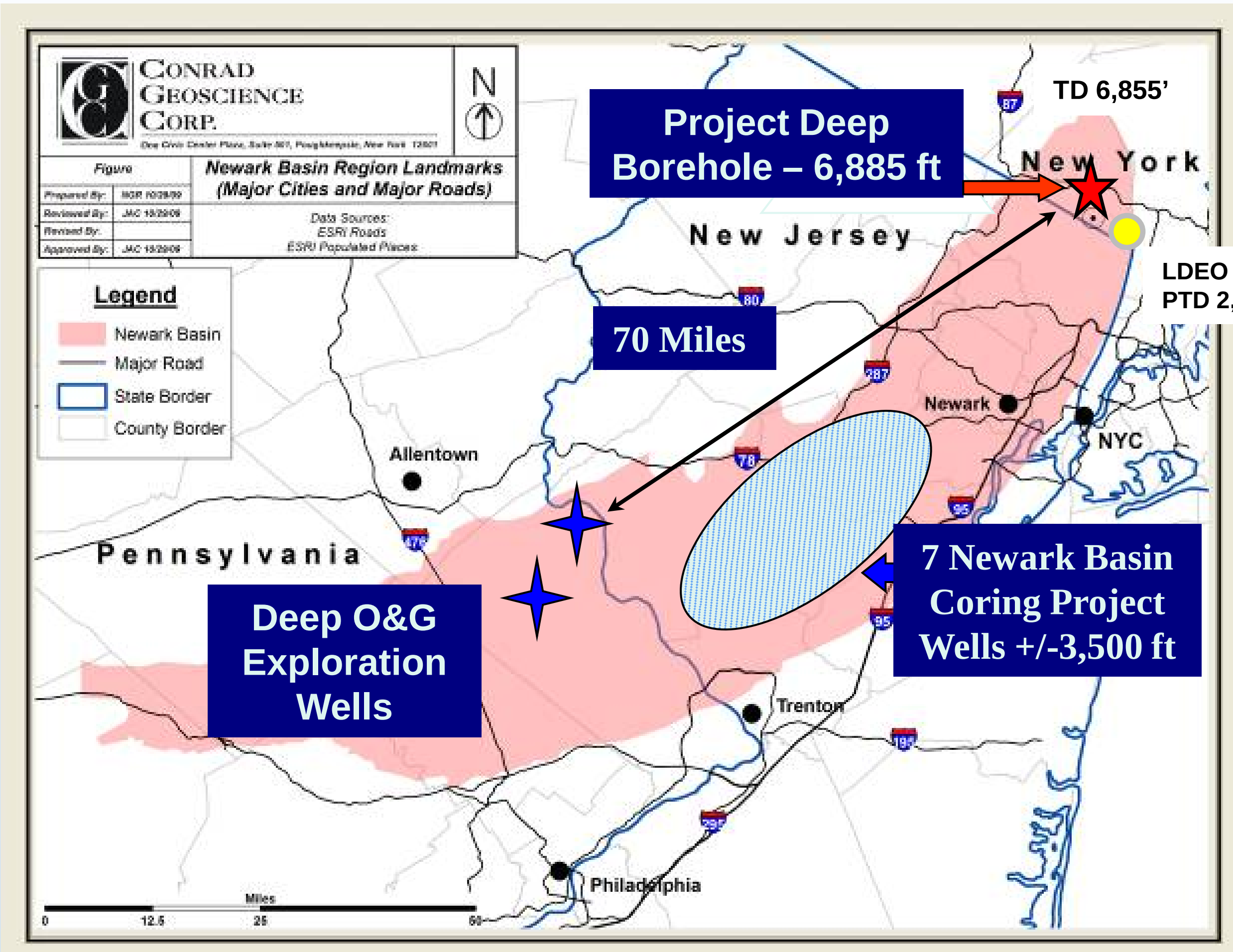
Presentation Outline

- Project Benefits to the Program
- Project Overview - Objectives, Goals
- Project Accomplishments
- Technical Status
  - Shallow Core Hole Test Well at Lamont Doherty Earth Observatory
- Summary
  - Key Findings, Lessons Learned
- Future Plans
  - Lawrence Berkeley Nat. Lab - CO_2 Reactive Flow Modeling
  - Final Data Integration

Benefit to the Program

- Program Goals
  - Provide geologic characterization of potential storage and confining formations in the Northern Newark Basin
- Project Benefits Statement.
  - Assess CO_2 storage capacity in the under-explored Newark Basin in northeast corridor

Under-explored Newark Basin



- Newark Basin stretches from Rockland County, New York, southwest across northern New Jersey, and into southeastern Pennsylvania (140 miles long by 32 miles wide)
- Geographic extent ~ 2,700 square miles
- The Newark Basin is in close proximity to large population areas and a heavily industrialized section of the country (28 MM tons/year CO_2 in closest NY/NJ counties)
- Deep offsets (mid 1980s) are more than 70 miles away – oil and gas exploration
- 1990s 7 Newark Basin Coring Project wells Central New Jersey ~3,500 ft deep – chronostratigraphy focus

Project Overview:
Goals and Objectives

- **Primary Objective -** Demonstrate that geologic sequestration of CO_2 offers an effective and viable large-scale mitigation approach to managing greenhouse gas emissions from industrial sources in the northeastern United States
  - Identify presence/absence of commercial scale reservoirs at the northern end of the basin.
  - Identify presence of appropriate confining zone(s) and cap rock layers.
  - Evaluate geomechanics of potential injection scenarios.
  - Characterize hydro-geologic regime of the geologic section.
  - Perform laboratory kinetics and reactive/flow modeling of potential injection scenarios.

- Create meaningful near-term and long-term employment, building and initiating the foundation for a CCS industry using the Newark Basin geologic formations

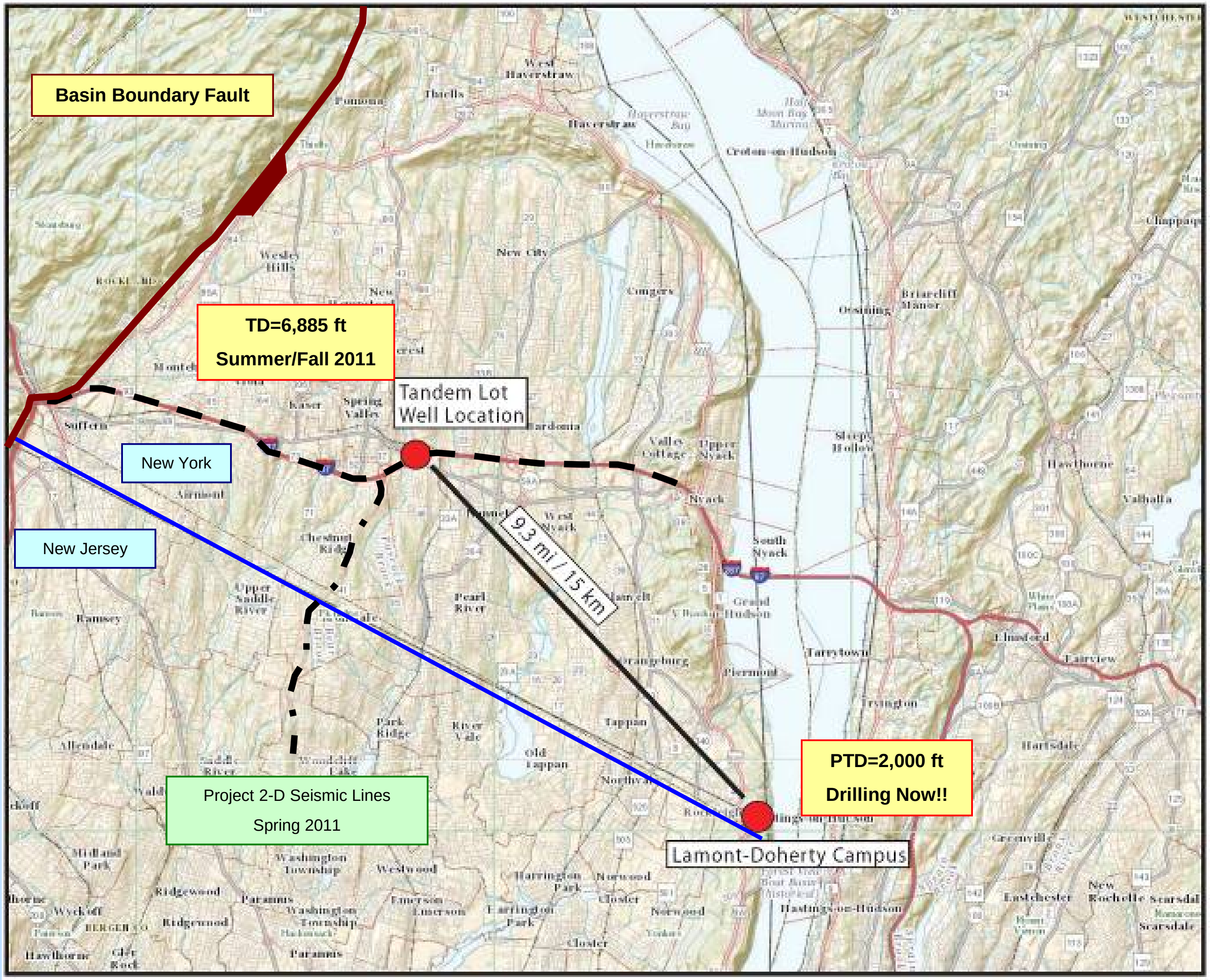
Technical Status

- Project is drilling it's Shallow Core Hole Test Well at the Lamont Doherty Earth Observatory Campus
- Well is located near eastern margin of the basin along the New York/New Jersey State Line against the Hudson River
- Anticipated depth to sedimentary basement is +/-2,000 feet below ground level
- Once well is logged, Field portion of project will be complete (well retained by Lamont Doherty Earth Observatory)

Lamont Doherty Earth Observatory - Shallow Core Hole

- Well is regulated by both New York State Department of Environmental Conservation and Rockland County Department of Health
- Project evaluated several new well and re-entry options versus State and County rules and guidance
- Optimal well design maximizes core sample recovery and geophysical well logging options
- Efficiencies gained by air hammering the first 650 feet of the Palisades Sill Intrusive Diabase
- Palisades Sill is expected to be +/-750 feet thick and is not productive of water

Newark Basin Project Seismic Lines & Well Locations



Regulatory Environment

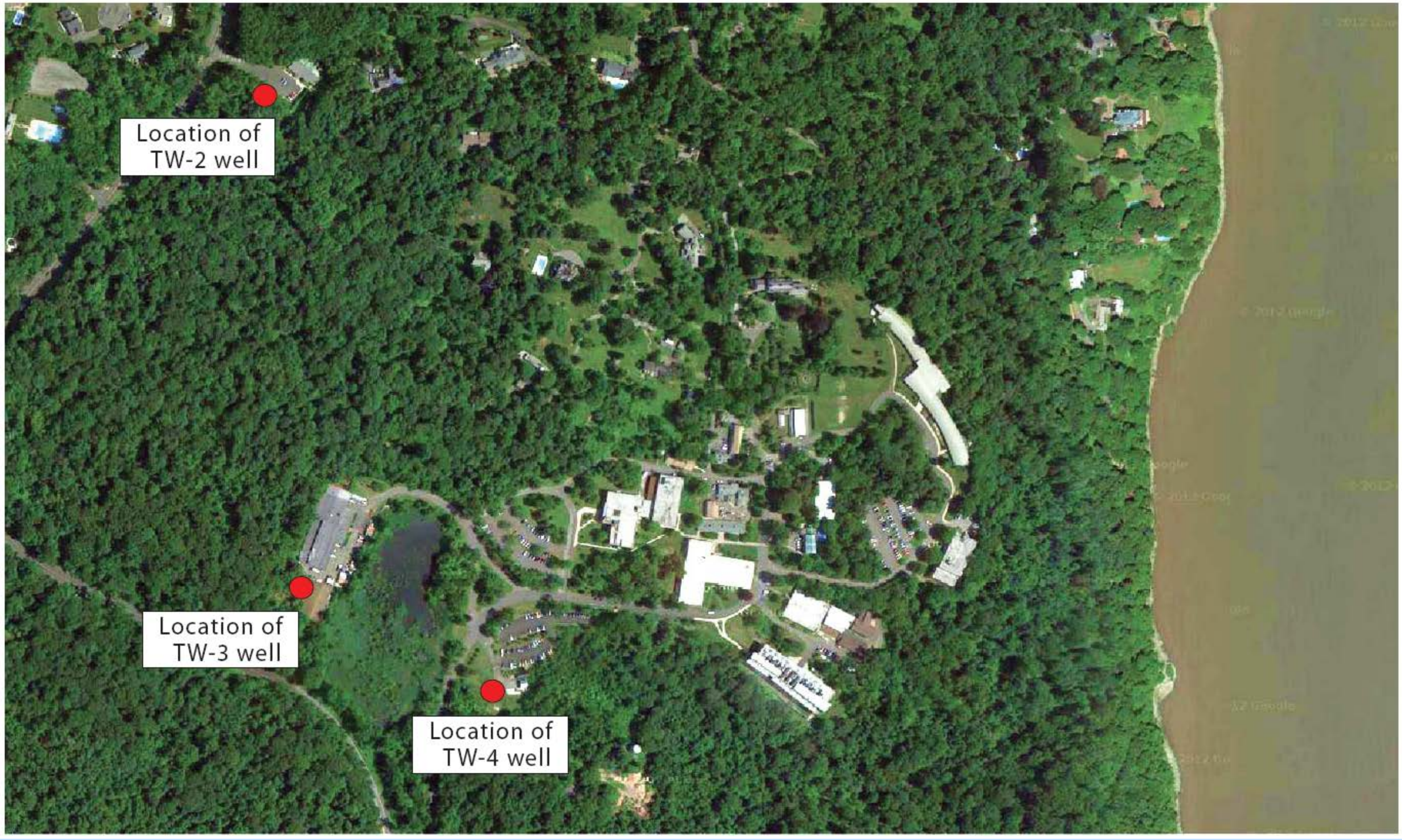
- **New York's "Oil, Gas and Solution Mining Law“ under New York State Department of Environmental Conservation**
- Section 23-0102 states that Article 23 of the Environmental Conservation Law "shall be known and may be cited as the oil, gas and solution mining law." However, this should not be construed as a complete list of well types covered by the law. The law and the corresponding rules and regulations apply to the following well types (see Article 23, Titles 3 and 13):
- all oil wells, regardless of depth
- all gas wells, regardless of depth
- all wells, regardless of depth, associated with underground storage in caverns or reservoirs of gas, liquefied petroleum gas, oil, petroleum products and petroleum byproducts
- all solution salt mining wells, regardless of depth
- **stratigraphic wells deeper than 500 feet**
- geothermal wells, including:
  - wells deeper than 500 feet for finding or producing hot water or steam
  - wells deeper than 500 feet for injecting fluids to recover heat from the surrounding geologic materials (including geothermal heat pump wells deeper than 500 feet)
- brine disposal wells deeper than 500 feet

Regulatory Environment 2

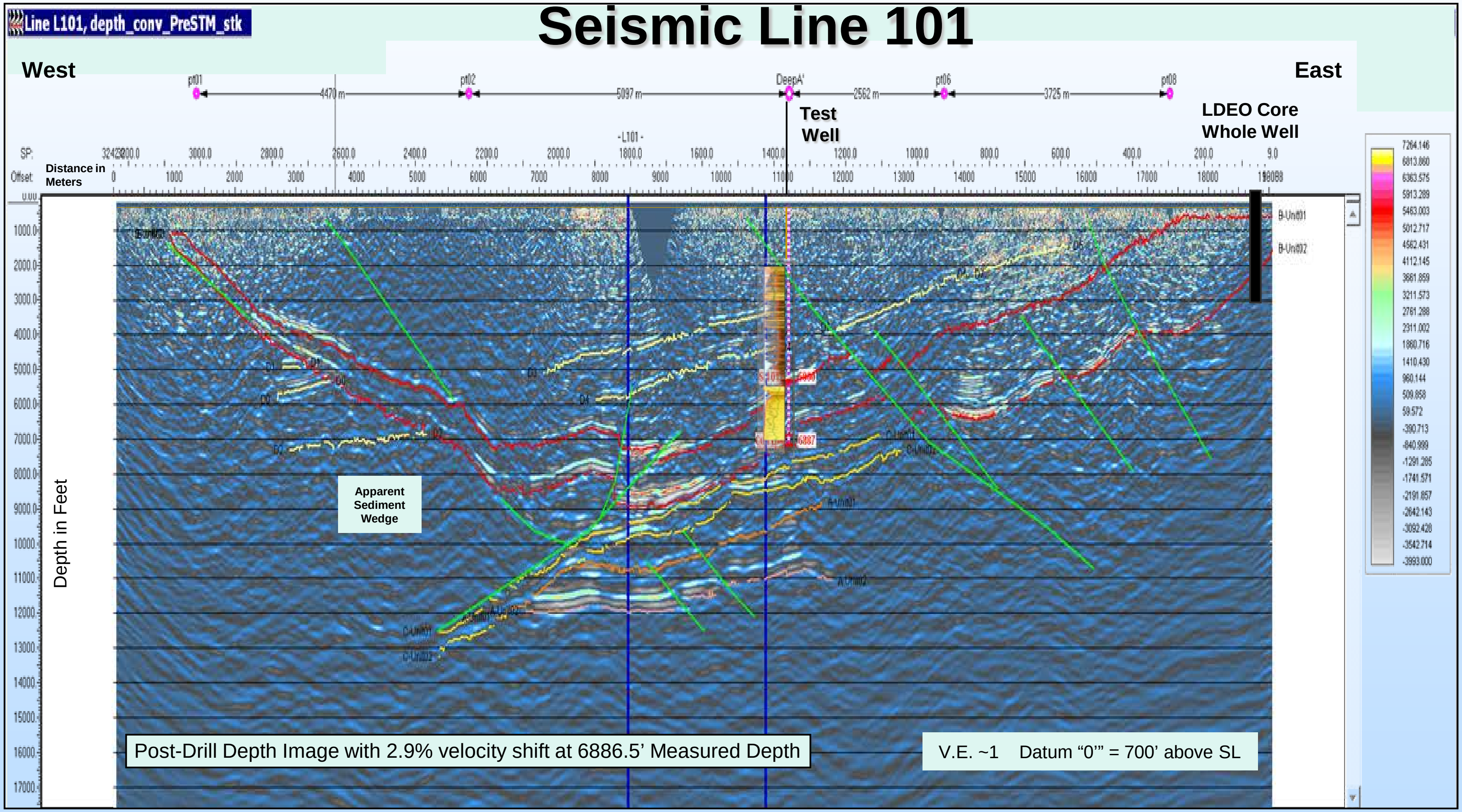
- **All wells drilled in Rockland County fall under the Sanitary Code enforced by the Rockland County Department of Health**
  - It is hereby declared to be the health policy of the Rockland Health District to protect present and potential future sources of water supplies, and to work to ensure that all residents have access to water that is safe and sanitary for washing, bathing, drinking, culinary or food processing purposes

- Article II, Section 2.2.14 defines Resource Evaluation Well states that Article 23 of the Environmental Conservation Law "shall be known and may be cited as the oil, gas and solution mining all oil wells, regardless of depth
  - The term "**resource evaluation well**" includes monitoring wells, air sparging wells, soil vapor extraction wells, recovery wells, wells or wellpoints installed for environmental investigation or remediation projects, test borings, probe holes, uncased holes drilled or otherwise constructed **for the purpose of obtaining soil or rock samples or data for engineering and/or geophysical, hydrological or geological purposes**, and borings involving the use of direct-push technologies.

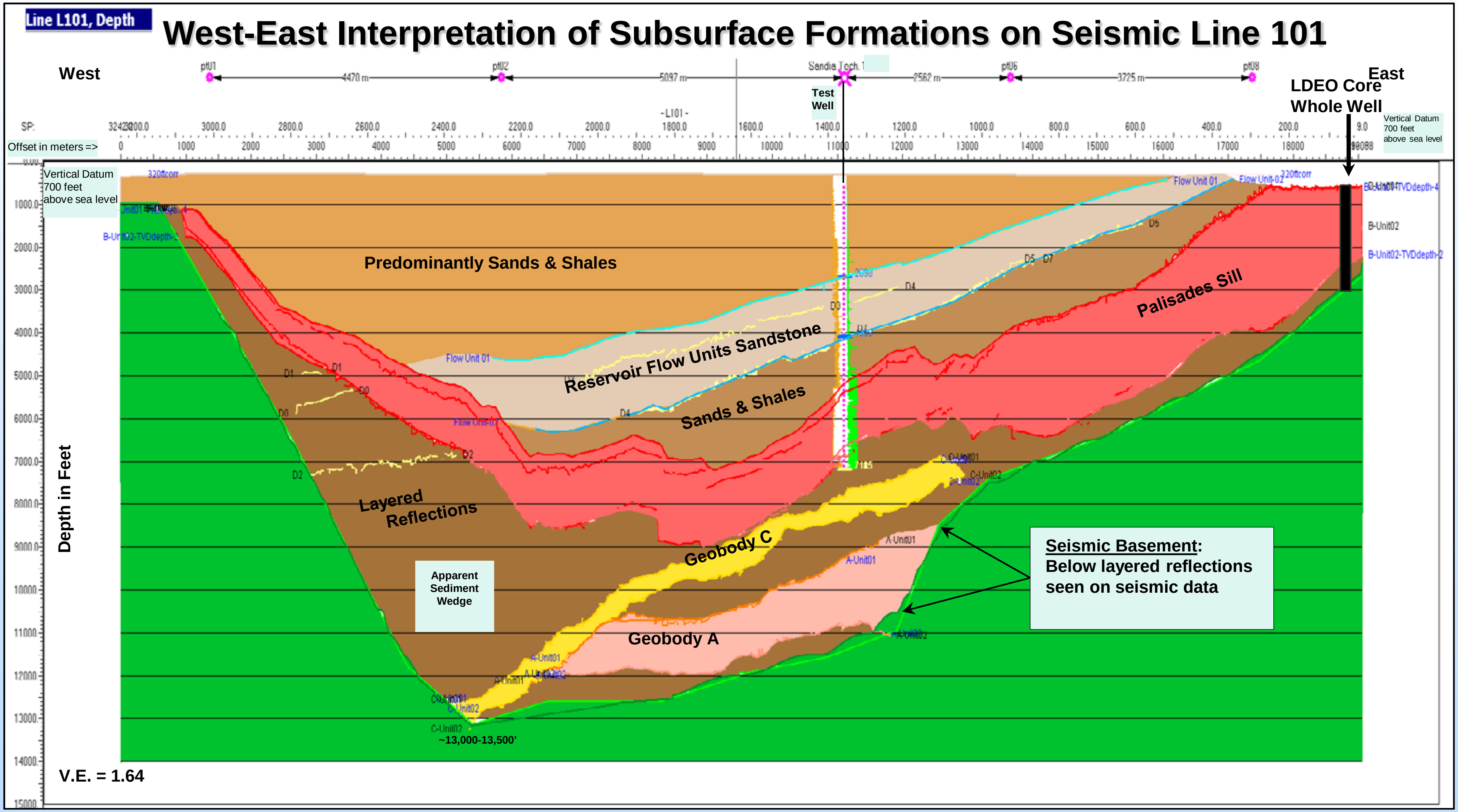
Aerial of Lamont Doherty Earth Observatory



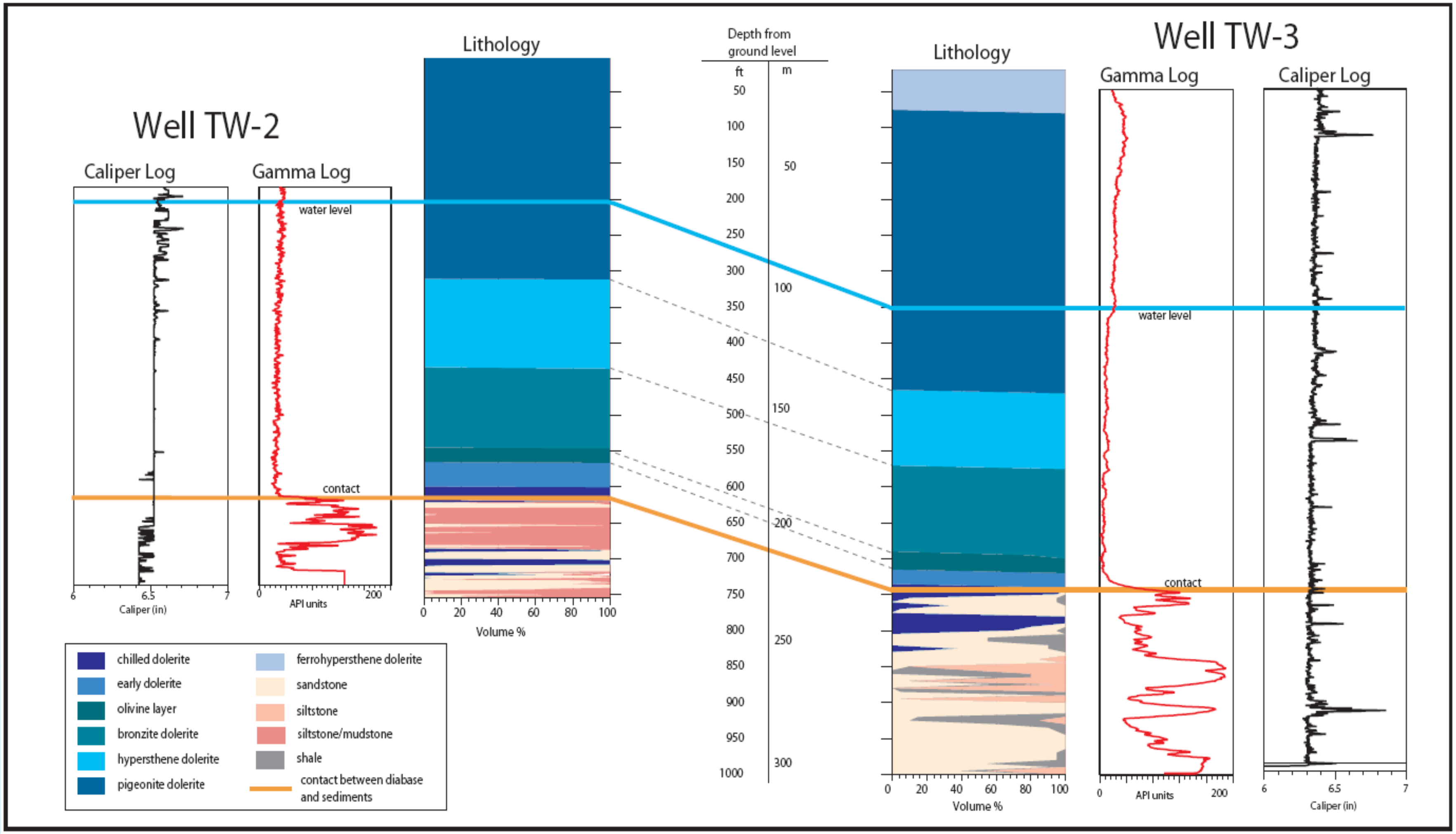
Project E-W Seismic Line 101



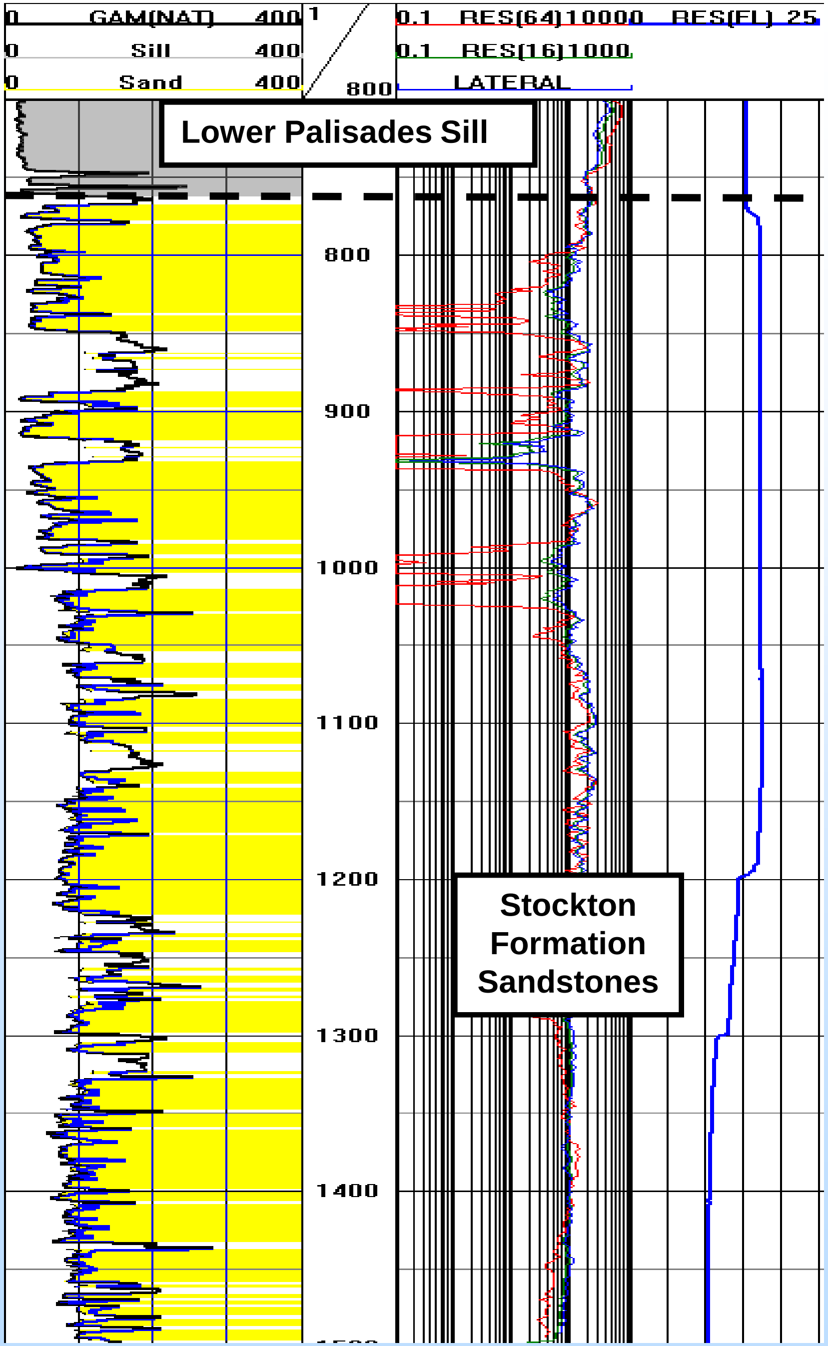
E-W Seismic Line Interpretation



Correlation Between LDEO Test Wells



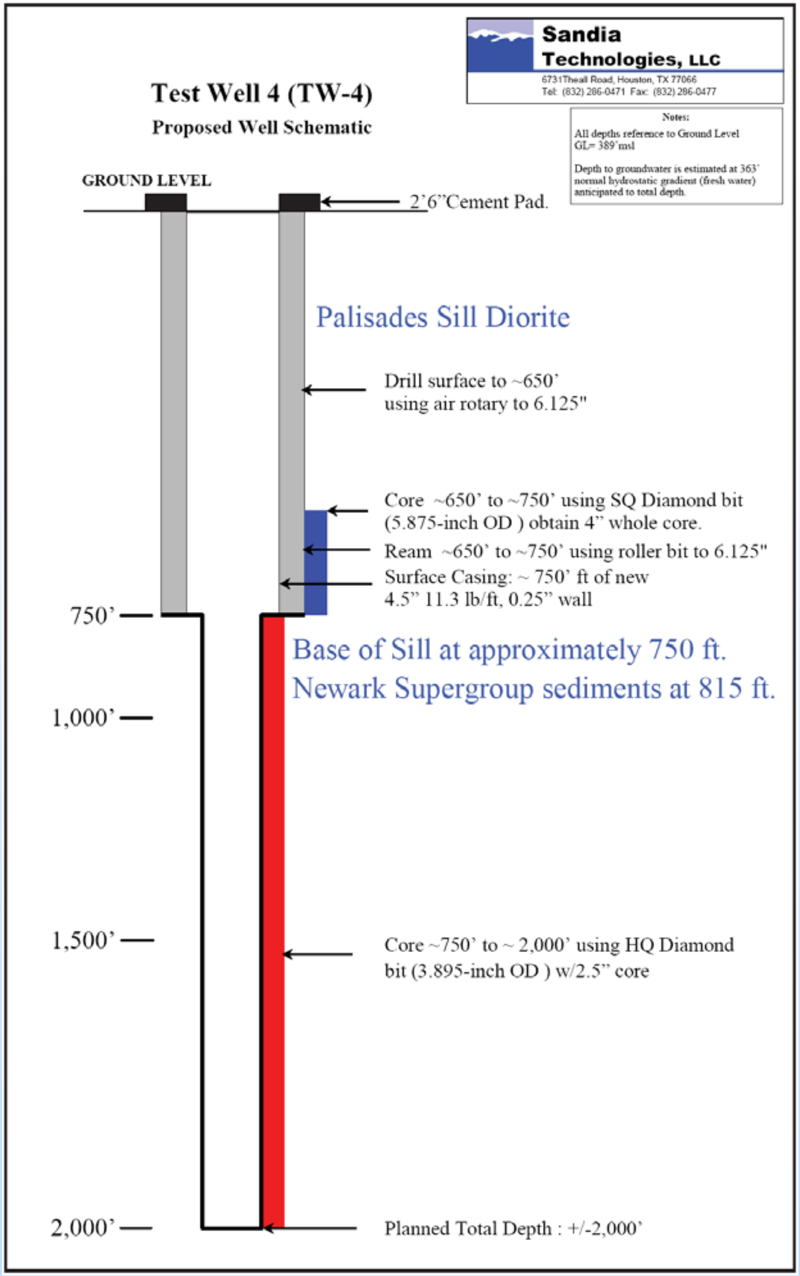
From Burgdorff & Goldberg, 2001



LDEO TW-3 Well

- 6-1/2-inch borehole drilled to +/-1,500 feet below ground level
- Larger diameter allows for a suite of logging tools that we are not able to run in the in the Core Hole Test Well
- No Whole or Rotary Cores taken in TW-3 (only cuttings samples)
- More sand-prone section is present under the Sill than we observed at the NYSTA Exit 14 Deep Well

Core Hole Test Well Design

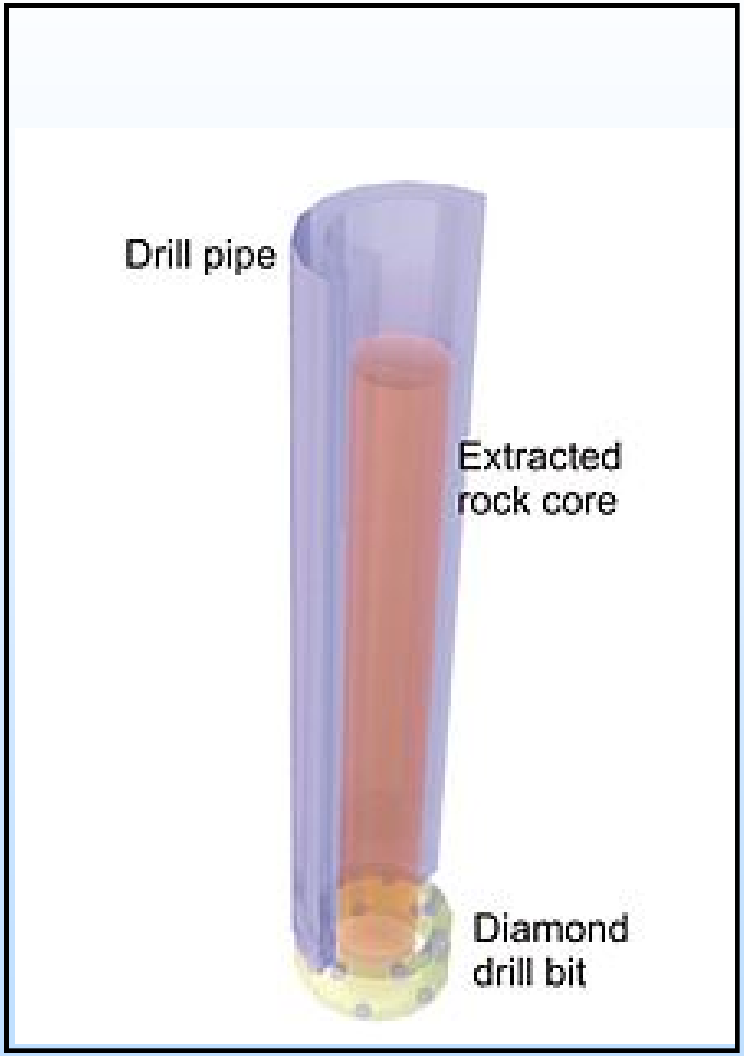


- Air Hammer borehole to +/-650 feet
- SQ Diamond Whole Core from 650 feet to 750 feet
- Ream cored hole to a diameter of 6-1/8-inches & set 4-1/2-inch casing to 750 Feet
- HQ Diamond Whole Core to +/-2,000 Feet
- Run Slim-hole logging program

Air Hammer Rig - Aquifer Drilling & Testing

- Short Conductor Casing set to 16 feet
- A 6-1/8-inch diameter borehole was air hammered to 650 feet between July 15-18
- Max penetration rate of 300 feet per day (day lights only)
- Drill cuttings samples collected by LDEO Staff from surface to 650 feet

Whole Diameter Coring



Core Method

Core Bits

Project Core Run

Boart-Longyear Coring Rig

- Anticipate 100 feet of SQ Core (4-inch diameter) from lower Palisades Sill through transition zone into the sedimentary section
- Ream cored section and set surface casing through the transition zone (known local water source)
- 1,250 feet of HQ Core (2.5-inch diameter)
- Oversight by LDEO Staff and New York State Museum Geologist

Anticipated Borehole Logging Program

- TW-4 Well (3-1/2-inch)
  - Slimhole Platform Express
  - Borehole Compensated Sonic Tool
  - Reservoir Saturation Tool

  Schlumberger Carbon Services will perform ELAN analysis

- Existing TW-3 Well (6-1/2-inch)
  - Slimhole Platform Express
  - Sonic Scanner Tool
  - Combinable Magnetic Resonance Tool
  - Elemental Capture Sonde

  Schlumberger Carbon Services will perform ELAN and Sonic Scanner Tool analyses

LDEO Shallow Core Hole Test Well - Progress

- Successfully Permitted well at State and County levels
- Leveled location and set gravel pad – early July
- Successfully/quickly air hammered borehole to 650 ft – July 15-18
- Initiated whole coring on August 12th
- Cored base of Palisades Sill at 695 feet below ground depth on August 16th (end day at 713 feet in a diabase stringer)
- Setting surface casing today??

Accomplishments to Date

- ❖ Completed acquisition and processing of two 2-D seismic lines (New York State Thruway and Garden State Parkway) – March/June 2011
- ❖ Permitted and completed drilling, coring, & logging of a deep (6,885 ft) stratigraphic test boring – July/October 2011
- ❖ Completed routine and advanced whole and rotary core plug analyses – Spring 2013
- ❖ Developed Integrated Seismic/Well Structural Model – July 2012 (presented last year)
- ❖ Permitted and started LDEO Shallow Core Hole in upper 650 feet of the Palisades Sill (air hammer) – late July 2013
- ❖ Initiated whole diameter coring in the LDEO Shallow Core Hole – August 19, 2013 – Anticipate completion and logging in September 2013

Summary

– Key Findings
– Lessons Learned
– Future Plans

Key Findings

- At the deep test well location, sandstone development decreases with depth, however, three Reservoir Flow Units are identified (Unit 1 ~2,100 to 2,500 ft, Unit 2 ~ 2,800 – 3,200 ft, Unit 3 ~ 3,650 – 4,250 ft) – limited sandstone development below 4,250 feet
- Measured formation pressures indicate a freshwater gradient, placing the supercritical CO_2 window below a depth of 2,500 feet
- MDT Formation water samples down to 3,058 feet indicate brackish waters only (<10,000 ppm NaCl)

  i.e. all flow units would be classified as an "underground source of drinking water".
- Deep test well confirmed presence of abundant lithified, low permeability mudstones/siltstones that can act as confining caprock layers. Minifrac testing of confining intervals were run up to tool limits of +/-5,500 psi (3,055 feet and 3,510 feet) without formation breakdown, indicating >1.55 psi/ft fracture pressure.
- Additional potential trapping mechanism occurs where flow units are cross-cut by the Palisades Sill
- Intra-basin faulting may add more potential localized reservoir traps

Key Findings

- At the deep test well location sandstone development decreases with depth, however, 3 Reservoir Flow Units identified (Unit 1 ~2,100 to 2,500 ft, Unit 2 – 2,800 – 3,200 ft, Unit 3 ~ 3,650 – 4,250 ft) – poor sandstone development below 4,250 feet
- Formation Pressures indicate a freshwater gradient, placing supercritical CO_2 window below a depth of 2,500 feet
- MDT Formation water recovery at 3,058 feet and lab analyses indicate brackish waters only (<10,000 ppm NaCl)

  i.e. interval would be classified as underground source of drinking water.

- Well confirmed presence of abundant lithified, low permeability mudstones that can act as confining caprock layers. MDT Minifrac testing of intervals ran up to tool limits of +/-5,500 psi (3,055 feet and 3,510 feet), show >1.5 psi/ft minimum fracture pressure.
- Basin stress regimes identified with borehole FMI, geomechanics, magnetic data
- Potential added trapping mechanisms are in homoclinal dip of sediments being cross-cut by the Palisades Sill and below the sill
- Faulting adds more potential localized reservoir traps

Lessons Learned

- County regulatory concerns/requirements may not necessarily agree with State permit requirements – may result in increased well construction costs, i.e. local request for additional string of "intermediate" surface casing to seal off potable water sources
- Research Field Work can be accomplished in an urban-suburban "developed" setting. However, costs will be higher than in more rural less developed areas, i.e. seismic on NYS Thruway, permitting charges, traffic control, work hour limits
- Early outreach to local Rockland Co. and township officials helped facilitate education outreach to key stakeholders and wider public
- Northern end of the basin is significantly more complex than originally anticipated, with faulting, igneous dikes, metasediments
- Palisades Sill thickness was approximately 1100 feet, with halo zones of meta-sediments, altered intervals above-below diabase.
- Defined Reservoir Flow zones are indicated from logs, cores, MDT fluids, integrated ELAN
- Integrated Seismic-Geologic structure, thickness information show effect of the sill on sediments, faulting, thinning
- Apparent deeper wedge of sediments may exist to 13,500 feet
- Middle deeper Newark Basin (NJ) may contain better (saline)

Key Findings

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Lessons Learned

- County regulatory concerns/requirements may not agree with state Permit requirements – may result in increased well construction costs, i.e. local request for additional surface casing
- Research Field Work can be accomplished in an urban-suburban "developed" setting, however, costs will be higher than budgeted, i.e. seismic on NYS Thruway, permitting charges, access
- Early outreach to local Rockland Co., NY officials helped facilitate educational outreach to key stakeholders and wider public
- Northern end of the basin is more complex than originally anticipated, with intra-basin faulting, igneous dikes and sills, and metasediments above and below the Palisades Sill
- Palisades Sill was thicker than estimated (+/-1,575 feet), with halo zones of meta-sediments, altered intervals above-below diabase.
- Defined Reservoir Flow zones are indicated from logs, cores, MDT fluids, integrated ELAN
- Integrated Seismic-Geologic structure, thickness information show effect of the sill on sediments, faulting, thinning
- Deeper wedges of "sediments" may exist down to 13,500 feet in the deepest part of the county

Future Plans - Next Steps

- Complete Shallow Core Hole Test Well (2,000 ft PTD at Lamont Doherty Earth Observatory Campus – 3rd Quarter 2013.

- Analyze geophysical well logs and Shallow Corehole Test Well cutting and whole core samples – Spring 2014.

- Lawrence Berkeley National Laboratory performing reaction experiments and reactive transport modeling – Summer 2014.

- Final project report and NATCARB data integration complete by September 30, 2014.

Questions?

End

Appendix

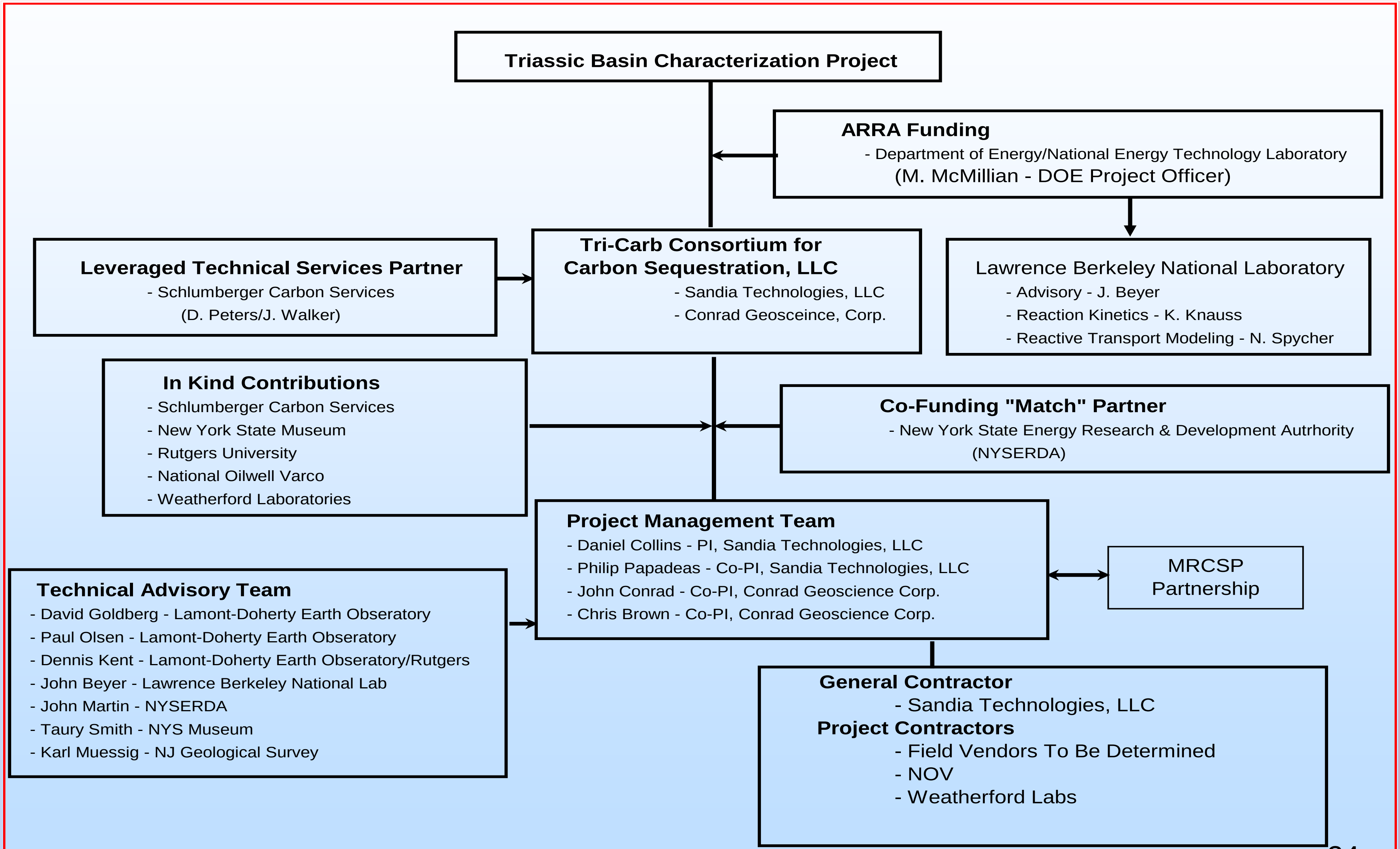
- These slides will not be discussed during the presentation, but are mandatory

Organization Chart

- Describe project team, organization, and participants.
  - Link organizations, if more than one, to general project efforts (i.e. materials development, pilot unit operation, management, cost analysis, etc.).

- Please limit company specific information to that relevant to achieving project goals and objectives.

Project Organization Chart



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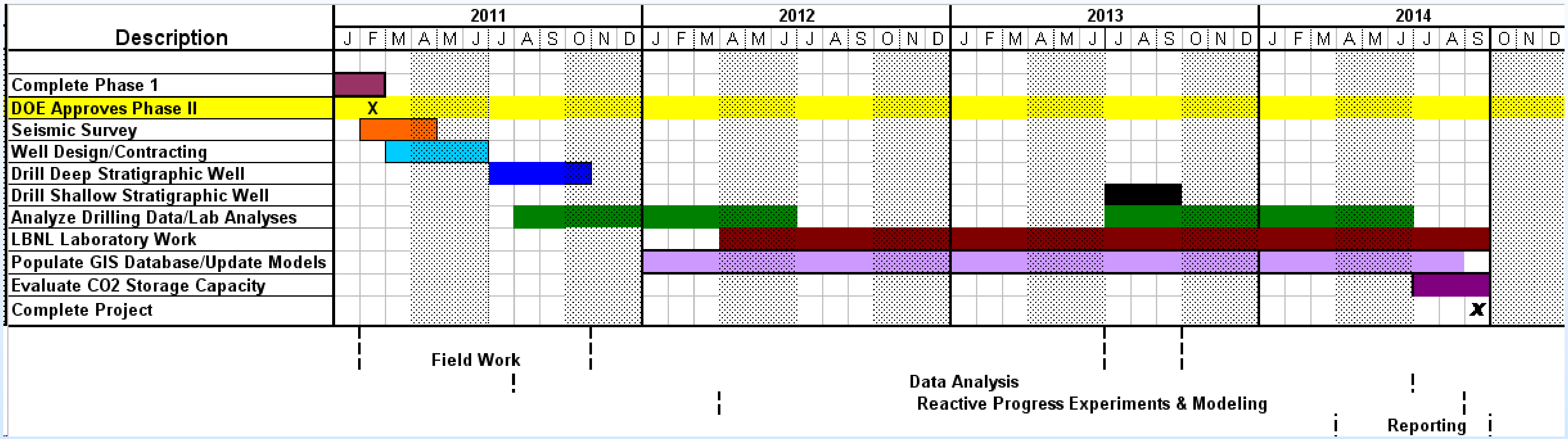
Gantt Chart

- Provide a simple Gantt chart showing project lifetime in years on the horizontal axis and major tasks along the vertical axis. Use symbols to indicate major and minor milestones. Use shaded lines or the like to indicate duration of each task and the amount of that work completed to date.

Gantt Chart


Description
2011
2012
2013
2014
J F M A M J J A S O N D
Complete Phase 1
DOE Approves Phase II
X
Seismic Survey
Well Design/Contracting
Drill Deep Stratigraphic Well
Drill Shallow Stratigraphic Well
Analyze Drilling Data/Lab Analyses
LBNL Laboratory Work
Populate GIS Database/Update Models
Evaluate CO2 Storage Capacity
Complete Project
X
Field Work
Data Analysis
Reactive Progress Experiments & Modeling
Reporting

Bibliography

List peer reviewed publications generated from project per the format of the examples below

- None