PMTurkeyCOLPEm Resource

From: Comar, Manny
Sent: Thursday, July 24, 2014 3:43 PM
To: Candelario, Luissette; Heeszel, David; Jackson, Diane; Plaza-Toledo, Meralis; Seber, Dogan; Stieve, Alice; Takacs, Michael; Vega, Frankie; Walsh, Lisa; Xi, Zuhan
Cc: Patel, Pravin; Thomas, Vaughn; TurkeyCOL Resource
Subject: FW: Presentations for the July 29, 2014 NRC/FPL Public Meeting
Attachments: PTN_GeoTech_NRC Presentation_MASTER REV 0_Reduced.pdf

FYi

From: Franzone, Steve [mailto:Steve.Franzone@fpl.com]
Sent: Thursday, July 24, 2014 3:15 PM
To: Comar, Manny
Cc: Maher, William; Burski, Raymond
Subject: RE: Presentations for the July 29, 2014 NRC/FPL Public Meeting

Manny
Apparently the original pdf file was too big. I have reduced the file size and I am re-sending it. Please let me know if you received this email.

Thanks
Steve Franzone
NNP Licensing Manager - COLA
"It is wise to direct your anger towards problems - not people; to focus your energies on answers - not excuses."
William Ward
561.694.3209 (office)
754.204.5996 (cell)
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From: Franzone, Steve
Sent: Thursday, July 24, 2014 3:07 PM
To: Manny Comar
Cc: Maher, William; Burski, Raymond
Subject: Presentations for the July 29, 2014 NRC/FPL Public Meeting

I have attached the presentation for your use during our public meeting next week.

Any questions, please call Ray Burski or myself.

Thanks
Steve Franzone
NNP Licensing Manager - COLA
"It is wise to direct your anger towards problems - not people; to focus your energies on answers - not excuses."
William Ward
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754.204.5996 (cell)

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From: Comar, Manny

Created By: Manny.Comar@nrc.gov

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FSAR 2.5 – Geotechnical Engineering
Turkey Point Units 6 and 7

Bill Maher

Senior Licensing Director – New Nuclear Projects

July 29, 2014

Agenda

- Introduction & Overview [NRC/FPL]
- Supplemental Geotechnical Site Investigation [FPL]
- Supplemental Laboratory Testing [FPL]
- Supplemental Analysis [FPL]
- General Discussion Geology / Seismology (FPL/NRC)
- Impact of Updated Properties on Seismicity (Section 2.5.2) [FPL]
- Impact of Updated Properties on Seismic Design (Ch. 3) [FPL]
- Opportunity for Public Comment
- Summary of discussions, path forward and wrap-up [FPL/NRC]
- Adjourn

FPL

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Supplemental Geotechnical Site Investigation - Subsurface

Investigation Scope (RAI 02.05.04-3)

- **Initial investigation was performed in 2008**
- **Supplemental investigation was conducted in 2013 to:**
  - Drill additional borings at the center of Turkey Point Units 6 & 7
  - Obtain additional undisturbed soil samples for laboratory testing
  - Drill two inclined borings under vegetated surface depressions to study potential fractures or potential karstic features
  - Perform pressuremeter tests in the power block areas
  - Perform P-S Suspension logging to supplement existing data
  - Perform high resolution televiewer imaging to study potential fractures
  - Perform two additional Cone Penetration tests (CPT) in the footprint of safety related structures
  - Collect surficial muck deposits to provide additional information related to the recent geologic history at the site

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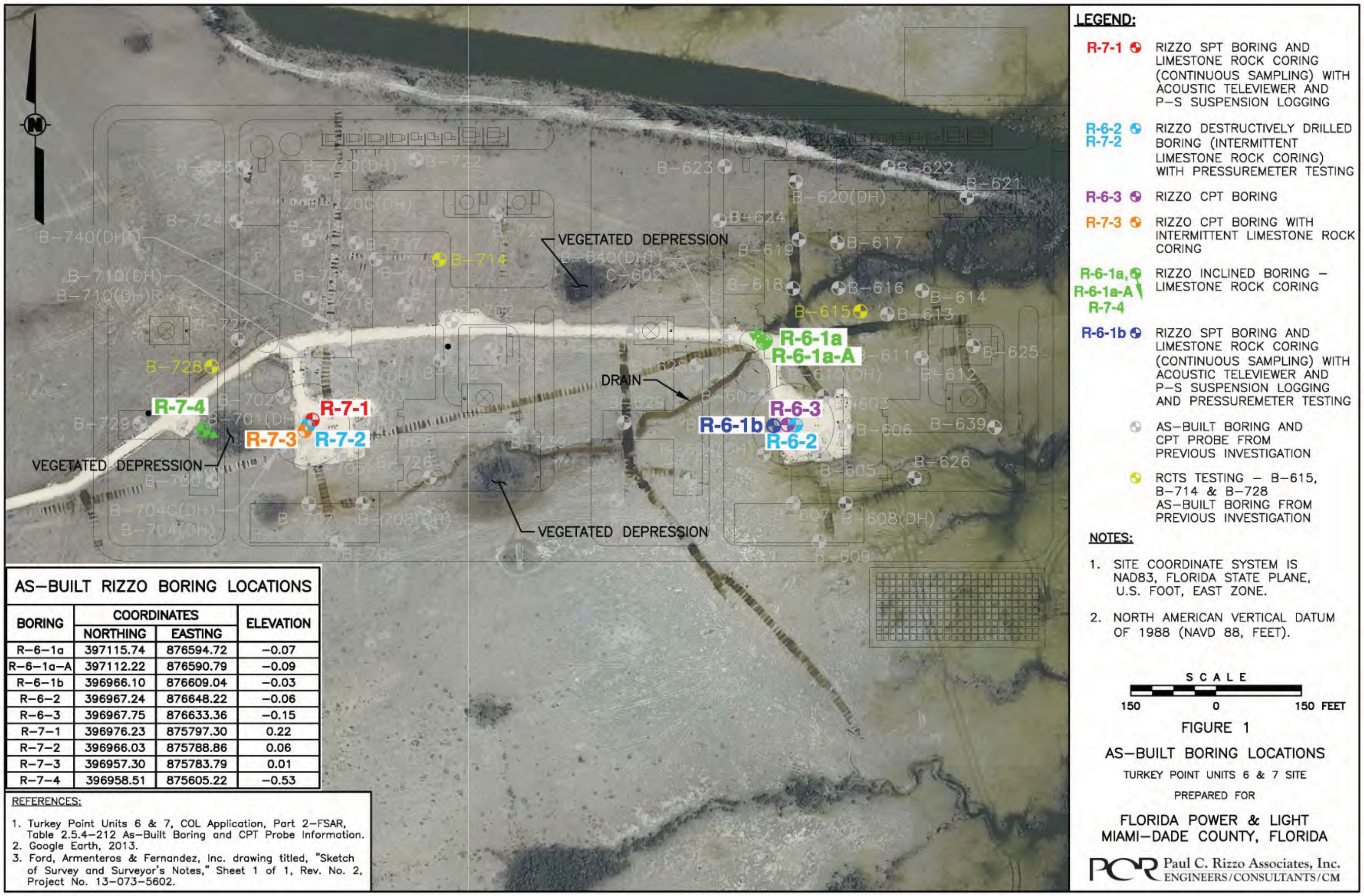
Supplemental Geotechnical Site Investigation - Subsurface



AS–BUILT RIZZO BORING LOCATIONS

BORING	COORDINATES		ELEVATION
	NORTHING	EASTING	
R–6–1a	397115.74	876594.72	–0.07
R–6–1a–A	397112.22	876590.79	–0.09
R–6–1b	396966.10	876609.04	–0.03
R–6–2	396967.24	876648.22	–0.06
R–6–3	396967.75	876633.36	–0.15
R–7–1	396976.23	875797.30	0.22
R–7–2	396966.03	875788.86	0.06
R–7–3	396957.30	875783.79	0.01
R–7–4	396958.51	875605.22	–0.53

REFERENCES:

1. Turkey Point Units 6 & 7, COL Application, Part 2–FSAR, Table 2.5.4–212 As–Built Boring and CPT Probe Information.
2. Google Earth, 2013.
3. Ford, Armenteros & Fernandez, Inc. drawing titled, "Sketch of Survey and Surveyor's Notes," Sheet 1 of 1, Rev. No. 2, Project No. 13–073–5602.

Surficial Muck Deposits Field Investigation

General Sampling Locations

- Late September 2013
- 5 different areas
- 9 Sampling locations
- McCauley Peat Sampler on floating platform

Surficial Muck Deposits Field Investigation

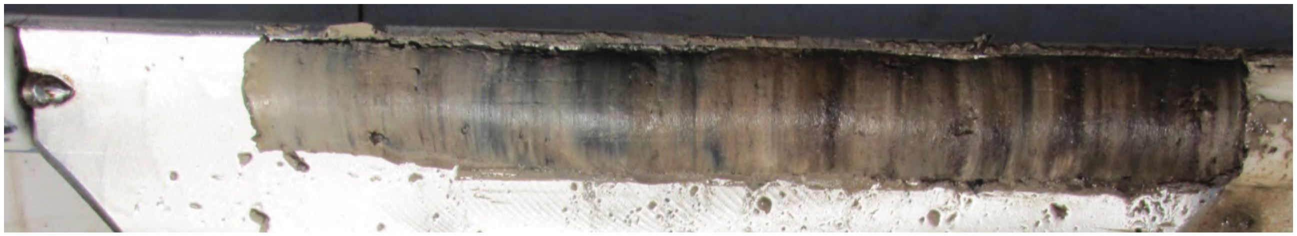
Elastic Silt

M-6-2a
Depth: 0.0 to 1.625 ft

Where present, the elastic silts represent the uppermost surficial sediments: soft; 95 % fines; low to medium plasticity; less than 5 % organic matter

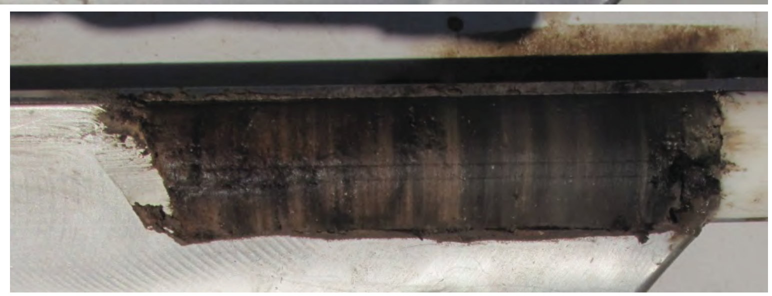
Surficial Muck Deposits Field Investigation

Organic-rich Elastic Silt



M-7-2c
Depth: 0.0 to 1.625 ft

Depth: 1.625 to 3.35 ft



Depth: 3.35 to 4.05 ft

Widespread, but not within vegetated depressions: soft; 90 to 95 % fines; low plasticity; isolated fragments of discoidal gastropods up 0.5 inches in diameter (*Planorbella* spp.); isolated root fragments up to 0.5 inches in diameter; between 5 and 30 % organic matter

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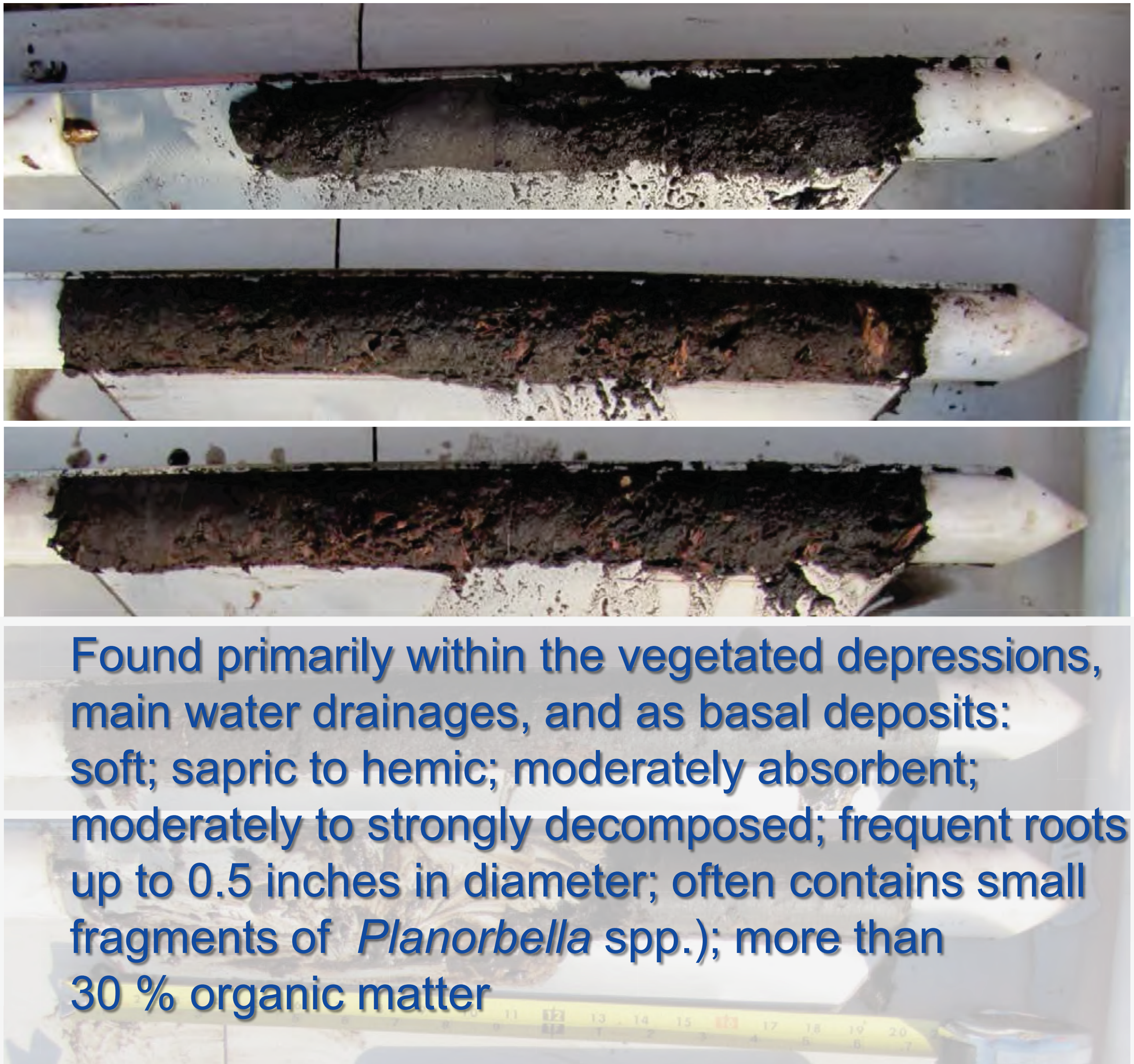
Surficial Muck Deposits Field Investigation

Peat



M-7-2a
Depth: 0.0 to 1.625 ft

Depth: 1.625 to 3.35 ft

Depth: 3.35 to 4.975 ft

Depth: 4.975 to 6.60 ft

Depth: 6.60 to 7.125 ft

Found primarily within the vegetated depressions, main water drainages, and as basal deposits: soft; sapric to hemic; moderately absorbent; moderately to strongly decomposed; frequent roots up to 0.5 inches in diameter; often contains small fragments of *Planorbella* spp.); more than 30 % organic matter

Surficial Muck Deposits Field Investigation

SUMMARY AND CONCLUSIONS

- Top of Miami Limestone, on average, at -5.32 ft NAVD 88. Top of Miami Limestone elevation in the sampled locations below -7.75 ft NAVD 88
- The sediment layers within the vegetated surface depressions should be characterized as peat
- Surficial deposits generally correspond to the sediment sequences observed in other coastal Florida wetlands, and coastal wetlands in the wider circum-Caribbean region
- No storm bed, tsunamigenic deposits (upward fining clastic sequences), peaks in sand content (sand sheets), nor erosive surfaces, were identified in any borings at the site

The sediment record provided no direct evidence for material and sedimentary structures that could be interpreted as evidence for high-energy depositional events (e.g., hurricane or tsunami landfalls).

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FPL

Supplemental Laboratory Testing – Core Borings

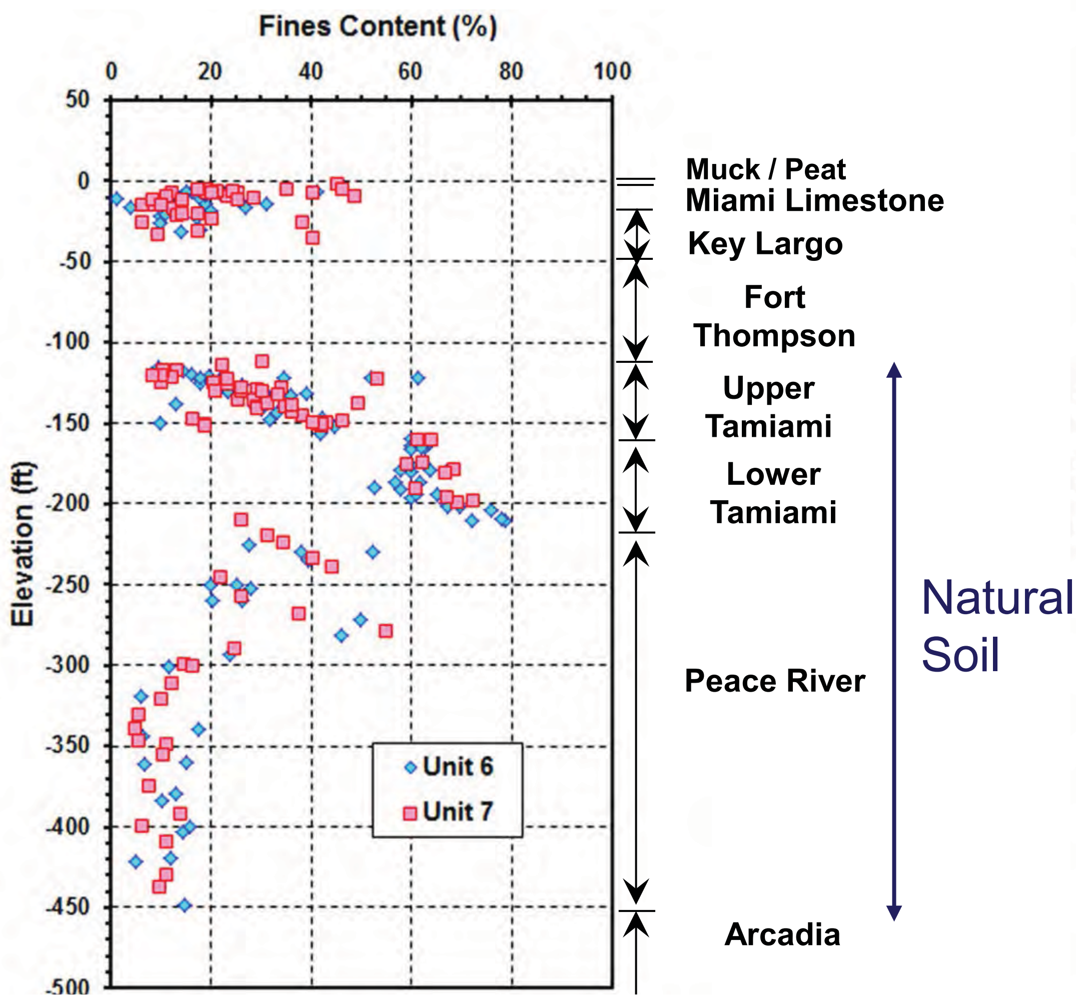
Summary of Supplemental Testing Program

TEST	TEST QUANTITY[1]
Unit Weight	43
Sieve Analysis	41
Hydrometer Analysis	41
Atterberg Limits	41
Moisture Content	43
Specific Gravity of Soil Solids	35
Consolidated Undrained (CU) Triaxial Test	20
One Dimensional Consolidation	16
Resonant Column Torsional Shear (RCTS) Test - Soil	3
RCTS Test - Rock	4
Chemical Tests	8
Unconfined Compressive Strength (UCS)	4

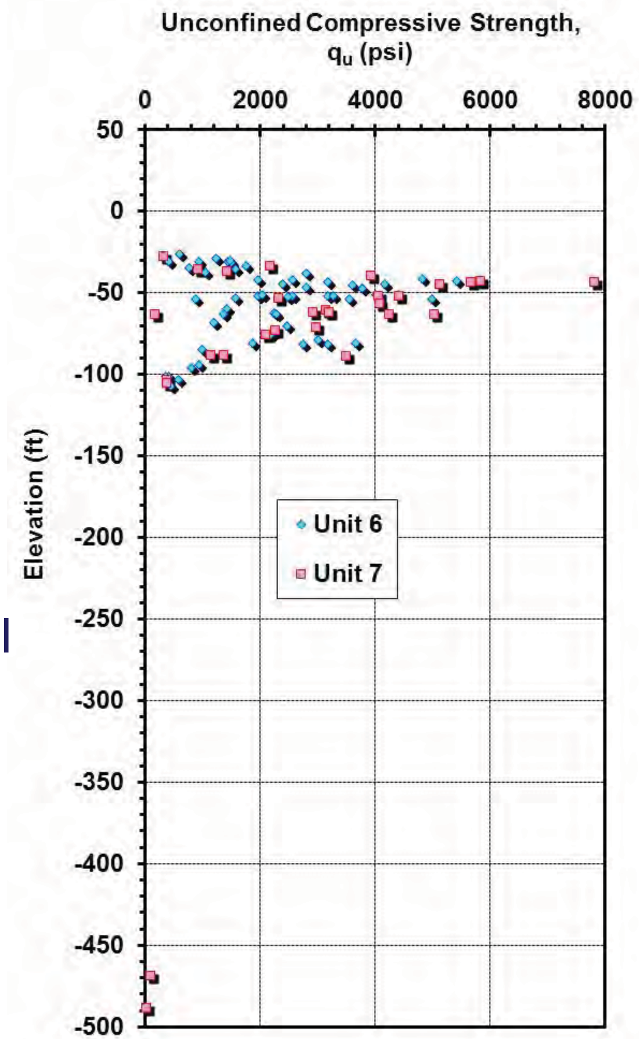
[1] Quantity of tests is based on number of samples, not number of sections tested. Quantity of unit weight and moisture content tests do not include unit weight and moisture content determined during RCTS testing.

Supplemental Laboratory Testing – Core Borings

Gradation Results
(RAI 02.05.04-3)



UCS Results
(RAI 02.05.04-4)



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Material Properties

Soil Formations

- **Index Properties**
  - Based on laboratory tests
- **Friction Angle and Cohesion**
  - Based on triaxial tests for Lower Tamiami and Peace River formations
  - Based on 1 triaxial test result and 3 correlations according to 3 SPT and 1 CPT correlations for Upper Tamiami Formation
- **Stiffness**
  - Based on compilation of in-situ and laboratory tests
  - Based on P-S Suspension logs, triaxial tests (E50), SPT (undrained stiffness)
  - Based on CPT tests (drained stiffness for Upper Tamiami and Peace River formations and undrained stiffness for Lower Tamiami Formation)
  - All results are compiled as drained stiffness

FPL

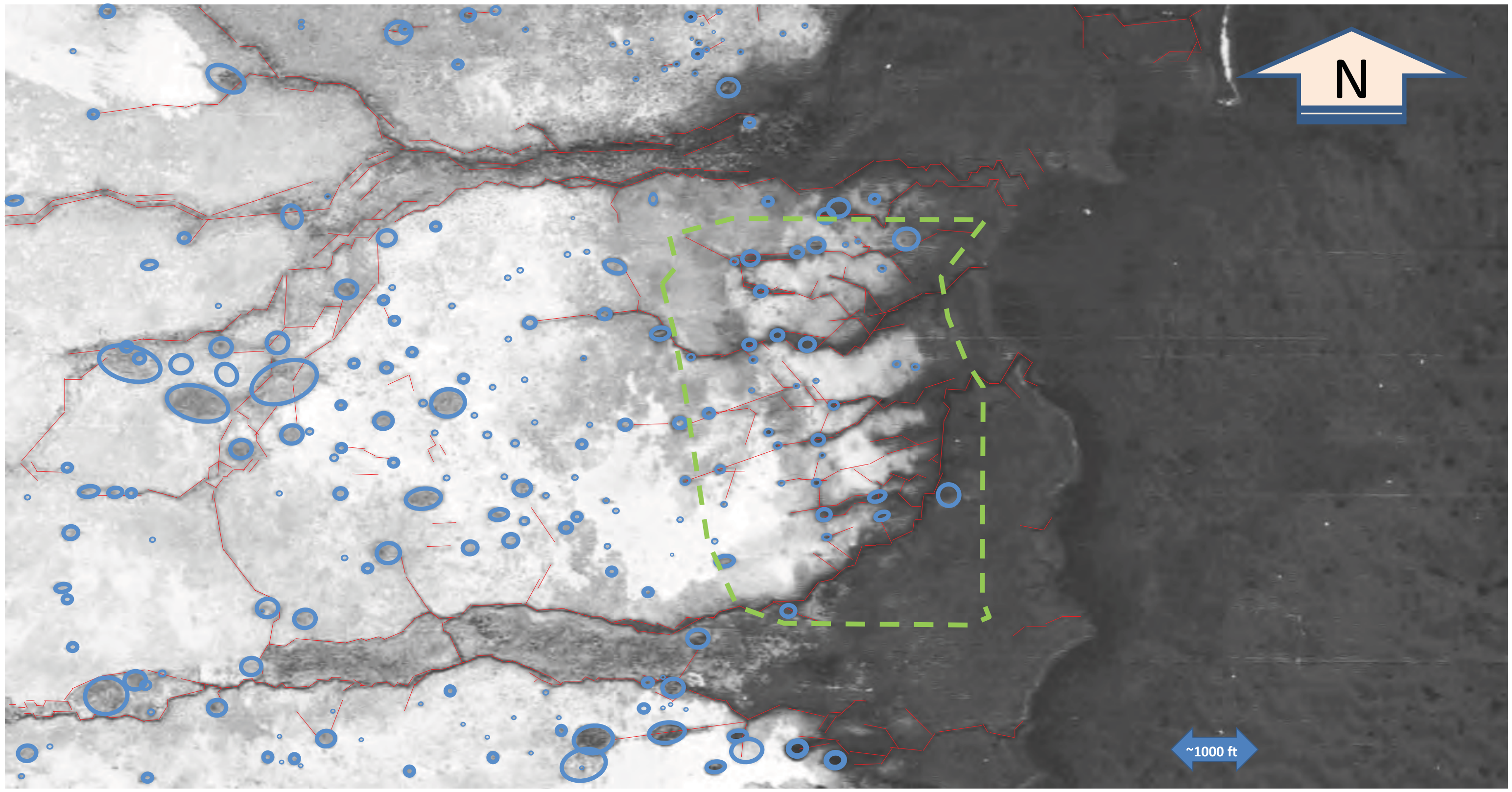
Material Properties

Rock Formations

- **Index Properties**
  - Based on laboratory tests
- **Friction Angle and Cohesion**
  - Based on Hoek-Brown criteria, utilizing unconfined compressive strength test results and GSI
- **Rock Mass Evaluation**
  - Rock Quality Designation (RQD)
  - Rock Mass Rating (RMR)
  - Geological Strength Index (GSI)
  - Fracture Density (FD)

Potential Subsurface Voids and Lineaments/ Fracture Patterns

1940s Aerial Photo of the Site Area with Interpreted Lineaments and Probable Vegetated Depressions (RAI 2.5.4-1)

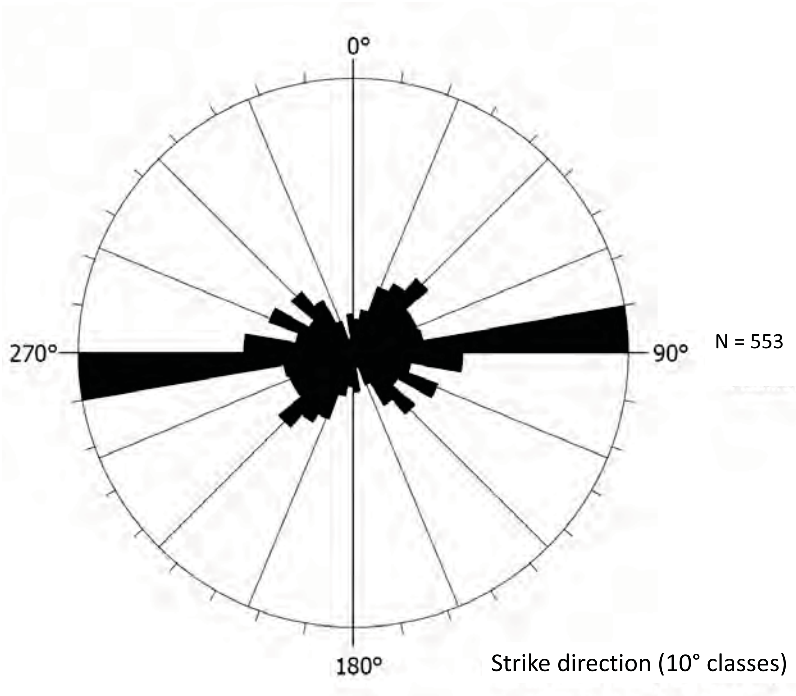


Approx site Location — Interpreted Lineaments — Probable Depressions

Potential Subsurface Voids and Lineaments/ Fracture Patterns

Lineaments and Fracture Patterns (RAI 2.5.4-1)

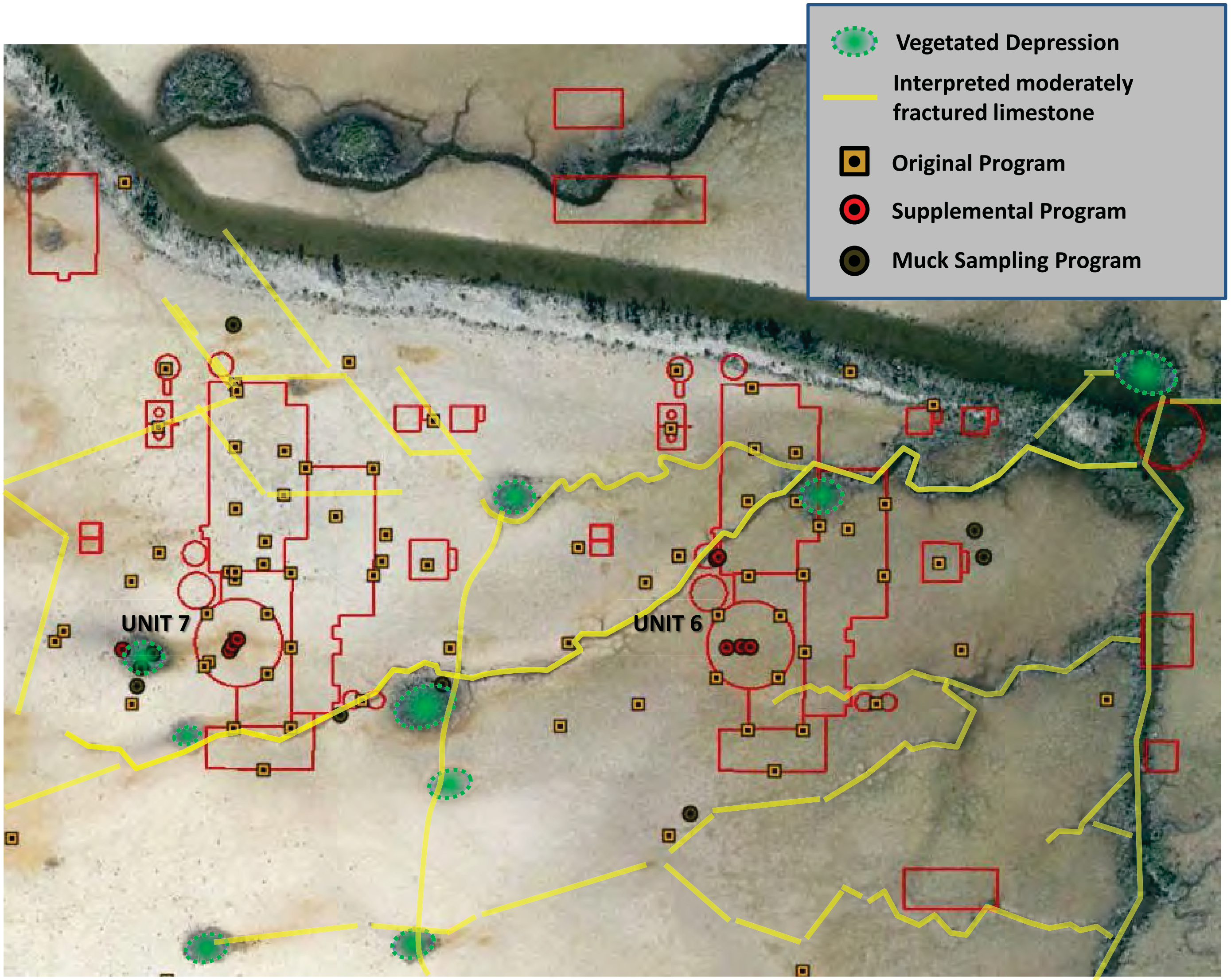
Orientations of all Lineaments



Orientations Omitting Lineaments Related to the East-West Drainages

– east-west
– northeast-southwest
– northwest-southeast
– east-northeast-west-southwest

Material Properties – Rock Formations



Google earth image 1/30/2005 U.S. Geological Survey

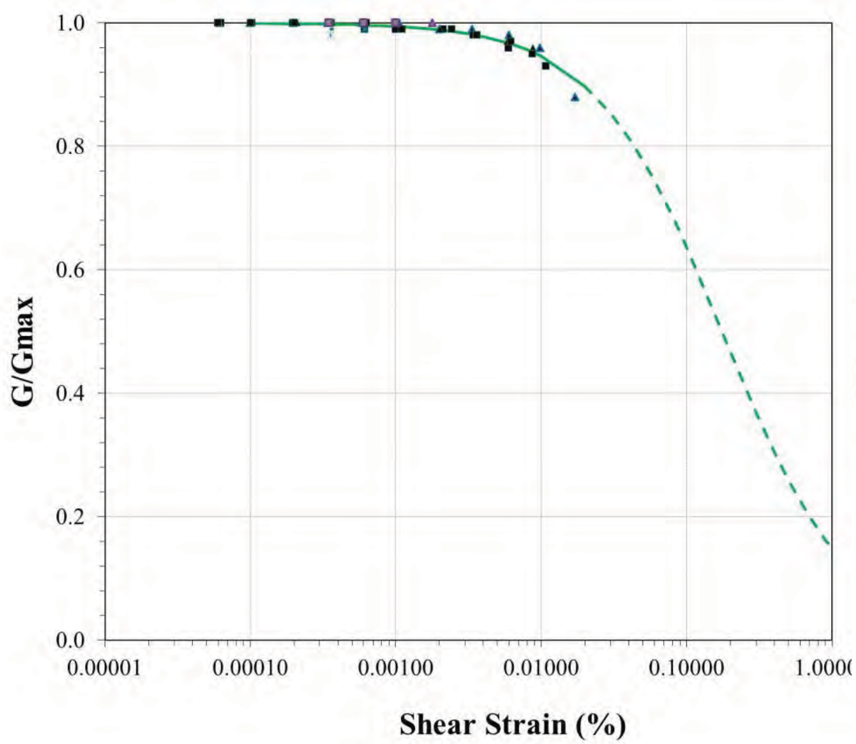
Interpreted FD4 zones are considered in the settlement and bearing capacity analyses

Material Properties – Rock Formations

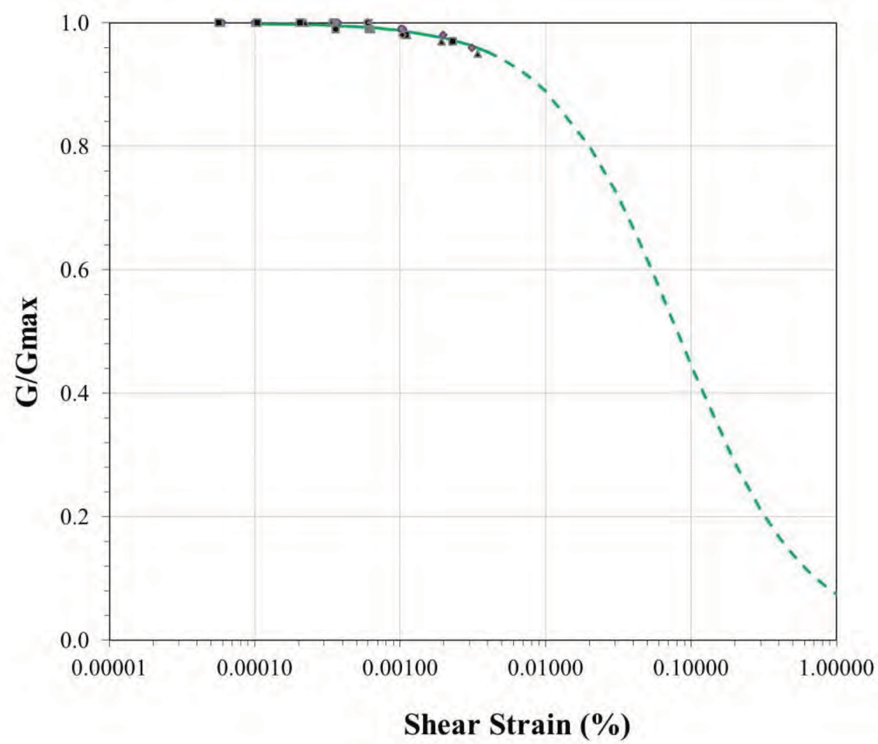
G/G_{max} curves and Damping

- 4 new RCTS tests (2 samples from Key Largo & 2 samples from Fort Thompson formations)
- Linear elastic behavior at low strains

Key Largo Formation



Fort Thompson Formation

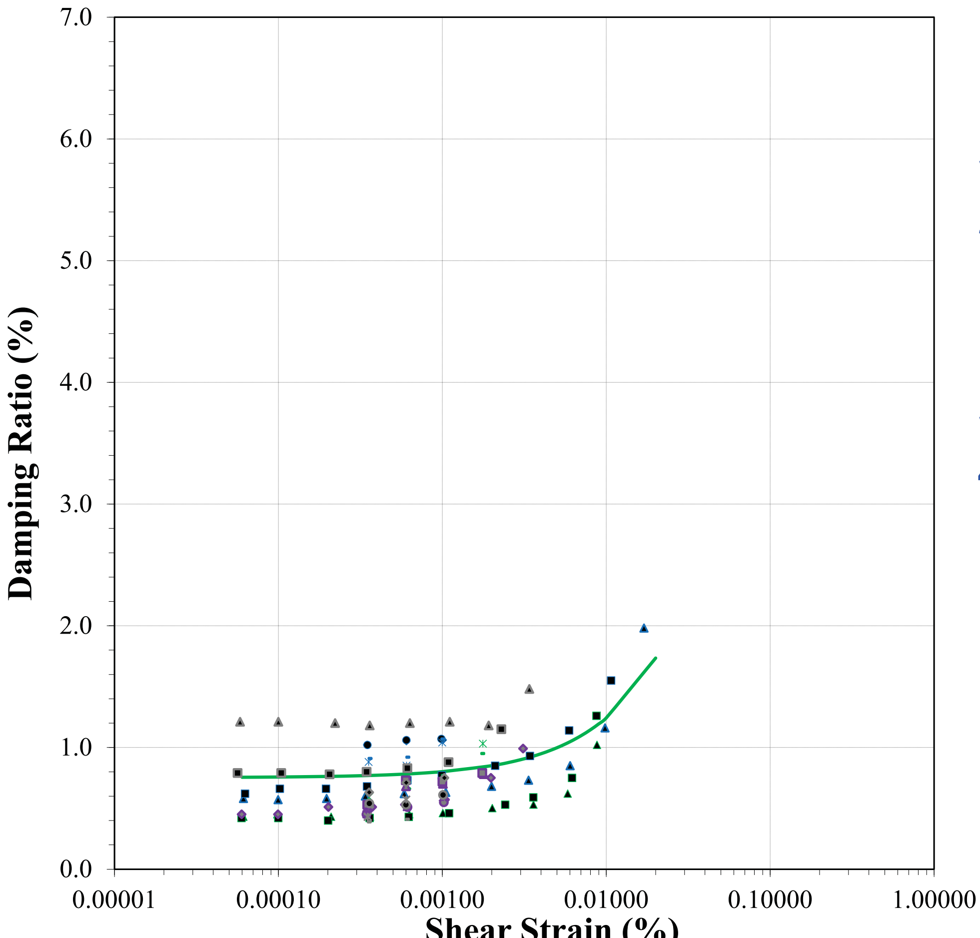


Maximum shear strain from the site response analysis is less than 0.005%

Material Properties – Rock Formations

G/G_{max} and Damping Curves

- **Roughly constant damping close to 1% at low strains**



Key Largo Formation samples are from depths of 29.4 ft and 32.6 ft

Fort Thompson Formation samples are from depths of 47.6 ft and 53.7 ft

Maximum shear strain from the site response analysis is less than 0.005%

Material Properties

High Strain Stiffness – Rock Formations

- **Slightly Fractured Rock (FD1): Design stiffness based on RMR, P-S Suspension logs, unconfined compression test results, and pressuremeter test results**
- **Moderately Fractured Rock (FD4): Design stiffness based on RMR**
- **Recommended Geotechnical Properties**

Stratum	1	2	3	4	5	6	7	8	Fill
Description	Muck/ Peat	Miami	Key Largo	Ft. Thompson	Upper Tamiami	Lower Tamiami	Peace River	Arcadia	–
Elevation of top of layer (ft)	–1.1	–4.7	–26.9	–49.4	–115.4	–167.6	–217.8	–454.8	–
USCS symbol	SM, MH, PT, SP-SM	GM, GP, GP-GM, SP-SM, SM, GW, SC, SW-SM, Limestone	GM, SW-SM, SP-SM, SM, Limestone	SM, Limestone	SM, ML, SC-SM, SP-SM, GM, GW-GM	ML, CL-ML, SM, CL	SM, SP-SM, ML, SC-SM, SC, SW-SM, SP	Limestone	–
Effective cohesion, c' (ksf)	–	6.2 (FD1) 2.0 (FD4)	22.6 (FD1) 6.9 (FD4)	22.5 (FD1) 8.9 (FD4)	–	–	–	–	–
Effective friction angle, ϕ (deg)	–	56 (FD1) 55 (FD4)	55 (FD1) 56 (FD4)	52	–	–	–	–	33
Elastic modulus for soils (high strain), E_H (ksf)	–	–	–	–	1,150	1,950	2,700		1,100
Elastic modulus for rock (high strain), general (ksf)	–	34,500	83,900	46,600	–	–	–	145,200	–
Elastic modulus for rock (high strain), moderately fractured zones (ksf)	–	11,500	32,200	26,900	–	–	–	–	–
Shear wave velocity, V_s (ft/sec)	850	3,400	6,250	4,450	1,500	1,600	1,600	3,650	860
Compression wave velocity, $V_{c'}$ (ft/sec)	4,900	7,450	11,750	9,000	5,650	5,700	5,850	7,950	1,600

Material Properties

Lower Bound Parameters

- **Lower Bound material properties are determined for use in settlement, bearing capacity, and site uniformity analyses (RAI 2.5.4-9)**

Strata		Unit Weight (kcf)	Cohesion c' (ksf)	Friction Angle (degrees)	E (ksf)
Unfractured (FD1)	Key Largo	0.125	7.95	55	48,102
	Fort Thompson	0.125	2.59	48	20,483
Fractured (FD4)	Key Largo	0.125	2.38	55	18,100
	Fort Thompson	0.125	3.60	50	20,483
Upper Tamiami		0.116	0.00	34	704
Lower Tamiami		0.115	0.25	28	1,281
Peace River		0.117	0.00	33	1,685
Arcadia		0.125	0.00	33	108,442

DCD Site Uniformity Criteria

- **In Table 2-1 of the DCD, the "Lateral Variability" item reads:**
  - Soils supporting the nuclear island should not have extreme variations in subgrade stiffness. This may be demonstrated by one of the following:
    - -- Soils supporting the nuclear island are uniform in accordance with Regulatory Guide 1.132 if the geologic and stratigraphic features at depths less than 120 feet below grade can be correlated from one boring or sounding location to the next with relatively smooth variations in thicknesses or properties of the geologic units, or
    - -- Site-specific assessment of subsurface conditions demonstrates that the bearing pressures below the nuclear island do not exceed 120% of those from the generic analyses of the nuclear island at a uniform site, or
    - -- Site-specific analysis of the nuclear island basemat demonstrates that the site-specific demand is within the capacity of the basemat.

FPL

Dipping Angles at Formation Interfaces (RAI 2.5.4-9)

- The calculated dip is less than 5 degrees in 95 percent of layer interfaces between adjacent borings
- In four places, the interfaces dip is between 5 degrees and 10 degrees at the top and bottom of the upper Tamiami layer
- In one place, the dip is steeper than 20 degrees due to interpretation of the interface in adjacent borings

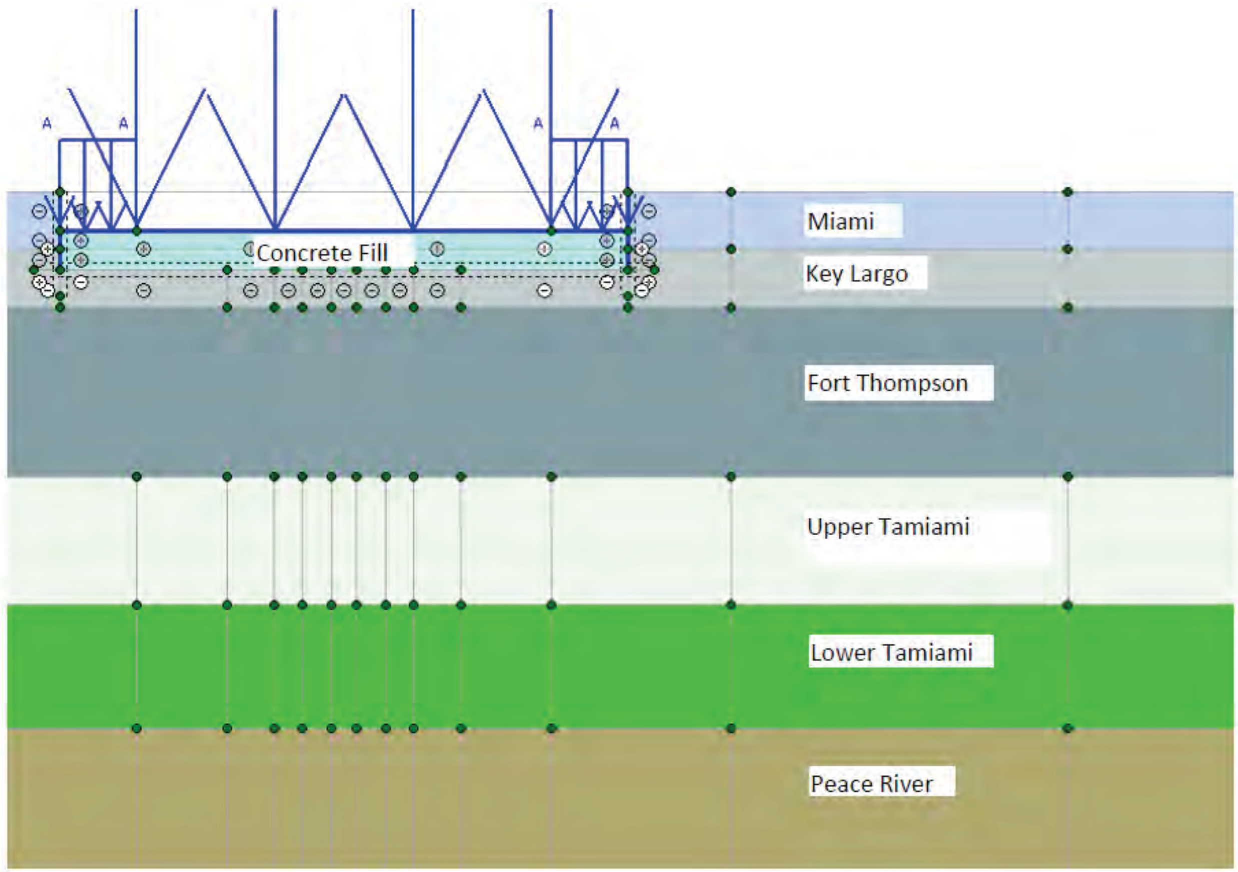
Geologic and stratigraphic features at depths less than 120 feet below grade can be correlated from one boring or sounding location to the next with relatively smooth variations in thicknesses.

Bearing Pressure Assessment (RAI 2.5.4-9)

- To evaluate the bearing pressures for site-specific conditions, a two dimensional plane-strain PLAXIS 2D model is developed
- Half of the foundation rests on the softer soil/rock column (lower bound properties) and half of the foundation rests on the stiffer soil/rock column (best estimate properties)
- To avoid numerical issues with this contrast of stiffness, a transition zone (TZ) is assigned between the soft and stiff zones. The width of the transition zone is taken as one-third, one-fifth, and one-sixteenth of B = 160 feet (Cases 2, 3 and 4)

Site Uniformity

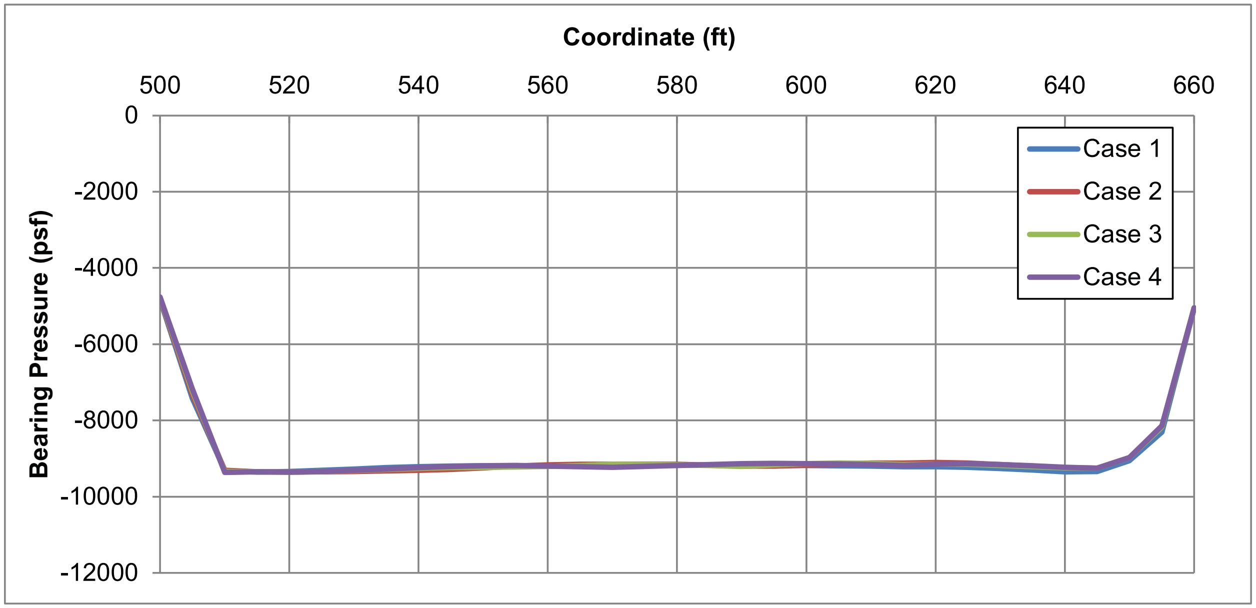
Bearing Pressure Assessment, PLAXIS 2D Model (RAI 2.5.4-9)



Site Uniformity

Bearing Pressure Assessment (RAI 2.5.4-9)

- **For all cases considered, the maximum bearing pressure difference is less than 5 percent**

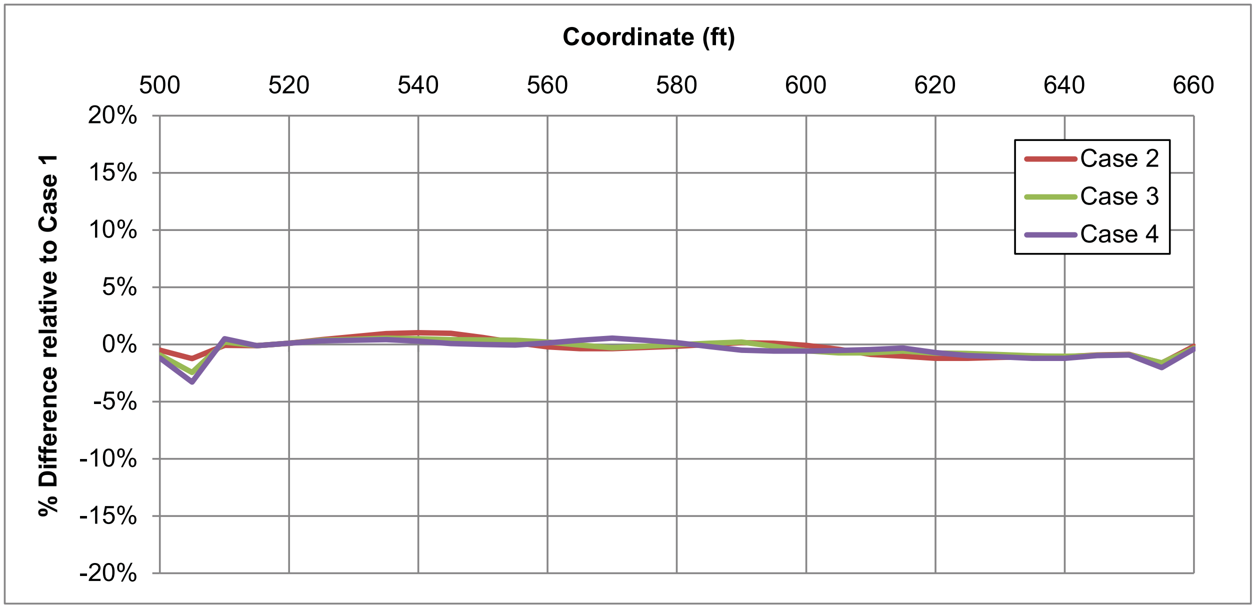


The DCD Criterion 2 for lateral uniformity in DCD as cited earlier is satisfied

Site Uniformity

Bearing Pressure Assessment (RAI 2.5.4-9)

- For all cases considered, the maximum bearing pressure difference is less than 5 percent



The DCD Criterion 2 for lateral uniformity in DCD as cited earlier is satisfied

Considered Failure Modes (RAI 2.5.4-18)

1. Bearing Capacity as if Founded on Soil

- General Shear Failure
- Local Shear Failure

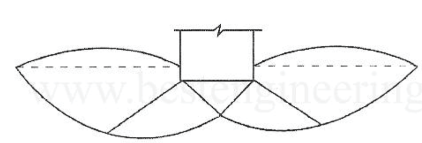


Fig 1 General shear failure

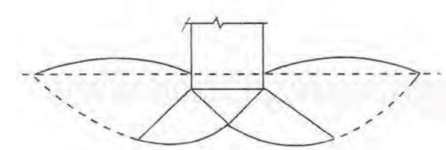
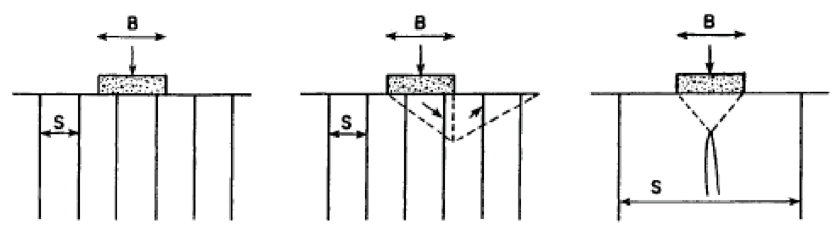


Fig 2 Local shear failure

Following Methodology of Vesic (1973) and Vesic (1975)

2. Bearing Capacity as if Founded on Rock

- Local Failure
- Wedge Failure



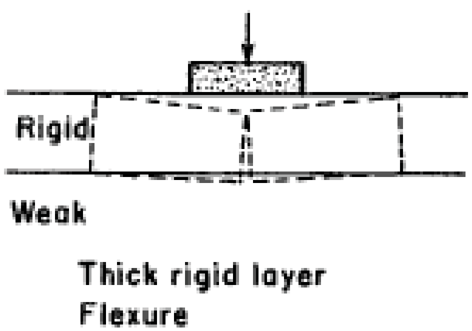
Following Methodology of USACE (1994) and Carter & Kulhawy (1988)

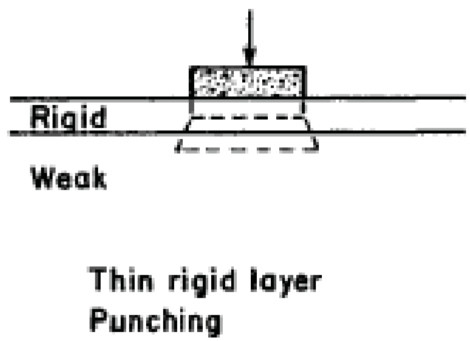
Reactor Building is founded on lean concrete overlying Key Largo Limestone

Bearing Capacity

Considered Failure Modes (RAI 2.5.4-18)

3. **Bearing Capacity for Foundation founded on Rock overlying softer Soil**
   - Beam Tension Failure
   - Punching Failure





Following Methodology of Wyllie (1999) and Numerical Models – SLOPE/W & PLAXIS 2D

Reactor Building is founded on lean concrete overlying Key Largo Limestone

Bearing Capacity

Cases Considered (RAI 2.5.4-18)

- **Rock**
  - Joints are not open, so FD1 rock used for Punching and Beam Tension failure analysis
  - Local Wedge failure uses weighted averages
    - -- Case 1: Best Estimate FD1, both rock layers
    - -- Case 2: Best Estimate FD4, both rock layers
    - -- Case 3: Lower Bound (LB) FD4, both rock layers
    - -- Case 4: FD4 rock & Best Estimate soil, to depth 2B
    - -- Case 5: FD4 rock (LB) & Best Estimate soil, to depth 2B
- **Soil**
  - Founded on upper Tamiami – weighted average to depth of 2B
    - -- Case 1: Best Estimate
    - -- Case 2: Lower Bound (upper Tamiami only)

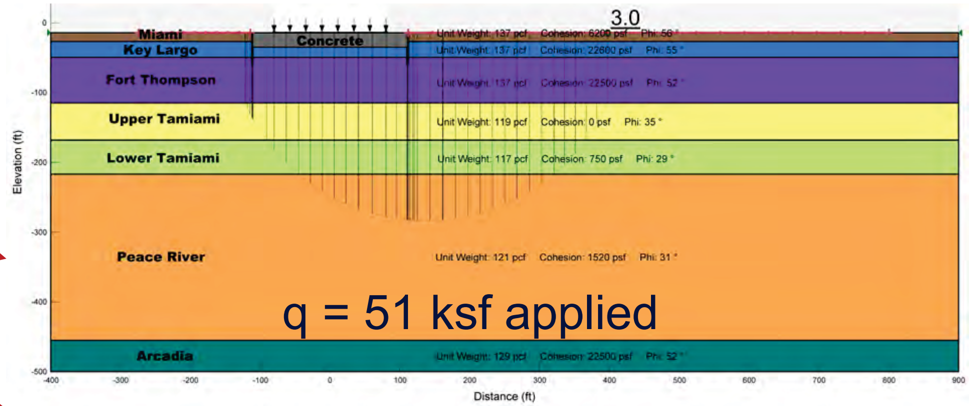
Need for Numerical Models (RAI 2.5.4-18)

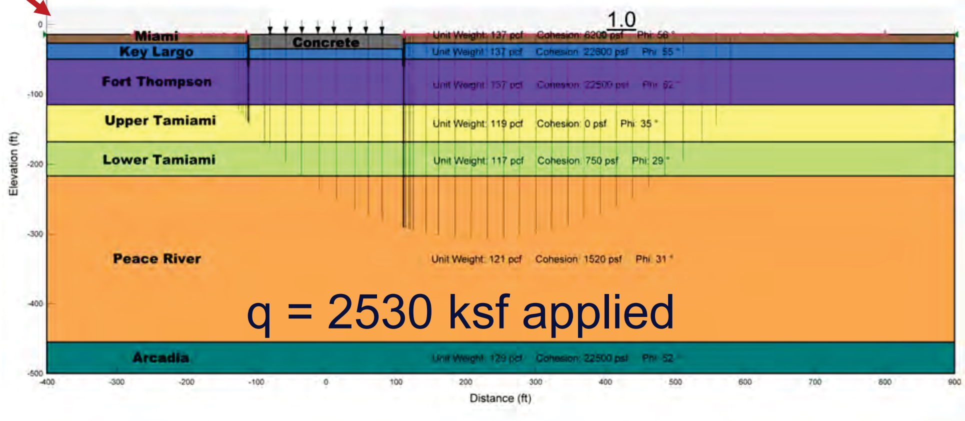
- **Limitations of Hand Calculations**
  - Homogenous substrata, rock and soil contrast not accounted for
  - Failure mode predetermined
- **Beam tension failure**
  - Model is more accurate than empirical equations
  - Tension properties of rock input into Plaxis 2D
  - Model checked for tension failure mode
- **Limit Equilibrium vs Finite Elements**
  - SLOPE/W gives factors of safety for prescribed failure surfaces
  - Plaxis 2D validates failure mode in hand calculations and SLOPE/W

Bearing Capacity

Numerical Model – SLOPE/W (RAI 2.5.4-18)

- **Two different approaches**
  - Find q at:
    - -- FOS=3 (required),
    - -- FOS=1 and divide by 3

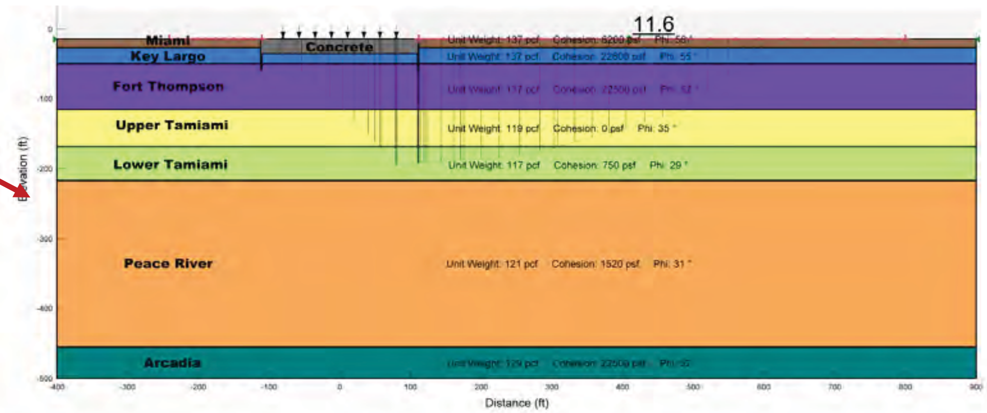


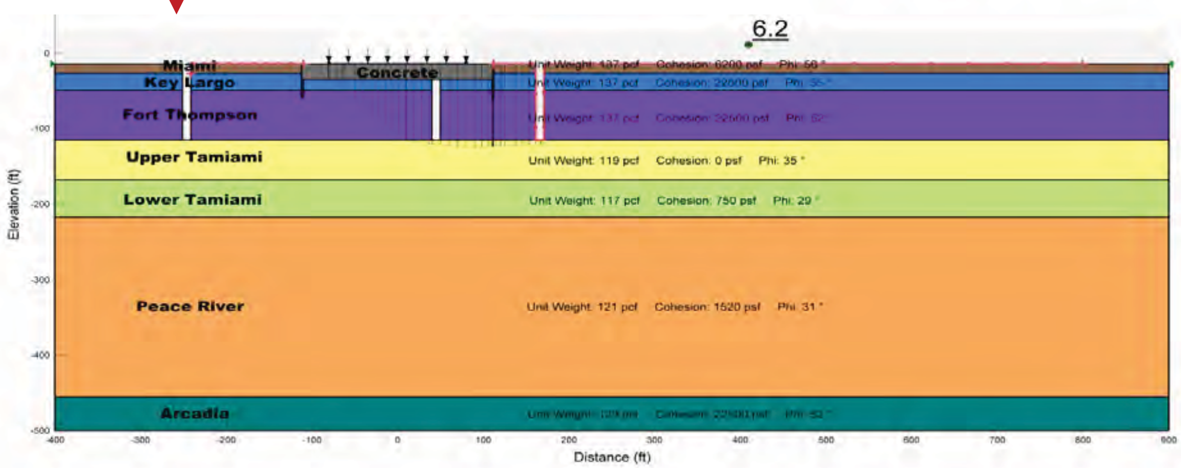


Bearing Capacity

Numerical Model – SLOPE/W (RAI 2.5.4-18)

- **Joint effects**
  - With and without open joints



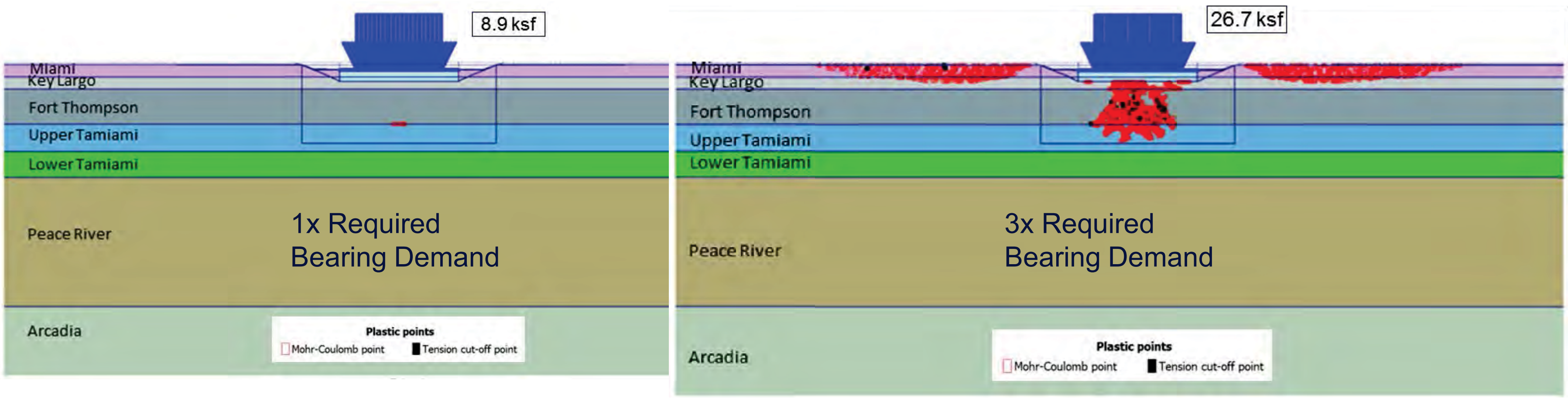


FPL

Bearing Capacity

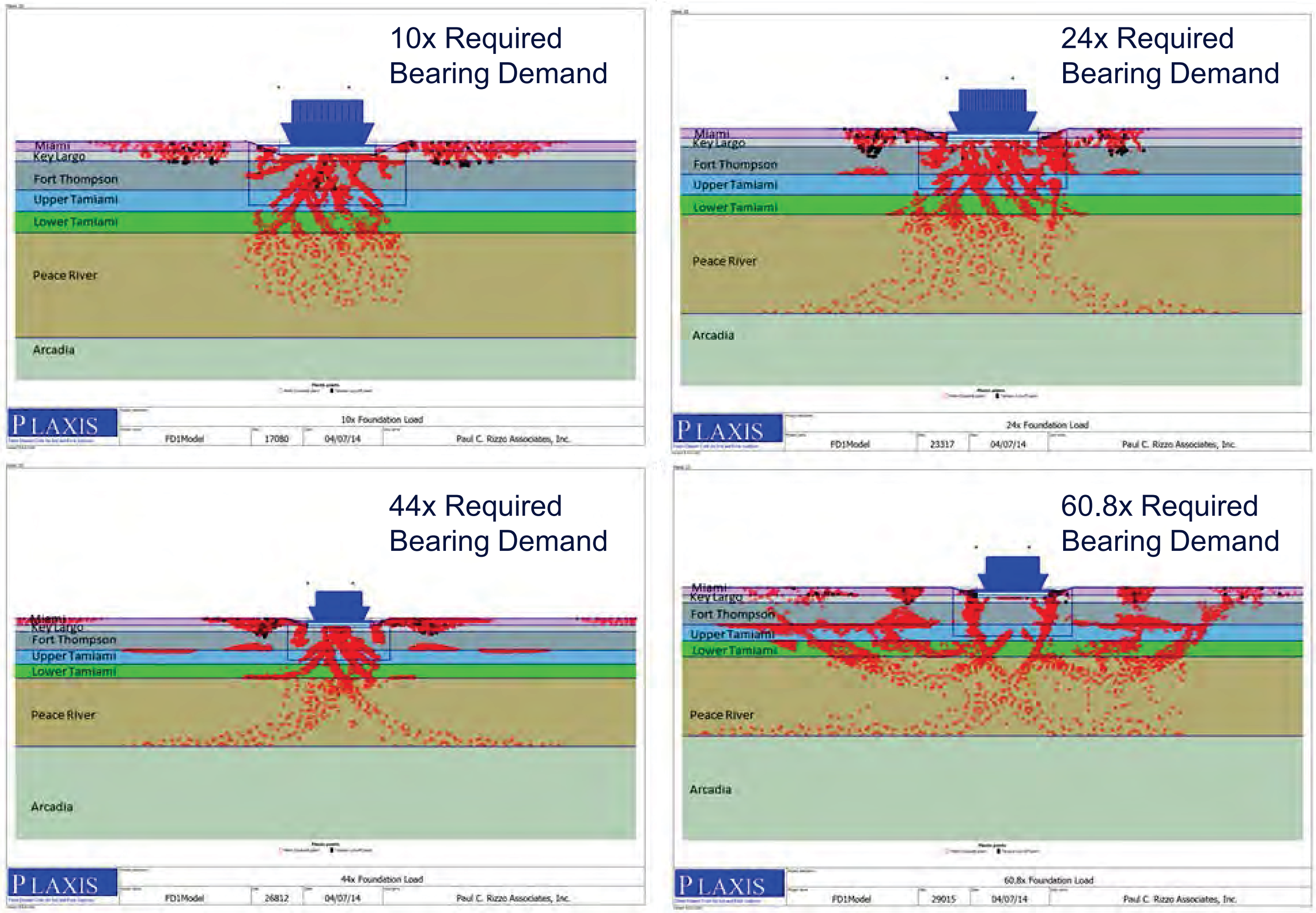
Numerical Model – PLAXIS 2D (RAI 2.5.4-18)

- **Used to predict failure mode**
  - check for Beam Tension Failure
  - show projected failure progression
  - validate SLOPE/W Failure mode



Bearing Capacity

Numerical Model – PLAXIS 2D (RAI 2.5.4-18)



FPL

Bearing Capacity

Conclusions from Hand Calculations and Numerical Models (RAI 2.5.4-18)

- **SLOPE/W**
  - The bearing capacities are different at failure with FOS=3 and at failure with FOS=1 where the resulting bearing capacity is divided by 3
  - Open joints do not have a significant effect
- **PLAXIS 2D validates SLOPE/W and hand calculation failures**
  - Beam tension failure mode is not an issue and there is no reported failure of this type in South Florida (Kaderabek & Reynolds, 1981)
- **Final Bearing Capacity recommendation is based on LB material properties and jointed rock mass (FD4) properties**
- **Dynamic results are conservative because DCD Bearing Demand is based on 0.3g and applies to the edge of foundation only**

Recommended allowable bearing capacity for Turkey Point Units 6 & 7 is 39 ksf static and 43 ksf dynamic, and exceed the DCD requirements

Bearing Capacity

Conclusions from Hand Calculations and Numerical Models (RAI 2.5.4-18)

Evaluation Method	Foundation Width, B (ft)	Properties	Local Shear Failure				Hoek-Brown[1]		Punching[2]	
			Static, q_{ULT}	Static, q_{ALL}	Dynamic, q_{ULT}	Dynamic, q_{ALL}	Static, q_{ULT}	Static, q_{ALL}	Static, q_{ULT}	Static, q_{ALL}
Rock-Only Hand Calculation	88	FD1 Rock	2,623	874	3,701	1,851	1629	543	408	136
Rock-Only Hand Calculation	160	FD1 Rock	3,603	1,201	4,640	2,320			273	91
Rock-Only Hand Calculation	88	FD4 Rock	1,790	597	2,104	1,052				
Rock-Only Hand Calculation	160	FD4 Rock	2,771	924	2,999	1,500				
Rock-Only Hand Calculation	88	LB FD4 Rock	1,063	354	1,411	706				
Rock-Only Hand Calculation	160	LB FD4 Rock	1,748	583	2,214	1,107				
Rock & Soil Hand Calculation	88	FD4 Rock & BE Soil	386	129	658	329				
Rock & Soil Hand Calculation	160	FD4 Rock & BE Soil	329	110	401	201				
Rock & Soil Hand Calculation	88	LB FD4 Rock & BE Soil	279	93	485	243				
Rock & Soil Hand Calculation	160	LB FD4 Rock & BE Soil	280	93	339	170				
Soil-Only Hand Calculation	88	BE Soil	165	55	87	44				
Soil-Only Hand Calculation	160	BE Soil	251	84	138	69				
Soil-Only Hand Calculation	88	LB Soil	157	52	87	43				
Soil-Only Hand Calculation	160	LB Soil	244	81	138	69				
SLOPE/W	88	FD1 Rock & BE Soil		81						
SLOPE/W	160	FD1 Rock & BE Soil		51						
SLOPE/W	160	LB FD4 Rock & LB Soil		39						
Minimum/Recommended (ksf)			157	**39**	87	**43**	1629	543	273	91

39 ksf static and 43 ksf dynamic bearing capacity are larger than DCD requirements (8.9 ksf static and 35 ksf dynamic)

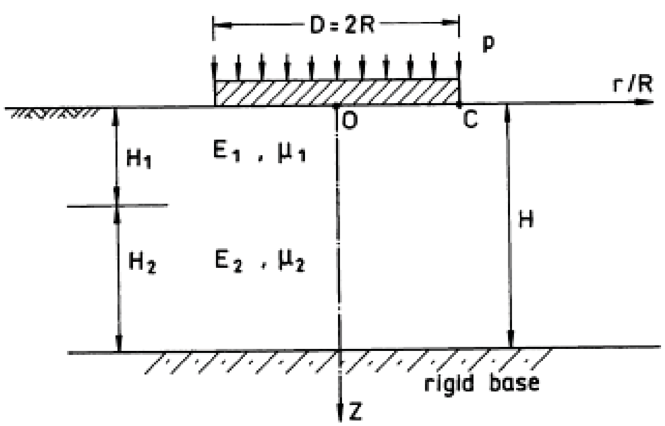
Settlement – Concepts to Address (RAIs 2.5.4-19 and 2.5.4-20)

- **Large stiffness contrast between the rock and soil layers**
- **Stiffness characterization of rock & soil layers is updated**
- **Boussinesq calculations may not sufficiently capture the 3-D or layering effects**
  - Settlement hand calculation is updated using stress distributions for layered systems
  - 3-D finite element method (FEM) model was created using PLAXIS 3D

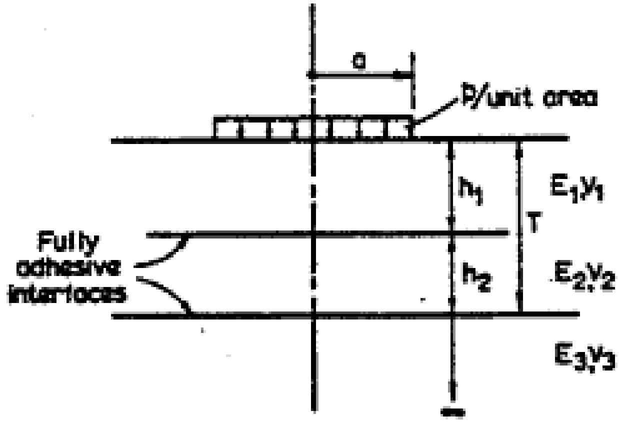
Hand Calculation

- **Revised to use stress distributions for layered systems, instead of the Boussinesq distribution (RAI 2.5.4-20)**
  - For the NI a stress distribution for a two-layered system is used (Milovic, 1992)
  - For the remaining buildings (Turbine, First Bay, Annex, and Radwaste) a stress distribution for a three-layered system is used (Poulos and Davis, 1974)

Geometry of the Two-Layered System



Geometry of the Three-Layered System



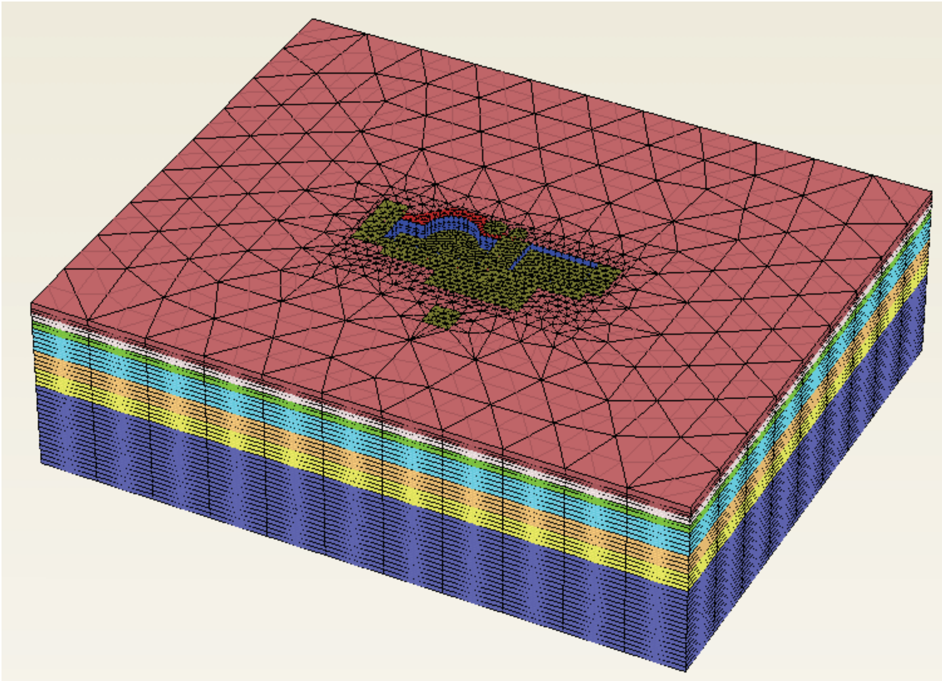
Hand Calculation

- **Two material cases are considered for the settlement hand calculation (RAI 2.5.4-19):**
  - Best estimate using the design stiffness for each layer
  - Lower bound, using lower bound stiffness for two layers (the Upper Tamiami and Peace River)
    - -- Lower bound is defined as the 16th percentile, indicating a 16 percent probability of that or a lower stiffness occurring
    - -- Probability of having two layers with lower bound stiffness is approximately 2.5 percent

Settlement

PLAXIS 3D Calculation – Modeled Sequence

- **The PLAXIS 3D model includes the following phases (RAI 2.5.4-19):**
  1. Initial Conditions
  2. Dewatering
  3. Excavation and Lean Concrete Placement
  4. Construction of Power Block Structures (Excluding the NI)
  5. Construction of the NI
  6. Rewatering



Settlement

PLAXIS 3D Calculation – Sensitivity Analyses (RAI 2.5.4-19)

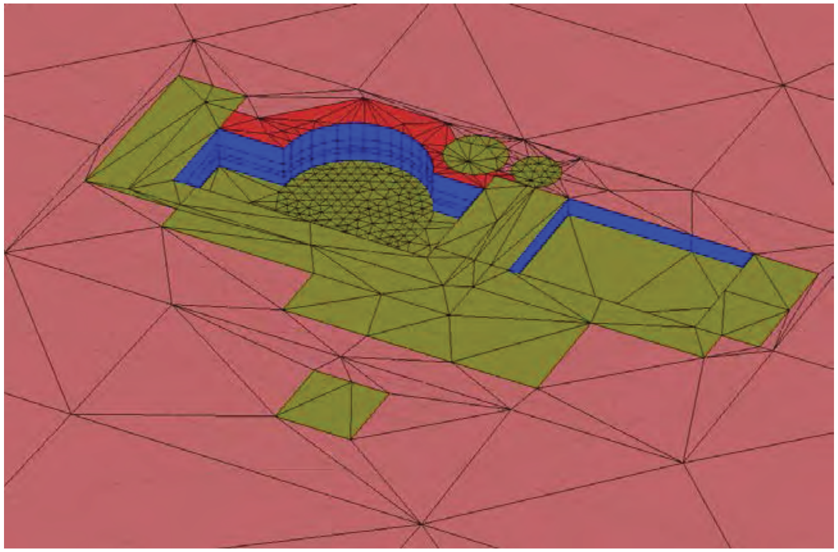
Design Model → 3

Model #	Sensitivity Analysis	Mesh	Stiffness Properties	Model Type
1	Mesh Size	Very Coarse - 11,514 elements	BE for soil, FD1 for rock	Mohr Coulomb
2		Moderately Coarse - 25,650 elements		
3		Design - 70,152 elements		
4		Finest - 115,810 elements		
5	Fracture Density	Design - 70,152 elements	BE for soil, FD1 with FD4 zones incorporated for rock	
6	Soil Constitutive Behavior		BE for soil, FD1 for rock	Hardening Soil
7	Lower Bound		LB for soil, FD1 for rock	Mohr Coulomb

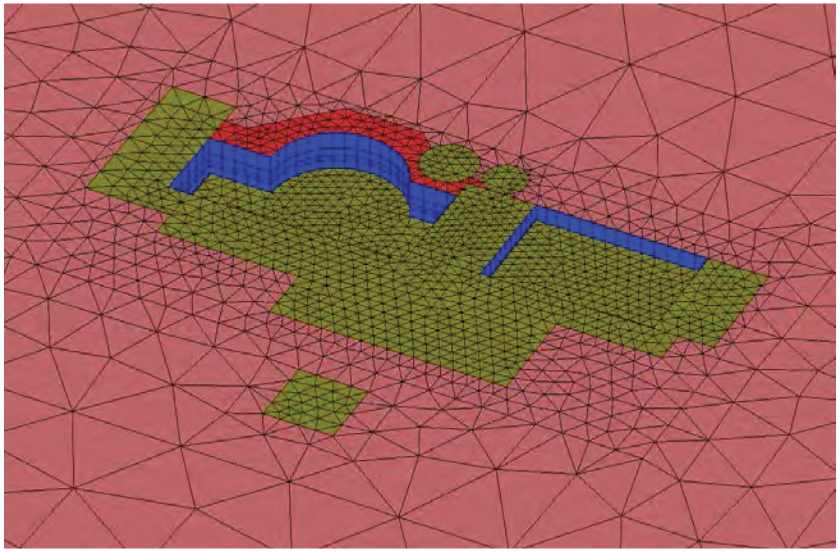
BE = Best Estimate Properties
FD1 = Slightly Fractured (Best Estimate) Properties
FD4 = Moderately Fractured (Best Estimate) Properties

Mesh Size Sensitivity Analysis (RAI 2.5.4-19)

Very Coarse Mesh

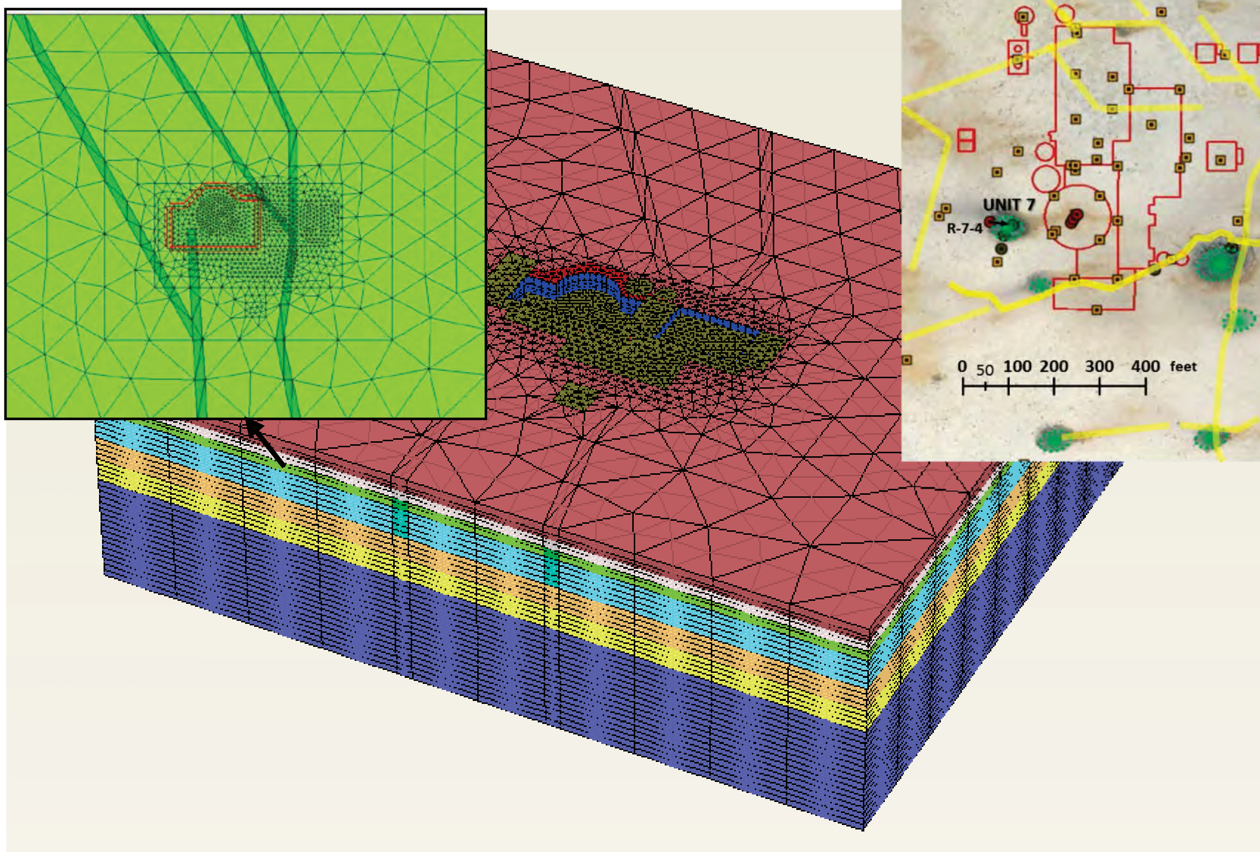


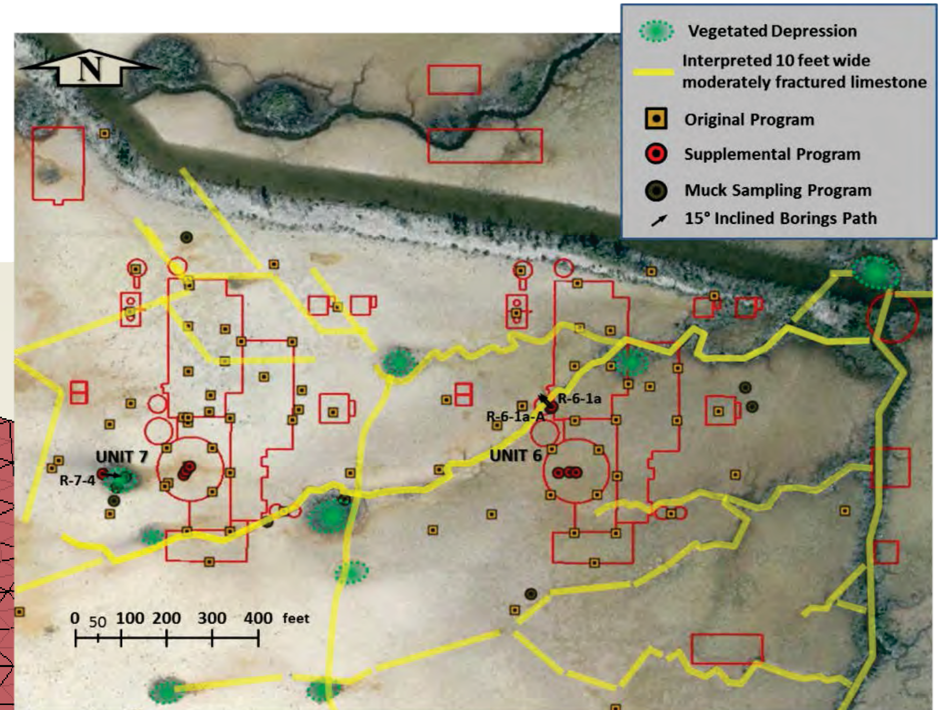
Finest Mesh



Settlement

Fracture Density Sensitivity Analysis (RAI 2.5.4-19)





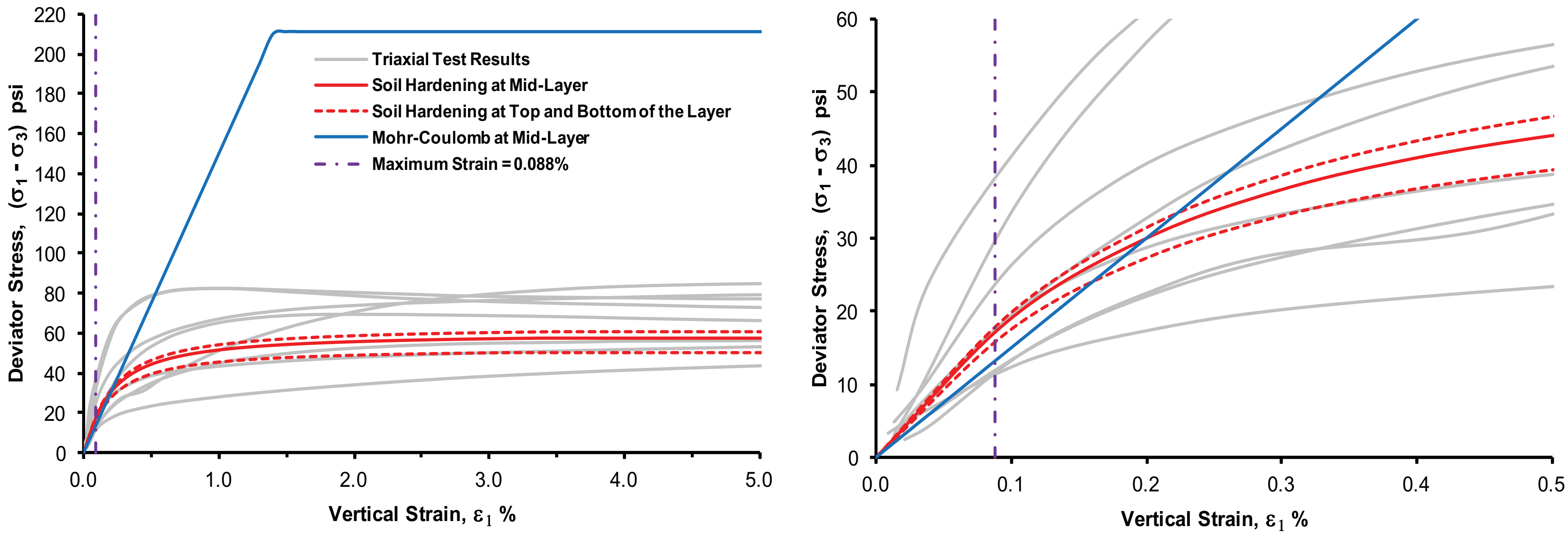
Google earth image 1/30/2005 U.S. Geological Survey

FPL

Settlement

Soil Constitutive Behavior Sensitivity Analysis (RAI 2.5.4-19)

Plot of Soil Hardening Calibration for the Lower Tamiami Formation



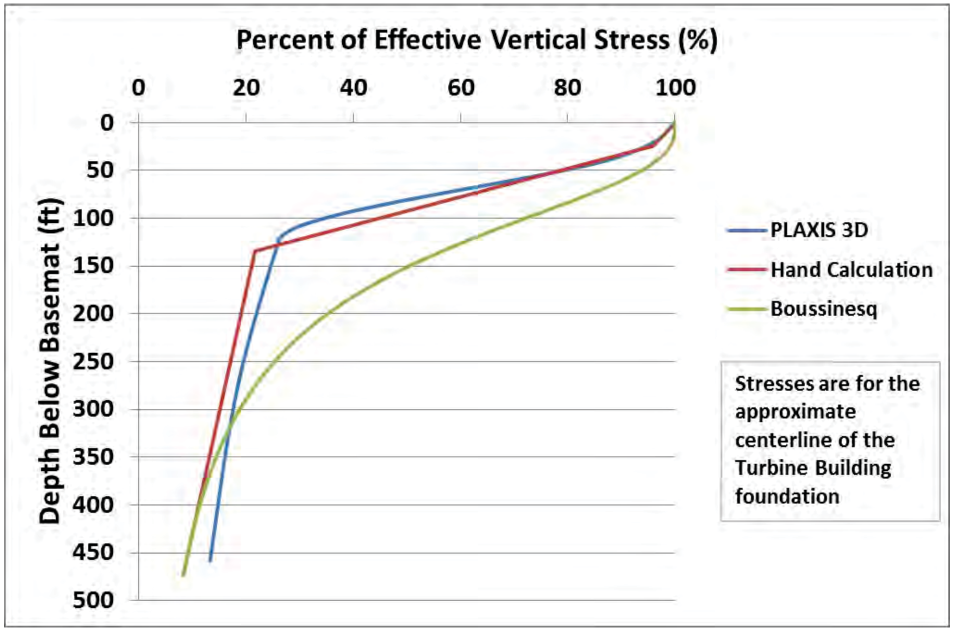
Results – PLAXIS 3D Sensitivity (RAI 2.5.4-19)

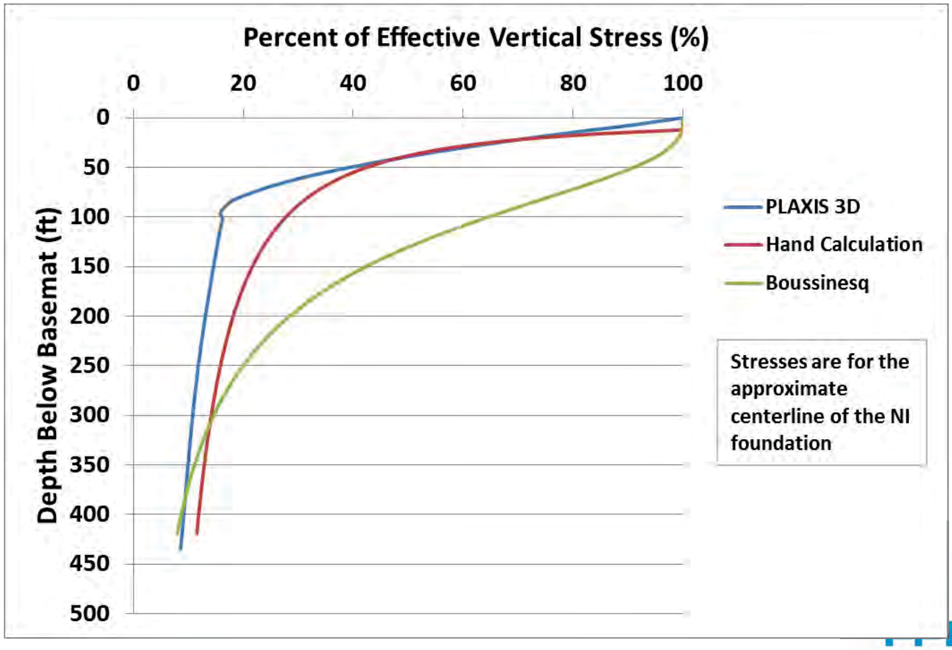
- **Maximum settlement predicted for the NI varies from the design model by (RAI 2.5.4-19):**

Model #	Sensitivity Analysis	Variation from the Design Model (%)
1	Very Coarse	0.1
2	Moderately Coarse	0.1
3	Design	n/a
4	Finest	0.1
5	Fracture Density	1
6	Soil Constitutive Behavior	2
7	Lower Bound	30

Results – Stress Distribution

- **Comparison of stress distributions demonstrate that (RAI 2.5.4-20):**
  - Stress distributions for layered systems (Milovic, Poulos and Davis) are similar to PLAXIS 3D stress distributions
  - Boussinesq is highly conservative

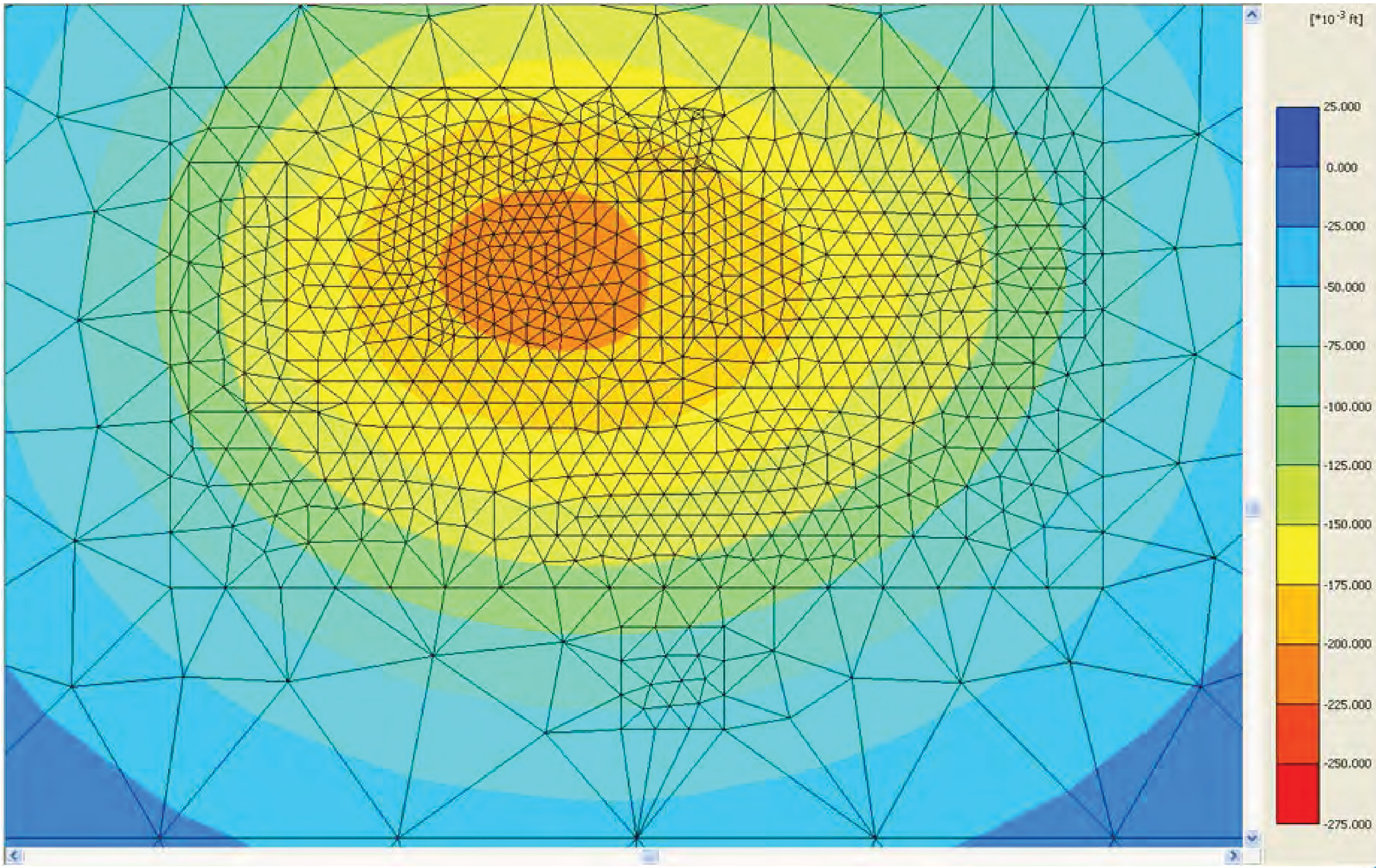




Settlement

Results – Total Settlement

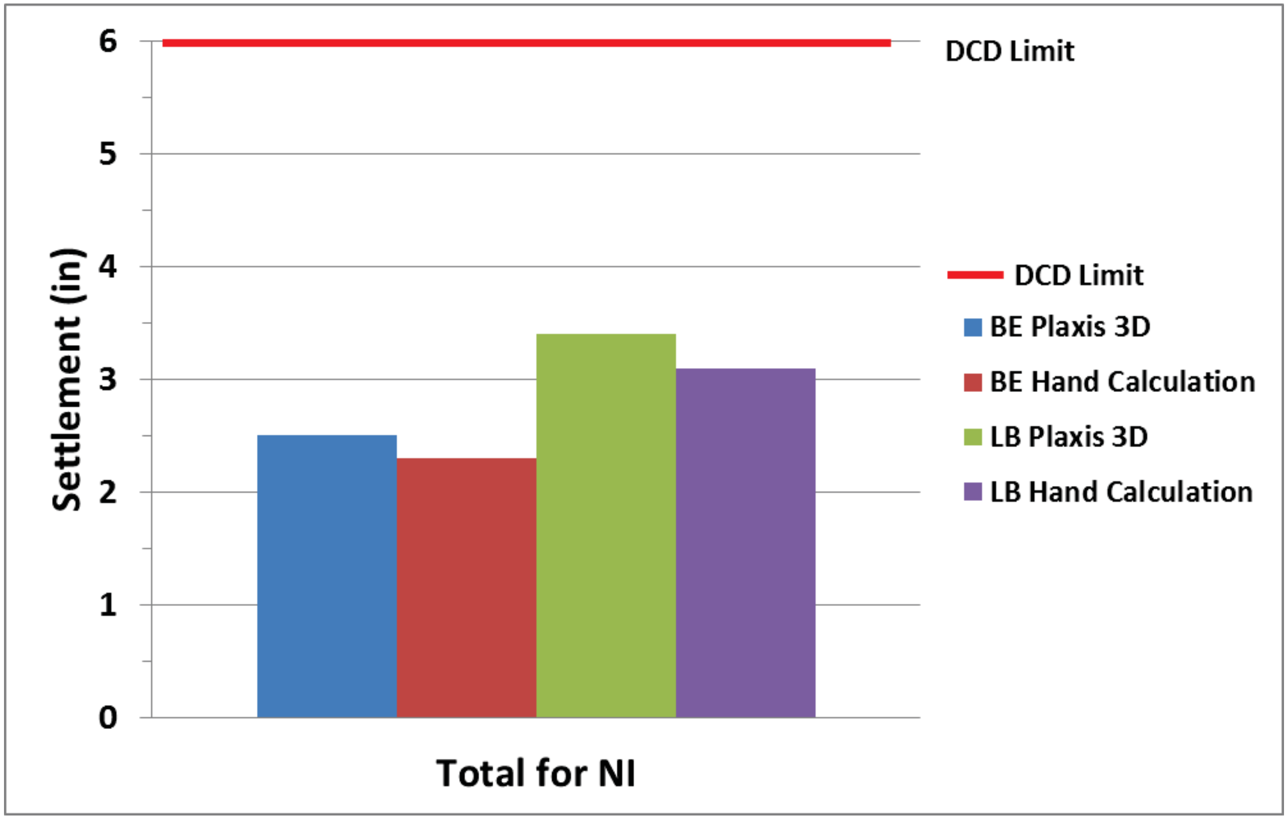
- **PLAXIS 3D Best Estimate Model Total Settlement After Loading (RAI 2.5.4-19)**



Maximum Settlement = 2.5 in

Settlement

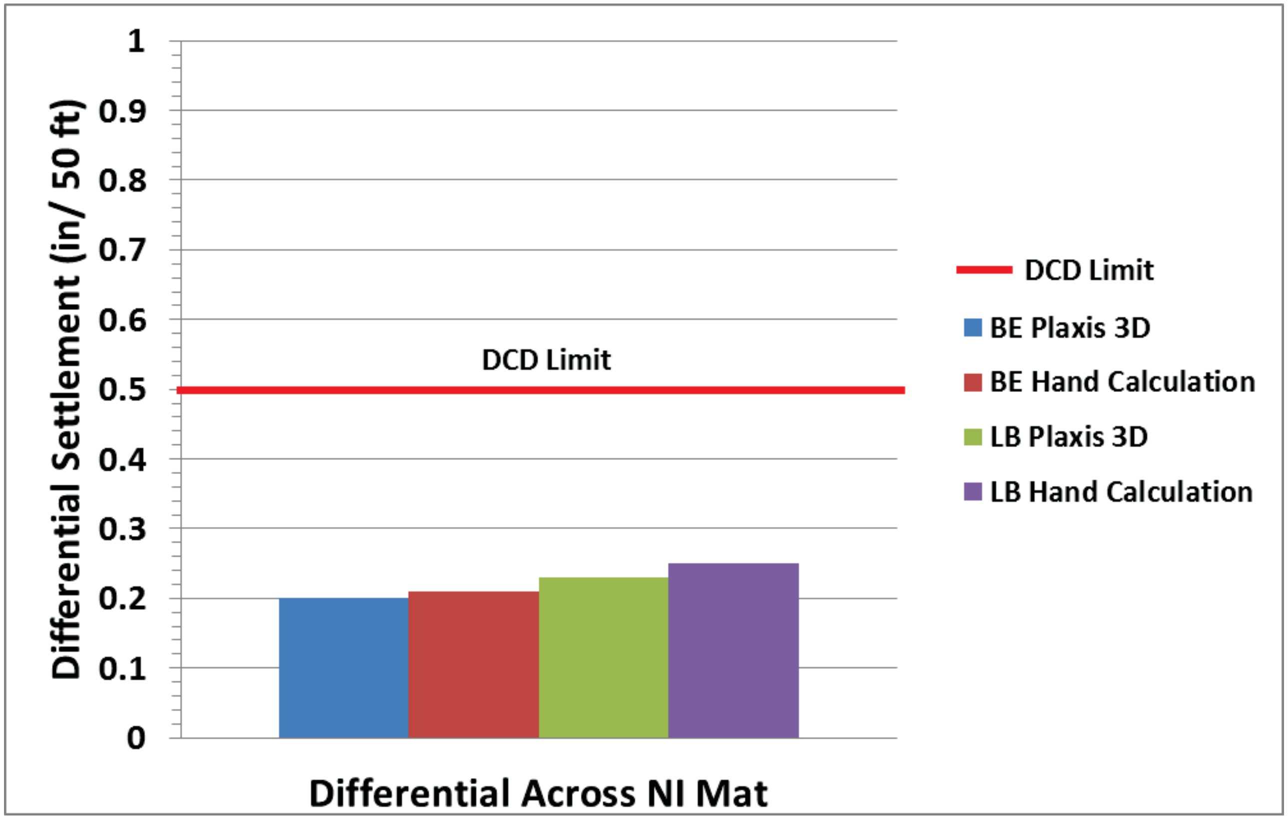
Results Versus DCD Criteria (RAI 2.5.4-19)



Settlements presented exclude the rewatering phase

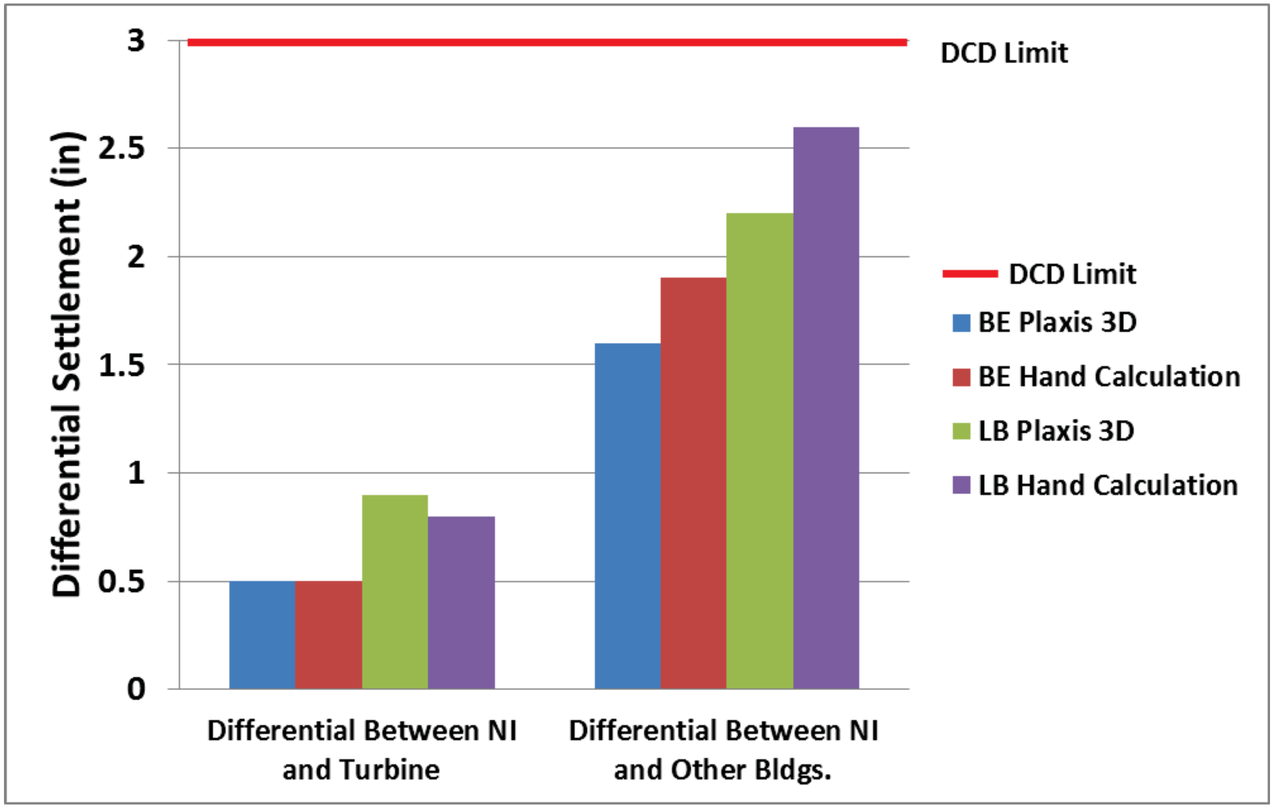
Settlement

Results Versus DCD Criteria (RAI 2.5.4-19)



Settlement

Results Versus DCD Criteria (RAI 2.5.4-19)



1) Differential settlement is measured at the center of the NI and the center of adjacent structures
2) Maximum differential settlement occurs between NI and Radwaste buildings

Results Versus DCD Criteria

- **Comparison of Limits of Acceptable Settlement without Additional Evaluation (RAI 2.5.4-19)**

		Differential Across Nuclear Island Foundation Mat (in per 50 ft)	Total for Nuclear Island Foundation Mat (in)	Differential Between Nuclear Island and Turbine Building[(1)] (in)	Differential Between Nuclear Island and Other Buildings[(1)(2)] (in)
DCD Requirement		**0.5**	**6**	**3**	**3**
Best Estimate	Plaxis 3D	0.20	2.5	0.5	1.6
	Hand Calculation	0.21	2.3	0.5	1.9
Lower Bound	Plaxis 3D	0.23	3.4	0.9	2.2
	Hand Calculation	0.25	3.1	0.8	2.6

1) **Differential settlement is measured at the center of the nuclear island and the center of adjacent structures**
2) **Maximum differential settlement occurs between NI and Radwaste buildings**
3) **Settlements presented exclude the rewatering phase**

Conclusions

- **Stress distributions for layered systems used for the settlement hand calculation from Milovic (1992) and Poulos and Davis (1974) are similar stress distributions found from the PLAXIS 3D model**
- **Boussinesq stress distributions are shown to be highly conservative for the site and are not used**
- **Sensitivity analyses demonstrate that:**
  - Design mesh is adequate
  - Fracture density variations in rock does not impact the resultant settlements
  - Mohr-Coulomb model type used in the Design Model is accurate

Predicted best estimate and lower bound settlement cases (from both the hand calculation and PLAXIS 3D model) are within the limits provided by the DCD

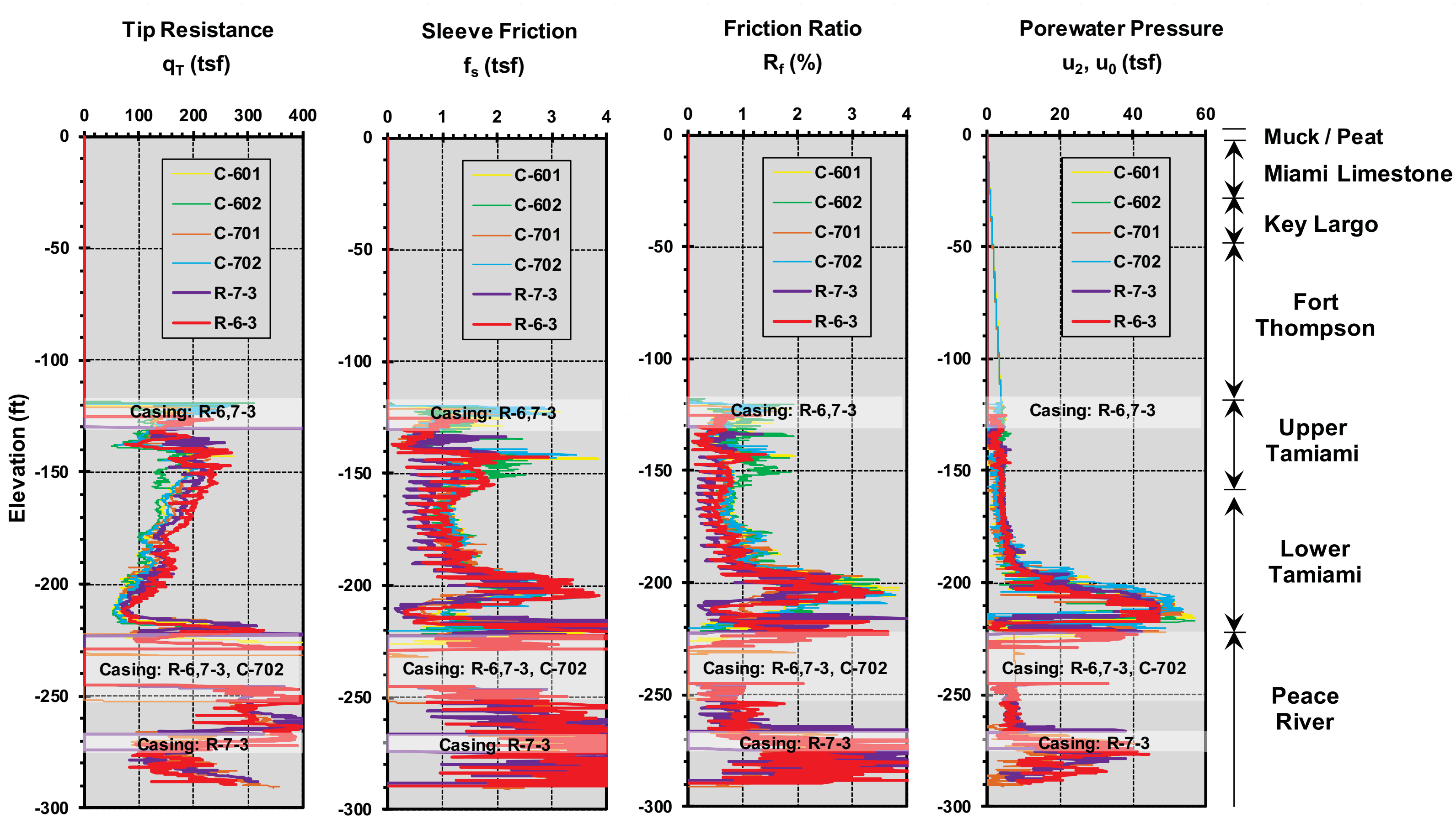
FPL

Methodology (RAI 2.5.4-17)

- Liquefaction analysis based on methodology outlined in Youd et al. (2001)
- CPT, SPT and V_s measurements used for liquefaction evaluation
- CSR calculated based on simplified formula provided in Youd et al. (2001) based on PGA and rd
- PGA and M_w assumed conservatively as 0.1g (scaled up GMRS PGA) and 7.3, respectively. PGA larger than the expected PGA. Mw corresponds to the highest value from the controlling magnitudes from deaggregation, FSAR Table 2.5.2-225
- A constant rd value of 0.5 assumed for depths larger than 98.4 ft (30m)

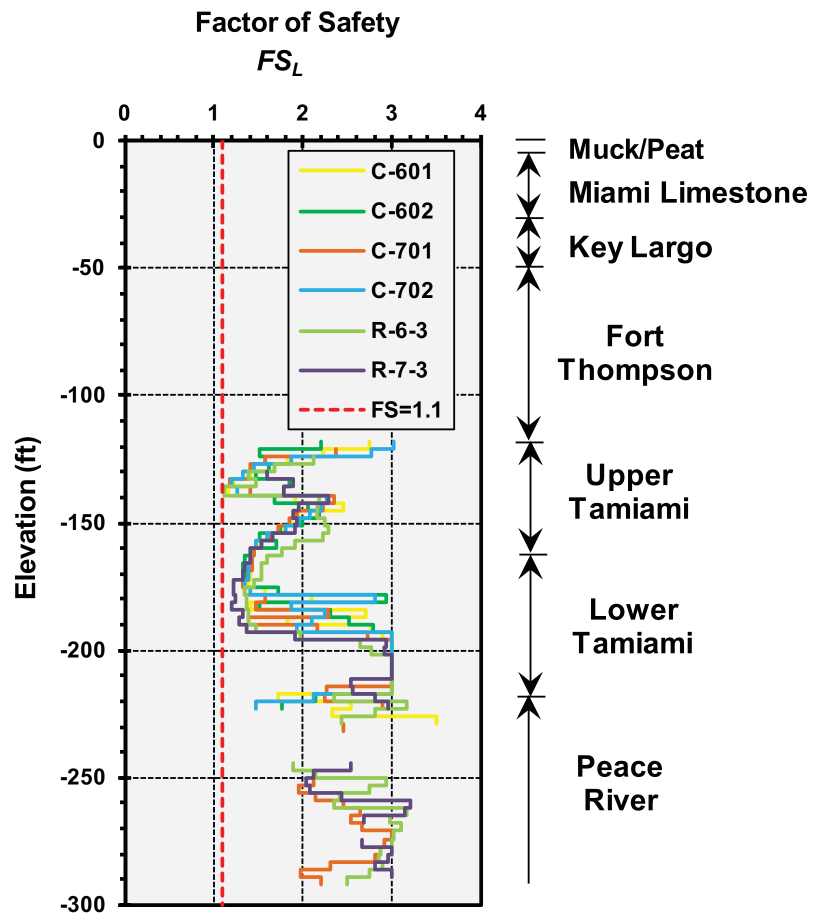
Liquefaction

Liquefaction Based on CPT Results (RAI 2.5.4-17)



Liquefaction

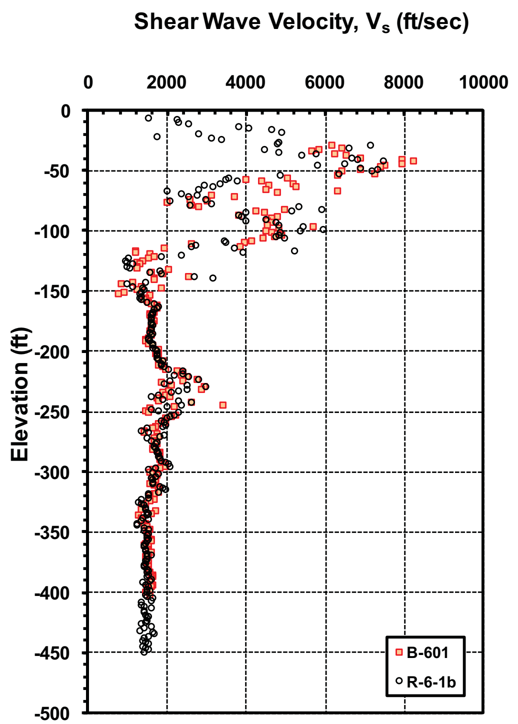
Liquefaction Based on CPT Results (RAI 2.5.4-17)

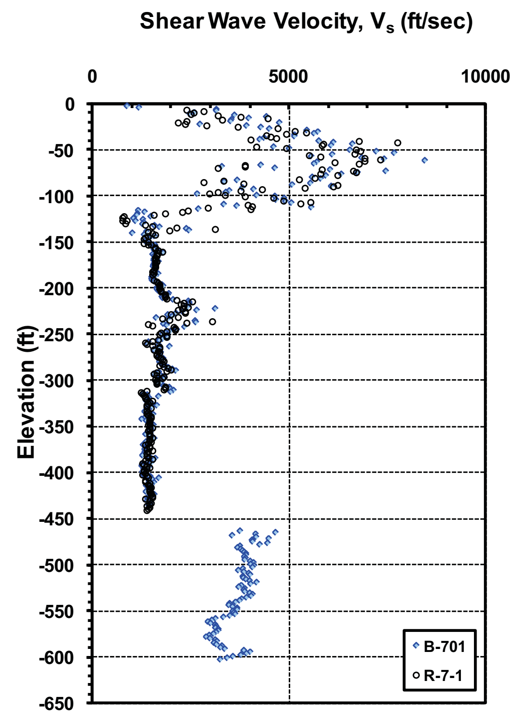


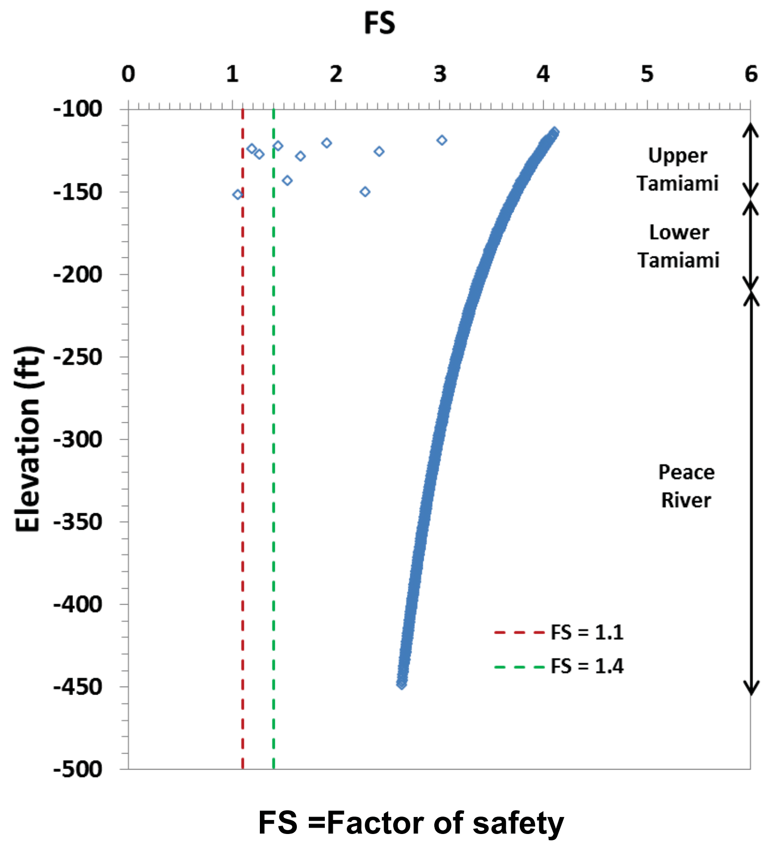
No liquefaction based on CPT results

Liquefaction

Liquefaction Based on Shear Wave Velocity, V_S (RAI 2.5.4-17)





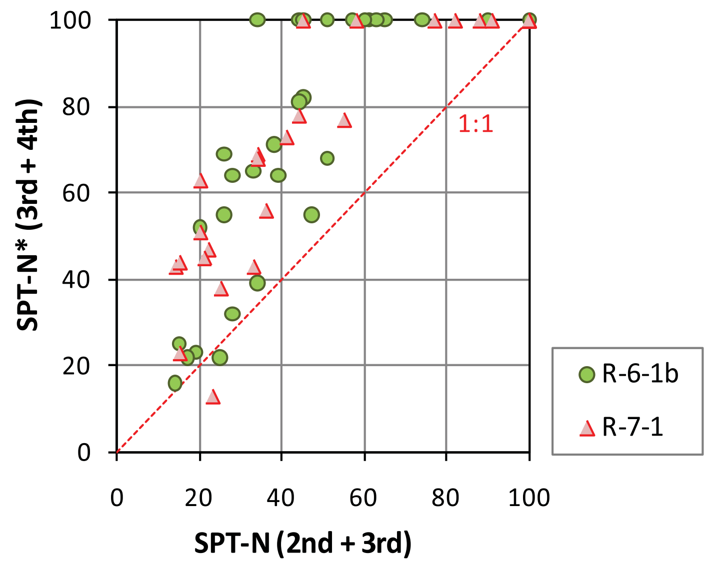


No liquefaction based on V_s results, Youd et al. (2001) recommend that small number of liquefiable points should not be considered as evidence of liquefaction

Liquefaction – Based on SPT Blow Counts

Lower Initial Investigation Blow Counts (RAI 2.5.4-2)

- **Blow counts from the initial investigation lower than expected**
- **24-inch sampler used to examine the reason**
- **Summations of the 3rd and 4th blow counts consistently higher than the summations of the 2nd and 3rd blow counts**
- **The soil zone penetrated by the 3rd and 4th blow counts considered to be less influenced by the washing and drilling conditions that affect the first two 6-inch increments**

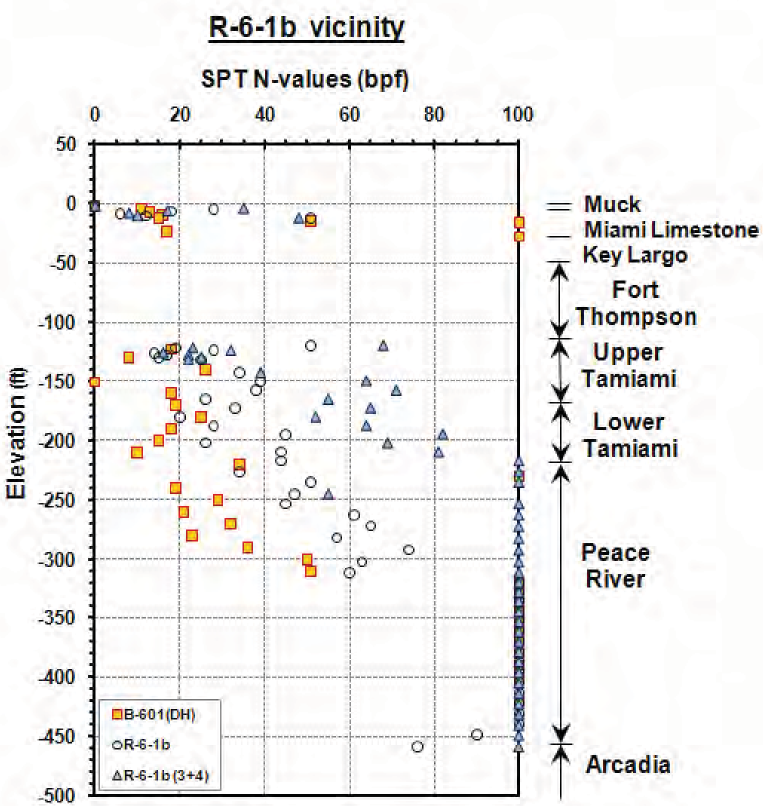


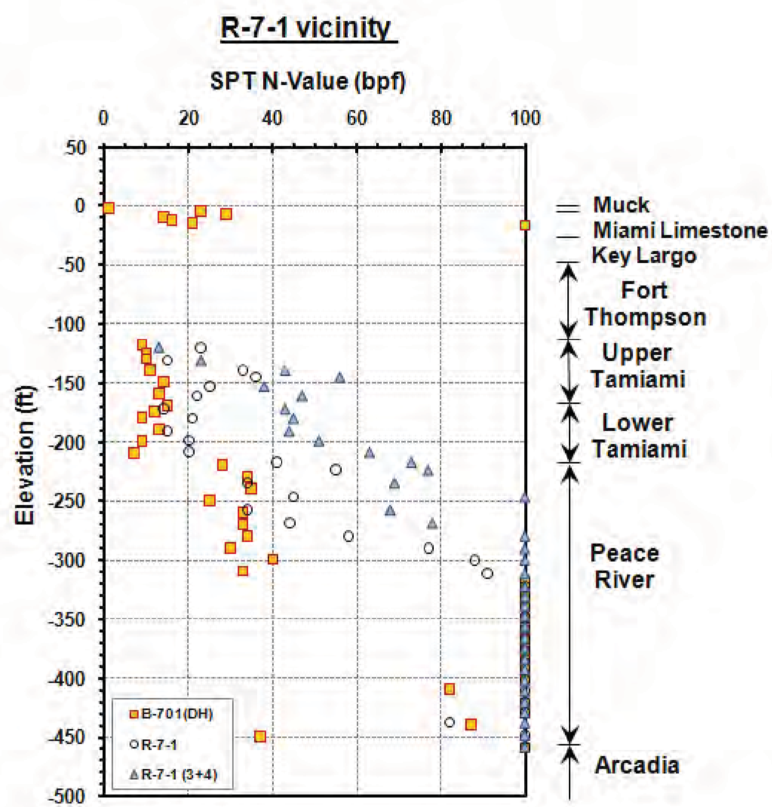
Note:
* Summation of 3rd and 4th blow count intervals

Lower blow counts from the initial investigation attributed to overwashing as defined in Table 13 of NAVFAC DM 7.1

Liquefaction – Based on SPT Blow Counts

SPT Blow Counts from Initial and Supplemental Investigations (RAI 2.5.4-2)





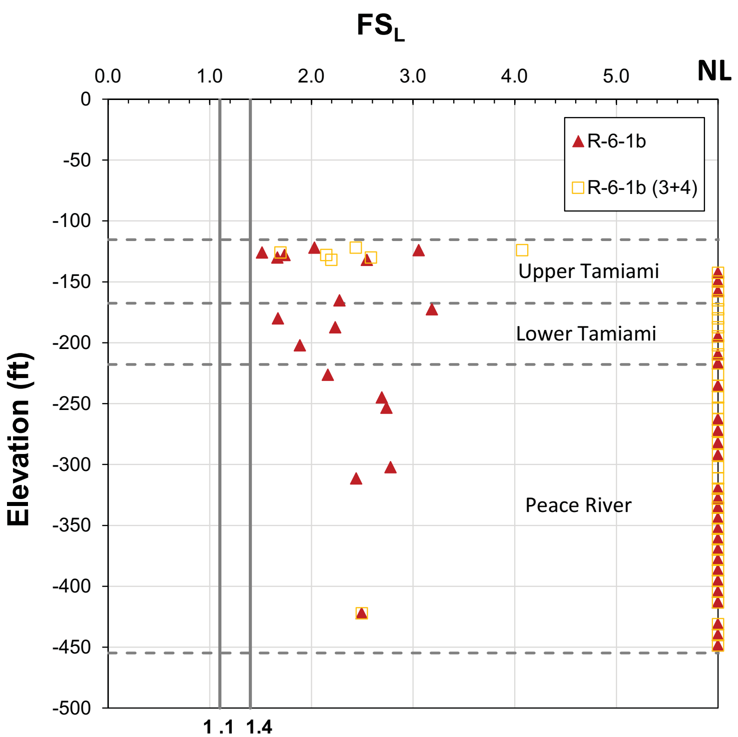
The "SPT N" values obtained from the supplemental investigation are consistently higher than those obtained during the initial investigation for both testing/sampling locations.

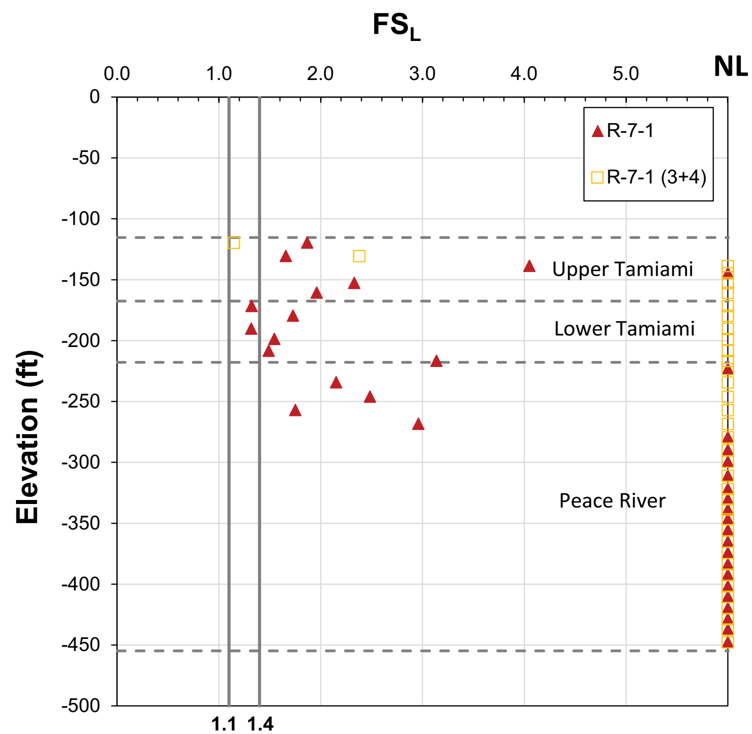
FPL

Liquefaction – Based on SPT Blow Counts

Liquefaction Based on SPT (RAI 2.5.4-17)

FS =Factor of safety





No liquefaction based on SPT Results.

FPL

Microgravity Survey - Potential Subsurface Voids

Microgravity (RAI 2.5.4-1)

- Microgravity survey was performed in 2009
- 12200 ft of data acquired
- 11 survey lines
- Gravity stations spaced at 20-ft intervals

Microgravity Survey - Potential Subsurface Voids

Microgravity (RAI 2.5.4-1)

- **Surficial sediment sampling during the supplemental investigation revealed peat in surficial depressions**
- **Significantly lower density of peat explains anomalies encountered during the original microgravity survey**
- **Results from surficial sediment sampling were used to re-model the original microgravity survey**

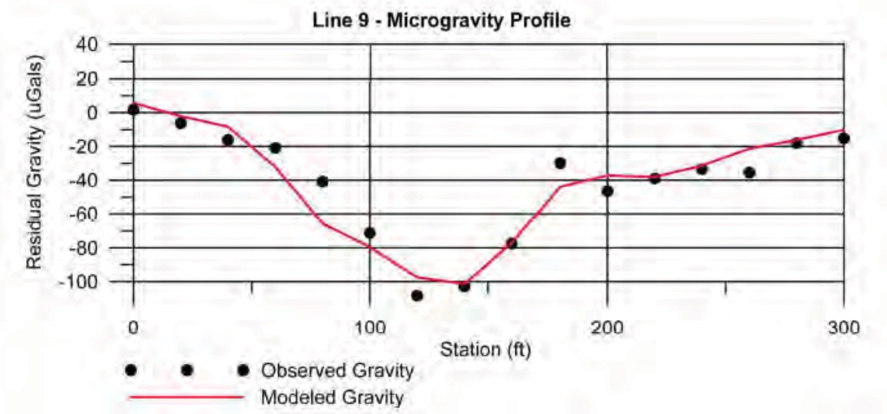
Material	Density
Peat	1.08 g/cc
Muck (elastic silt)	1.32 g/cc
Miami Limestone	2.0 g/cc
Key Largo	2.2 g/cc

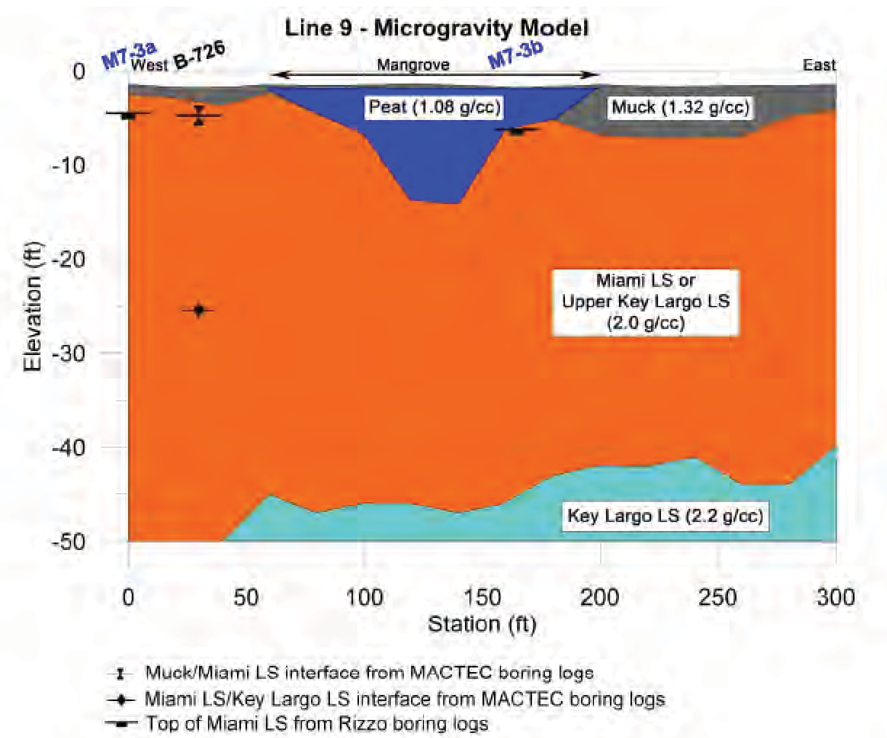
Results from the new microgravity model are in good agreement with the evidence derived from the sampling of surficial deposits and do not indicate the presence of large potential cavities

FPL

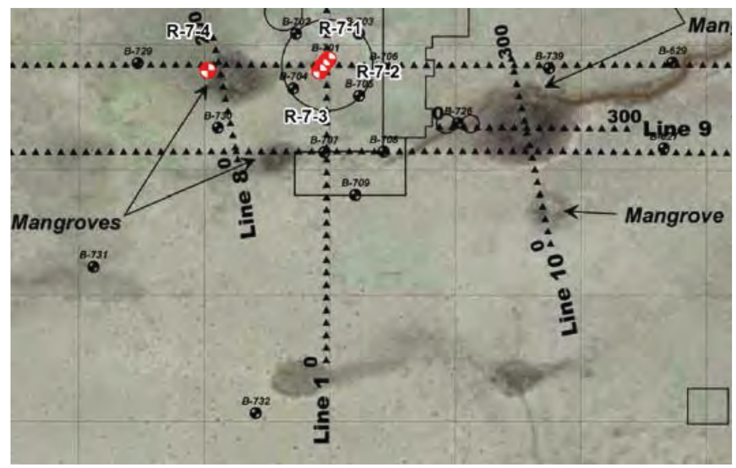
Microgravity Survey - Potential Subsurface Voids

Microgravity (RAI 2.5.4-1)





- **The modeled top of Miami limestone in microgravity models has a very good agreement with the muck sampling data**
- **The average absolute difference between the models and borings is 1.4 ft**



Potential Subsurface Voids and Lineaments/ Fracture Patterns

Interpreted Tool Drops (RAI 2.5.4-1)

- **Inclined borings drilled to find potential cavities**
- **No cavities of significant size were found under the targeted vegetated depression area or the drainage channels**
- **Evaluation of all data for vertical borings (outside of vegetated depressions and drainages) show 0.3% of interpreted tool drop length per total length of rock cored**
- **Individual drops (vertical borings) range from 0.4 ft to 4 ft**
- **Interpreted tool drops are found more often under vegetated depressions and drainages**
  - Evaluation of data for inclined borings show 4.3% of interpreted tool drop length per total length of rock cored

Tool drop size is limited to 1.5 ft within the power block area. Total extent of total drops is limited to 0.3% of the entire cored length.

FPL

Potential Subsurface Voids and Lineaments/ Fracture Patterns

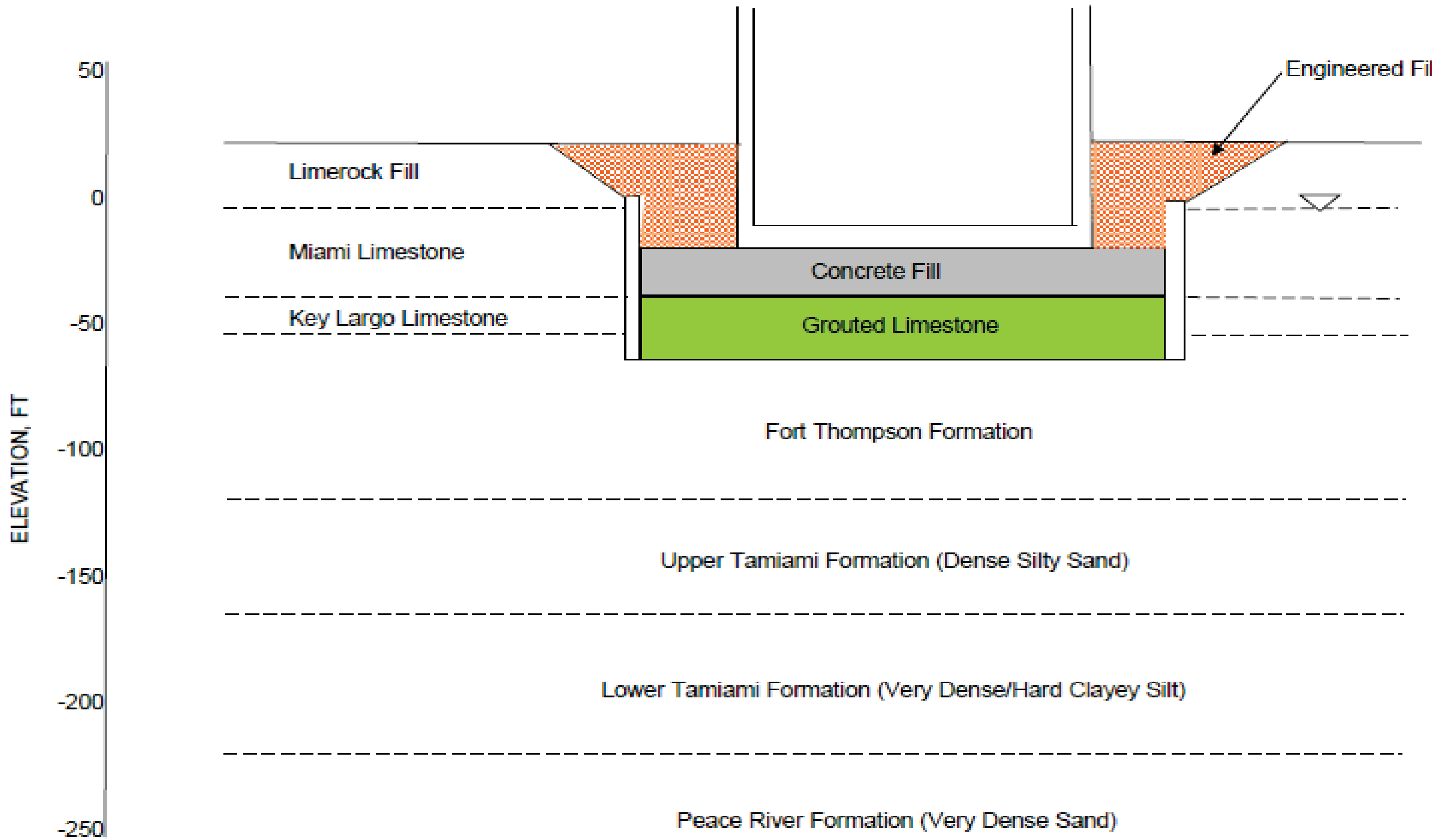
Conclusions (RAI 2.5.4-1)

- New microgravity model results are in good agreement with evidence derived from surficial deposits sampling
- Tool drop size is limited to 1.5 ft within the power block area. Total extent of total drops is limited to 0.3% of the entire cored length
- Evaluation of interpreted tool drops and secondary porosity indicates that in most cases, voids are filled with relatively softer materials, rather than just existing as empty open voids
- Documented vertical or near-vertical fracture orientations support the initial assumption that the lineaments identified in the Turkey Point site area were associated with fractures in the subsurface

The evidence does not indicate the presence of the potential cavities

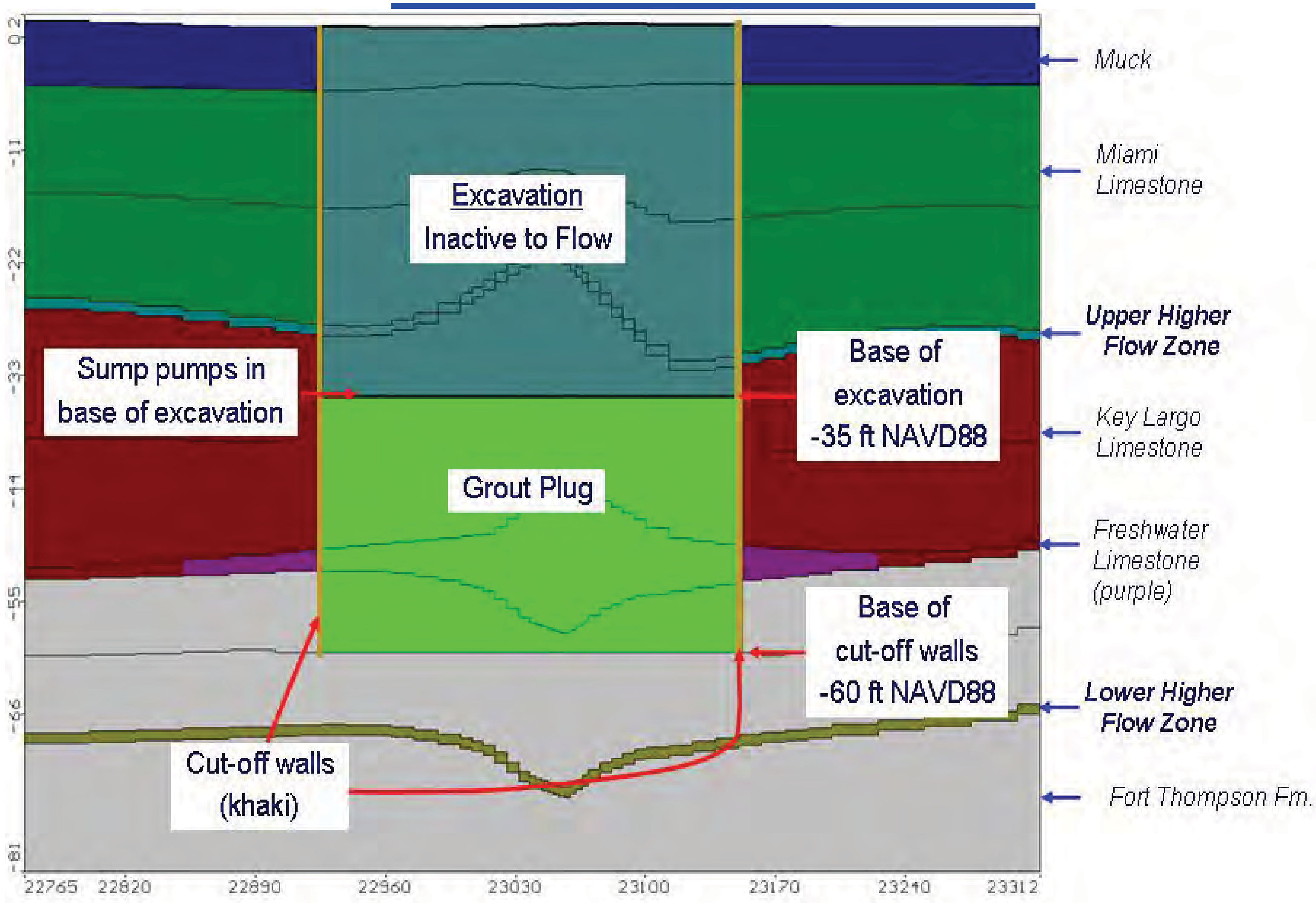
Grouting Plan

Location



Grouting Plan

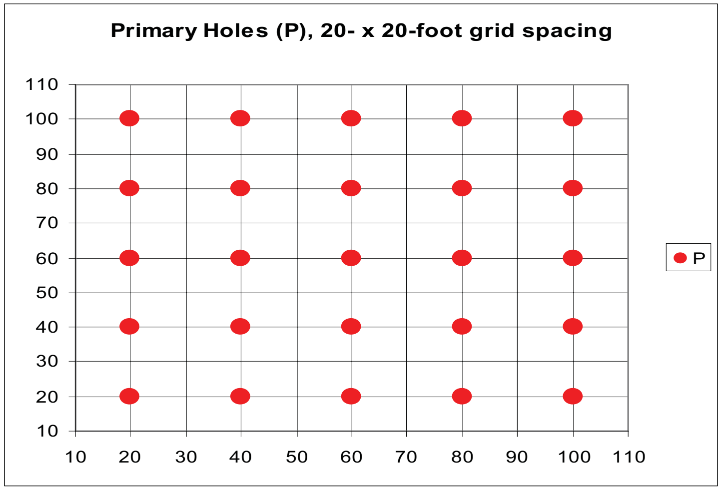
Location of Cut-off Walls

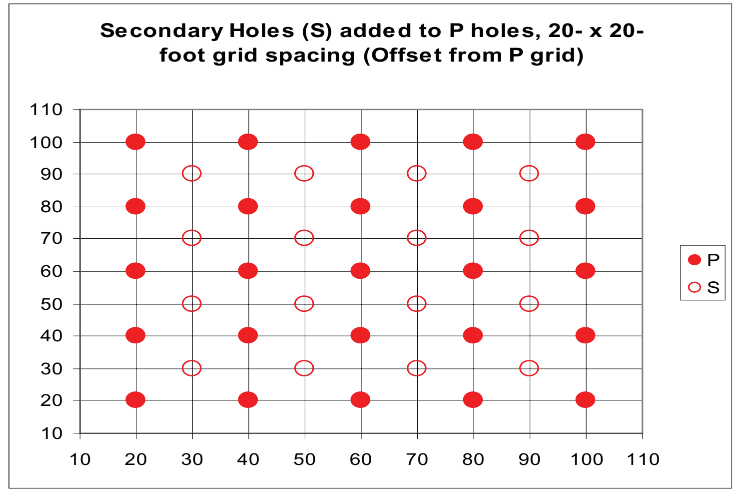


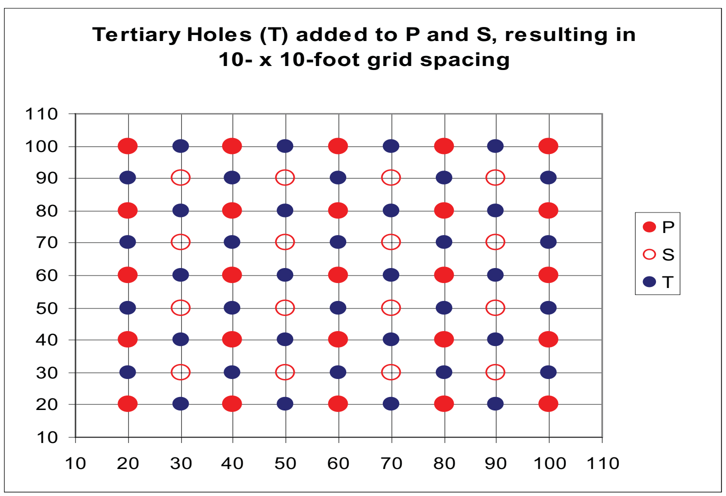
FPL

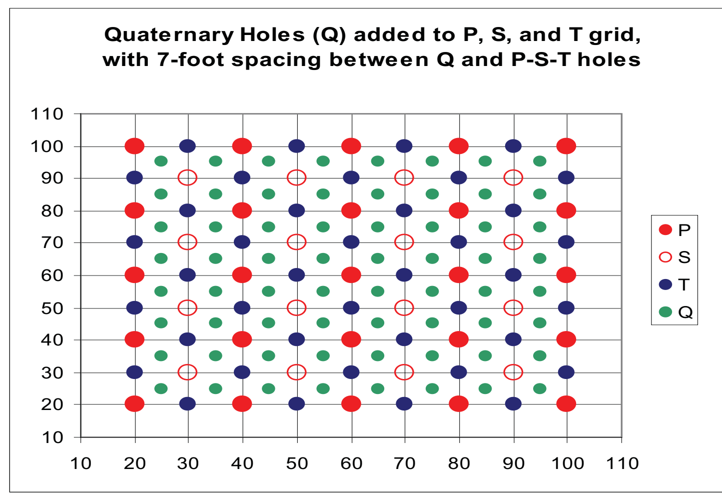
Grouting Plan

Grout Injection Sequence









Agenda

- Introduction & Overview [NRC/FPL]
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- **General Discussion Geology / Seismology (FPL/NRC)**
- Impact of Updated Properties on Seismicity (Section 2.5.2) [FPL]
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- Adjourn

FPL

General Discussion: Seismology

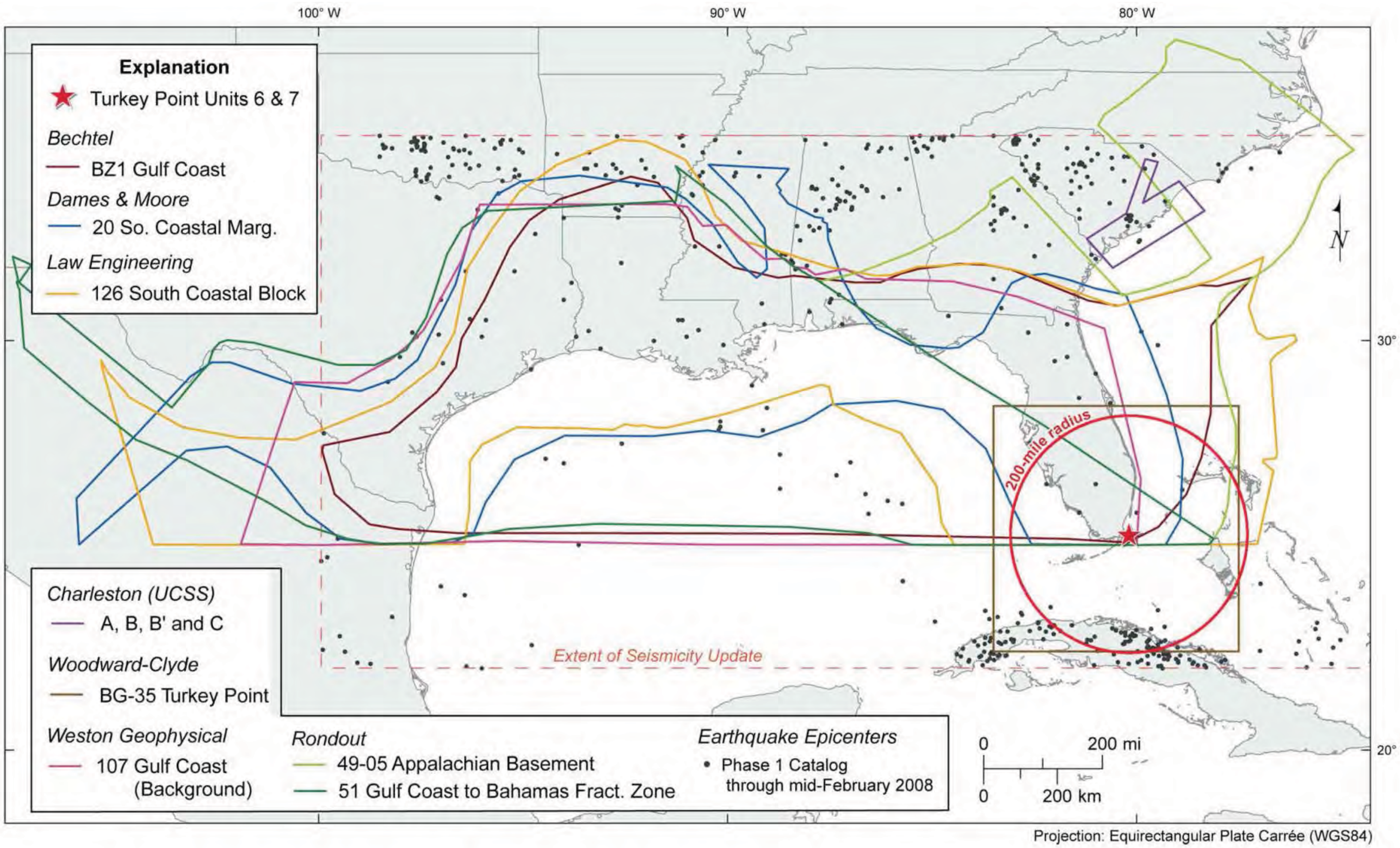
Topic Outline

- **EPRI-SOG seismic source model [SSM]**
  - Updated seismicity: 2 phases
  - Supplement to EPRI-SOG seismic sources south of Turkey Point within 200 miles
  - Cuba and Caribbean plate boundary faults
- **Caribbean ground motion model [GMM]**
  - An alternative to the EPRI (2004, 2006) GMPEs
  - Validation using observed ground motions
- **Sensitivity of Cuba seismic source model**
- **Hazard sensitivity to using 2012 CEUS SSC**

FPL

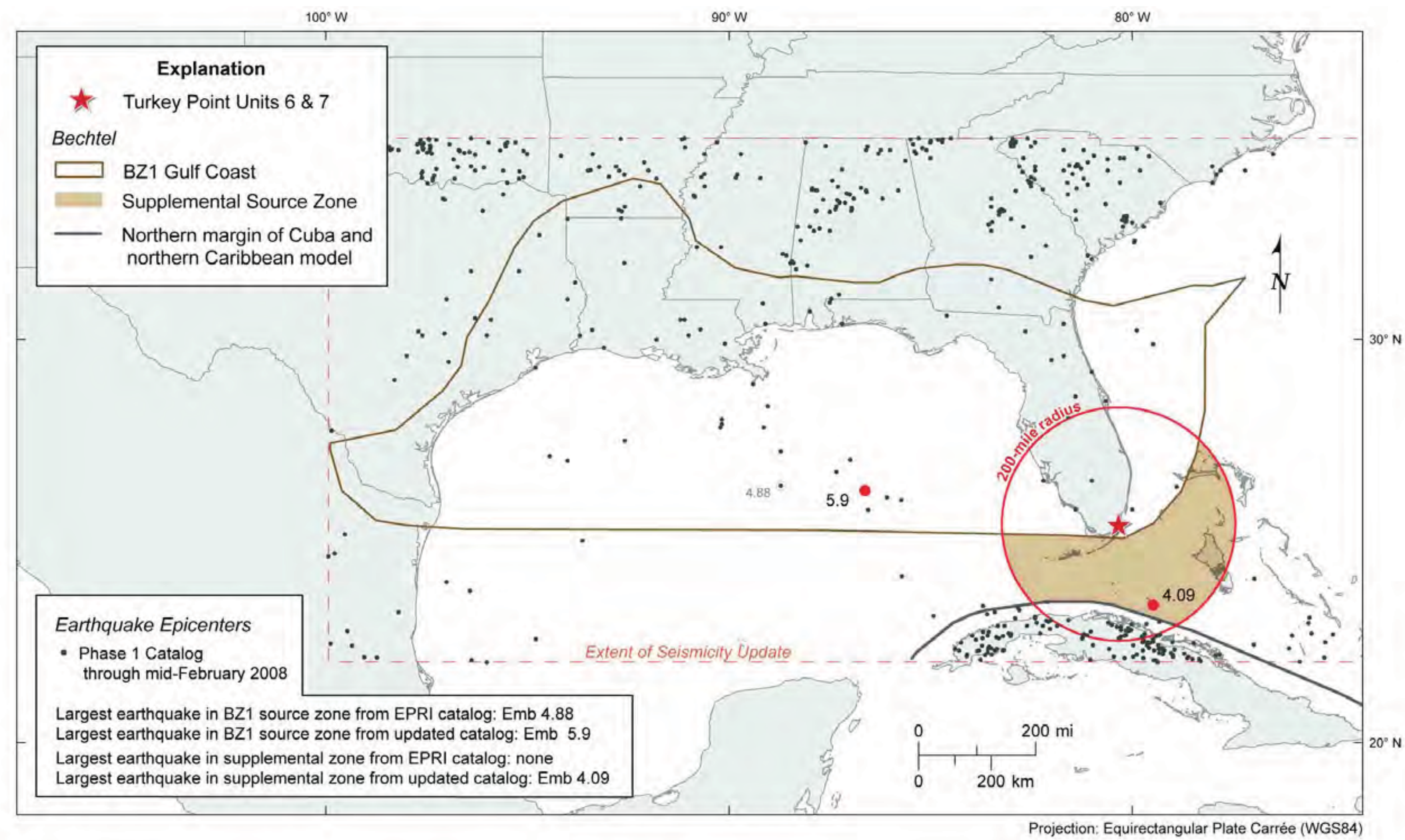
General Discussion: Seismology

EPRI Seismic Source Zones and Updated Charleston Seismic Source (UCSS) Model Sources



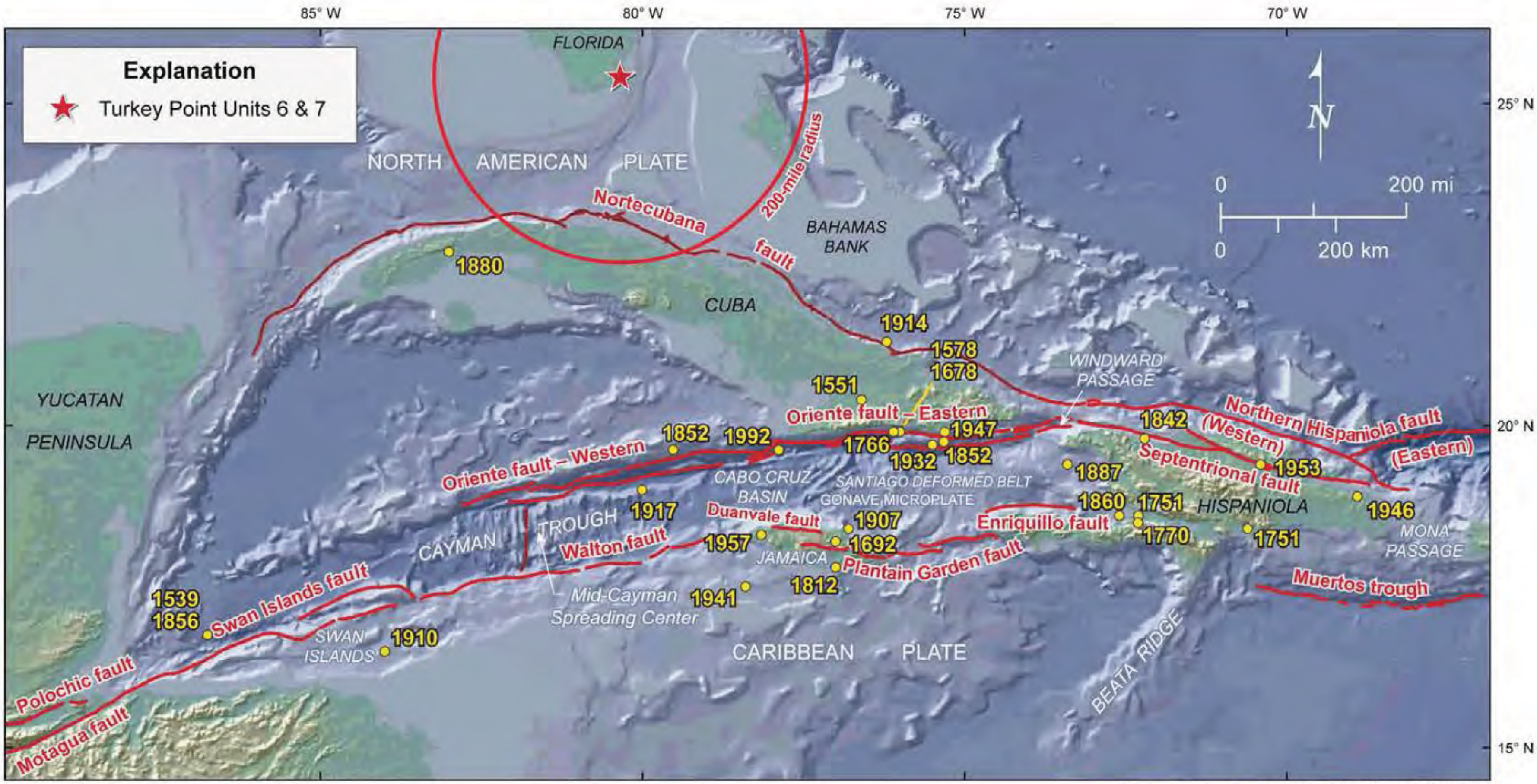
General Discussion: Seismology

EPRI and Supplemental Source Zones-Bechtel



General Discussion: Seismology

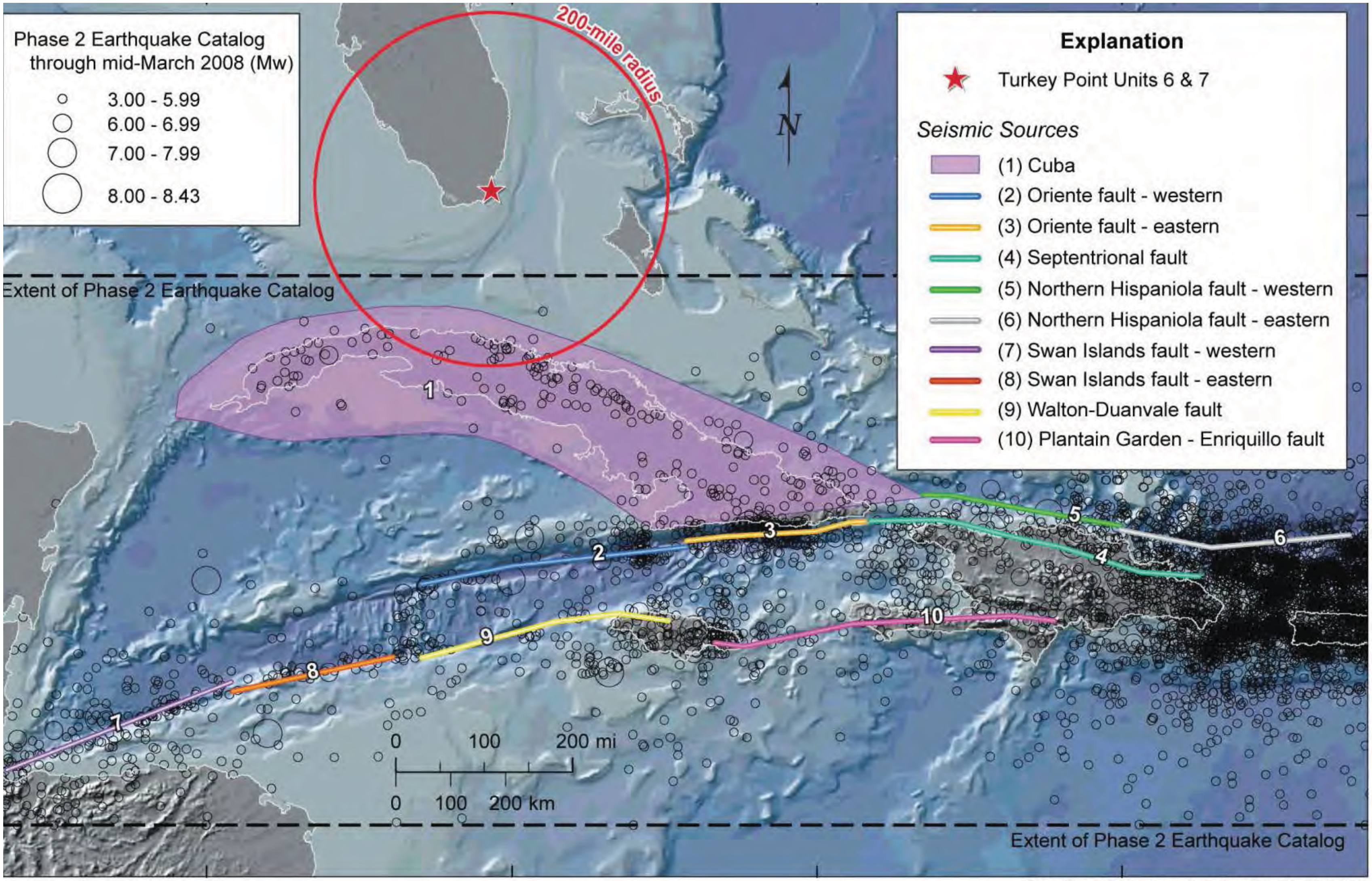
Tectonic Features & Significant Earthquakes of Cuba Area & the North America-Caribbean Plate Boundary Region



Projection: Equirectangular Plate Carrée (WGS84)

General Discussion: Seismology

Cuba and Northern Caribbean Seismic Sources



Projection: Equirectangular Plate Carrée (WGS84)

FPL

General Discussion: Seismology

Simulated Ground Motion Attenuation Data

- Ground motion prediction equations [GMPE] must consider the following functionality:

  Ground motion = f(Source), f(Path), f(Site)

  f(Source): earthquake source

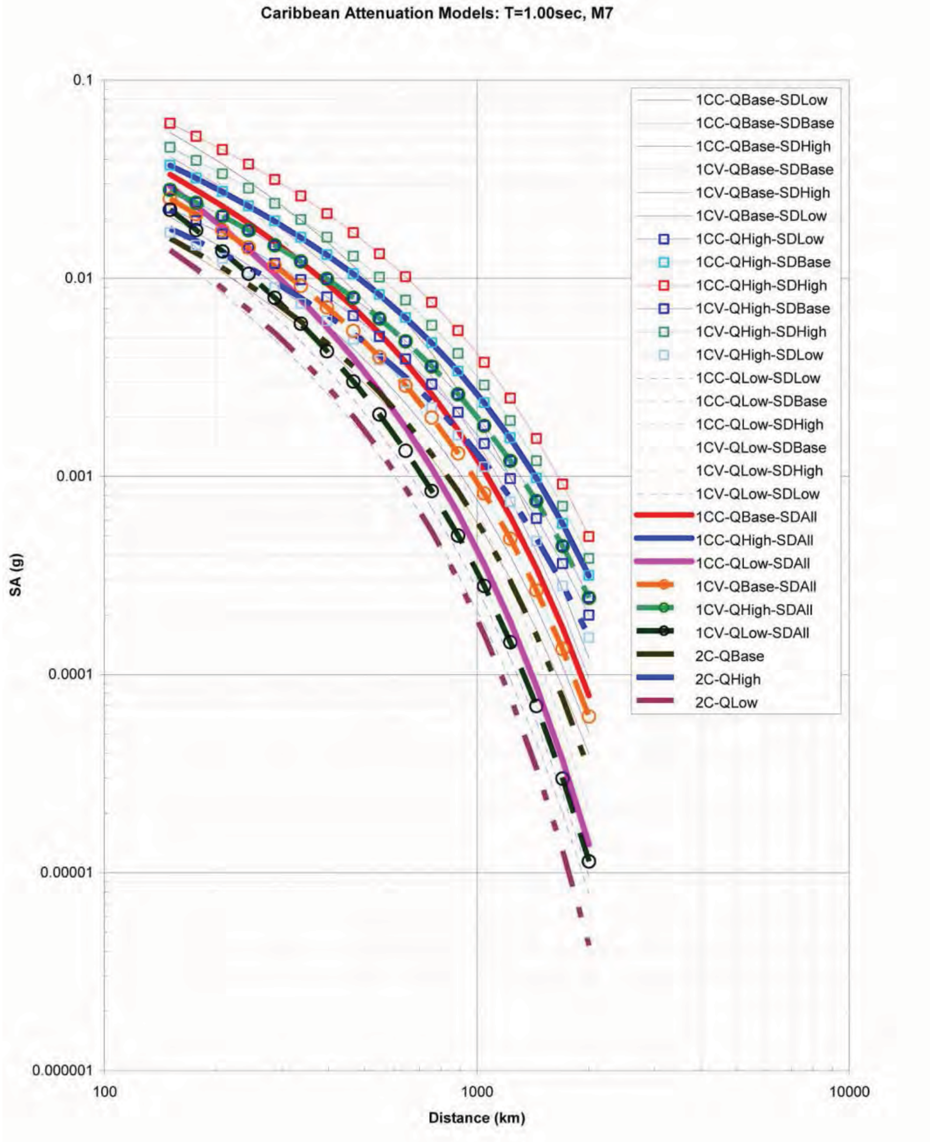
  f(Path): crustal conditions between the earthquake and the site

  f(Site): site conditions

- The f(Source) and f(Path) terms could not be assumed to be the same for Caribbean sources as for the CEUS. Therefore, alternatives to the EPRI (2004, 2006) GMM were examined and ultimately adopted for seismic sources in the Caribbean

Developed Caribbean GMM following conventional point source stochastic simulation techniques

Comparison of 1 Hz Attenuation Curves for the Cuba and Caribbean Region for a Mw 7 Earthquake



Initial suite of 21 models

Final suite of 9 models

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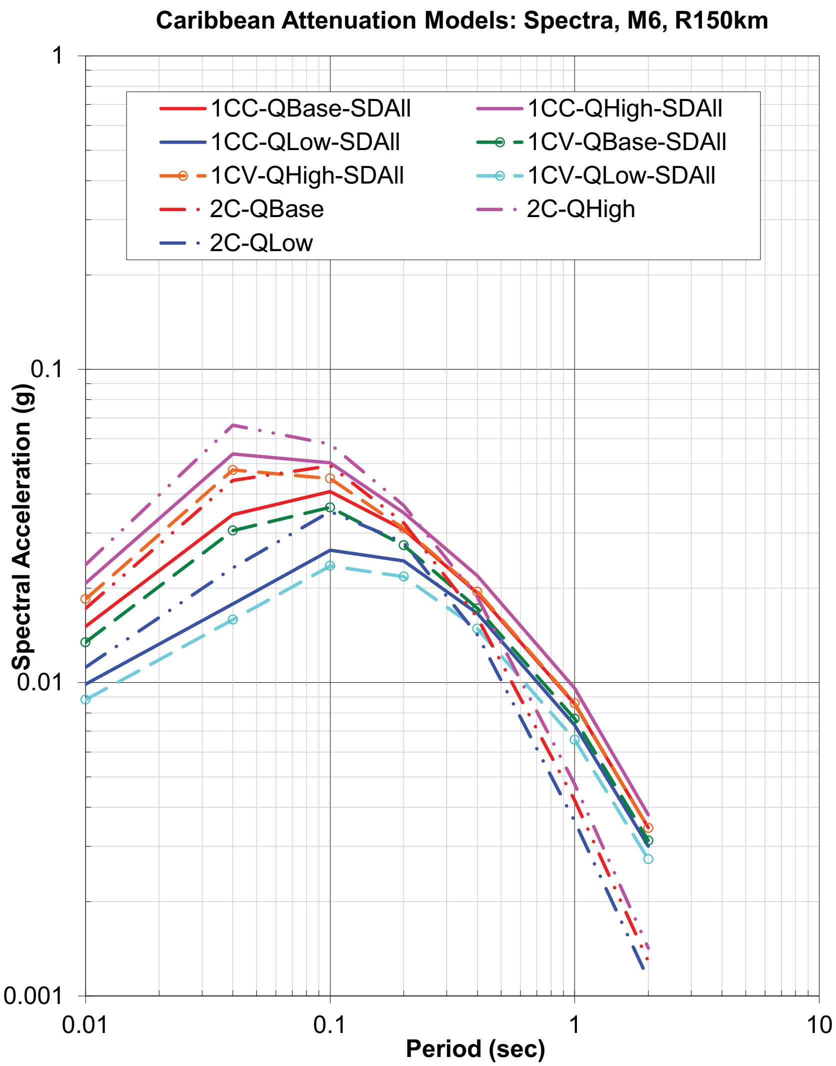
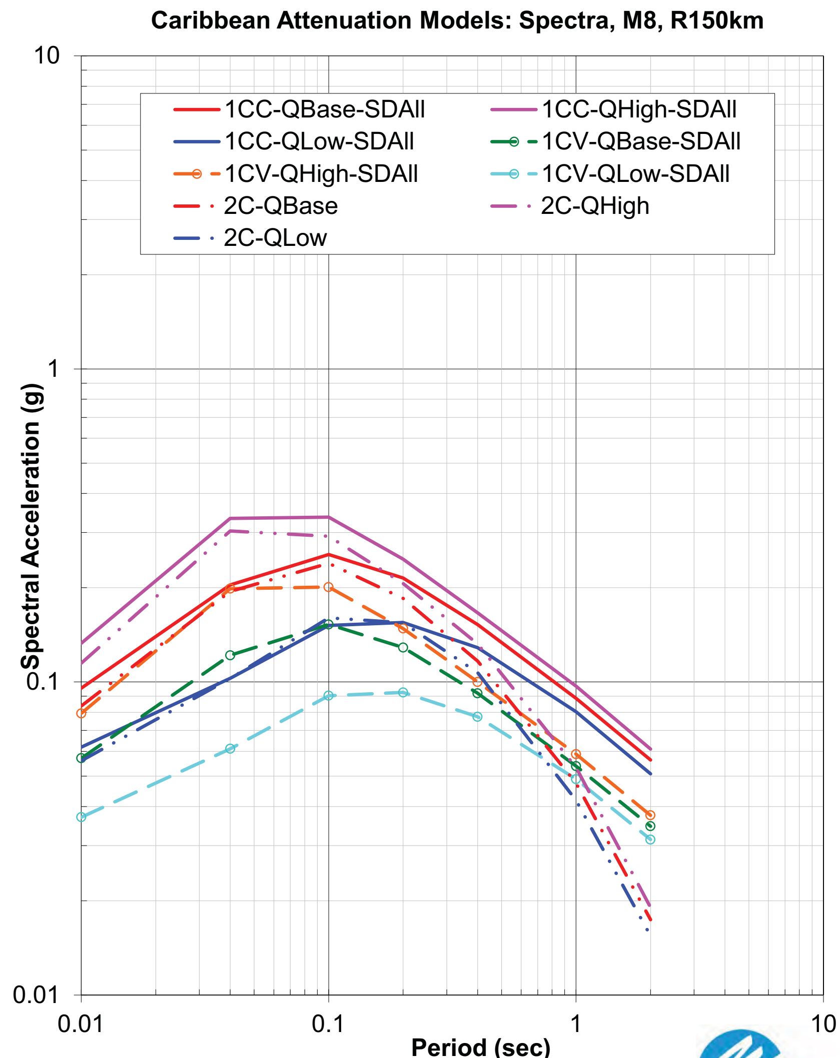
Caribbean Spectral Attenuation Models for Mw 6, 8 and R 150 km





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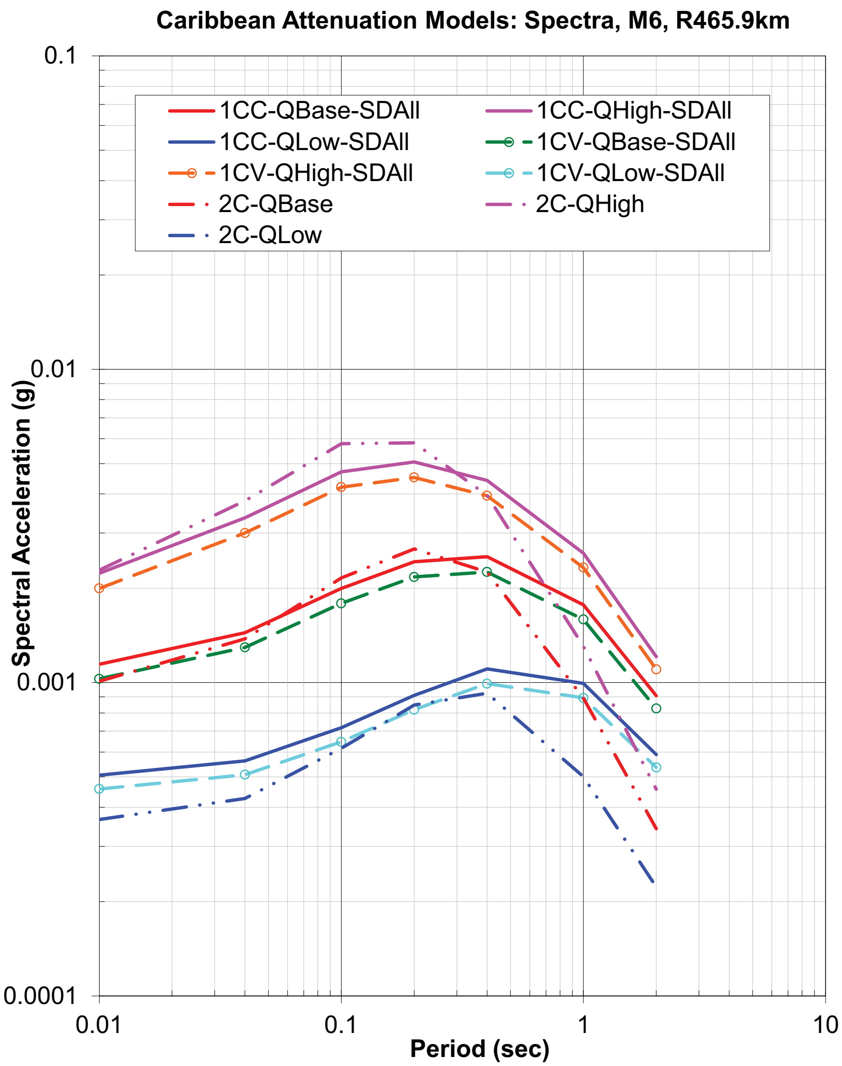
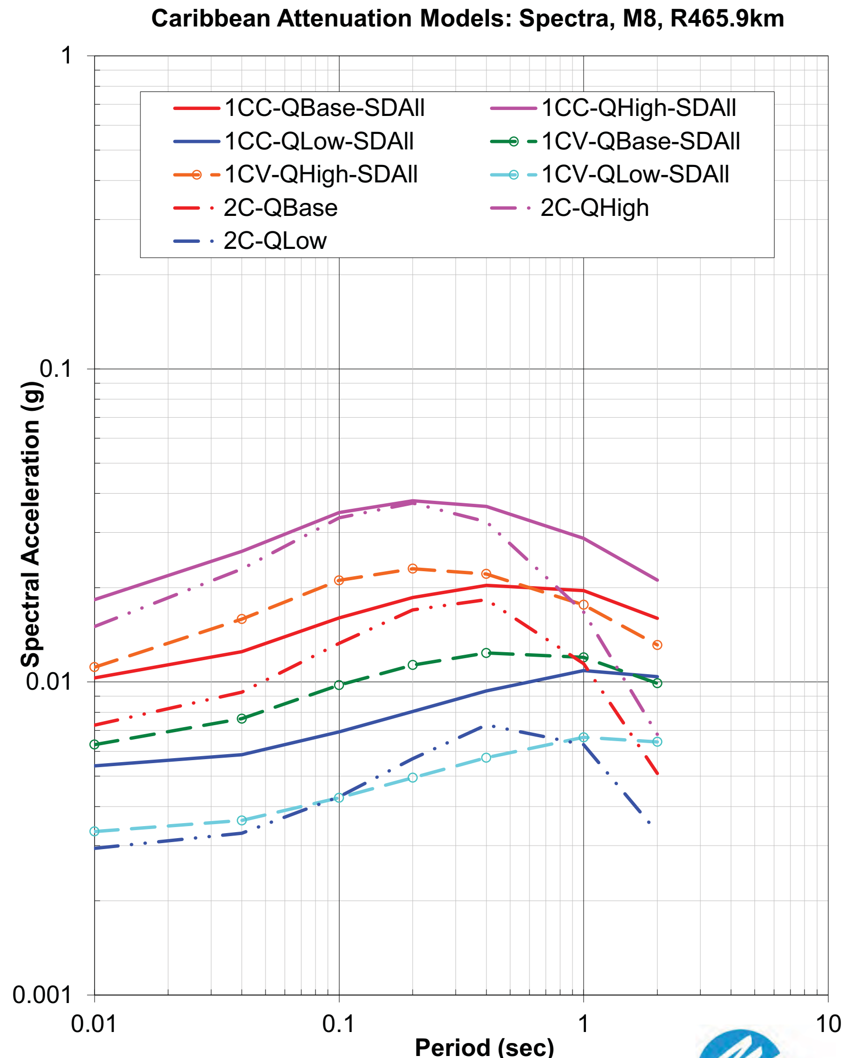
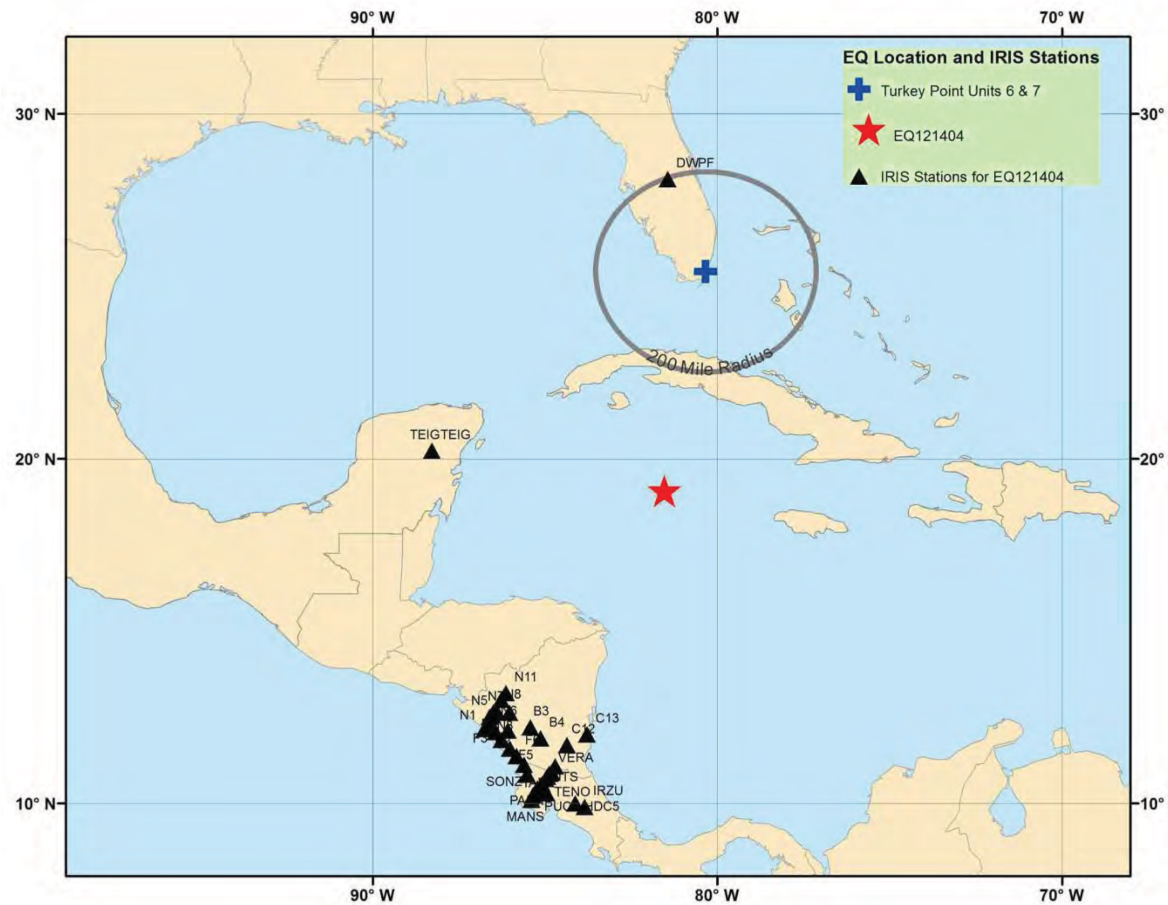
Caribbean Spectral Attenuation Models for Mw 6, 8 and R 465.9 km

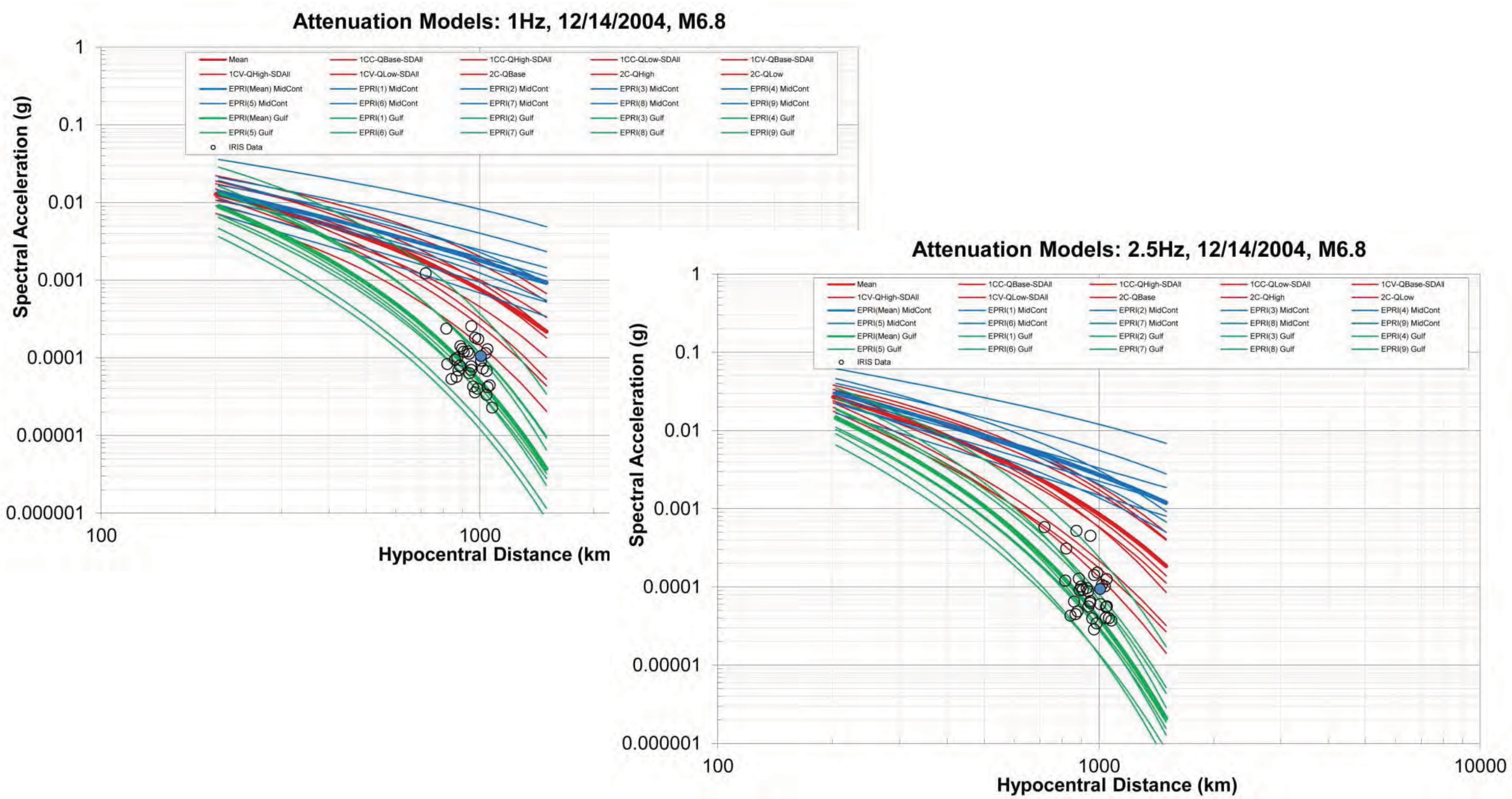




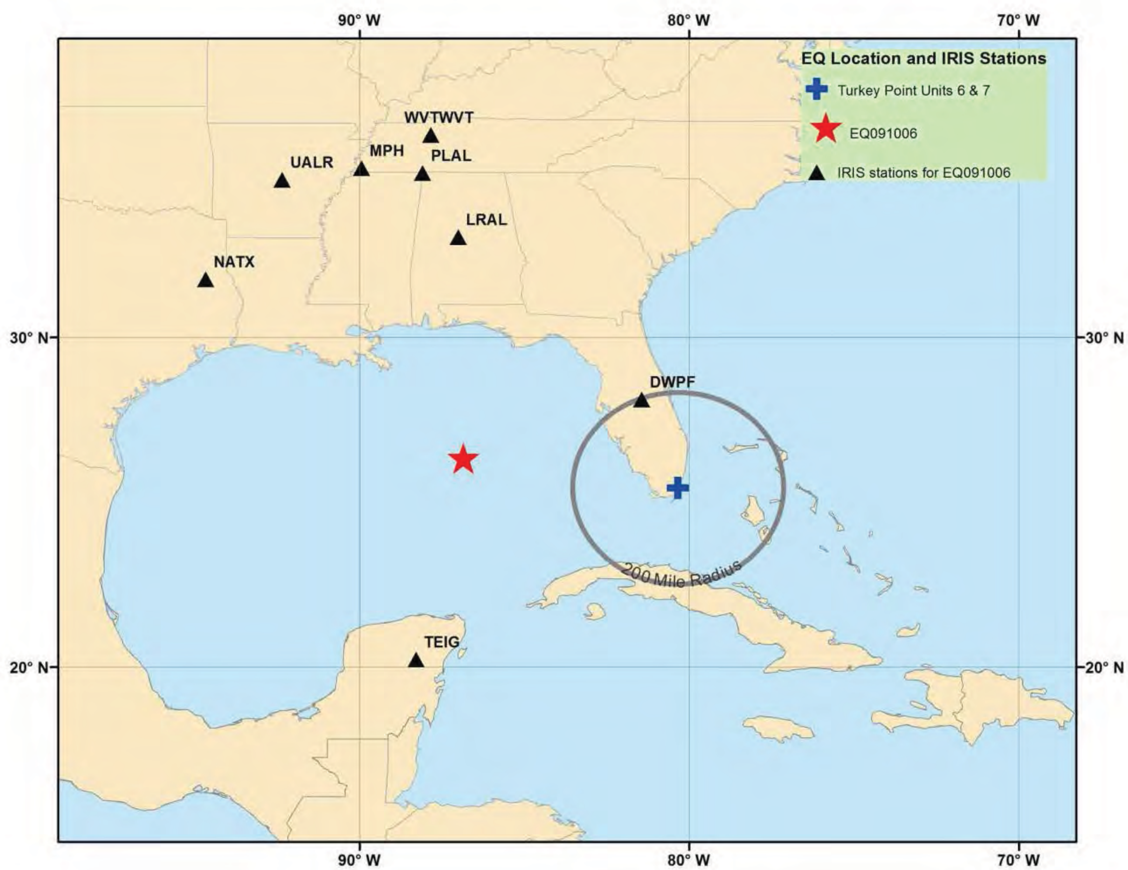
Earthquake location for the 12/14/2004 Caribbean Sea Region earthquake (Mw 6.8) and the IRIS station locations



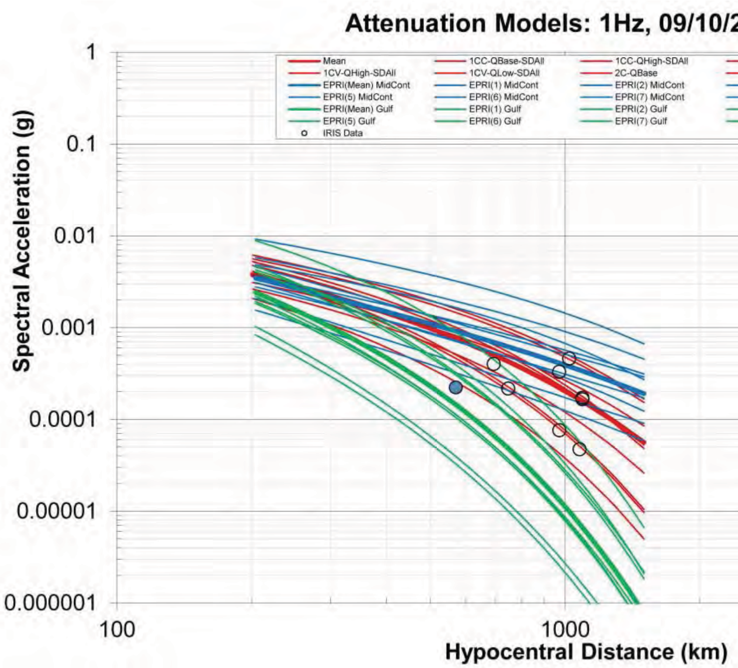
Comparison of Caribbean GMPE, EPRI Mid-Continent, and Gulf Coast Region GMPE and Empirical IRIS Processed Data for Frequencies of 1 and 2.5 Hz

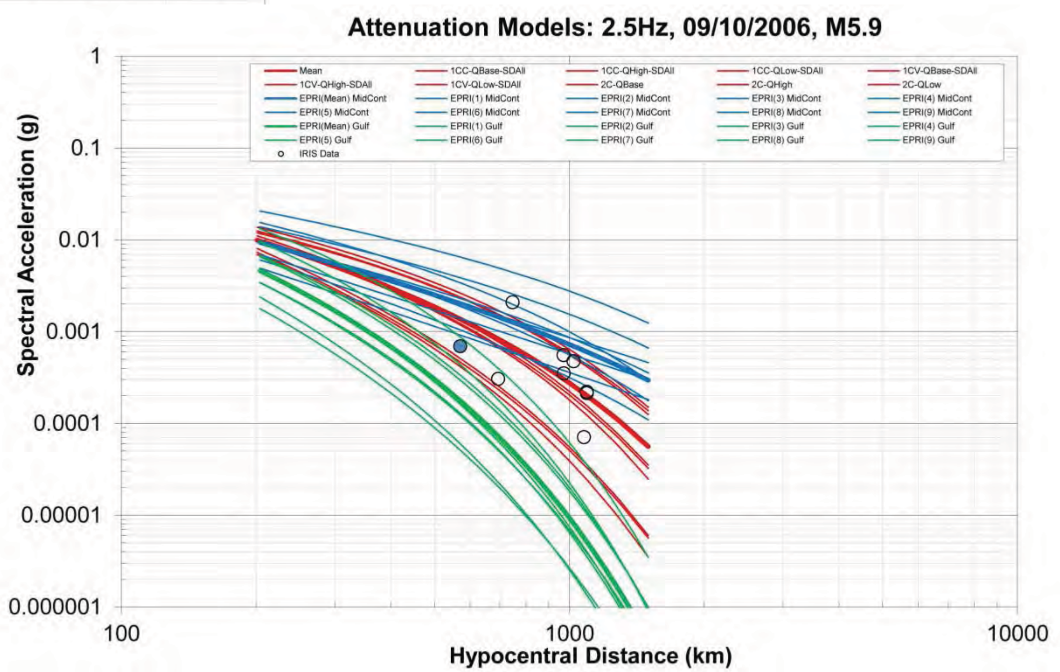


Earthquake location for the 09/10/2006 Gulf of Mexico Region earthquake (Mw 5.9) and the IRIS station locations



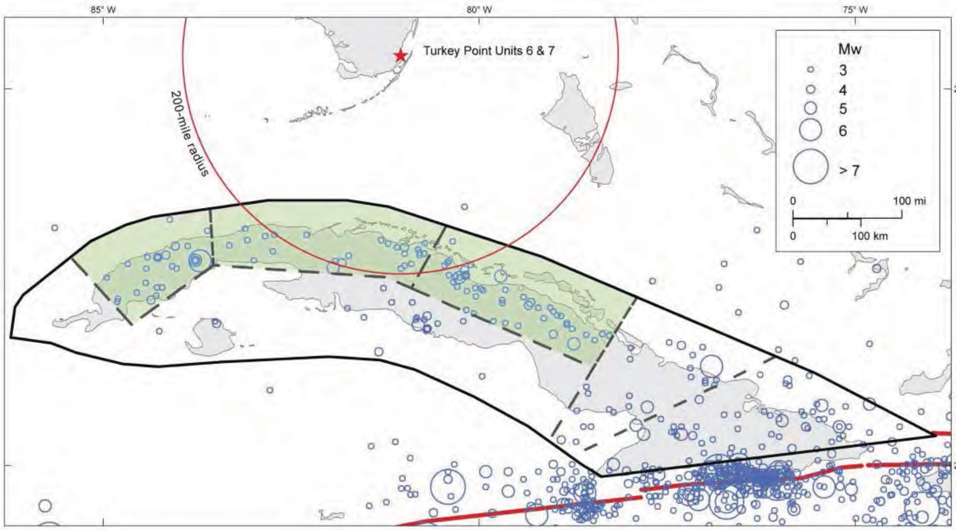
Comparison of Caribbean GMPE, EPRI Mid-Continent, and Gulf Coast Region GMPE and Empirical IRIS Processed Data for Frequencies of 1 and 2.5 Hz





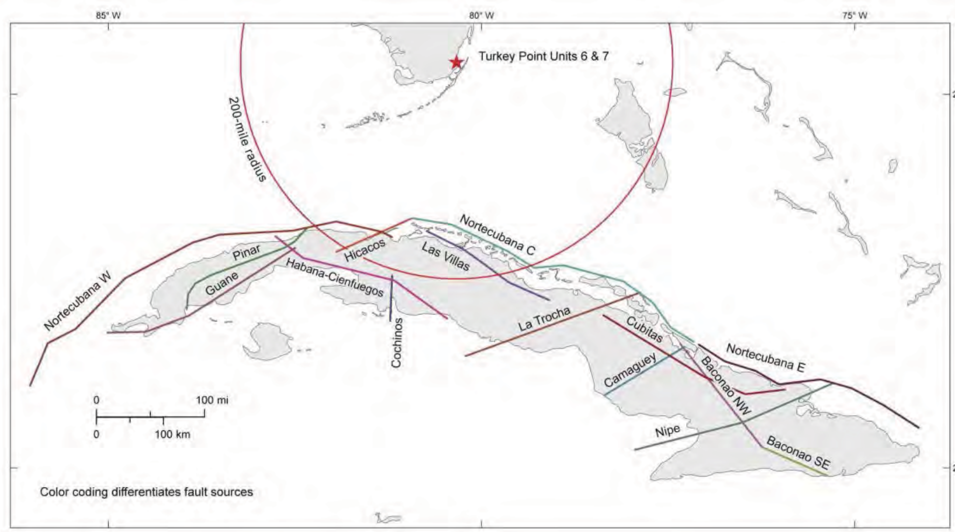
Cuba/Caribbean GMM is valid to use for the Turkey Point PSHA

Sensitivity of Cuba Seismic Source Model



Area source scenarios:

- Z1
- Z6
- Z11%



Fault source scenarios:

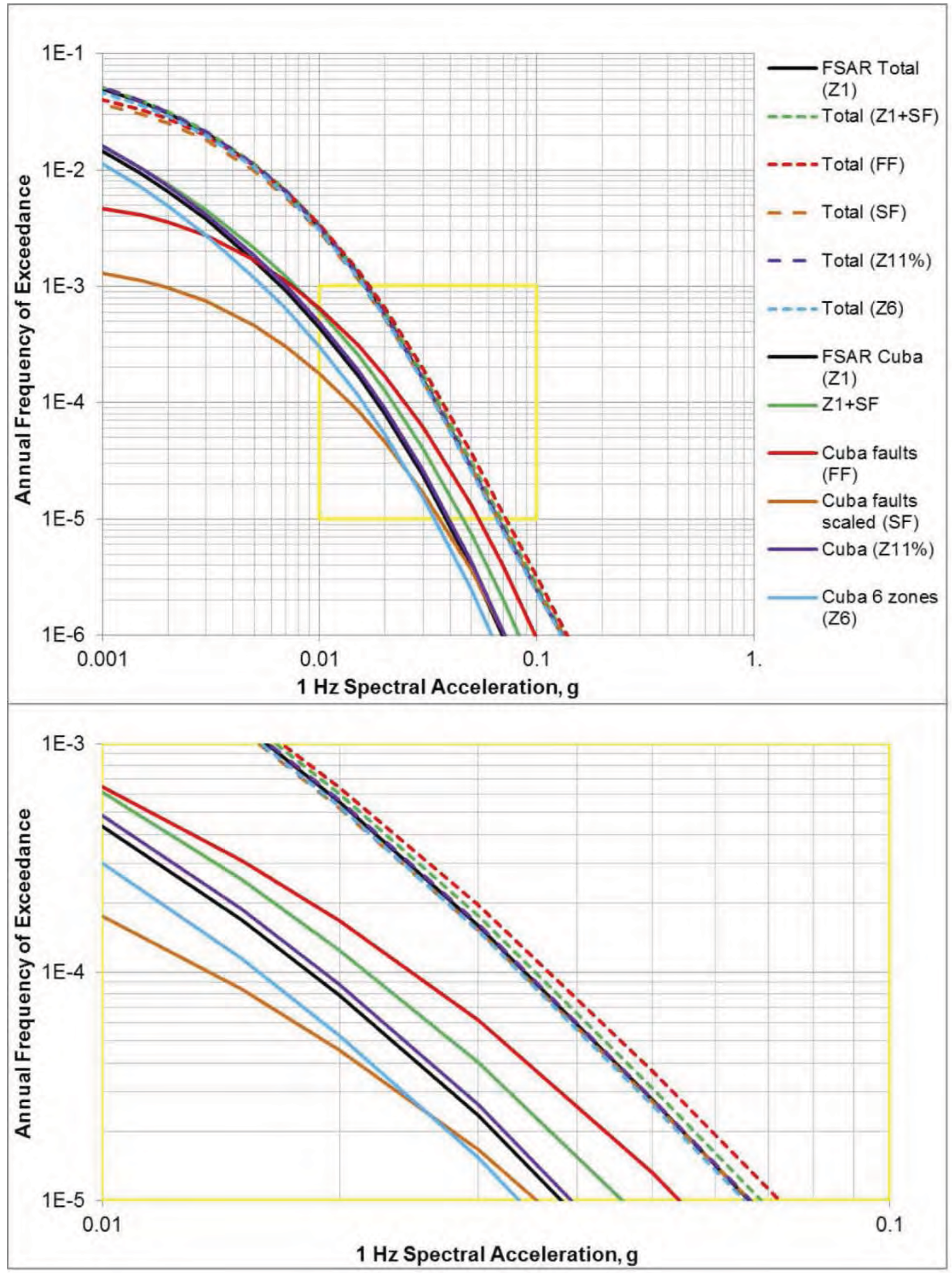
- FF
- SF

Sensitivity Analysis for Cuba Source Scenarios at 1 Hz

% Change in Ground Motion

Scenario	10^{-4}	10^{-5}
Z6	-1.5	-1.4
SF	-0.9	0.3
Z11%	0.6	0.3
Z1+SF	3.2	3.5*

* Corresponds to 0.002g

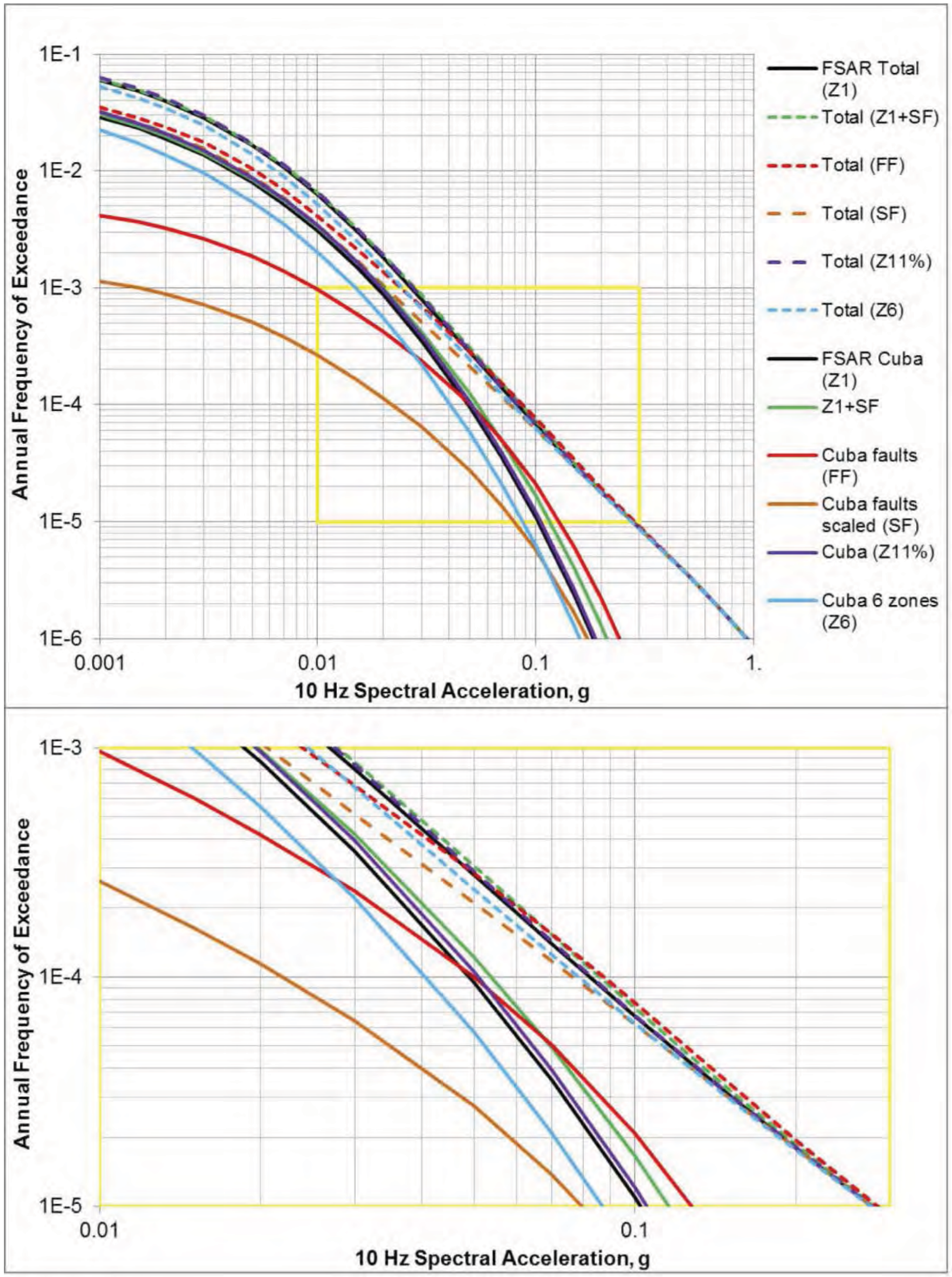


Sensitivity Analysis for Cuba Source Scenarios at 10 Hz

% Change in Ground Motion

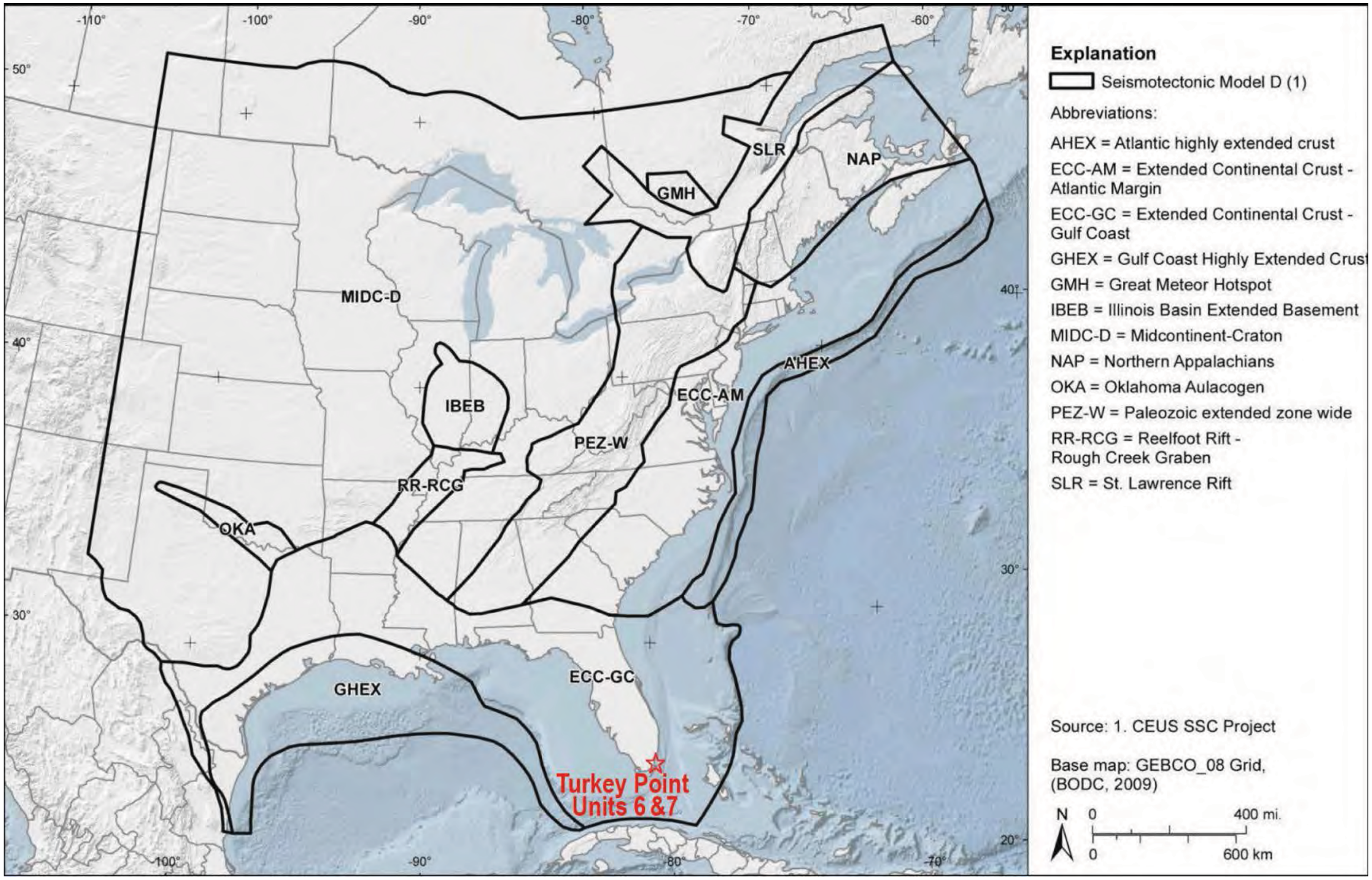
Scenario	10^{-4}	10^{-5}
Z6	-4.6	-0.7
SF	-6.9	0.0
Z11%	1.2	0.0
Z1+SF	4.4*	0.7

* Corresponds to <0.004g



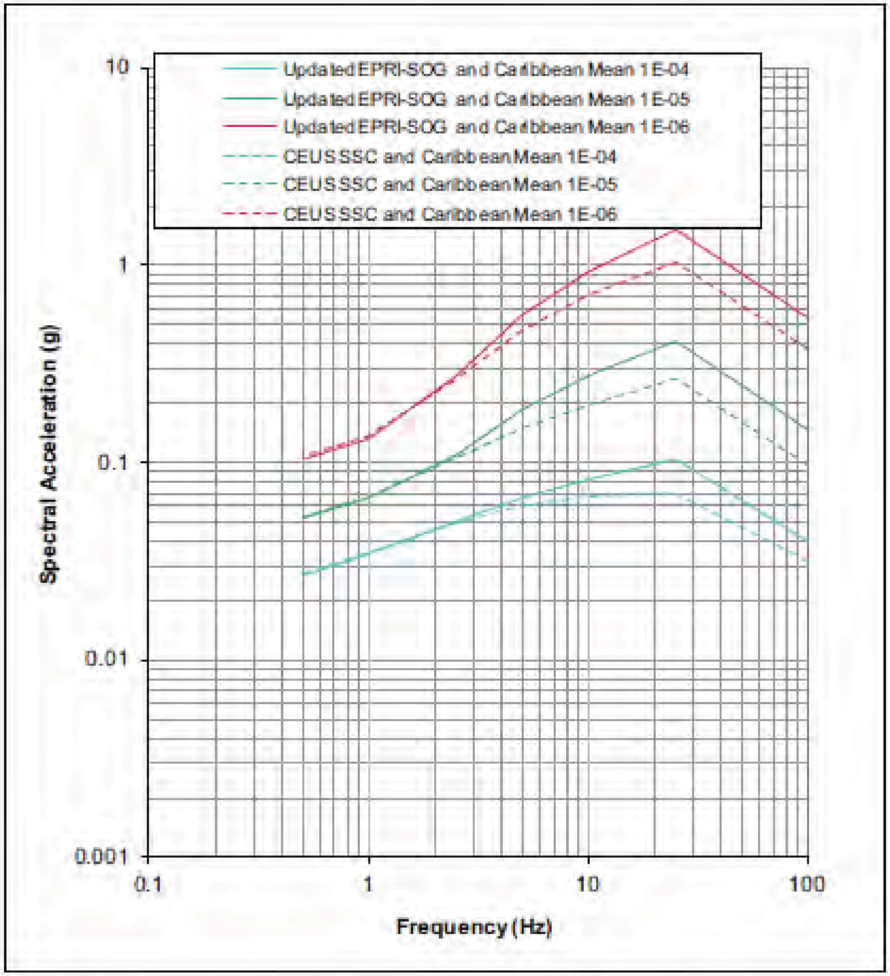
General Discussion: Seismology

Hazard sensitivity to using 2012 CEUS SSC



General Discussion: Seismology

Comparison of EPRI-SOG vs CEUS SSC Hard Rock UHRS



Note: Comparison between the hard rock UHRS based on the updated EPRI-SOG model plus Caribbean Sources, and the UHRS computed using the CEUS SSC model plus Caribbean sources.

General Discussion: Seismology

Conclusions

- The Seismic Source Model used was the EPRI-SOG model updated to better characterize the near-regional area and, most significantly, the Caribbean
- Project-specific GMPEs were developed for the Caribbean sources based on conventional point source stochastic simulation techniques and model parameters selected with the help of ground motion attenuation experts and validated in a series of sensitivity studies and comparison with available empirical data
- Cuba source characterization was shown to be adequate with a separate series of sensitivity studies in which results from a variety of possible moment release models were compared
- Comparison of the site-specific hard rock uniform hazard response spectra developed for the FSAR with alternatives developed using the CEUS SSC model shows that the FSAR UHRS are generally greater than the CEUS SSC-based UHRS

FPL

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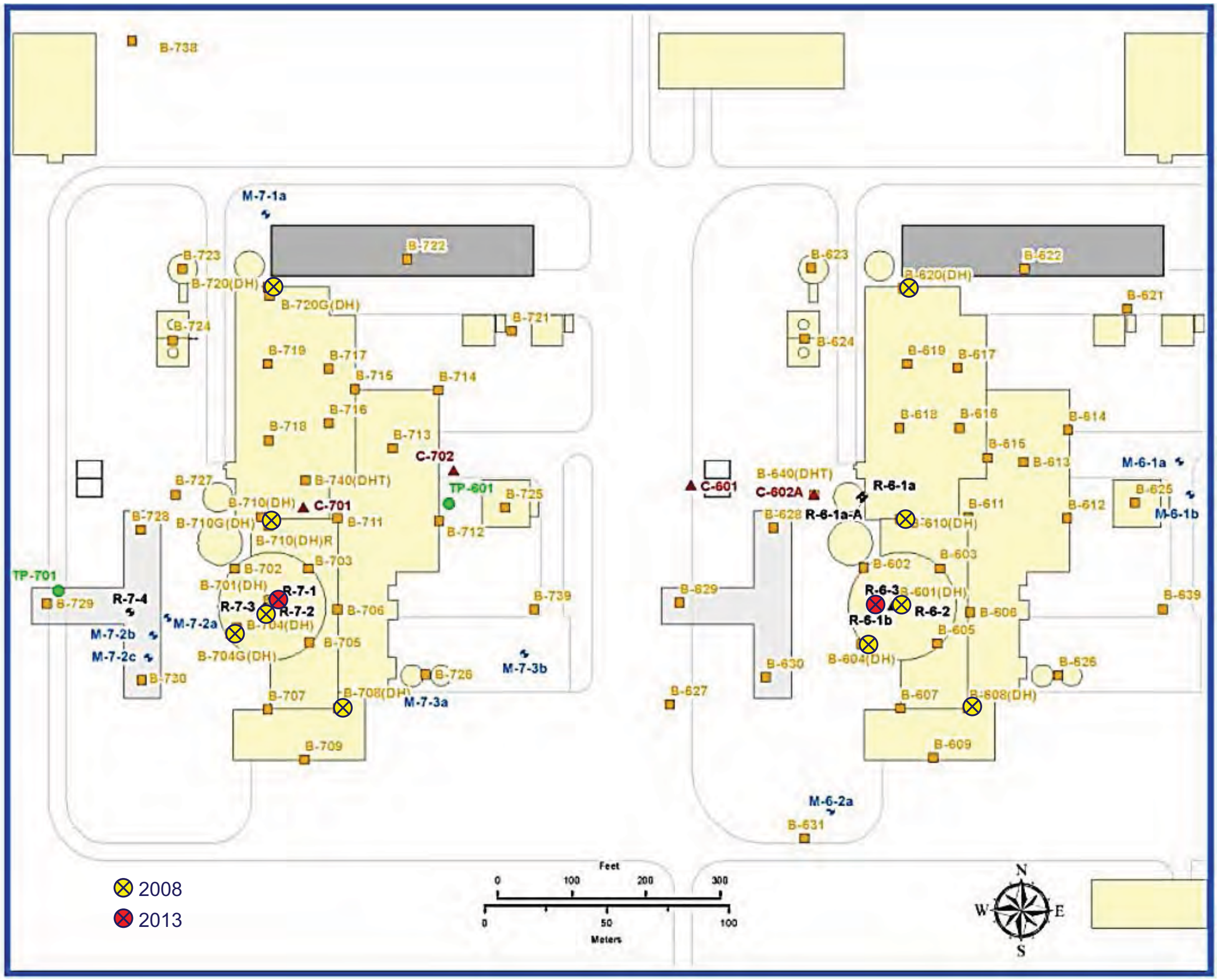
Evaluation of Original & Combined Shear Wave Velocity (V_S) Data

Locations of V_S Borings



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Evaluation of Original & Combined Shear Wave Velocity (V_S) Data

Details of 2008 and 2013 Boring with V_S Measurements

Boring	Ground Elevation (ft)	Max. V_S Depth (ft)	Date
B-601	-1.4	402	2008
B-604	-1.5	153	2008
B-608	-1.5	251	2008
B-610	-1.4	253	2008
B-620	-1.5	202	2008
B-701	-1.1	604	2008
B-704G	-1.3	151	2008
B-708	-1.4	249	2008
B-710G	-1.4	254	2008
B-720G	-1.1	202	2008
R-6-1b	0.0	450	2013
R-7-1	0.2	443	2013

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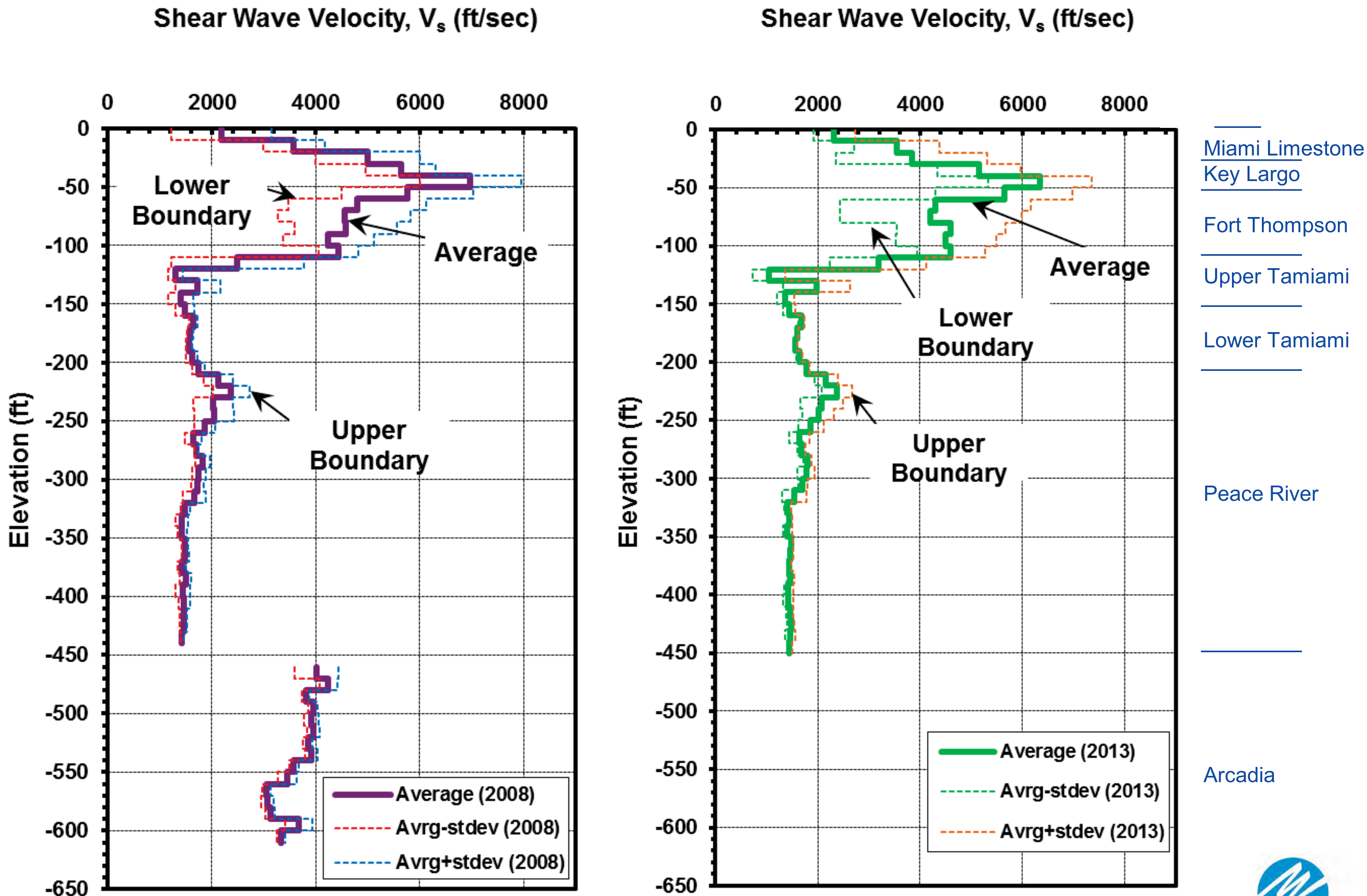
Evaluation of Original & Combined Shear Wave Velocity (V_S) Data

Development of Average V_S Profiles

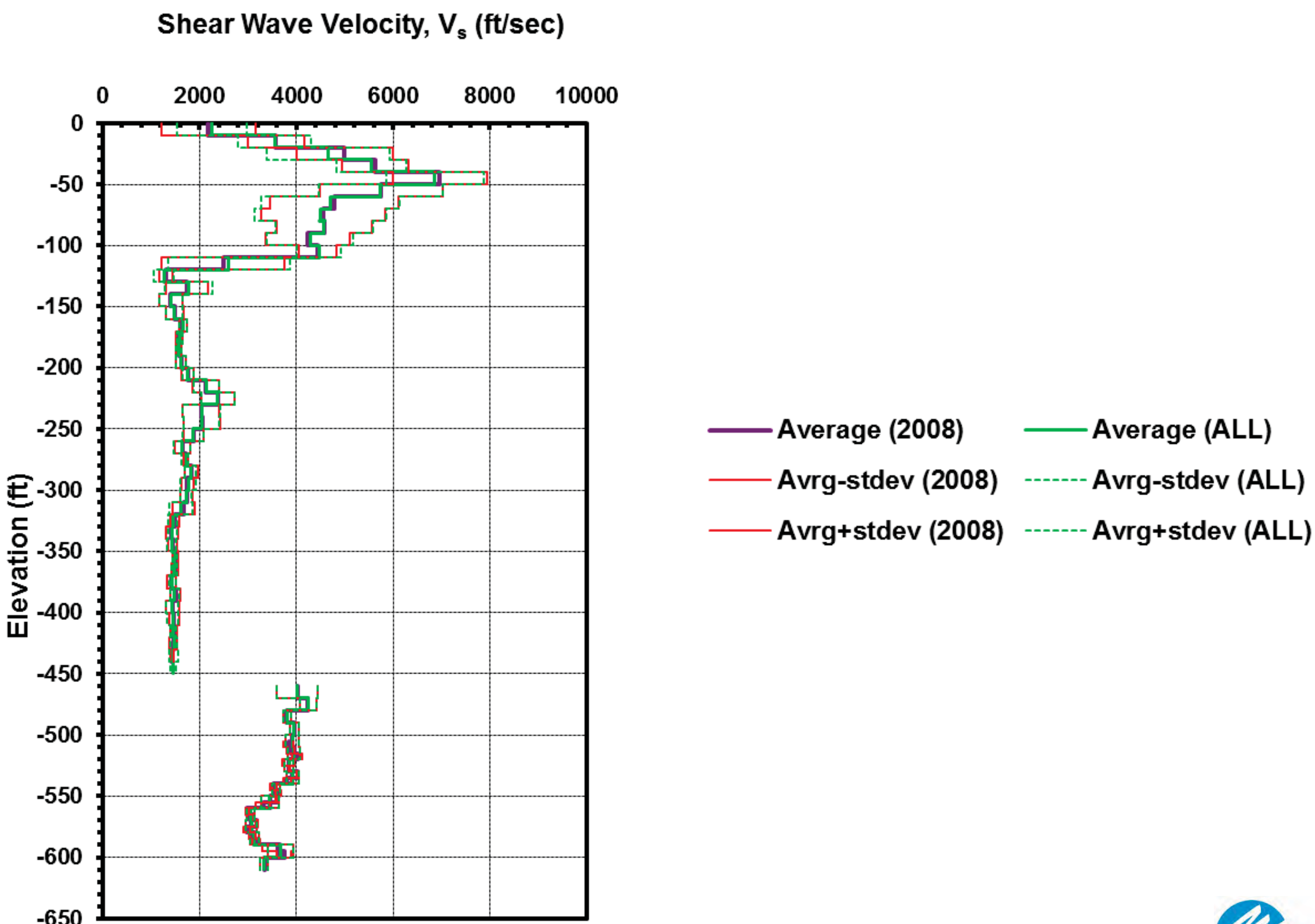
- All V_S measurements were obtained using P-S Suspension Logging
- V_S measurements were taken at 1.64-ft intervals
- For input to Site Response analysis, average and standard deviation of V_S were computed over 10-ft depth intervals
- Thus, for each boring, there were approx. 6 V_S measurements per 10-ft interval
- As an example, for 100-to-110-ft interval where V_S measurements were taken in all 12 borings, there were 12 x 6 = 72 V_S measurements from which to compute average and standard deviation of V_S
- As another example, for 500-to-510-ft interval where V_S measurements were taken in only one boring, there were 6 V_S measurements from which to compute average and standard deviation of V_S

Evaluation of Original & Combined Shear Wave Velocity (V_S) Data

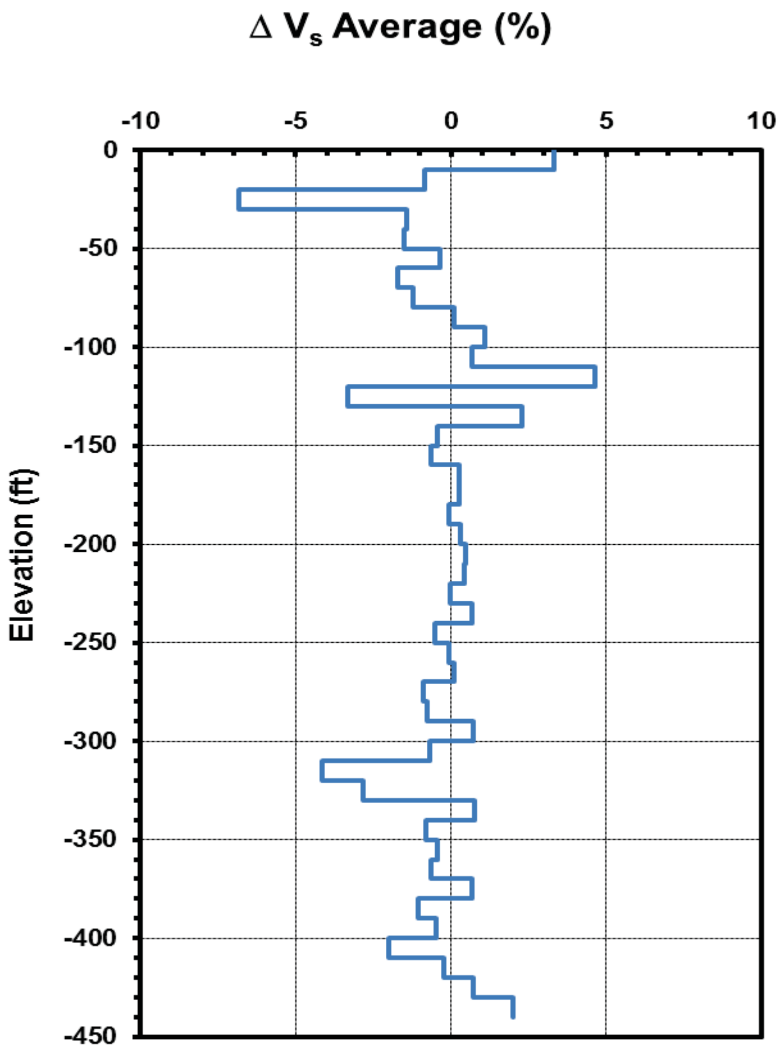
V_S Profiles for 2008 and 2013



Comparison of 2008 and 2008+2013 V_S Profiles



Average V_S Differences Between 2008 and 2008+2013 Data



$\Delta V_S = [(2008+2013)V_S - 2008V_S]/2008V_S$

Maximum Δ	=	– 6.83%
Minimum Δ	=	– 0.03%
Median Δ	=	– 0.28%
Median Δ (absolute value)	=	0.71%

Evaluation of Original & Combined Shear Wave Velocity (V_S) Data

Conclusion

- The differences in the two sets of V_S profiles (original and combined) are not significant
- Therefore, it is not necessary to re-run any analysis using the combined V_S profile

FPL

Evaluation of New Strain-Dependent Properties on Seismic Site Amplification

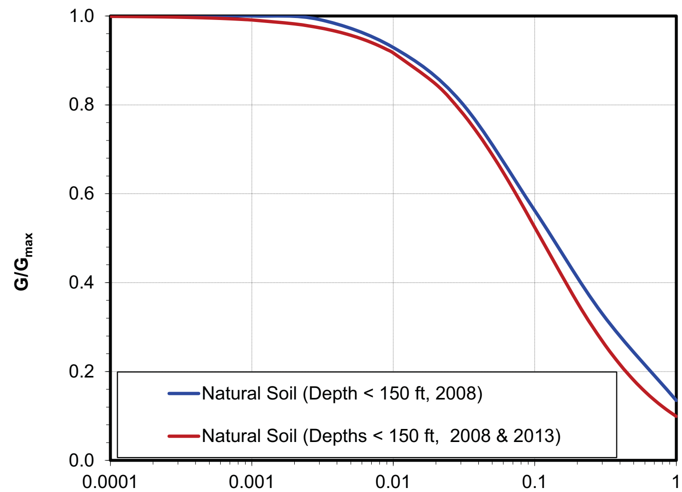
Strain-Dependent Properties

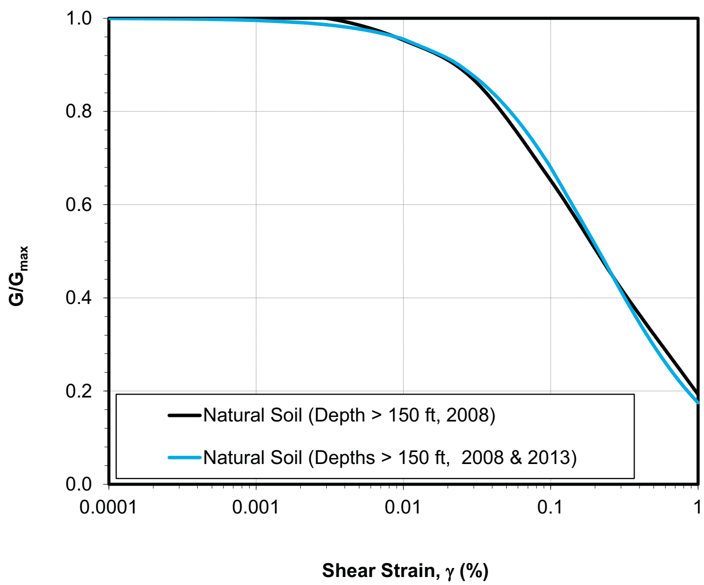
- **New Strain-dependent properties for soil & rock (2013)**
  - Updated shear-modulus reduction and damping ratio curves for the Key Largo and Fort Thompson formations (rock formations)
  - Updated shear-modulus reduction and damping ratio curves for "Natural soil" which includes the Tamiami Formation

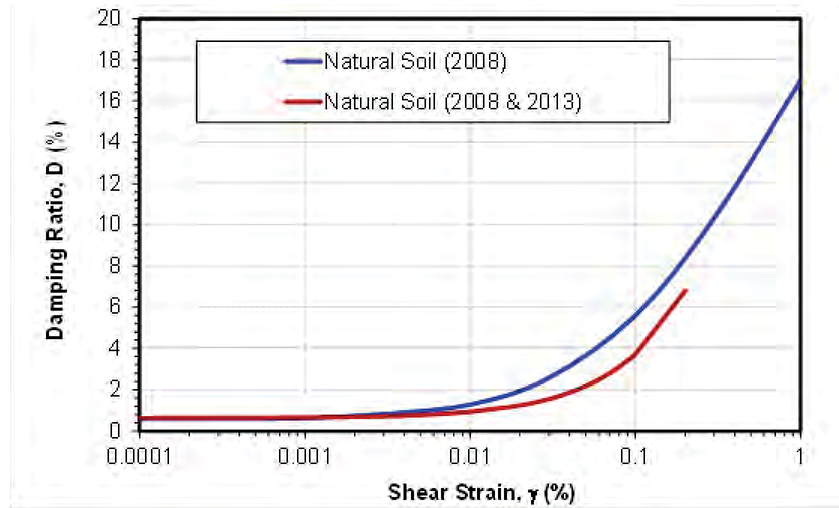
- **Original analysis (2008) used:**
  - Linear behavior and 1% strain-independent damping for rock
  - Shear-modulus reduction and damping ratio curves for "Natural soil" based on 2008 data

FPL

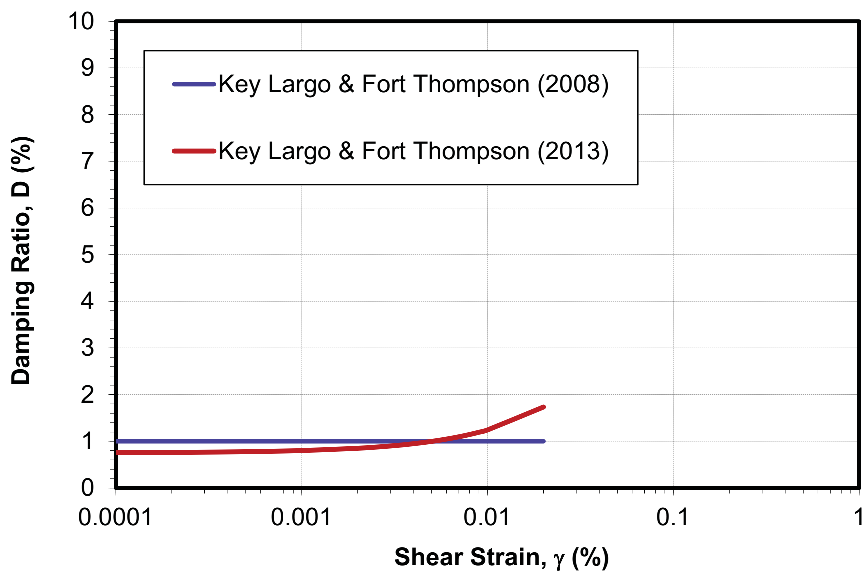
Comparison of Strain-Dependent Properties for "Natural Soil"



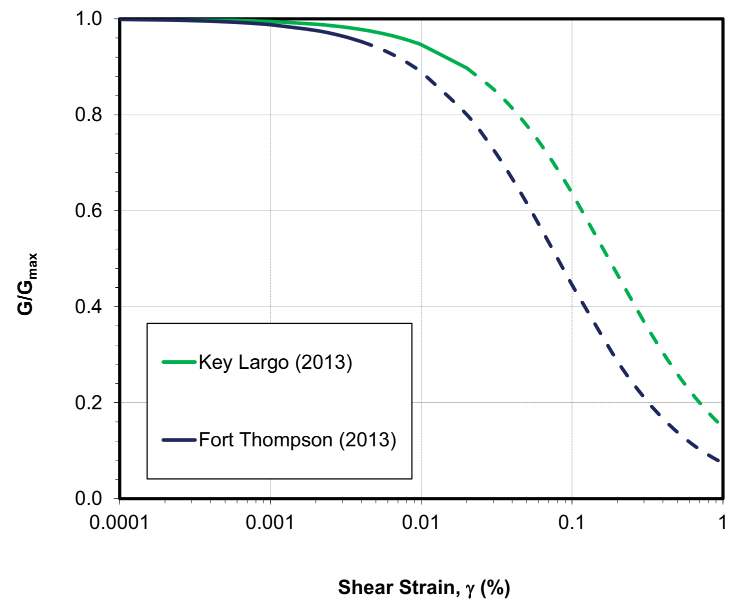




Comparison of Strain-dependent Properties for Rock



2008 used linear (no degradation)



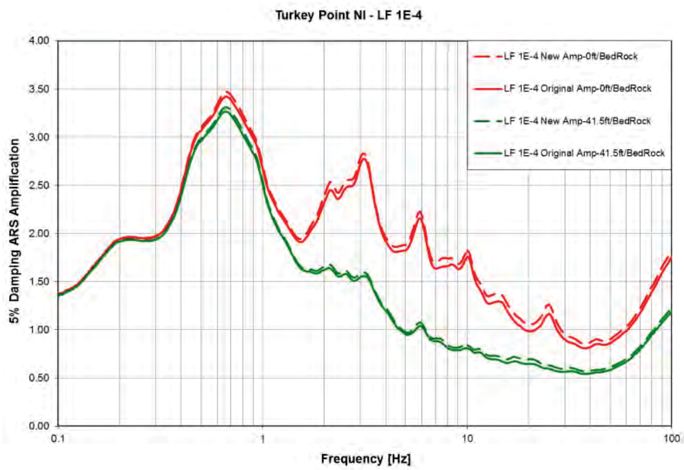
Evaluation of New Strain-Dependent Properties on Seismic Site Amplification

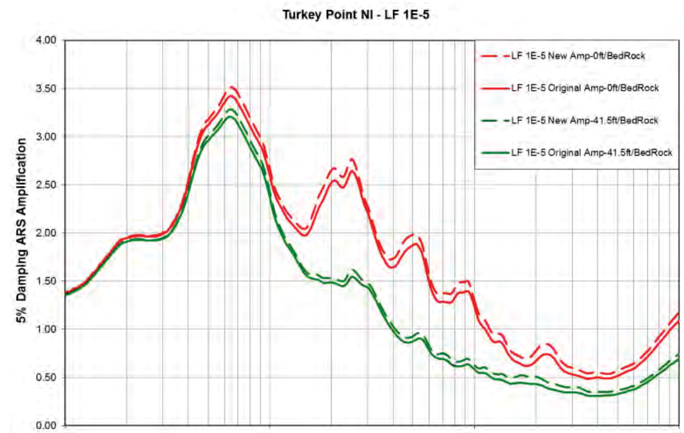
Sensitivity Analysis

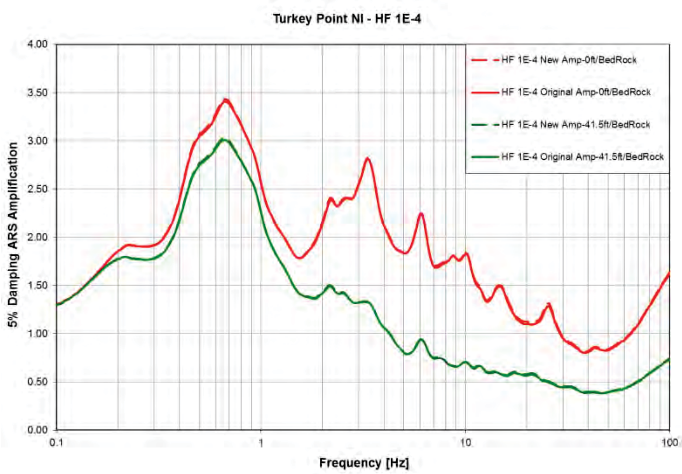
- **Analysis was conducted using the LB, BE and UB V_S profiles**
  - 1st set uses 2008 “Original” material non-linear properties for soil and rock
  - 2nd set uses 2013 “New” material non-linear properties for soil and rock
  - For both sets, only 2008 V_s profiles were used
- **Amplification Functions are calculated:**
  - At surface and at NI foundation elevation for both near and far from NI site conditions
  - At various input motion levels (LF and HF 1E-4, LF and HF 1E-5)
  - Average of LB, BE and UB response at each level

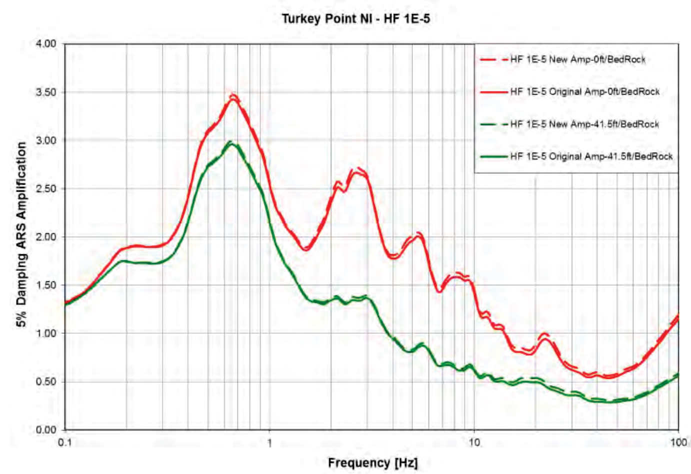
FPL

Near Nuclear Island (NI) Amplification Functions

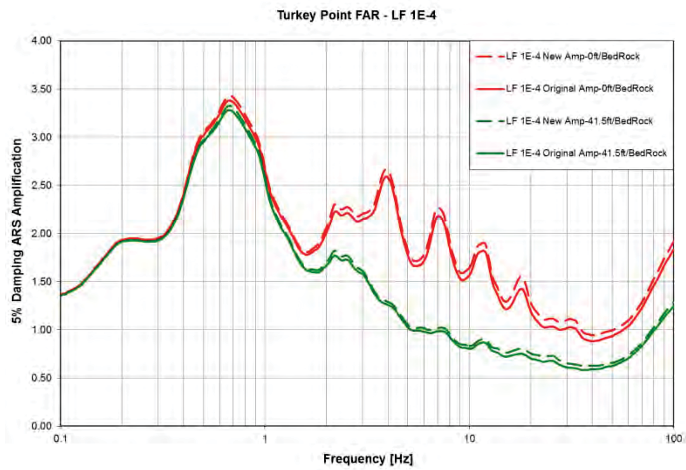


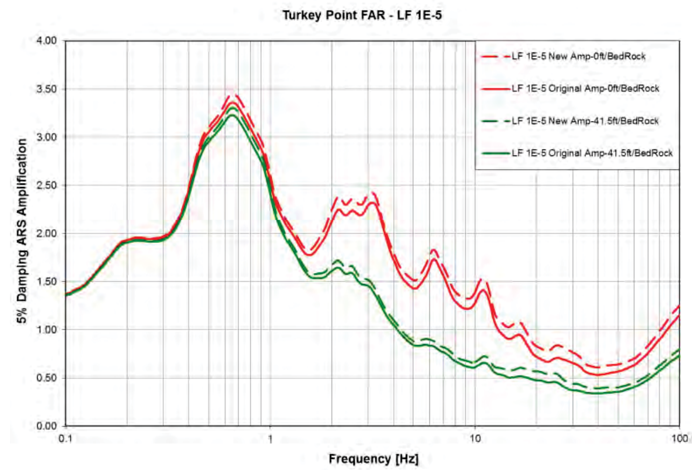


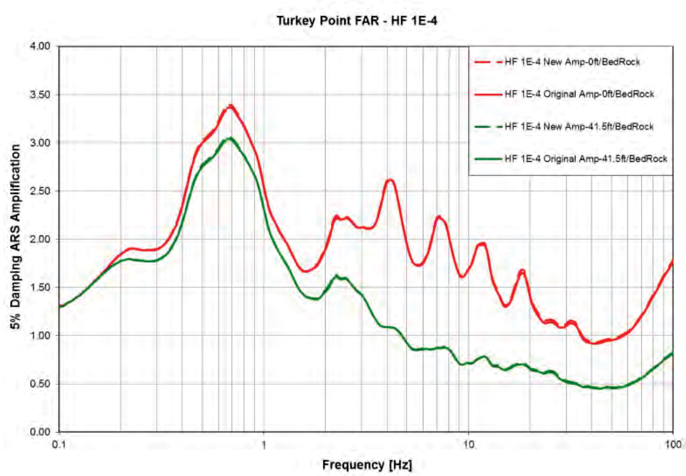


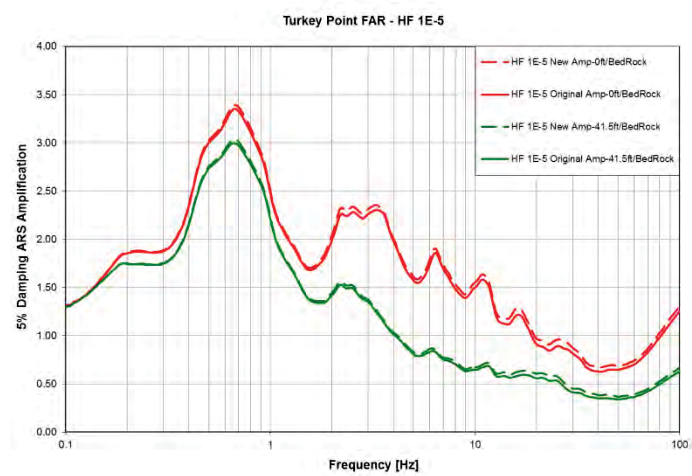


Far Field (FAR)
Amplification Functions

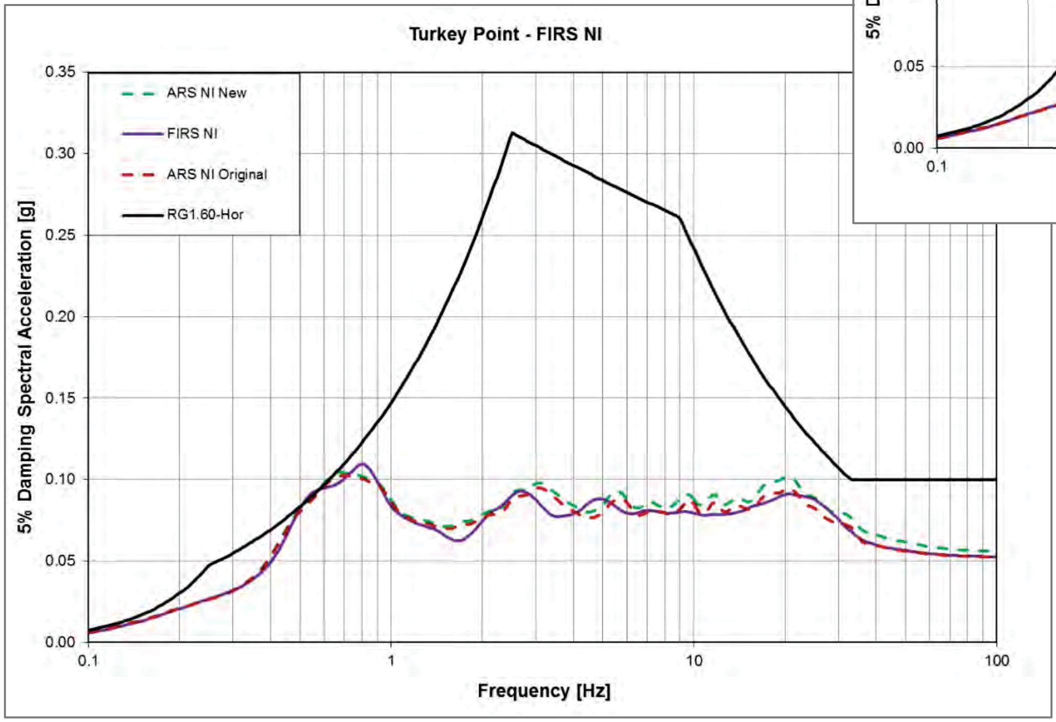


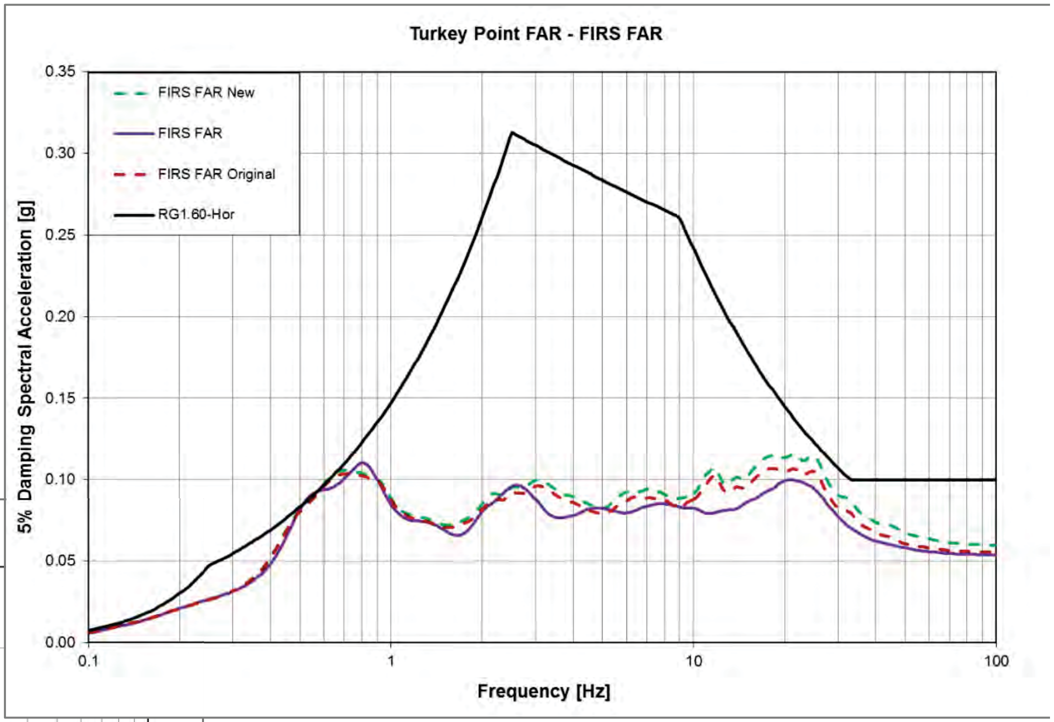






Effect on FIRS and SSE





Evaluation of New Strain-Dependent Properties on Seismic Site Amplification

Conclusions

- The newly acquired data has a small effect on the site amplification results, which were used to calculate the site-specific design response spectra for Turkey Point Units 6 & 7, resulting in an increased response
- A large margin exists between the site-specific motions and the broad-band Safe Shutdown Earthquake (SSE) response spectrum, adopted as the envelope of the Regulatory Guide 1.60 horizontal motion with a peak ground acceleration of 0.1 g and the site-specific Foundation Input Response Spectra (FIRS)
- The increase in seismic response is enveloped by the SSE at all frequencies, except at around 0.5 Hz, where the SSE exceedance is negligible (less than 2%), which is expected to reduce if 60 simulated profiles are used

Therefore, it can be concluded that the Turkey Point Units 6 & 7 SSE is not impacted by the new data, and no further analyses are required

FPL

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FPL

Impact of Updated Properties on Chapter 3.7 and 3.8

Seismic Input for Chapter 3.7 Analyses

- **The supplemental field investigation resulted in minor changes on shear wave velocity profile, G/G_{max} and damping curves input for Site Response Analysis**
- **Sensitivity study on Site Response Analysis indicate that input for seismic soil structure interaction (SSI) analysis remains unchanged**

Impact of Updated Properties on Chapter 3.7 and 3.8

Chapter 3.7 and 3.8 RAI Responses

- **RAI responses for Chapter 3.7 are still valid**
- **Minor changes to point to the relevant revised Chapter 2.5.4 RAI responses**
- **RAI 03.08.05-01 response will be revised to be consistent with the revised RAI 02.05.04-01 response**
- **Cross-Reference List**

Chapter 3 RAI	Corresponding Chapter 2.5.4 RAI
3.7.1-3	2.5.4-12
3.7.1-5	2.5.4-17
3.7.1-10	2.5.4-15, 2.5.4-16
3.7.1-14	2.5.4-12
3.7.1-19	2.5.4-15, 2.5.4-16
3.7.1-20	2.5.4-15

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- Impact of Updated Properties on Seismic Design (Ch. 3) [FPL]
- Opportunity for Public Comment
- Summary of discussions, path forward and wrap-up [FPL/NRC]
- **Adjourn**