Identification of High Pile Rebound Soils:

The Mysterious Case of the Bouncing Piles Phase II

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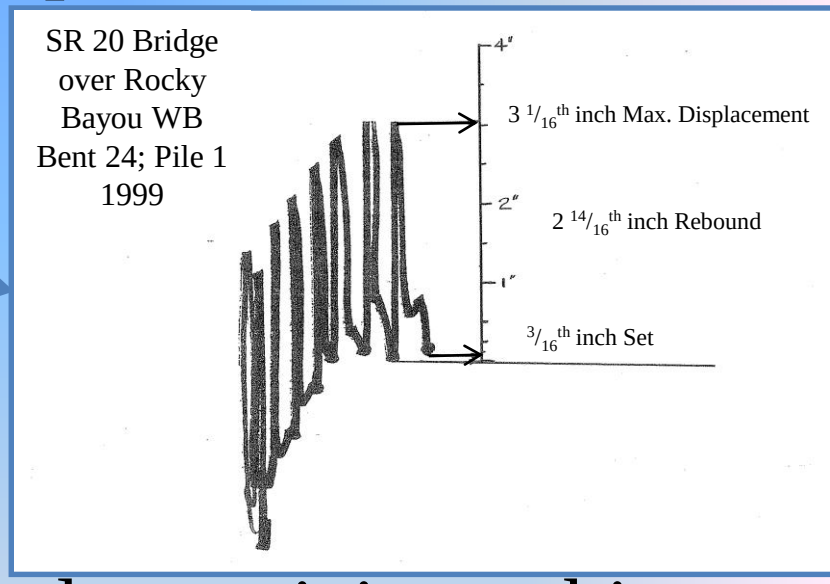
Defining the Problem

- **Excessive Pile Rebound and/or Bouncing**
  - ❖High Displacement Piles
  - ❖Typically Driven by Diesel Hammers
  - ❖Very Dense Saturated Silty Sands to Sandy Silts
- ***FDOT Section 455-5.10.3 Practical Refusal***
- **Design Capacities & Depths Not Achieved**

Project Overview

- Florida Pile Driving Sites experience > 0.25 inch rebound
  - Manual Data

SR 20 Bridge over Rocky Bayou WB Bent 24; Pile 1 1999



- Engineers & Contractors need to anticipate this problem

Approach

- Soil Property Evaluations
- Cyclic Loading Evaluations
- Field Testing Evaluations

Phase I

- Retested Soils at 3 sites
  - I-4/SR 408 Anderson Street Overpass
  - I-4/John Young Parkway
  - Ramsey Branch Bridge SR 83 US 331 over Choctawhatchee Bay: District 3
- SPT, CPT, PMT, DMT
- Shelby Tubes

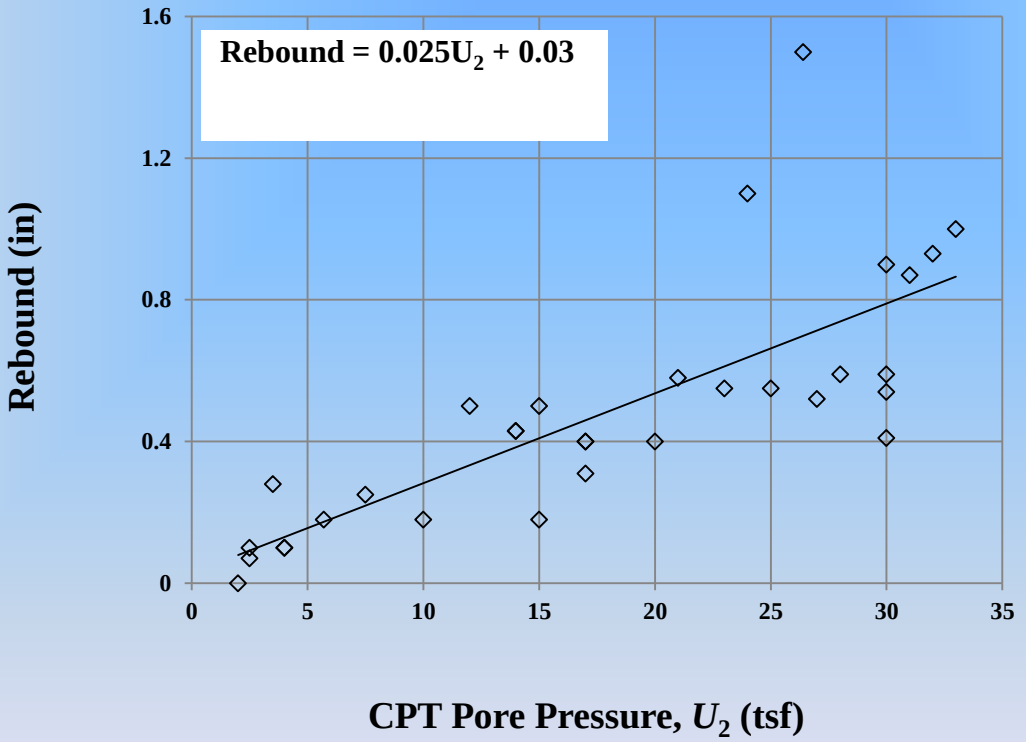
Fines Content and N-Value Summary

Site Name	Fines Content Rebound Soil (%)	N Rebound Soil (blows/ft)
Anderson Street	19	27
John Young	17	16
Ramsey Branch	20	7

Interim FIT research

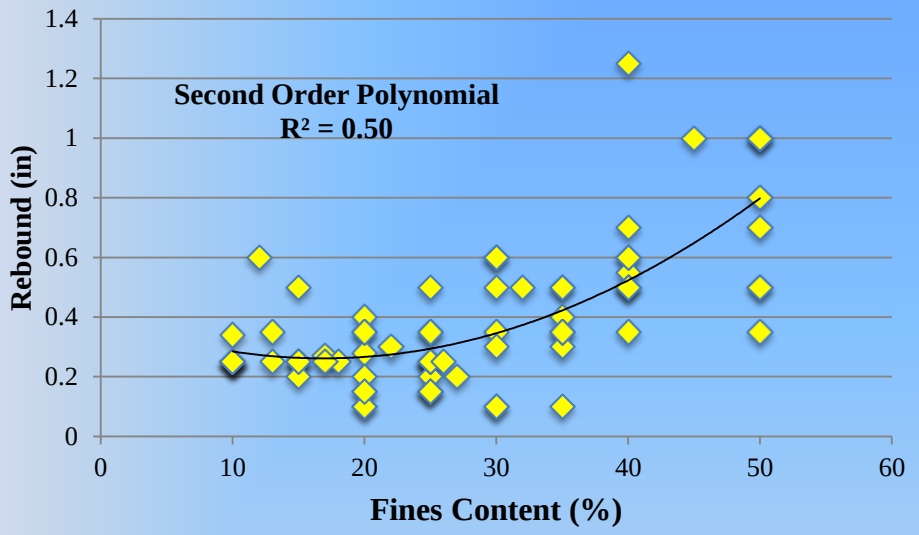
- FDOT SMO worked with us
- Jarushi (2012) tested additional sites
- Correlations
  - Fines content
  - SPT N-values
  - CPTu pore pressure
- Plotted data on Soil Behavior Charts

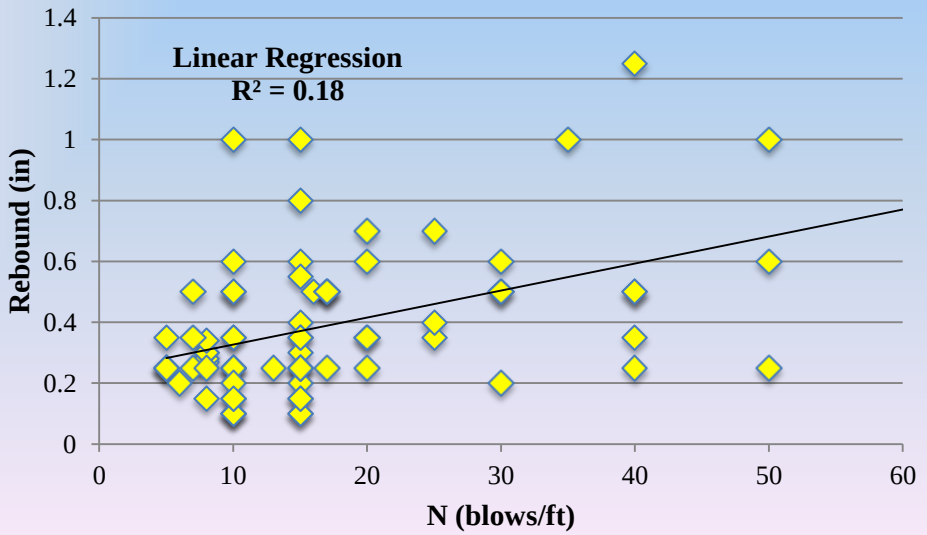
Rebound & CPT Pore Water Pressure



Soils: Typically Fine Sand with Silts or Clays

Fines Content and N vs Rebound





- Still under evaluation
- SPT will penetrate hard/dense layers
- CPT would not
- Weak correlations

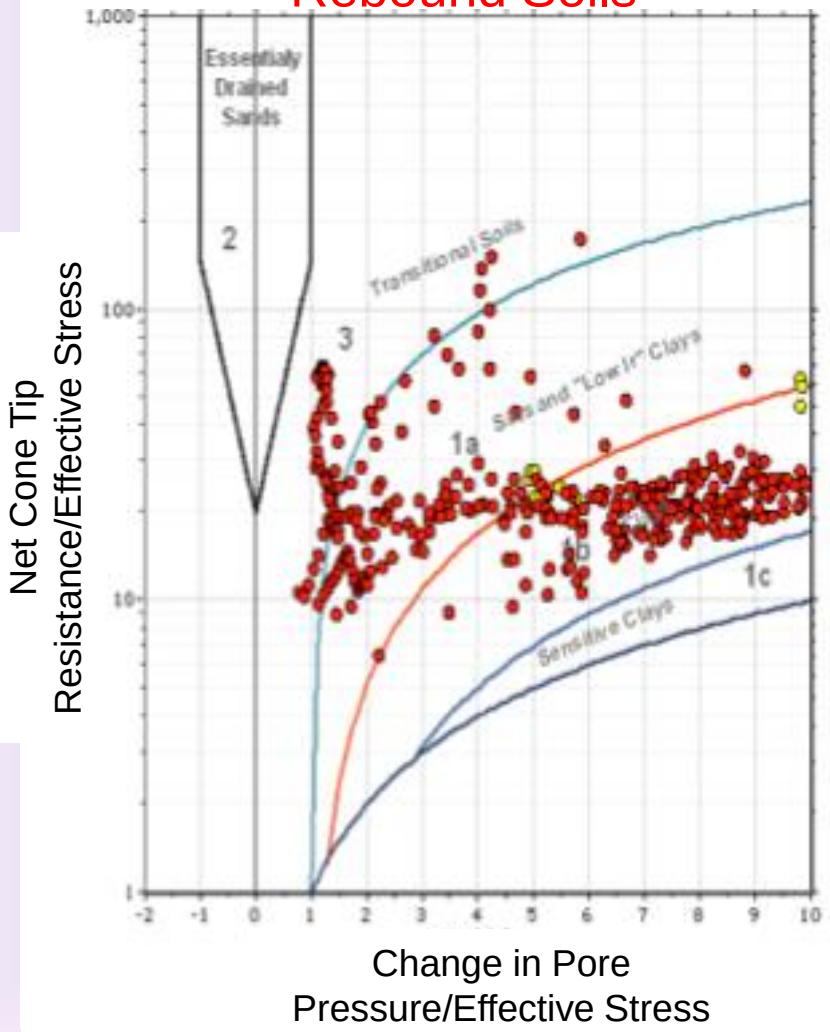
Soil Behavior Type [SBT] Charts

- Schmertmann (1978)
  - CPT $q_c - f_s$
- Eslami & Fellenius (2004)
  - CPTu $q_E - f_s$
- Robertson (1990)
  - $Q_{tn} - R_f$ CPT chart
- Robertson (1990)
  - Q_{tn} – Fr CPT
  - $Q_{tn} - B_q$ CPTu
- Schneider et al. (2008)
  - $q_{cnet}/\sigma_{vo} - [\Delta u_2/\sigma_{vo}]$ CPTu

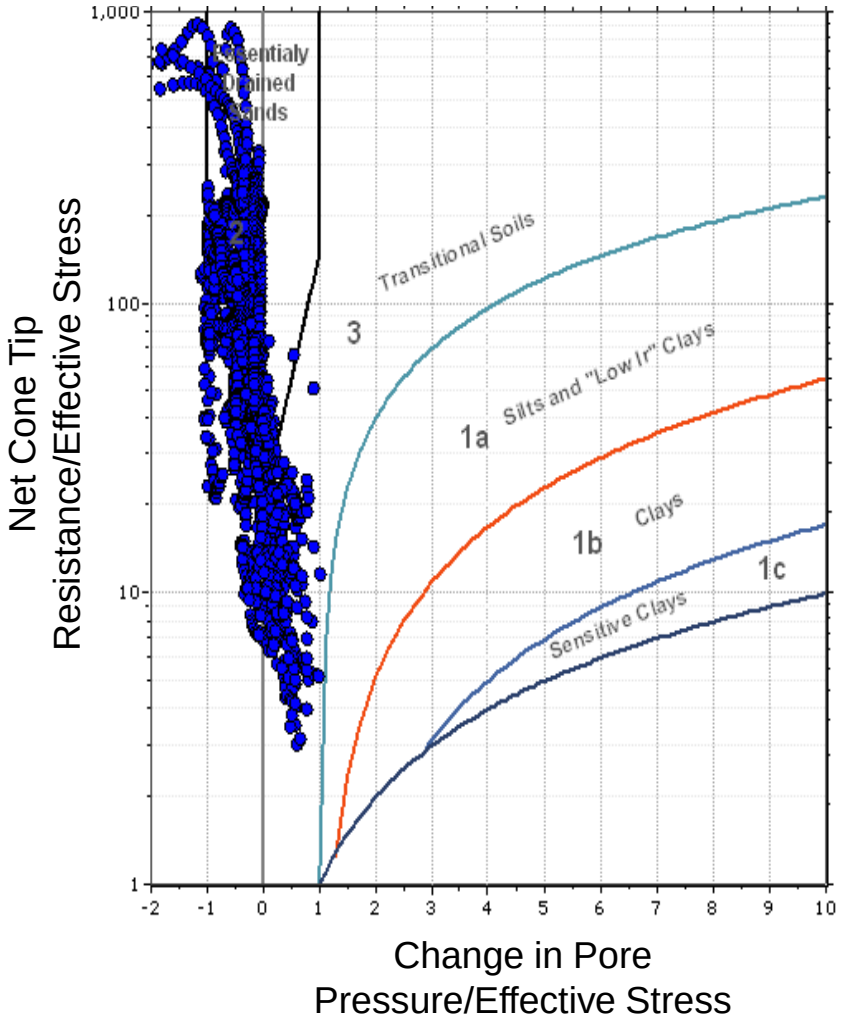
- Cone Point = q_c
- Effective Cone Point = q_E
- Friction = f_s
- Friction Ratio = R_f
- Normalized $q_t = Q_{tn}$
- $q_t = q_c - u_2(1-a)$
  - a= net pore pressure area ratio
- Normalized $f_s = F_r$
- Pore Pressure Ratio = B_q
- Normalized $q_{cnet} = q_t - \sigma_{vo}$

Schneider SBT

Rebound Soils



Non-rebound Soils



Interim Conclusions

- Rebound is a function of
  - Fines Content ?
  - N values ?
  - CPTu pore pressure
- Schneider et al SBT charts show clear differences

Phase II Research Objective

- Prove these correlations and SBT charts are reliable

Phase II Tasks

- Task 1 - Literature Search
- Task 2 - Develop Locations of New Testing Sites
- Task 3 - Test Program for New Testing Sites
- Task 4 - Field Data Reduction
- Task 5 - Laboratory Testing &Reduction of Disturbed Samples
- Task 6 - Laboratory Testing, Reduction &Analysis of Shelby Tube Samples
- Task 7 - Analyze Reduced Laboratory Data from Testing
- Task 8 - Analyze Reduced Field Data
- Task 9 - Technology Transfer for Reporting and Presentations

Literature Findings

- High Displacement Piles
- Florida -- Eastern Canada --Washington State
- Rebound & High Toe Quake occur
- Rebound Soils Dense or Hard

Critical Cyclic Parameters

Reference	CSL	LFC	Load Duration (s)	Soil Description
Putri at al. (2012)	0.3-0.38	N/A	N/A	Clay with sand
Awad (1975)	0.37-0.5	N/A	45	Silty clay
Moses and Rao (2003)	0.25-0.7	N/A	6, 12 ,20	Marine clay
Puppala et al. (2004)	0.2,0.4,0.6	N/A	1	Sandy clay soils
Shahin et al. (2011)	0.36, 0.71	N/A	1	Soft Clay
Okur et al. (2008)	0.35	N/A	10	Fine grain soils
Dash and Sitharam (2009)	0.128-0.154	21%	1	Silty sand

- CSL= Critical Stress Level 0.25 to 0.60 typical
- LFC= Limiting Fines Content Generally not reported
- Load Durations slow

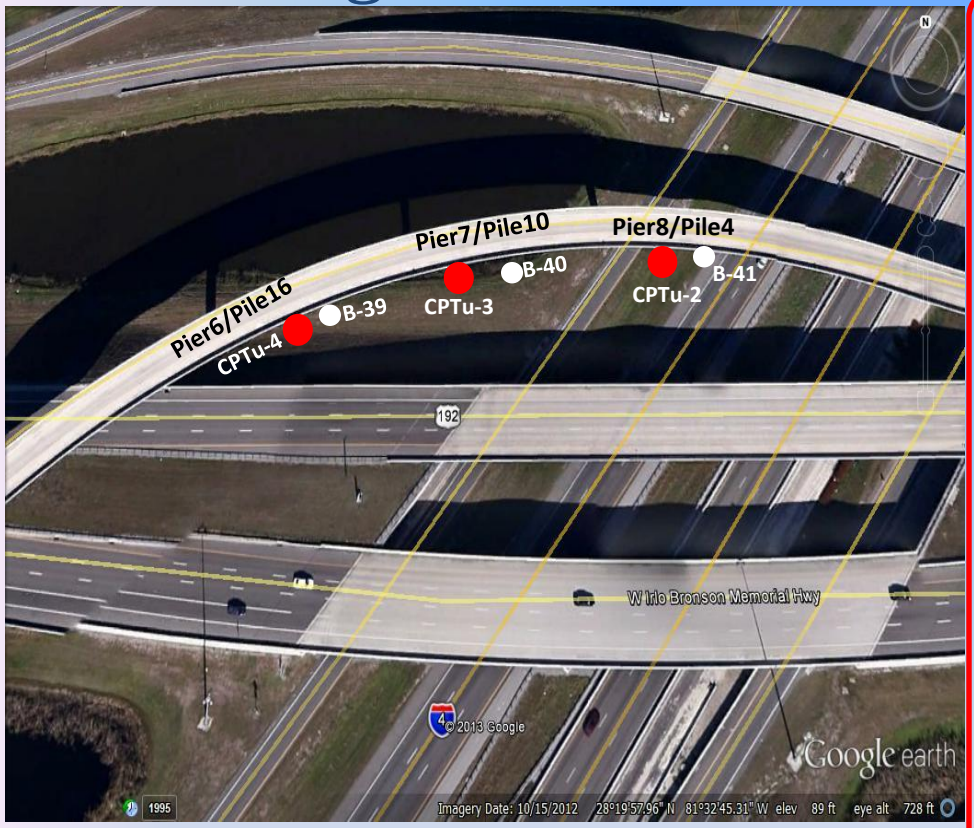
HPR Testing Summary

Sites No.	Description	County	Soil Data Retrieved	PDA Data Retrieved
1	Anderson St. Overpass at I-4/SR-408	Orange	Yes	Yes
2	I-4/SR-408 Ramp B	Orange	Yes	Yes
3	I-4/US-192	Osceola	Yes	Yes
4	I-4 Osceola Parkway	Osceola	Yes	Yes
5	I-4/SR-423 John Young Parkway	Orange	Yes	Yes
6	I-4/SR-482 Sand Lake Rd.	Orange	Yes	Yes
7	SR-50 and SR-436	Orange	Yes	Yes
8	SR -417 and International Drive	Osceola	Yes	Yes
9	SR-528 and US 441	Orange	Yes	Yes
10	SR-83 Ramsey Branch	Walton	Yes	Yes
11	SR-528 over Indian River	Brevard	Yes	Yes
12	I-10 at Chaffee Road	Jacksonville	Yes	Yes
13	Heritage Parkway Palm Bay	Brevard	No	Yes
14	I-4 Widening Daytona	Volusia	Yes	Yes
15	SR-83 Ramsey Branch Revisited	Walton	Yes	No

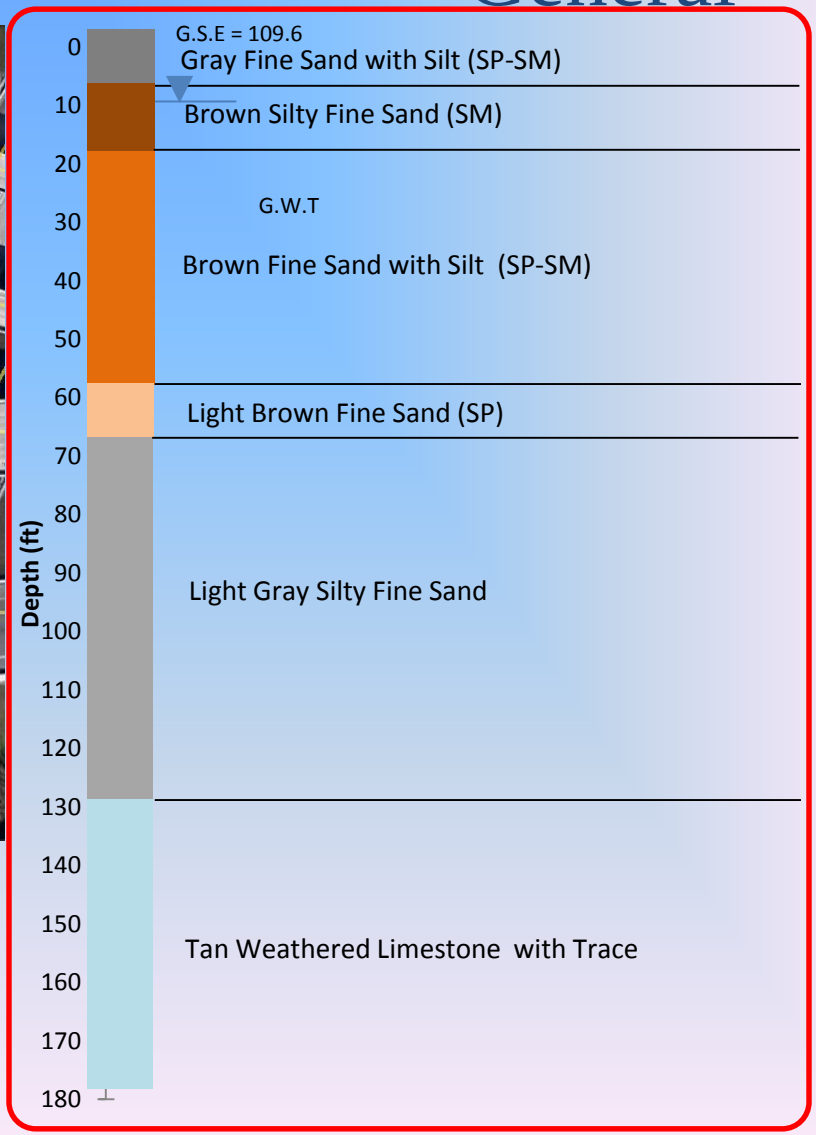
Florida Institute of Technology

I-4/US-192 …… Osceola County

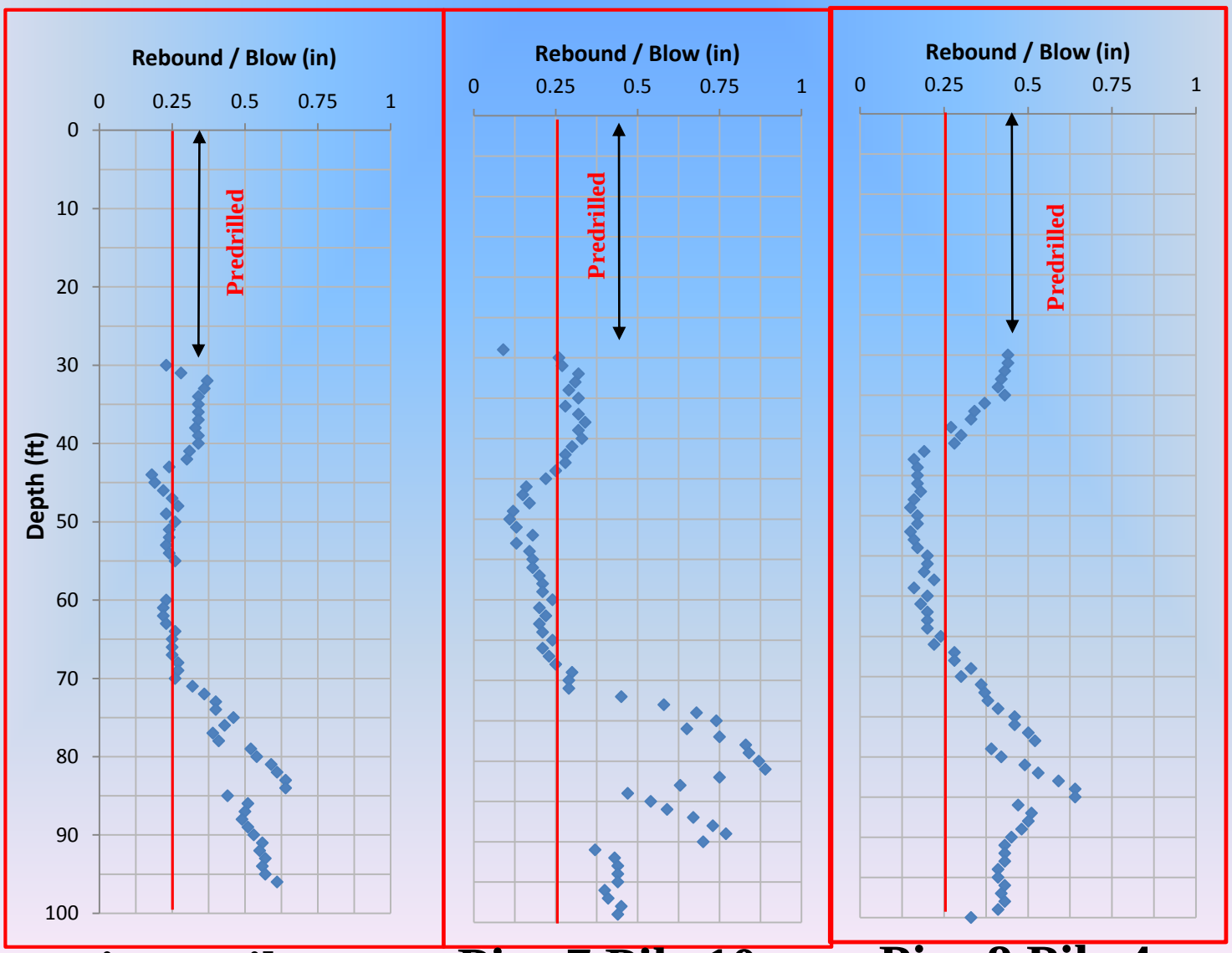
Testing Locations



General

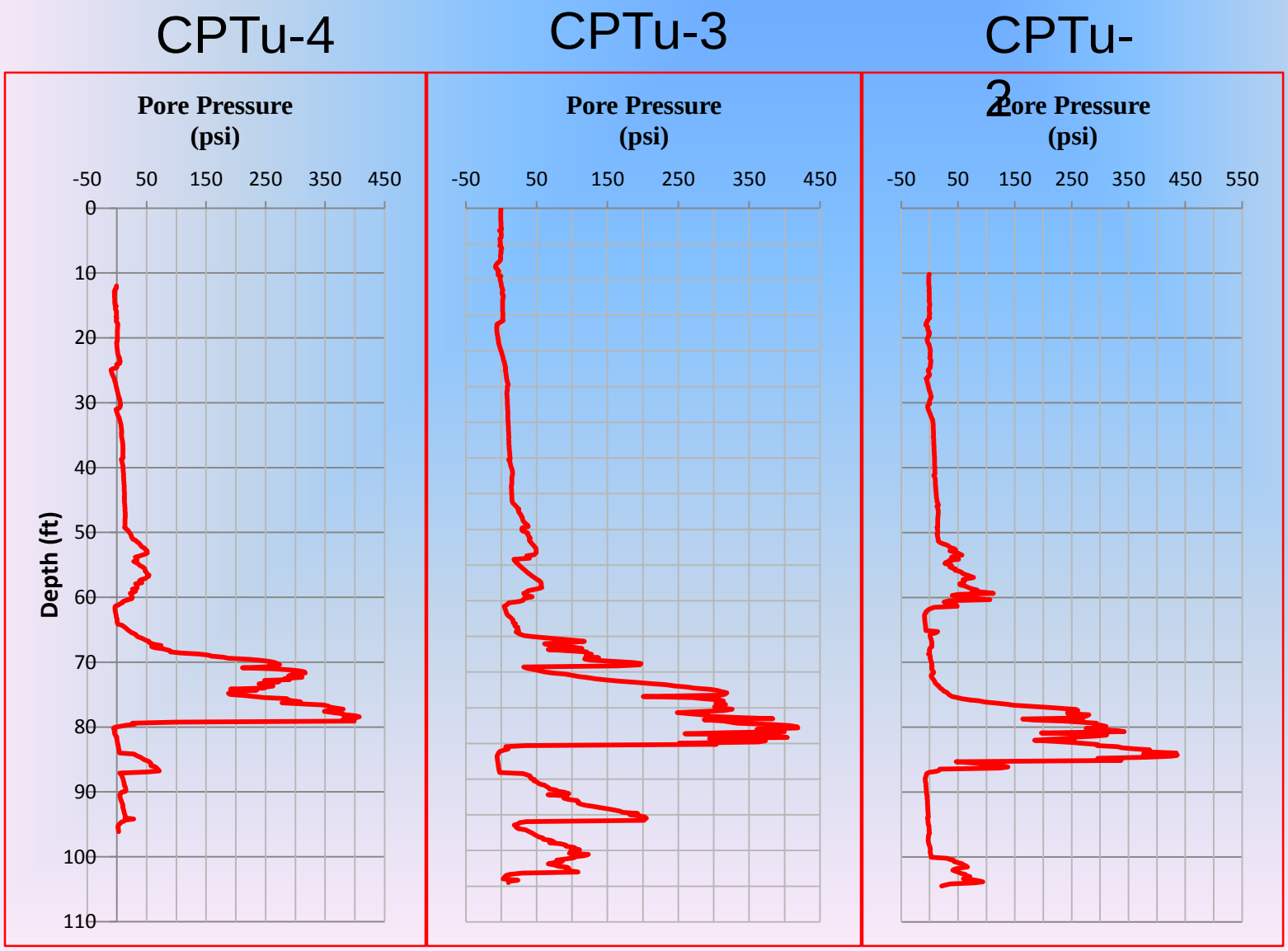


I-4/US-192 … PDA Data

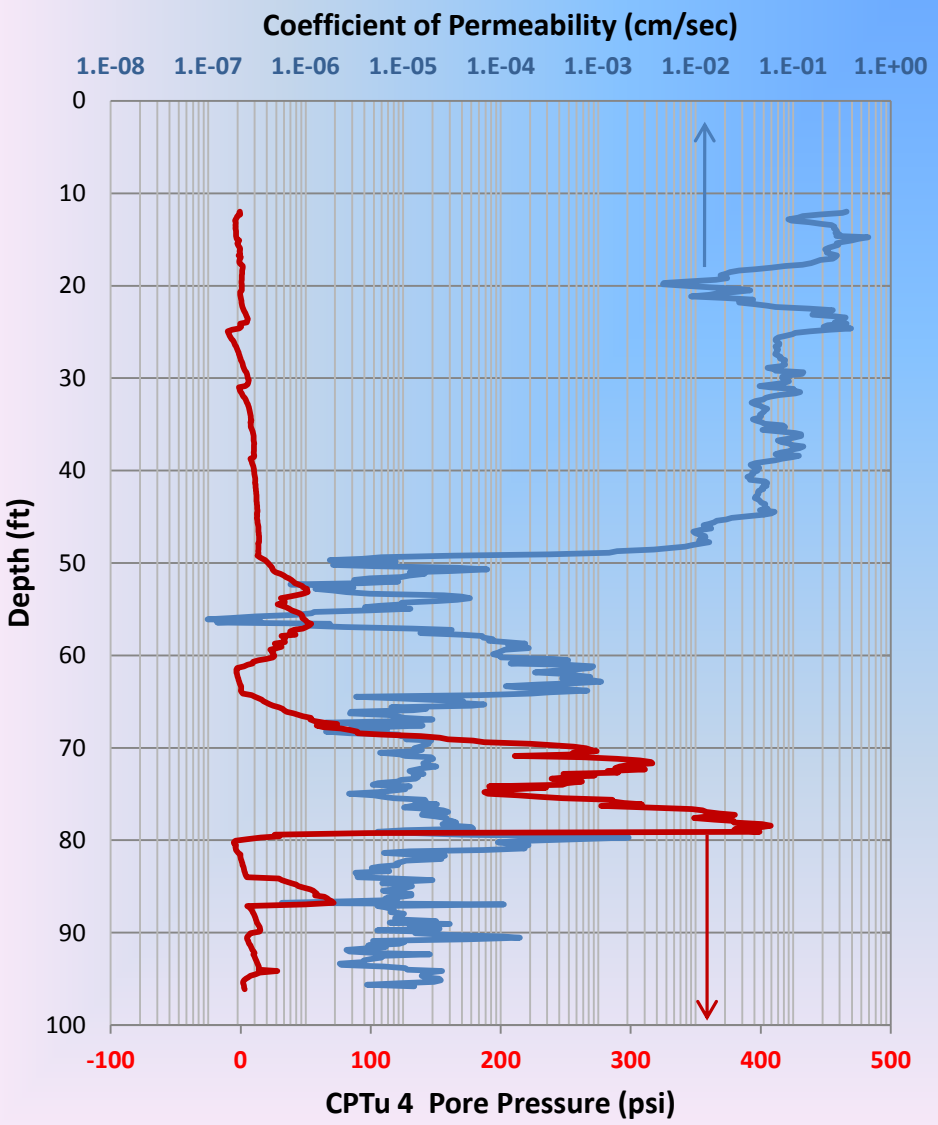


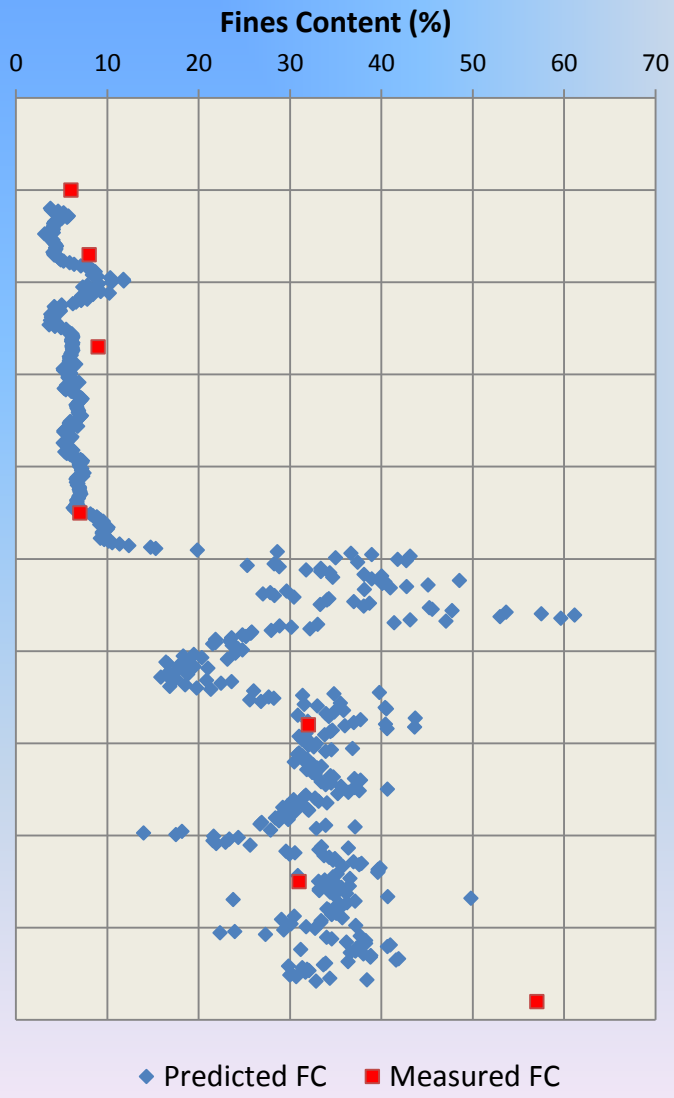
CPTu Data

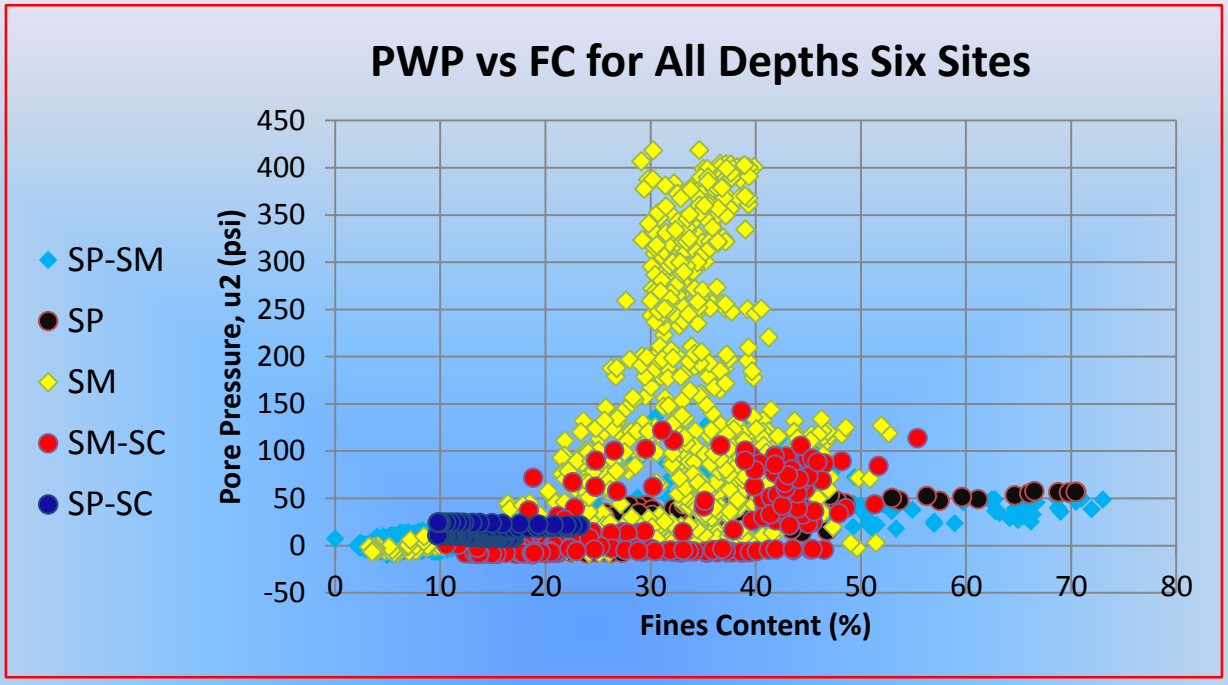
High Pore Pressure (over 400 psi) at rebound depth (70 ft)

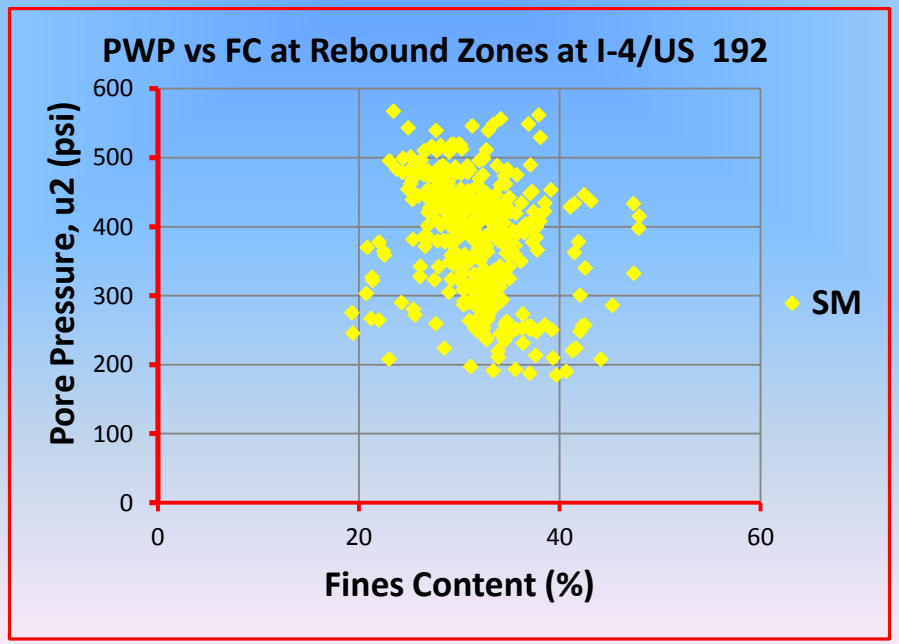


Estimated Soil Properties Based on CPTu Data

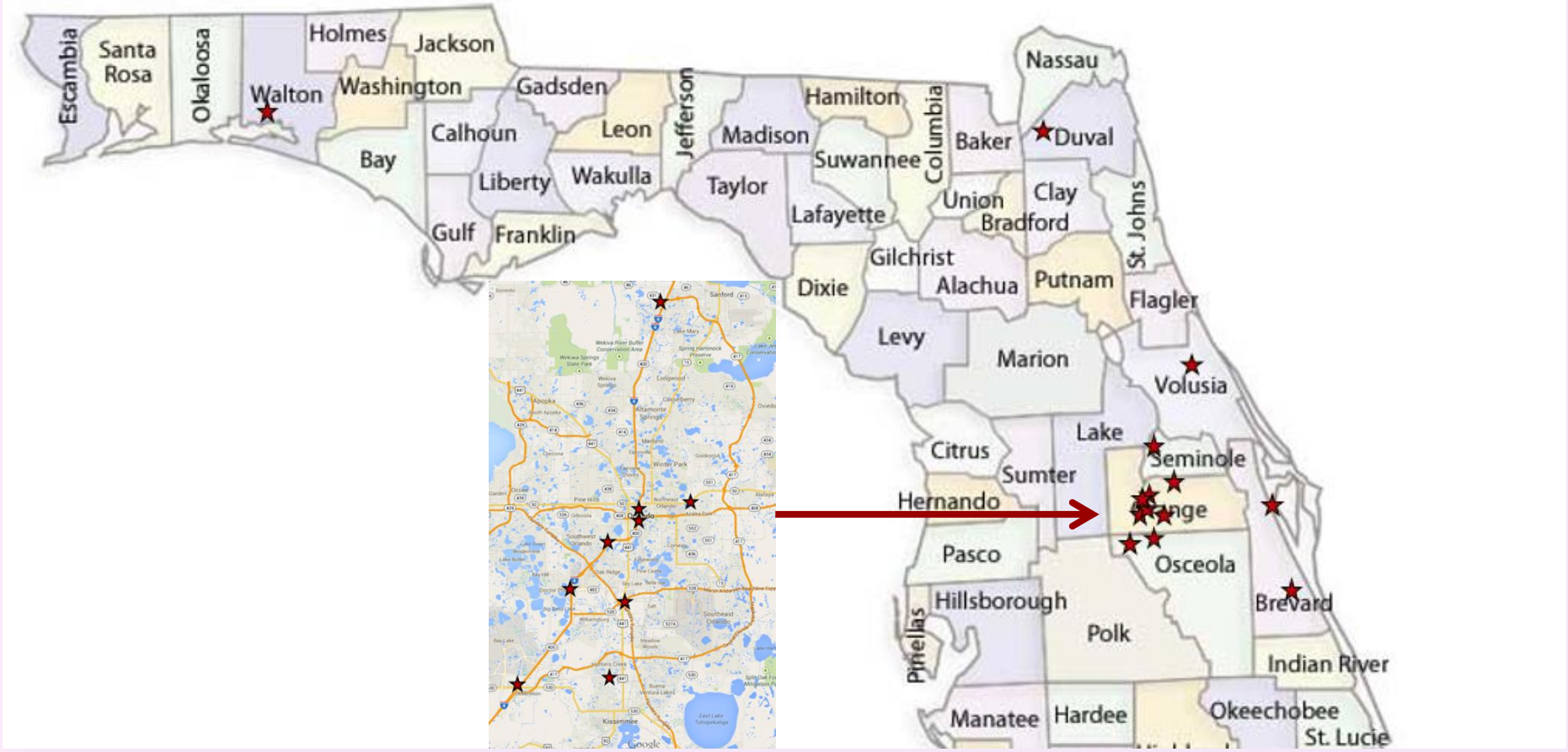





PWP vs FC for All Depths Six Sites
SP-SM
SP
SM
SM-SC
SP-SC
Pore Pressure, u2 (psi)
450
400
350
300
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80
Fines Content (%)


PWP vs FC at Rebound Zones at I-4/US 192
Pore Pressure, u2 (psi)
600
500
400
300
200
100
0
0
20
40
60
Fines Content (%)
SM

Questions ?


Escambia
Santa Rosa
Okaloosa
Walton
Holmes
Washington
Jackson
Bay
Calhoun
Gadsden
Liberty
Wakulla
Leon
Jefferson
Gulf
Franklin
Madison
Taylor
Hamilton
Suwannee
Lafayette
Columbia
Nassau
Duval
Baker
Union
Bradford
Clay
St. Johns
Gilchrist
Alachua
Dixie
Putnam
Flagler
Levy
Marion
Volusia
Lake
Citrus
Sumter
Seminole
Hernando
Pasco
Osceola
Hillsborough
Brevard
Polk
Pinellas
Indian River
Manatee
Hardee
Okeechobee
St. Lucie