

# UNINTENDED CONSEQUENCES

## KARST IN SOUTH CAROLINA'S LOW COUNTRY

Stephen Geiger, P.E.  
ECS Southeast, LLP  
April 9<sup>th</sup> to 11<sup>th</sup>, 2018



# SOUTH CAROLINA GEOLOGY

GGMS-1



## Generalized Geologic Map of South Carolina 2005

Revised by  
Willoughby, Howard, and Nystrom, 2005  
Original compilation by  
Maybin and Nystrom, 1997

### DESCRIPTION OF MAP UNITS

#### COASTAL PLAIN

##### QUATERNARY

- Holocene
- Pleistocene

##### TERTIARY

- Pliocene
  - Paleocene, Eocene, and Miocene
- ##### CRETACEOUS
- Upper Cretaceous

#### TRIASSIC

- Triassic basins

#### BLUE RIDGE AND PIEDMONT

- Blue Ridge
- Chauga belt
- Walhalla thrust sheet
- Sixmile thrust sheet
- Laurens thrust stack
- Kings Mountain terrane
- Charlotte terrane
- Carolina terrane (slate belt)
- Savannah River terrane
- Augusta terrane

#### INTRUSIVE IGNEOUS ROCKS

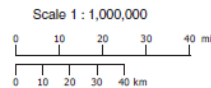
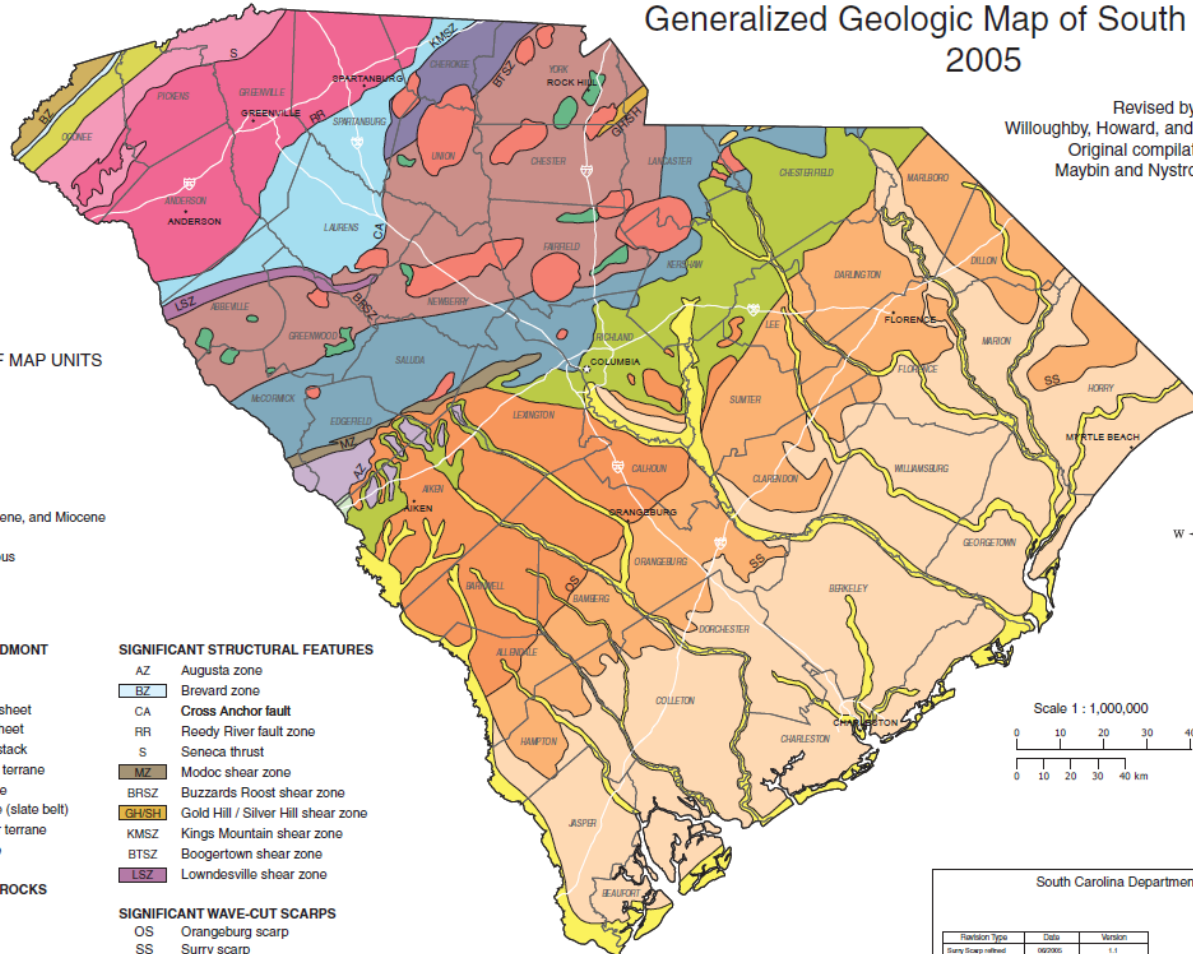
- Gabbro
- Granite

#### SIGNIFICANT STRUCTURAL FEATURES

- AZ Augusta zone
- BZ Brevard zone
- CA Cross Anchor fault
- RR Reedy River fault zone
- S Seneca thrust
- MZ Modoc shear zone
- BRSZ Buzzards Roost shear zone
- GHSH Gold Hill / Silver Hill shear zone
- KMSZ Kings Mountain shear zone
- BTSZ Boogertown shear zone
- LSZ Lowndesville shear zone

#### SIGNIFICANT WAVE-CUT SCARPS

- OS Orangeburg scarp
- SS Surry scarp



South Carolina Department of Natural Resources,  
Geological Survey  
5 Geology Road  
Columbia, SC 29212  
(803) 896-7708

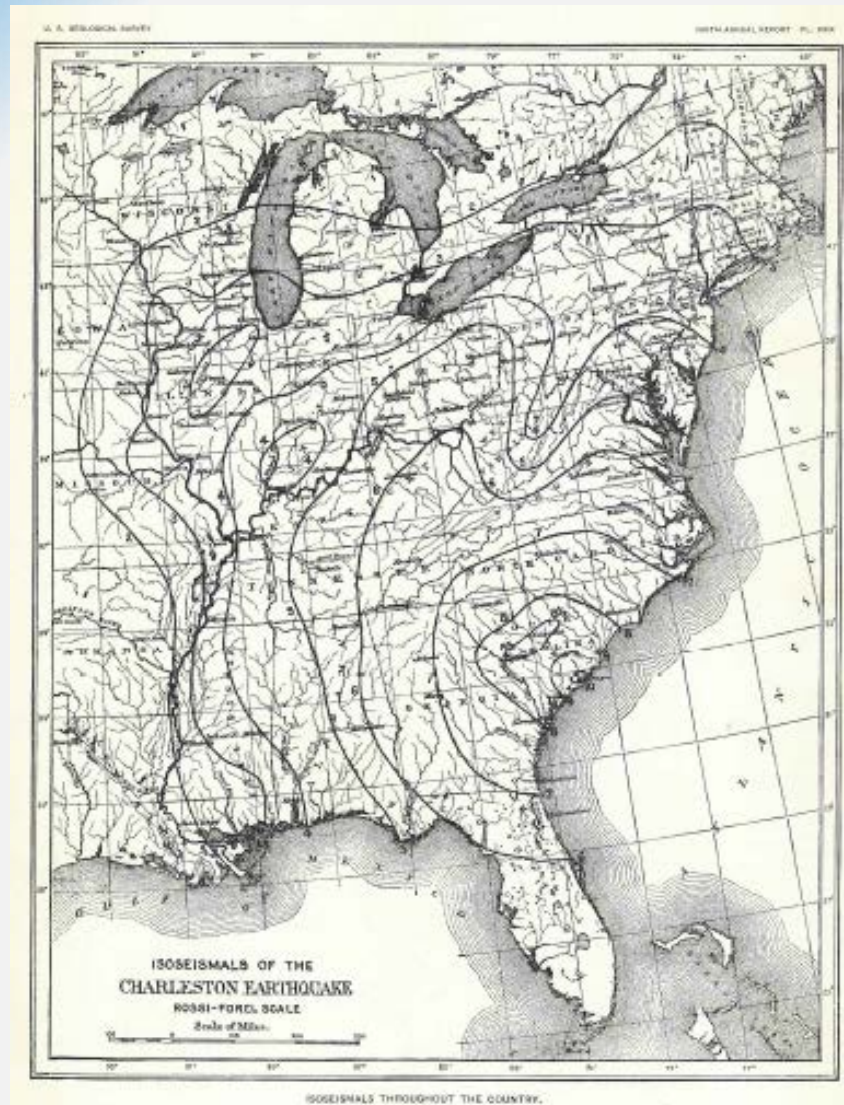
Revision Type	Date	Version
Survey Scope method	06/2006	1.1
Geology content	04/2006	2.0

For this and other publications please visit:  
[www.dnr.sc.gov/geology](http://www.dnr.sc.gov/geology)

















# SOUTH CAROLINA COASTAL PLAIN GEO-HAZARDS

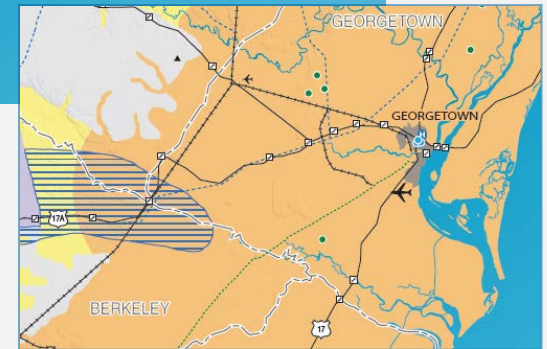
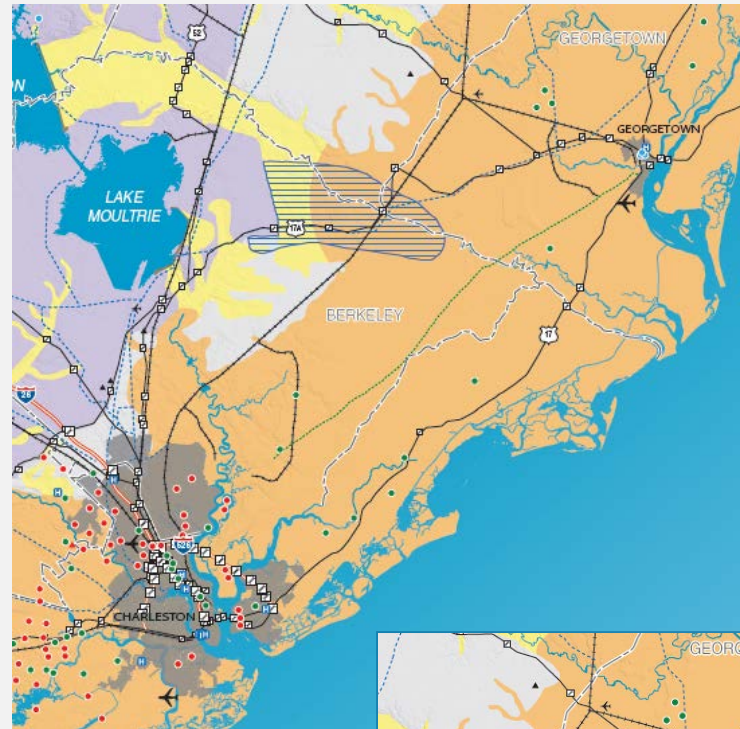


# SOUTH CAROLINA COASTAL PLAIN GEO-HAZARDS IN AREA OF INTEREST

## MAP GUIDE

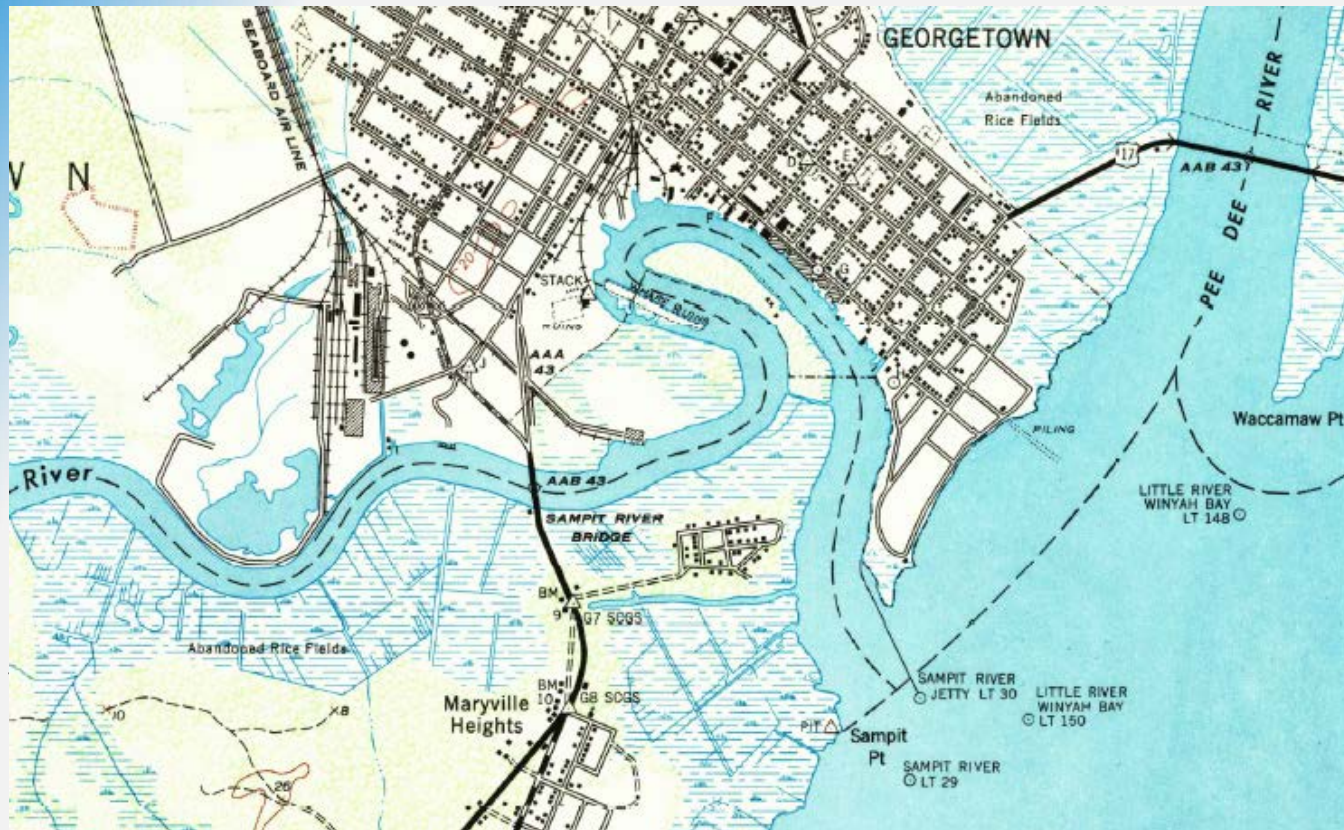
-  High Potential for Liquefaction \*
-  Low Potential for Liquefaction
-  Potential for Collaspe
-  Potential for Sinkholes \*
-  Potential for Landslide
-  Low geologic hazard potential
-  Fall Line

-  Liquefaction features caused by 1886 Charleston Earthquake
-  Prehistoric Liquefaction features \*
-  Known Sinkhole Occurrences \*
-  Limestone Cave
-  Landslide Occurrence



# GEORGETOWN, SOUTH CAROLINA

Third Oldest City in the United States  
Spaniards 1526, French 1562, English 1721, Chartered 1729

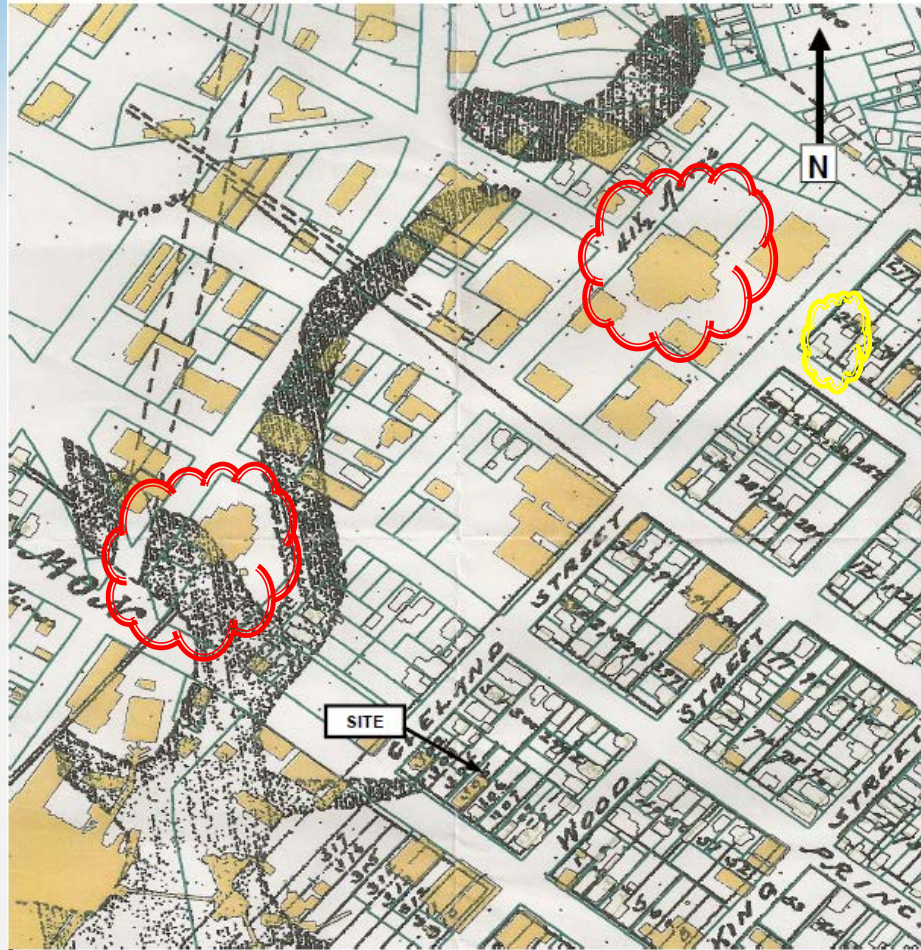


County Population = 63,000  
MHI = \$41,500

# GEORGETOWN'S "MOST" FAMOUS SON

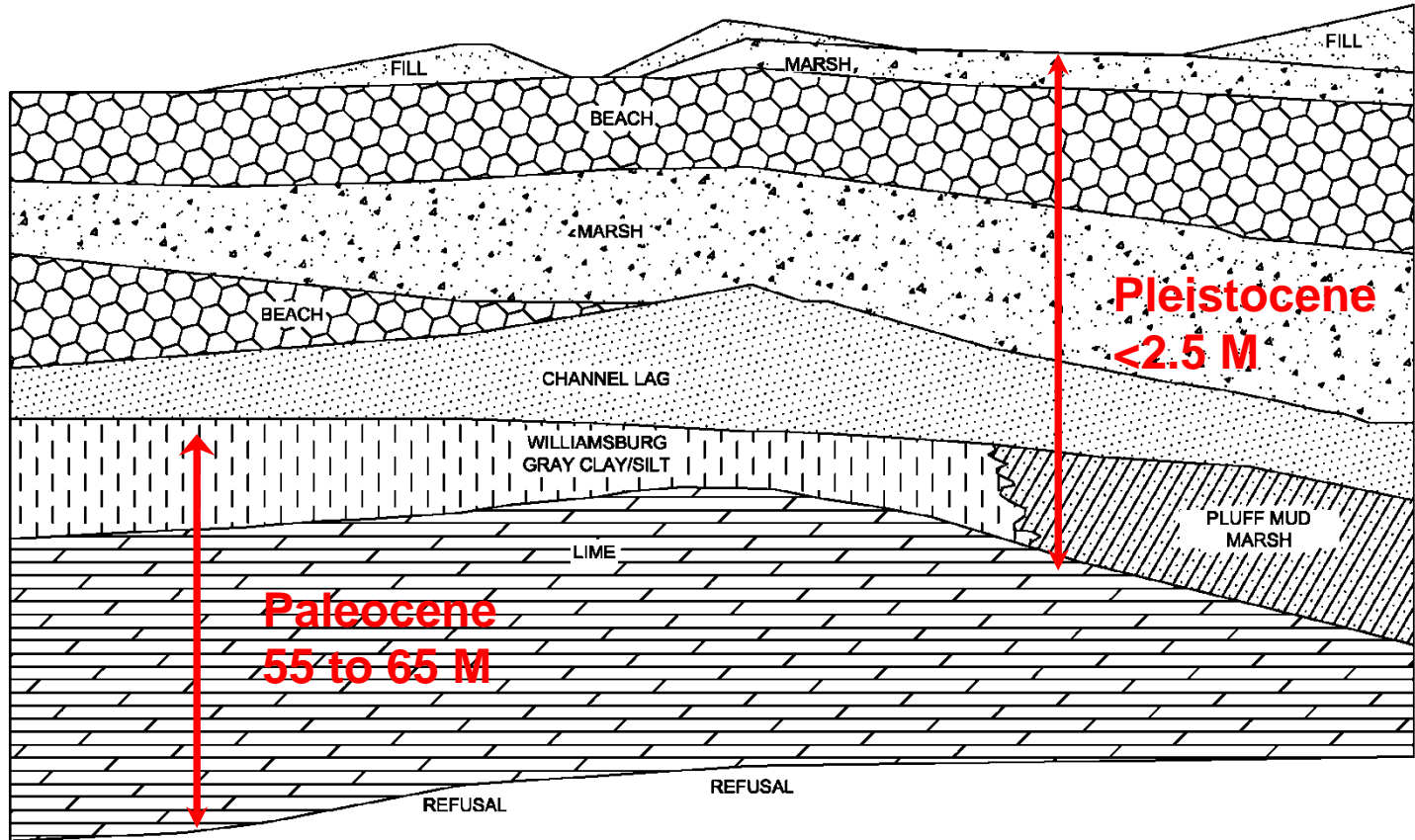


# DOWNTOWN AREA OF INTEREST



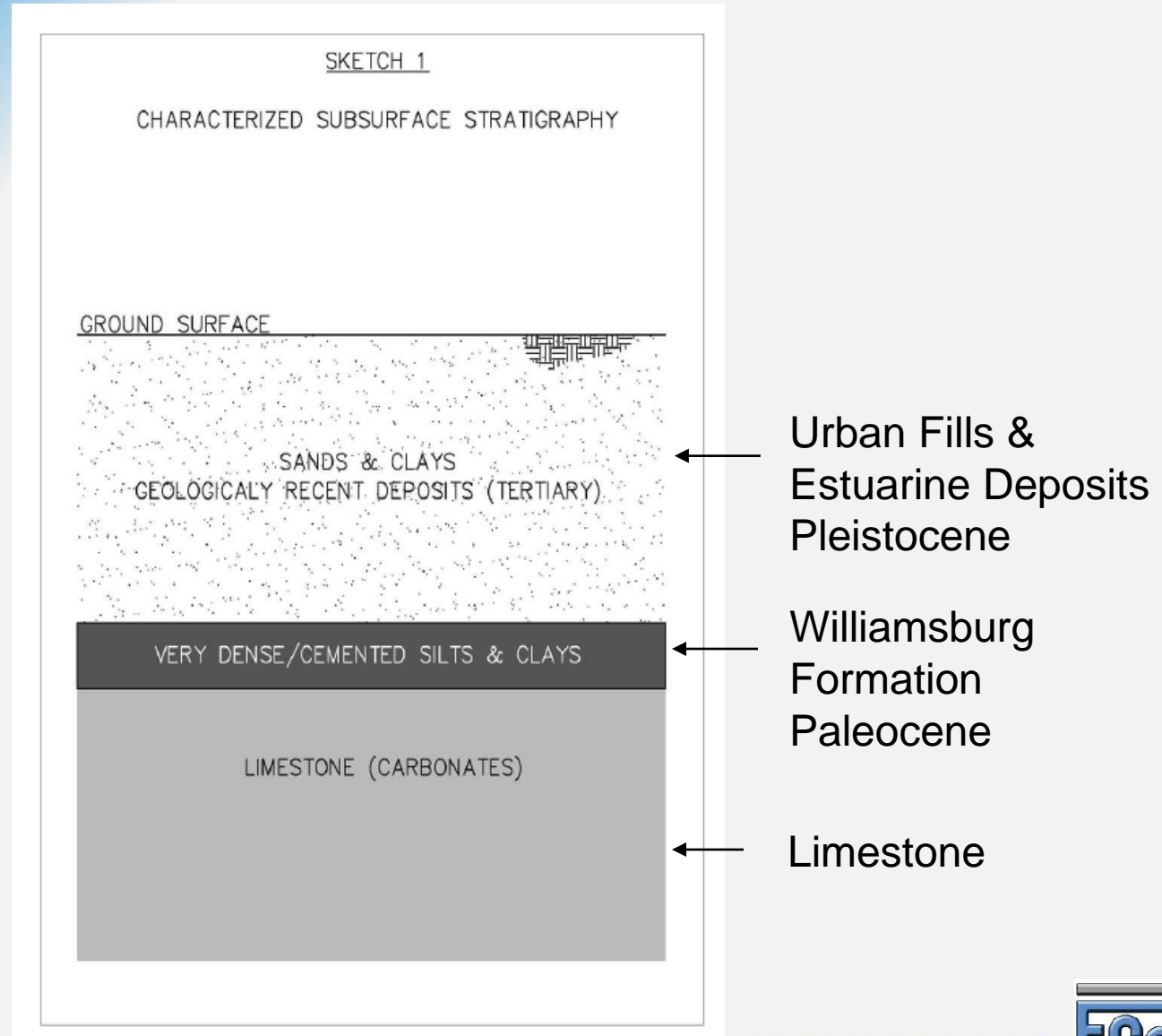


# GEOLOGY SNAP SHOT

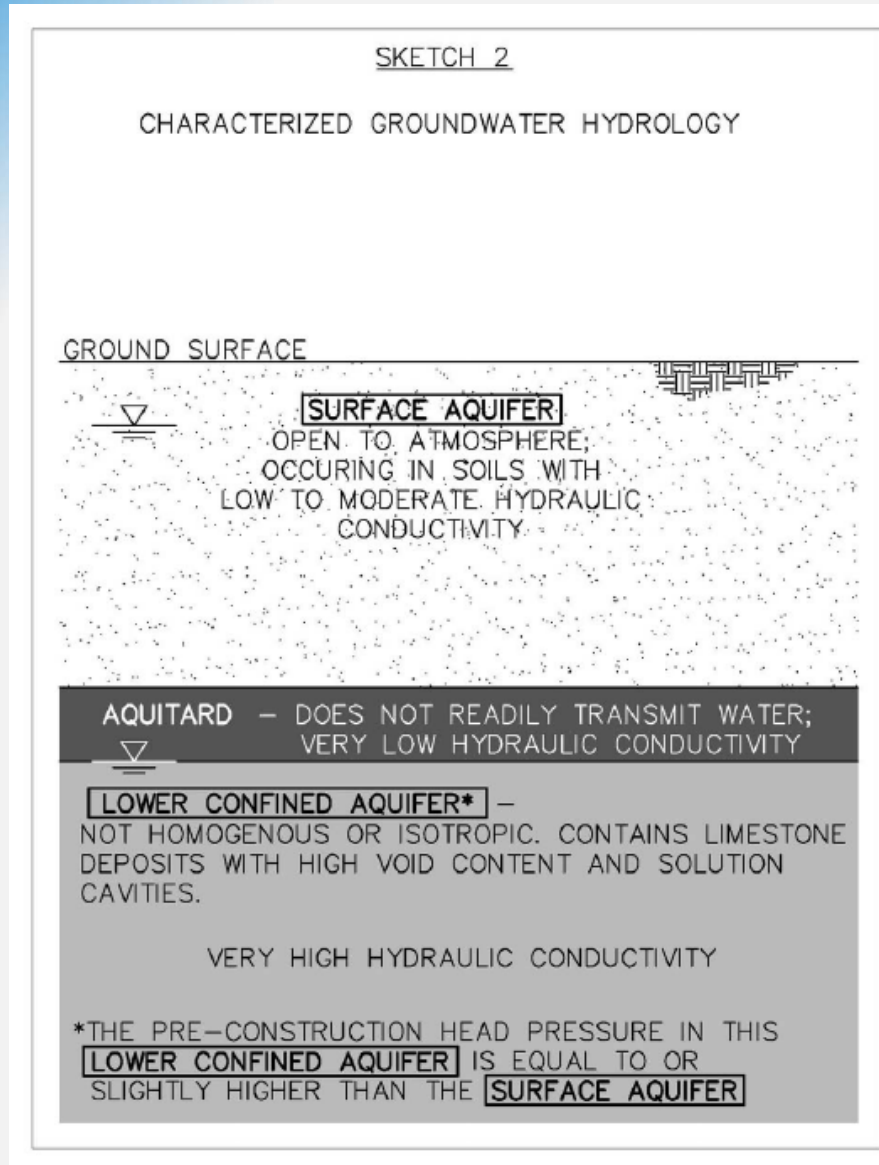




# SIMPLIFIED GEOLOGIC PROFILE



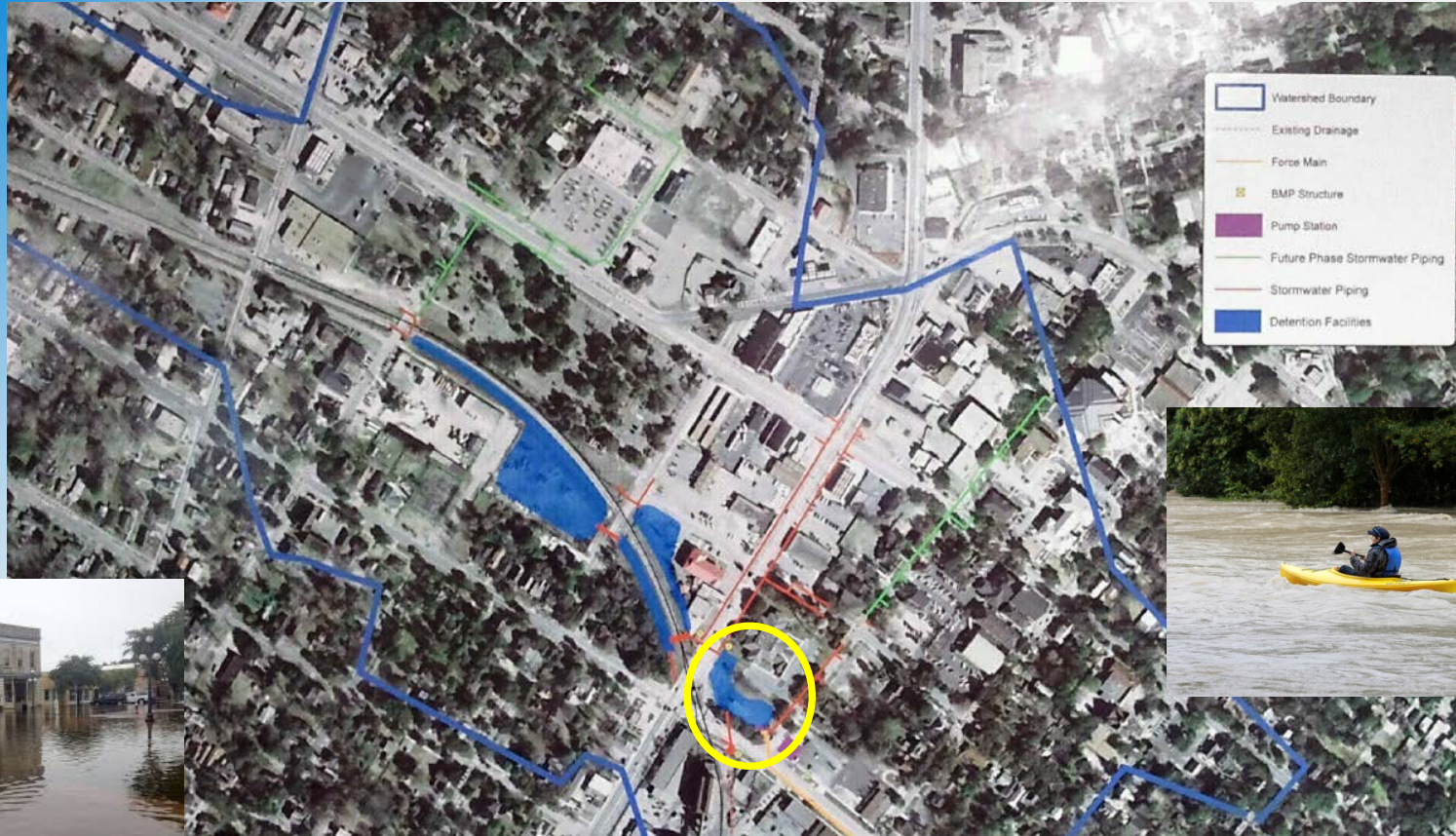
# SIMPLIFIED HYDRO-GEOLOGIC PROFILE



- Discontinuous
- High Void Content
- Solution Cavities
- Very High Hydraulic Conductivity



# STORMWATER DRAINAGE PROJECT

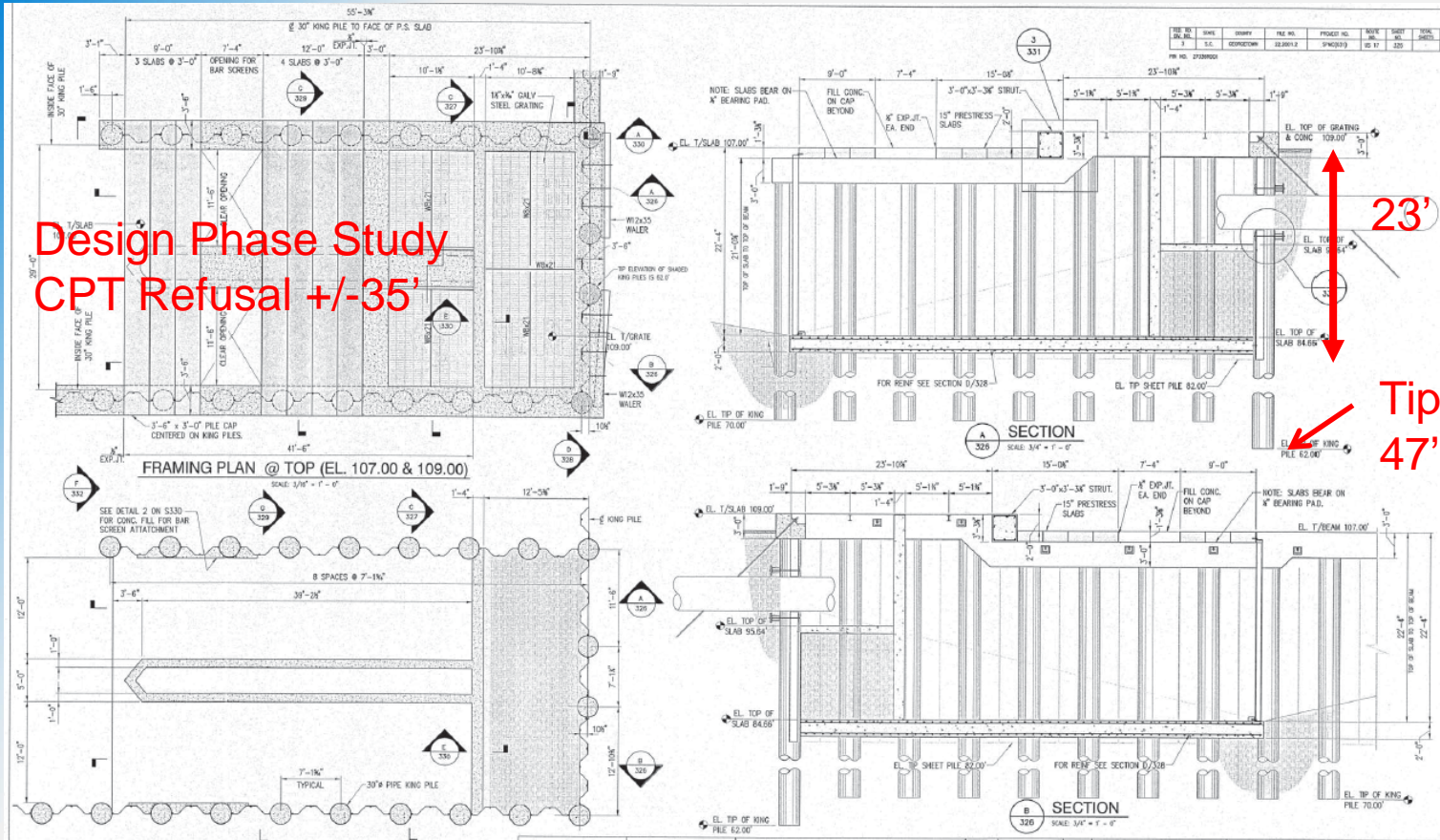


Significant Flooding During Heavy Rainfall and High Tide  
Confluence of 2 Major River Systems  
In Area Bounded by Blue Line





# WET WELL DESIGN KING PILE SYSTEM



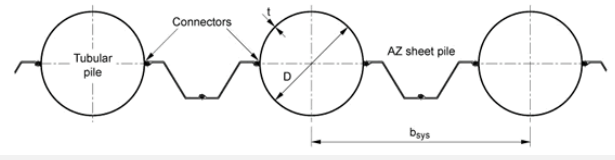
Design Phase Study  
CPT Refusal +/- 35'

23'

Tip 47'

PLAN

SECTION



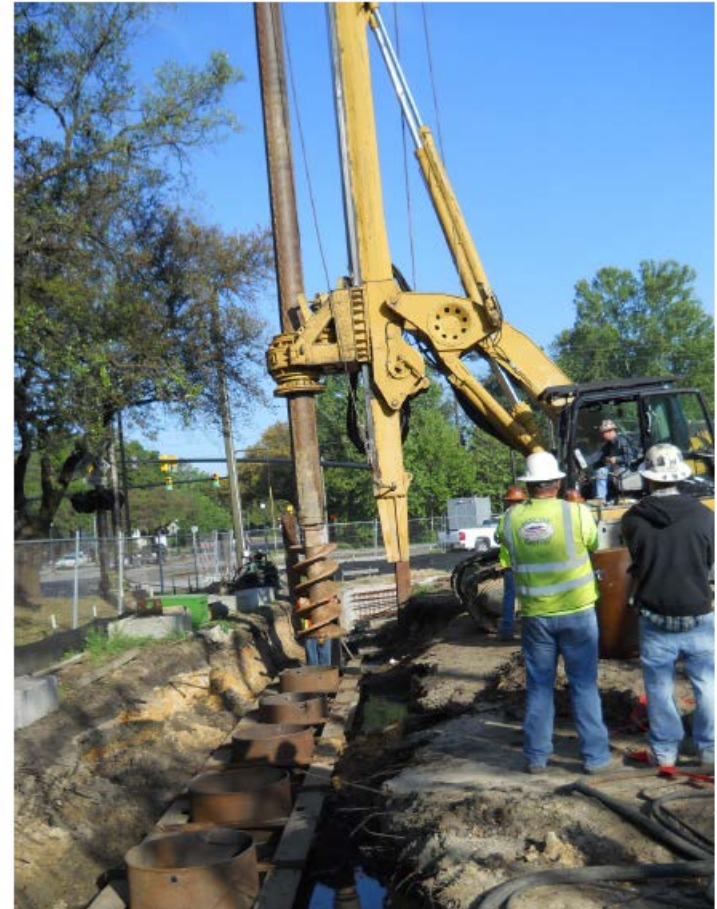
30" O.D. @ 7.25' O.C.



# KING PILE SYSTEM INSTALLATION



Temporary Steel Casing Installation  
Vibratory Hammer



Temporary Casing Clean Out





# KING PILE SYSTEM INSTALLATION



Pile Shell Installation



Steel Shell Driven To Design Tip Elevation



# KING PILE SYSTEM INSTALLATION



Installed System  
Prior to Concreting and Excavation



Concrete Placement  
Tremie Method



# KING PILE SYSTEM INSTALLATION



Artesian Conditions At Base of Wet Well Excavation



# KING PILE SYSTEM INSTALLATION

Deep Well

Williamsburg Formation



Finally A Dry Excavation!!



# KING PILE SYSTEM INSTALLATION



Discharge Rates From Flowmeter  
+/-90,000 Gallons Per Hour  
+/-2M Gallons Per Day



# “REAL” GEOLOGIC CROSS SECTION



Open Pit Limestone Mine – Holly Hill, SC

Open Cut @ Quarry  
< 20 Miles NW of Georgetown

NOT FOR DISTRIBUTION



# HYDRO-GEOLOGIC CONSIDERATIONS

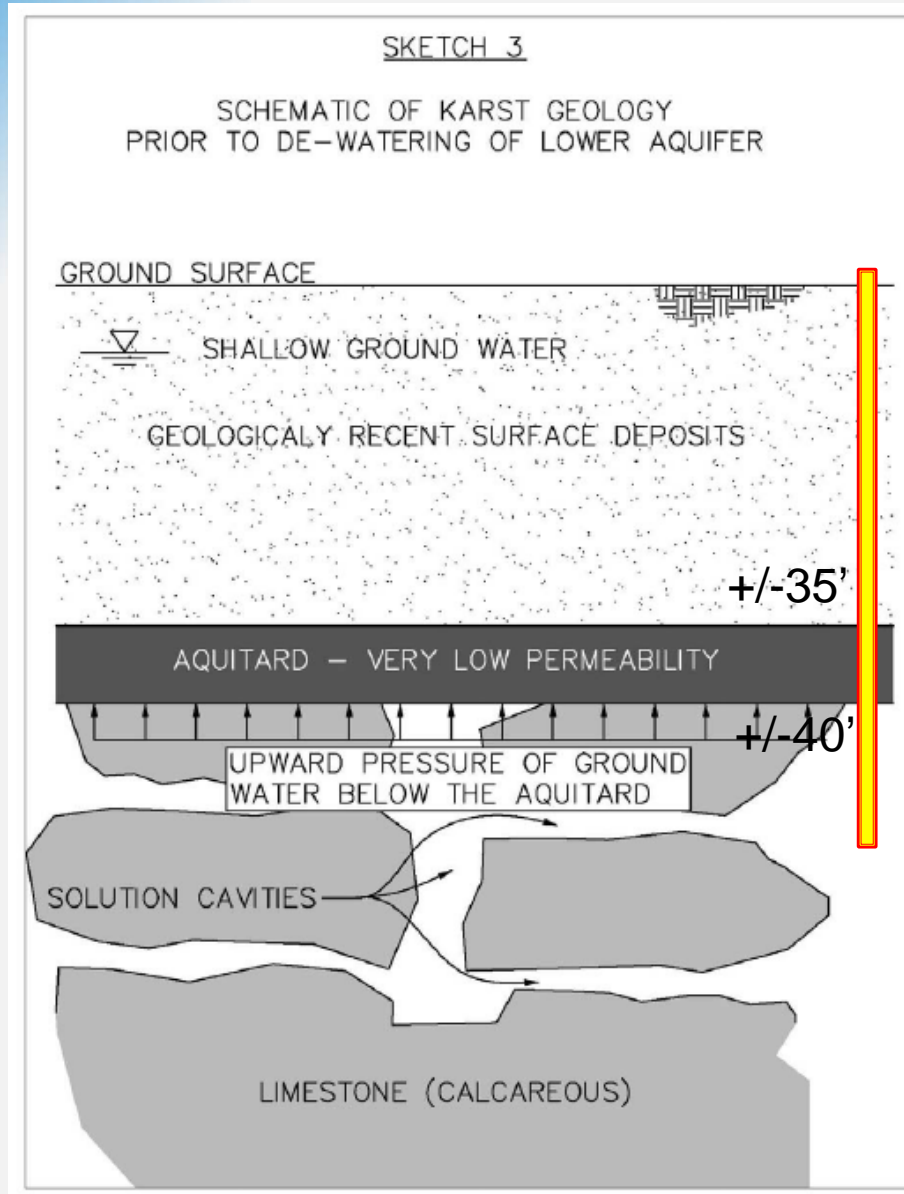
GEO VIRGINIA 2018

Shallow  
Dewatering

March/October  
2011

Deep  
Dewatering

October/November  
2011



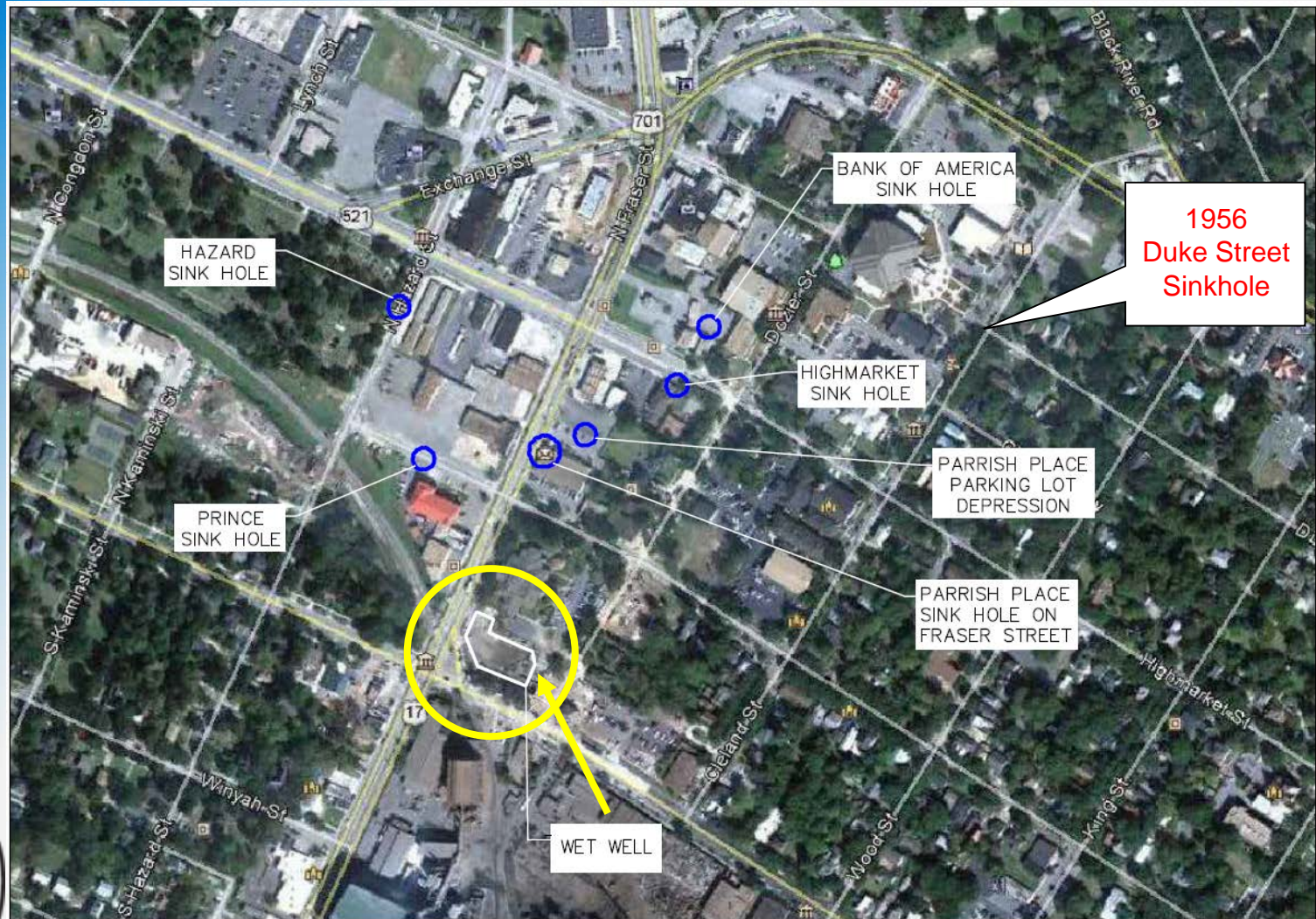
King Piles  
+/-47'

Conditions Prior To  
Wet Well Dewatering

NOT FOR DISTRIBUTION

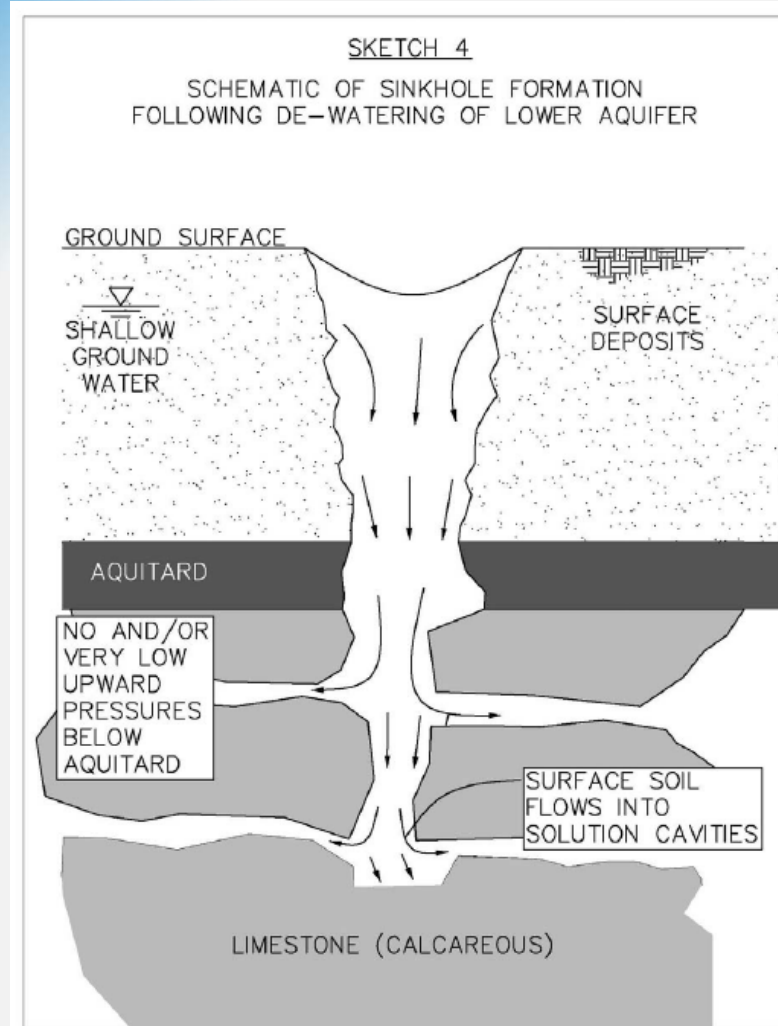


# DEWATERING EFFECTS





# COLLAPSE/SINK HOLE MECHANISM



Phenomena Documented In Coastal South Carolina Since 1975  
Jamestown Quarry +/-35M Gallons Per Day – Widespread Subsidence



# PARRISH PLACE PARKING FEATURE



Opportunity for A Safety Minute?



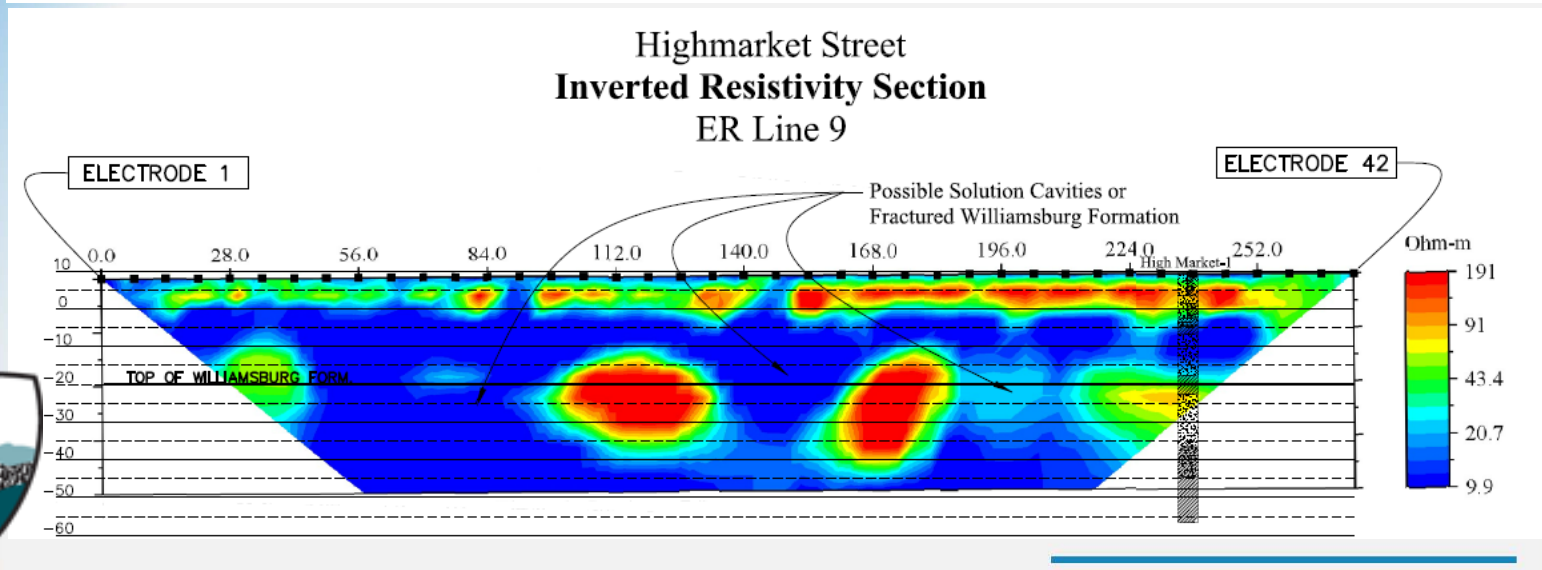
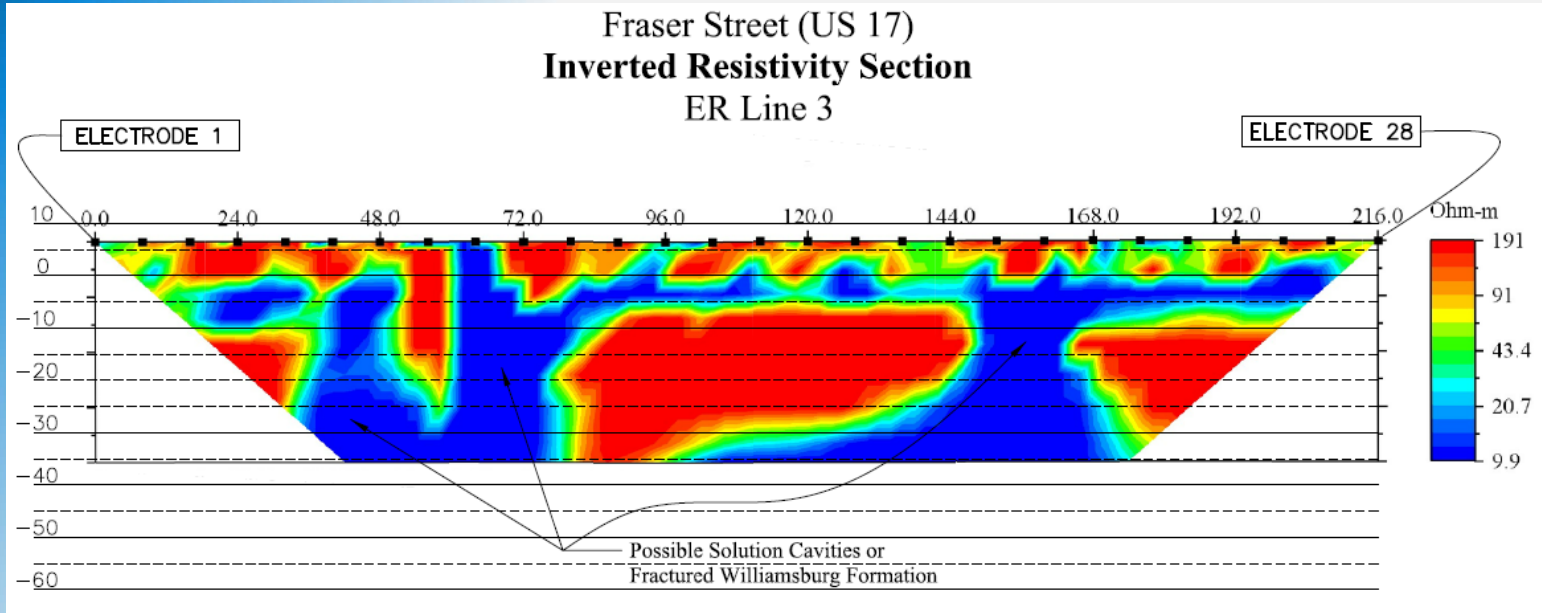
# UPS BUILDING COLLAPSE PARRISH PLACE



Collapse Occurred +/- 10pm November 17, 2011



# GEOPHYSICAL CHARACTERIZATION





# THE "PROJECT"

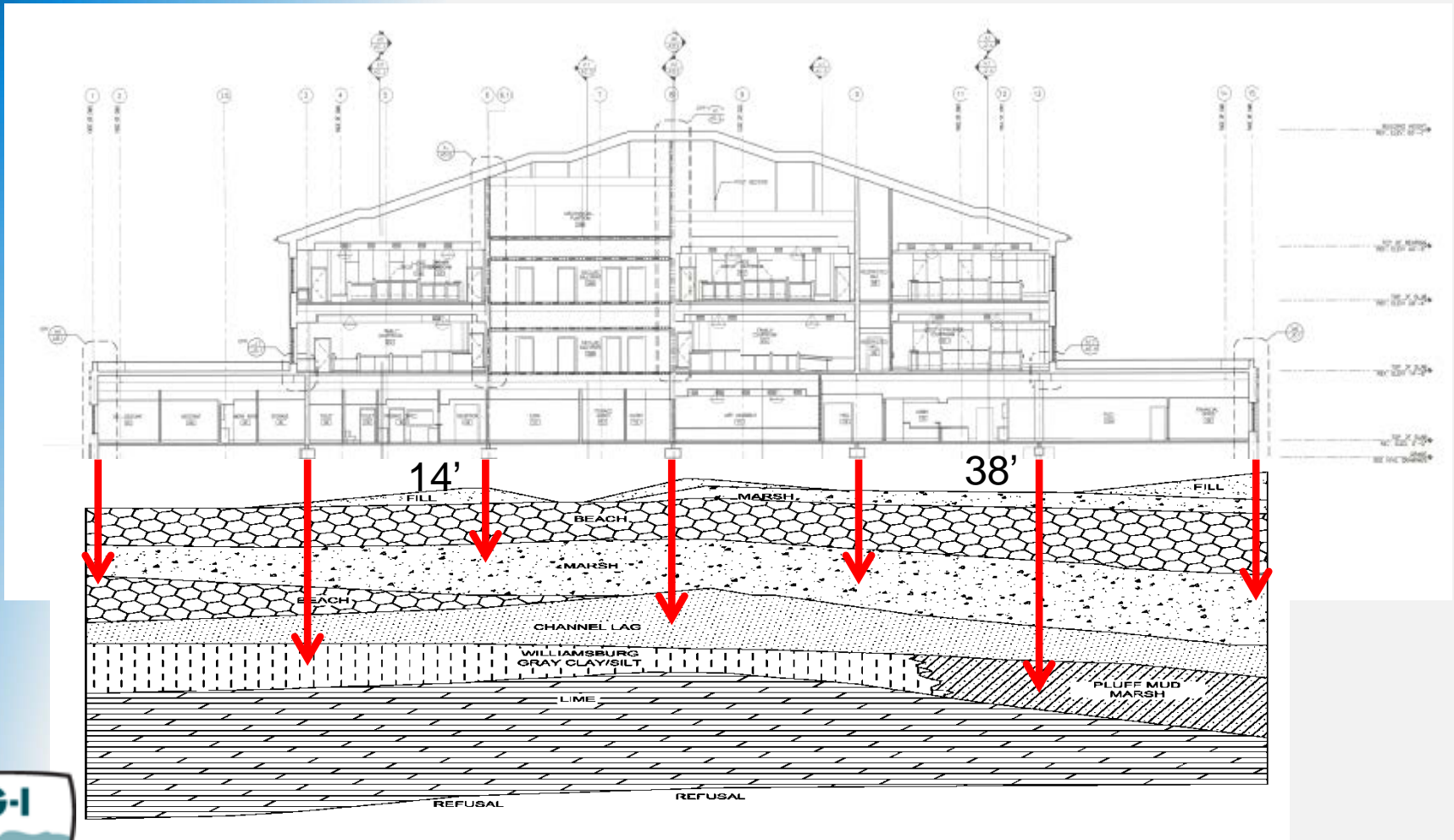


Steel and Masonry, 3-Story, 79,300 SF County Judicial Center  
Completed Spring 2008  
Construction Value +/- \$18,000,000

NOT FOR DISTRIBUTION



# THE "PROJECT"



# GEOTECHNICAL DESIGN

Site formerly occupied multiple generations of structures

Grades raised approximately 4 to 6 feet

8" Tip Southern Pine Timber Piles\*\* (VE)

35 feet minimum embedment

35 blows per foot at EOD

30 tons compression

10 tons uplift

4 tons lateral

Ground level concrete slab-on-grade \*\* (VE)

Geotechnical Exploration Methods?

Geotechnical Testing Protocol?

Conflicting Geotechnical Reports?

For The Sake of \$?





# GEOTECHNICAL CHALLENGES

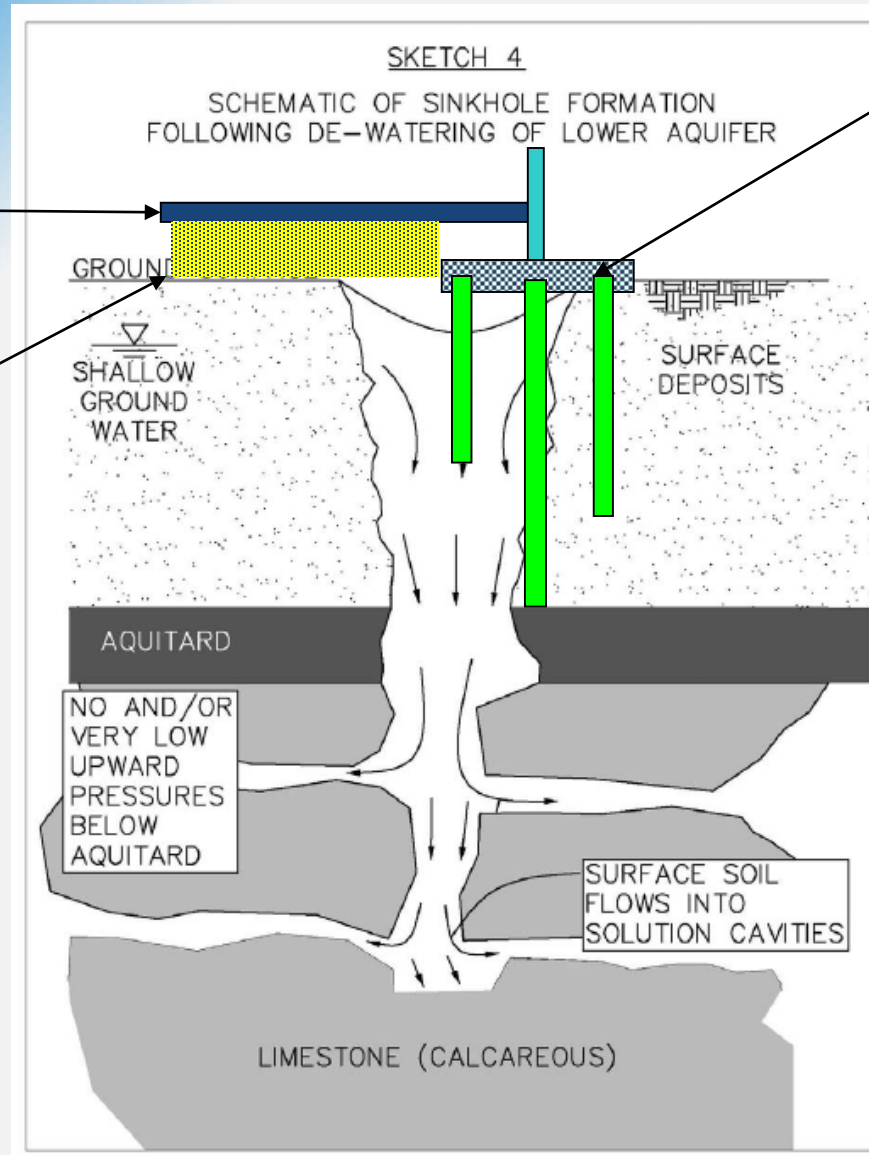


E.O.D. Resistances: 6 bpf to > 100 bpf



# GEOTECHNICAL CHALLENGES

First Floor  
Slab On  
Grade  
  
+/-4' to 6'  
New Fill

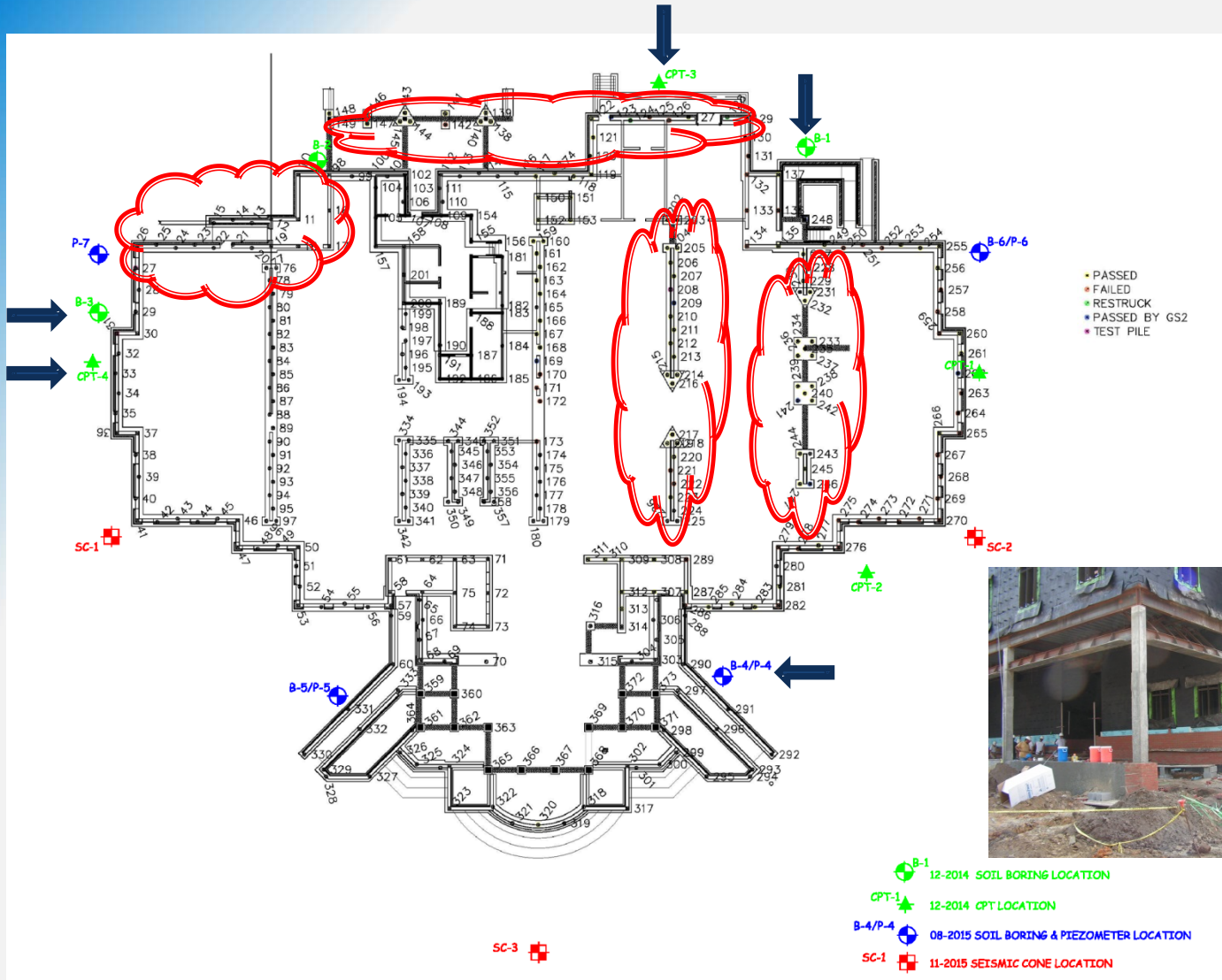


Pile Supported  
Load Bearing  
Elements

+/- 35' to 40'



# DISCOVERY AND CONSEQUENCE



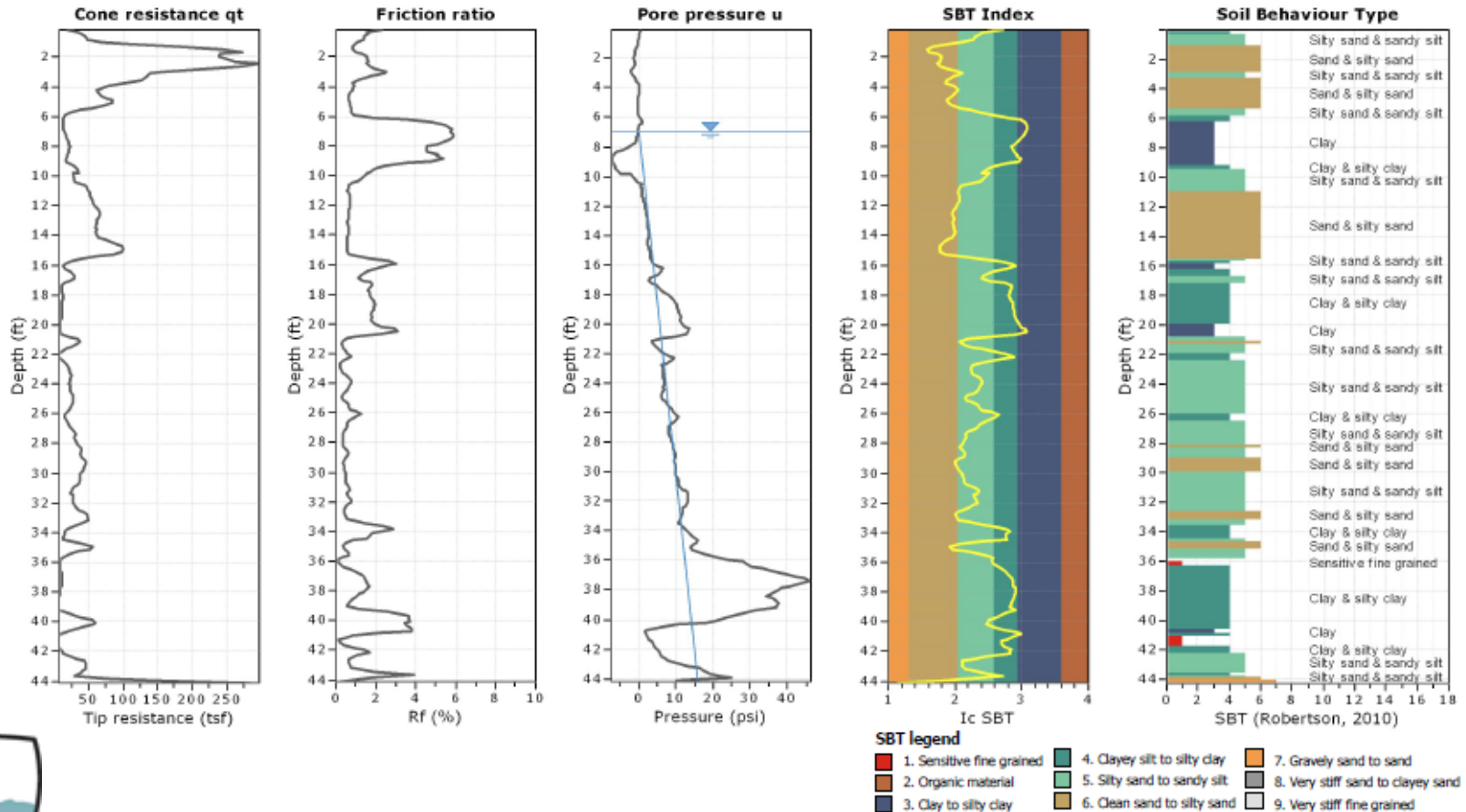


# SUBSURFACE CONDITIONS POST WET-WELL

Project: Georgetown Judicial Center  
Location: Georgetown, South Carolina

CPT: C-4

Total depth: 44.13 ft, Date: 2/16/2015

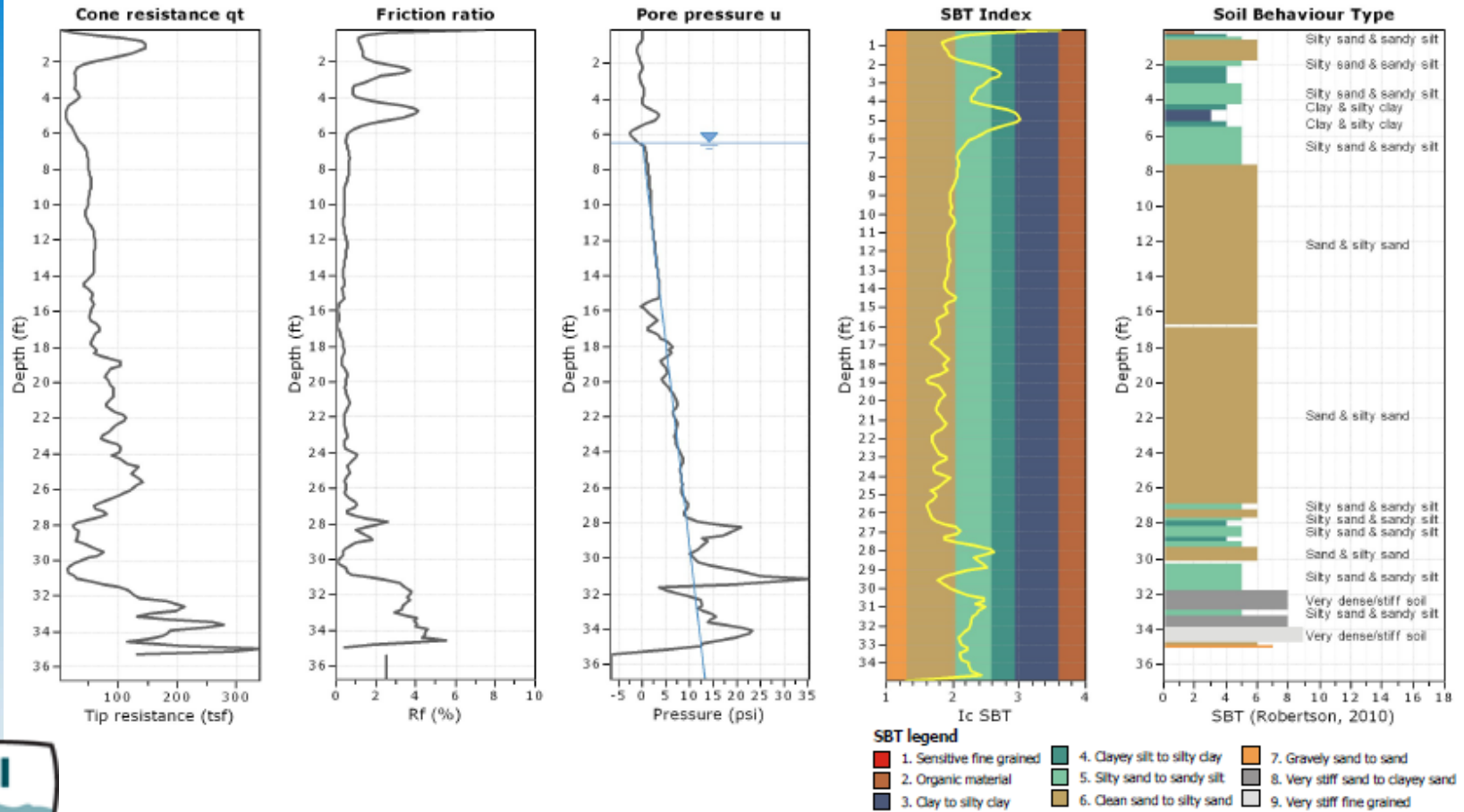


# SUBSURFACE CONDITIONS POST WET-WALL

Project: Georgetown Judicial Center  
Location: Georgetown, South Carolina

CPT: C-3

Total depth: 36.78 ft, Date: 2/16/2015



# WHERE ARE WE NOW?

Lawsuits Related To Drainage Project (>25)  
Lawsuits Against Judicial Center Design Team  
Protracted Litigation (> 6 Years)



Geotechnical and Structural Deficiencies

ECS Characterizes Geotechnical Deficiencies for Owner  
ECS Undertakes Independent Analyses for Owner

Forensic Assessment w/REA

CPT & SCPT Soundings

Mud Rotary SPT Borings

Refraction Microtremor

SSHA

Liquefaction Triggering Analysis

Foundation and Slab Repair Design w/REA



# WHERE ARE WE NOW?

## Key Geotechnical and Foundation Design Shortcomings

Liquefiable Deposits Upper 35 feet \*\* (+/-2" to 5")

Peat & Very Soft Marine Clay Layers (LL's > 85, PI's > 45,  $q_t < 5$  tsf) \*\*

Installed Pile Lengths 14 to 38 feet \*\*

### Working Pile Loads

Actual Compressive As Much As 25% Greater Than Design (REA)

Actual Uplift As Much As 20% Greater Than Design (REA)

Actual Lateral As Much As 75% Greater Than Design (REA)

Interpreted Pile Capacities As Low As 50% of Working Loads (FS=1)



Timber Piles Structurally Inadequate

Working Stresses During Lateral Loading >>>> Allowable



# WHERE ARE WE NOW?

## Conceptual Geotechnical Repairs

### Foundations

Underpinning w/ Cased Micropiles (\$5M per HBI) \*\*

### Ground Level Slab

New Micropile Supported Structural Slab (\$2M per HBI) \*\*

HDPE Grouting of Pleistocene Deposits (\$1M) X

Low Mobility Grouting of Limestone (\$2M to \$3M) X

### Collateral Work

Remove and Replace Existing Finishes (\$3M to \$4M)

Definition of “Sinkhole” – Engineering vs. Coverage

County Operations Relocation During Repairs (18 mos. @ \$6M to \$8M)

**Estimated Damages (\$15M to \$18M or more)**



# FUN FACTS

Originally Considered Driven 55' PSC or ACIP & Structural Floor Slab  
Value Engineered - Driven Timber Piles and Slab On Grade (\$600,000 net)

Hollow Stem Auger Borings by GER (Max. Depth 35')

No Laboratory Testing by GER

Conflicting Versions of GER Design Level Reports (seismic risks????)

Design Level Geotechnical Reports Don't Bear Firm or EOR Seals

+/-375 Timber Piles Installed September/October 2007

Production Pile Lengths 14 to 38 Feet

2 Pre-Production Static Load Tests w/Questionable Results

6 of 10 PDA Tests During Driving, Axial Capacity Concerns

GER Not Retained For Construction Observations (would it have mattered?)

CMT/SI Firm Refuses To Write Letter "Certifying" Foundations

GER Reviews SI Driving Records, "Certifies" Pile Capacity (FS = 1.5)



# THANK YOU !



Shameless Plug!!!!

