

## 2015 Technical Conference

# I-495 in Wilmington, DE – The Leaning Towers Lateral Squeeze Effects on Pile Supported Bridge Piers Due to Mudwave Emergency Response and Retrofit

Presented to: ABCD Susquehanna Chapter September 3, 2015





# AGENDA

Introduction

Response

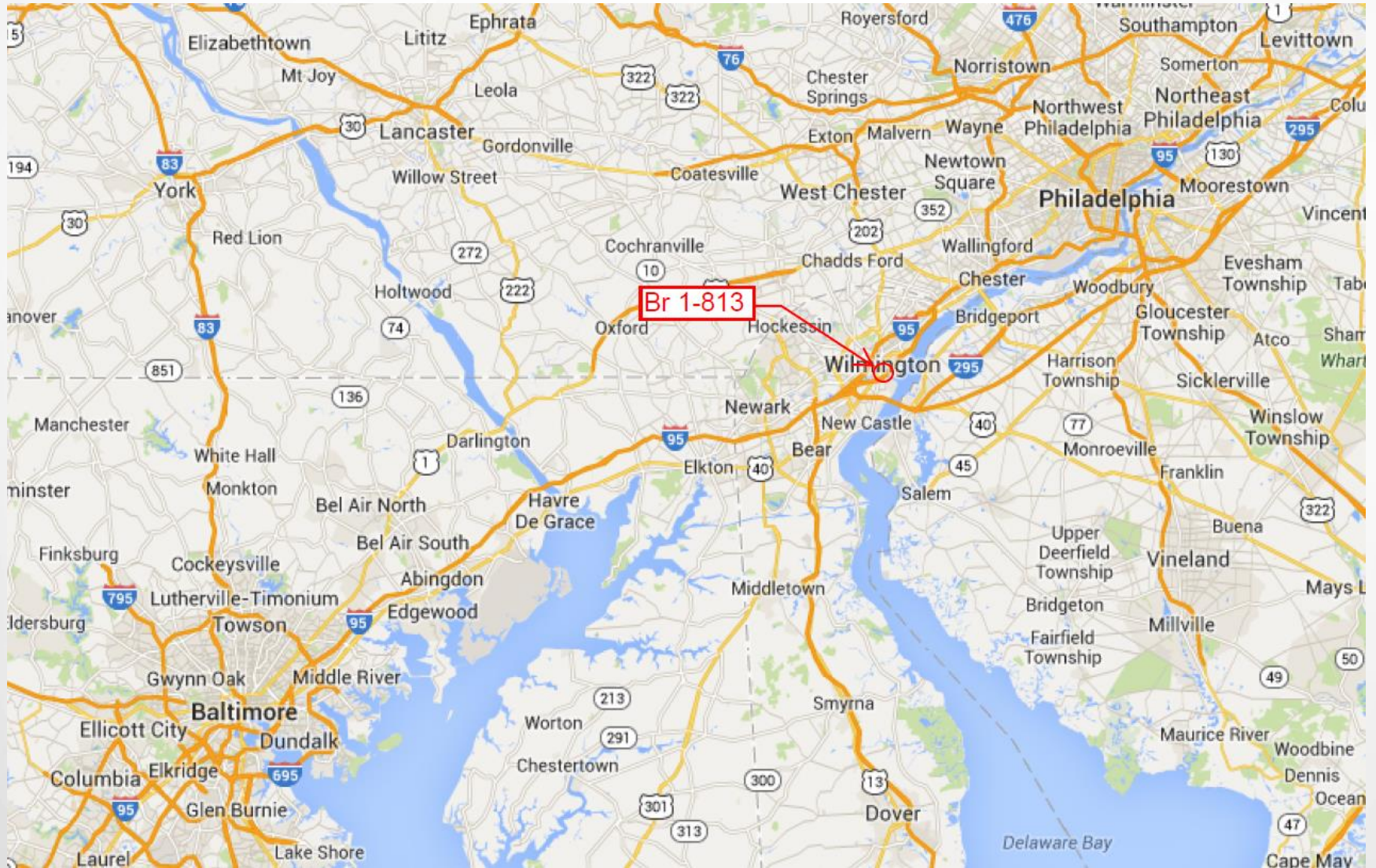
Foundation Design

Construction

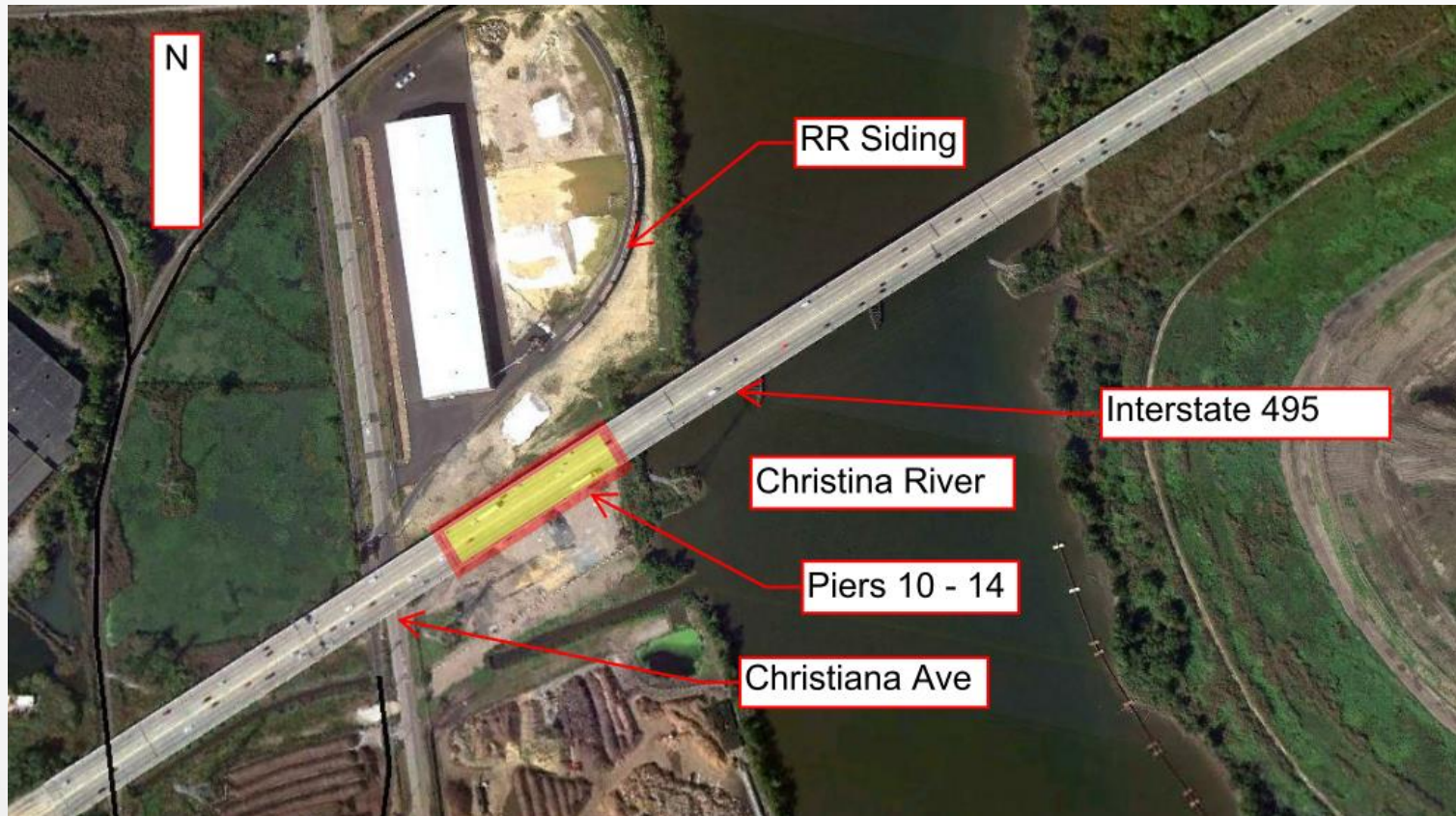
Conclusions

Acknowledgements

# Background



# Background



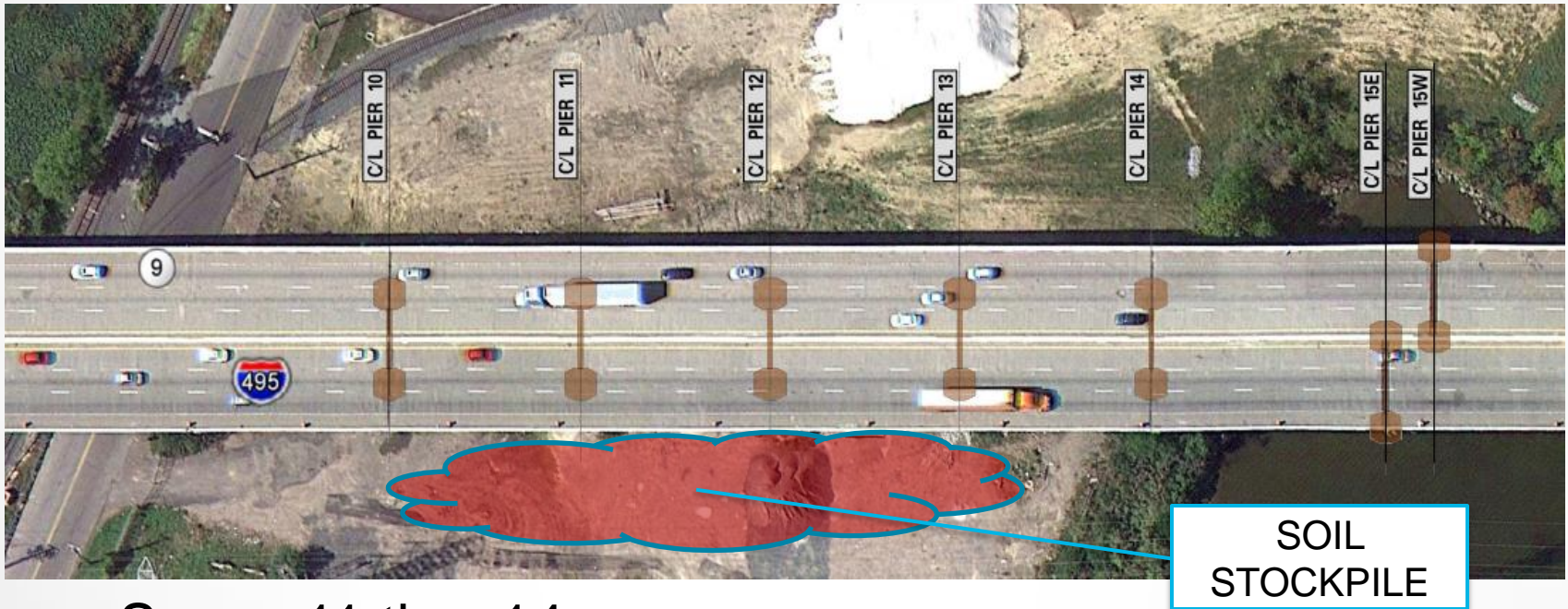
## Project Site Location Map

# Background

- BR 1-813
- I-495 over the Christina River
- ADT=90,000
- Length – 4,390-ft
- 38 spans
- Welded Steel Plate Girder Superstructure
- Pier Ht = +/- 60-ft
- Variable Foundations
- Inspected October 2012
  - No deficiencies



# Background



- Spans 11 thru 14
  - 4-span continuous
  - All spans 109-ft
  - Piers 10 thru 14
  - Pier 10 – Cast-in-Place Concrete Piles
  - Remainder – H-Piles
- Span 15
  - Simple span
  - SB – 160.03-ft
  - NB – 132.87-ft
  - Pier 15 – H-Piles

# Response

- June 2<sup>ND</sup> 2014 at 2:17 PM
  - AECOM arrived on-site  
4:00PM
- Piers Tilted
- Tension Cracks in Soil
- Displacement of Bridge Superstructure



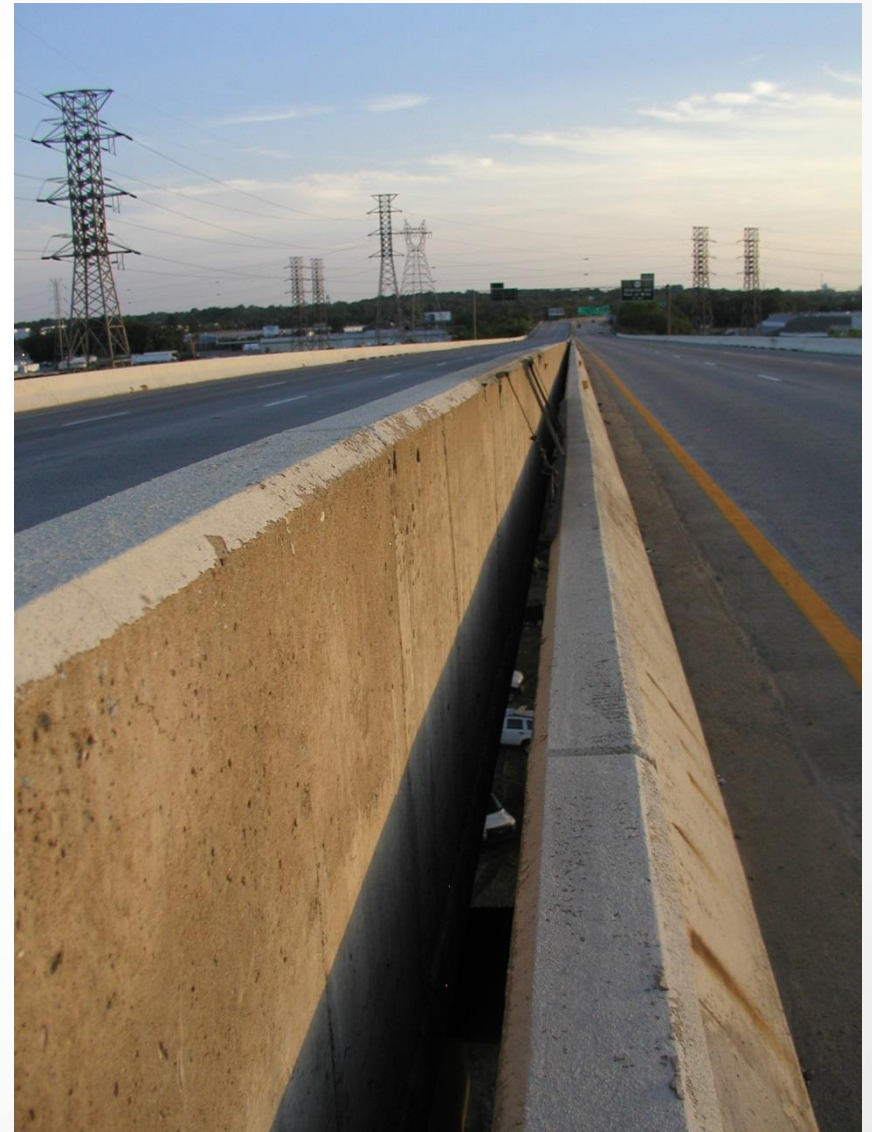
# Response



Embankment and Soil Tension Cracks East of Structure

# Response

- NB and SB Superstructure Rotated to the East
  - 18-inch difference in elevation of median barriers
  - + 3-inch gap in median barriers



# Response



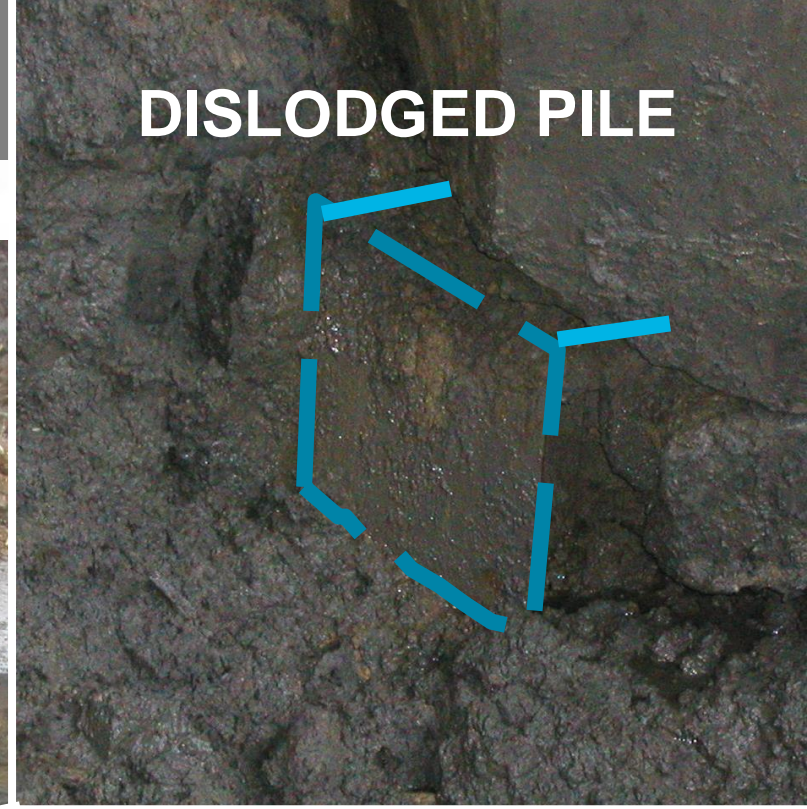
- Inspect Pile Caps
  - Damage
  - Pile Corrosion
- Conduct Subsurface Inv.
  - 12 CPTu Soundings
  - 6 SPT Borings w/ Rock Coring
  - 2 Open Standpipe Piezometers w/ VBW inst.
  - 2 Inclinometers
  - 1 Monitoring Well
- Identify Contractor
  - JD Eckman mobilized 6/5/2014
  - **AH Beck & R.E. Pierson mobilized 6/12/2014**

# Response

- Pile Cap Inspection
  - Large Horizontal Cracks
  - No Pile Corrosion
  - Local Buckling on One Pile

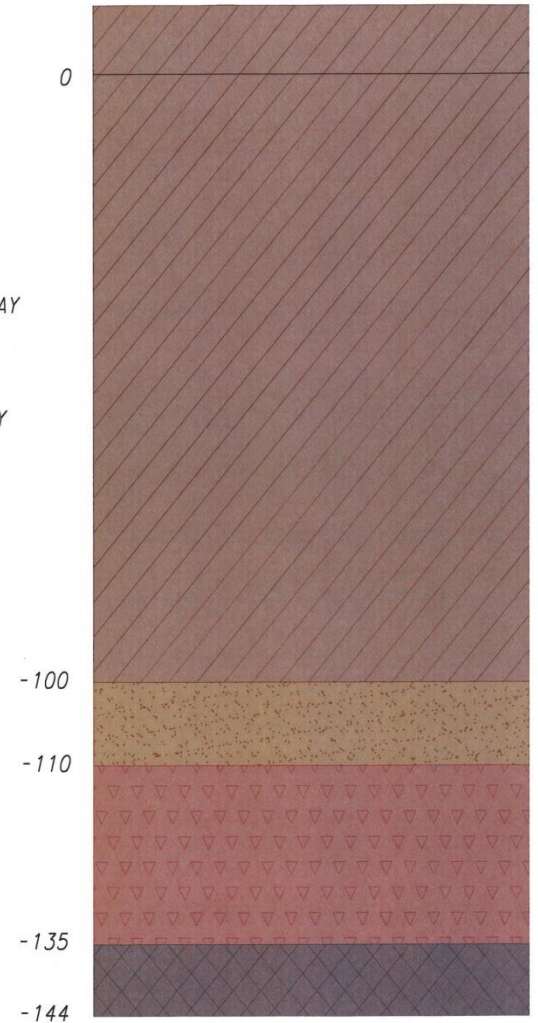


# Response

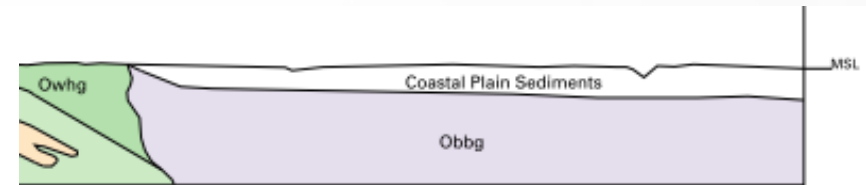
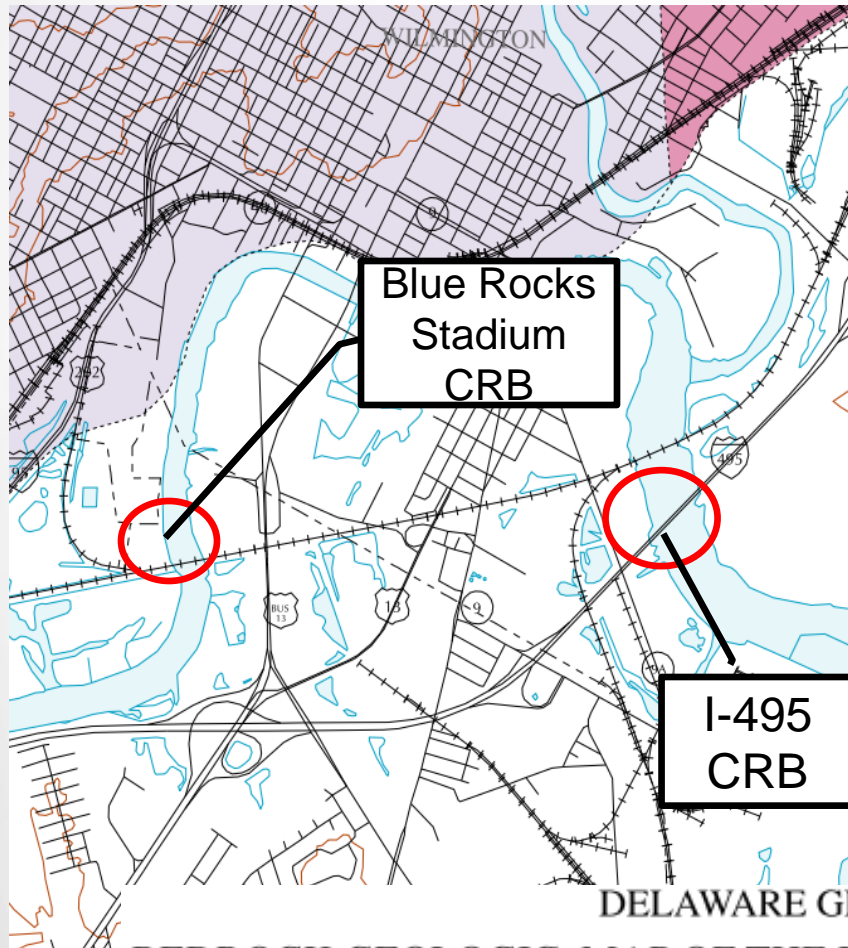


# Response

- Generalized Soil Profile
  - Soft Organic Clay
  - Dense Sand
  - Stiff Silty Clay
  - Bedrock



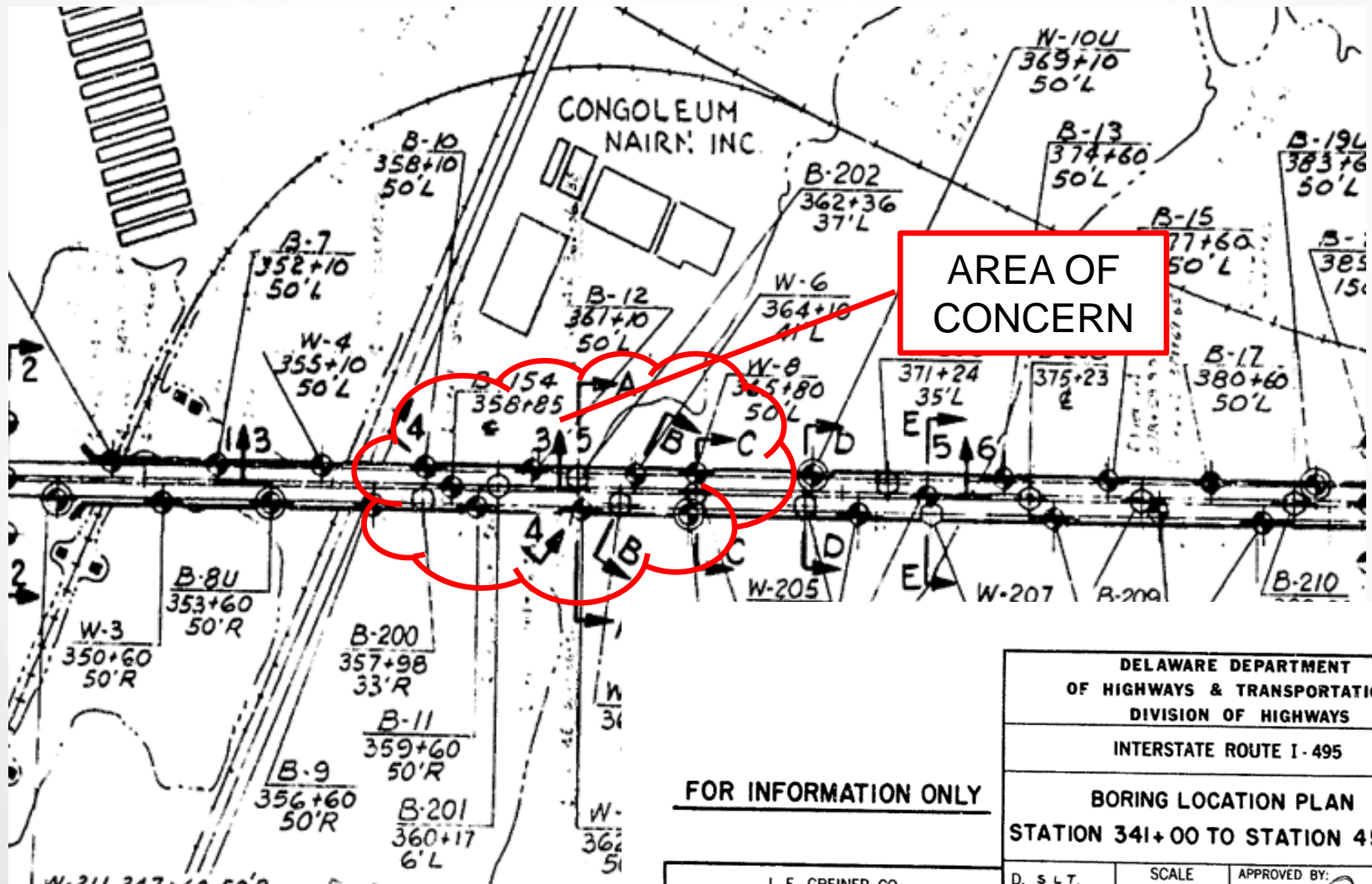
# Response



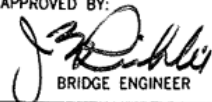
**Obbg** **Brandywine Blue Gneiss**  
Medium- coarse-grained granulites and gneisses composed of plagioclase, quartz, orthopyroxene, clinopyroxene, brown-green hornblende, magnetite, and ilmenite. Mafic minerals vary from < 5-30 modal percent. A lineation due to a preferred orientation of quartz and mafic minerals is obvious on weathered surfaces. Unit contains thin, discontinuous fine-grained mafic layers.

DELAWARE GEOLOGICAL SURVEY  
BEDROCK GEOLOGIC MAP OF THE PIEDMONT OF DELAWARE AND ADJACENT  
PENNSYLVANIA  
GEOLOGIC MAP SERIES, NO.10

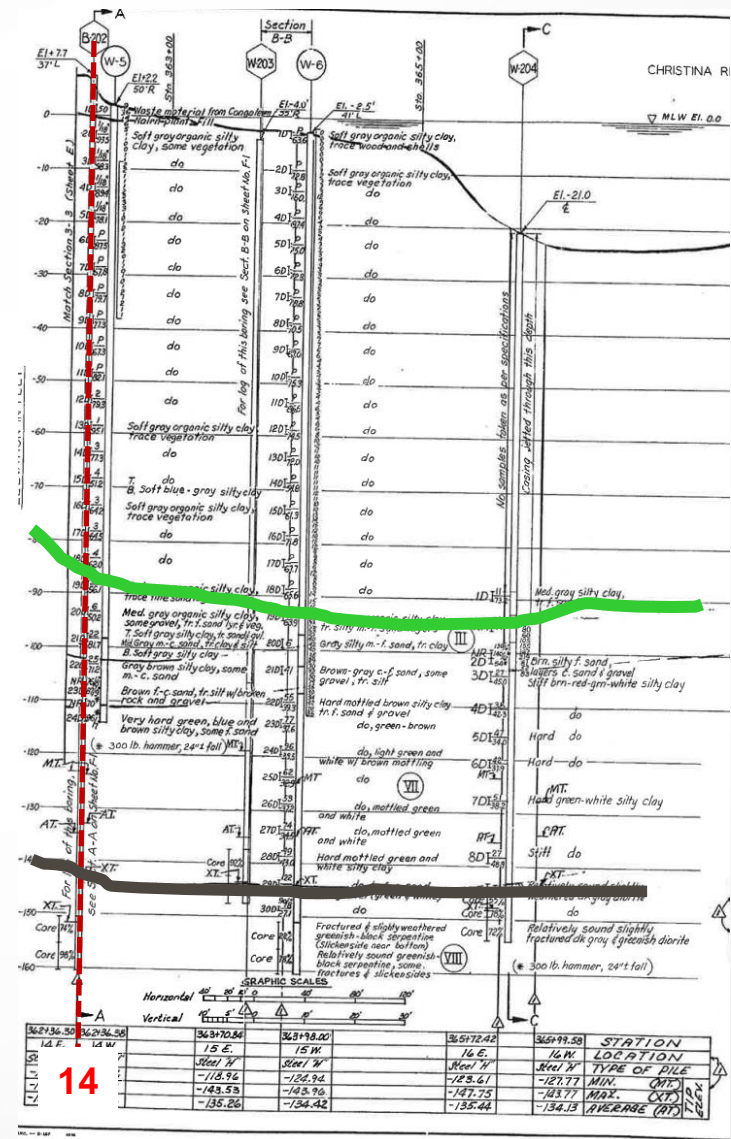
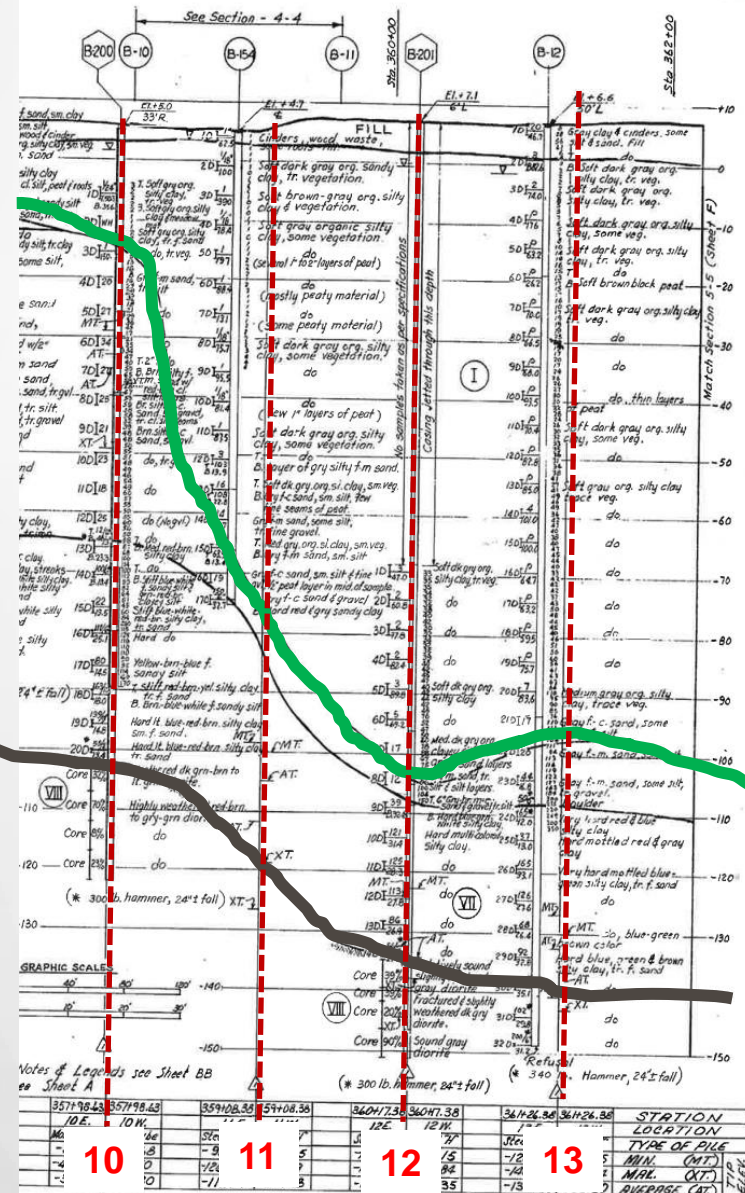
# Response



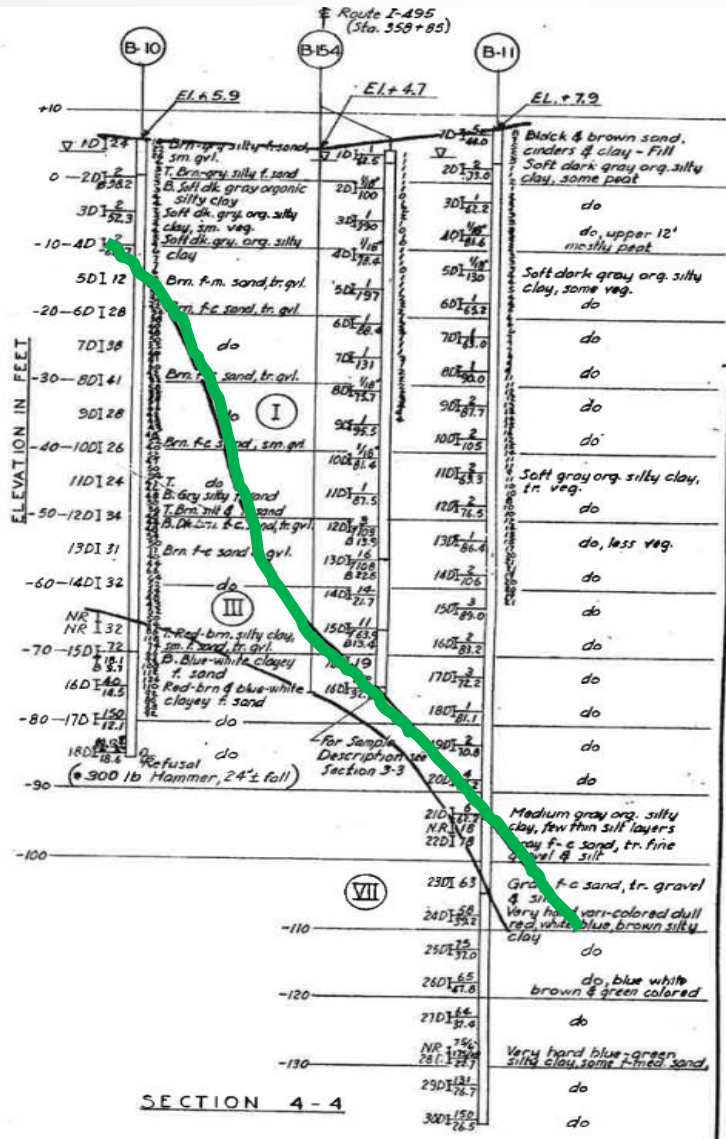
AREA OF CONCERN

DELAWARE DEPARTMENT OF HIGHWAYS & TRANSPORTATION DIVISION OF HIGHWAYS		
INTERSTATE ROUTE I-495		
BORING LOCATION PLAN STATION 341+00 TO STATION 459+27		
FOR INFORMATION ONLY		
J. E. GREINER CO. MORAN, PROCTOR, MUESER & RUTLEDGE CONSULTING ENGINEERS		D. S.L.T. T. L.S. C. R.C.H.
SCALE 1" = 400' DATE 3/1/63 - 7/1/71		APPROVED BY:  BRIDGE ENGINEER

# Response



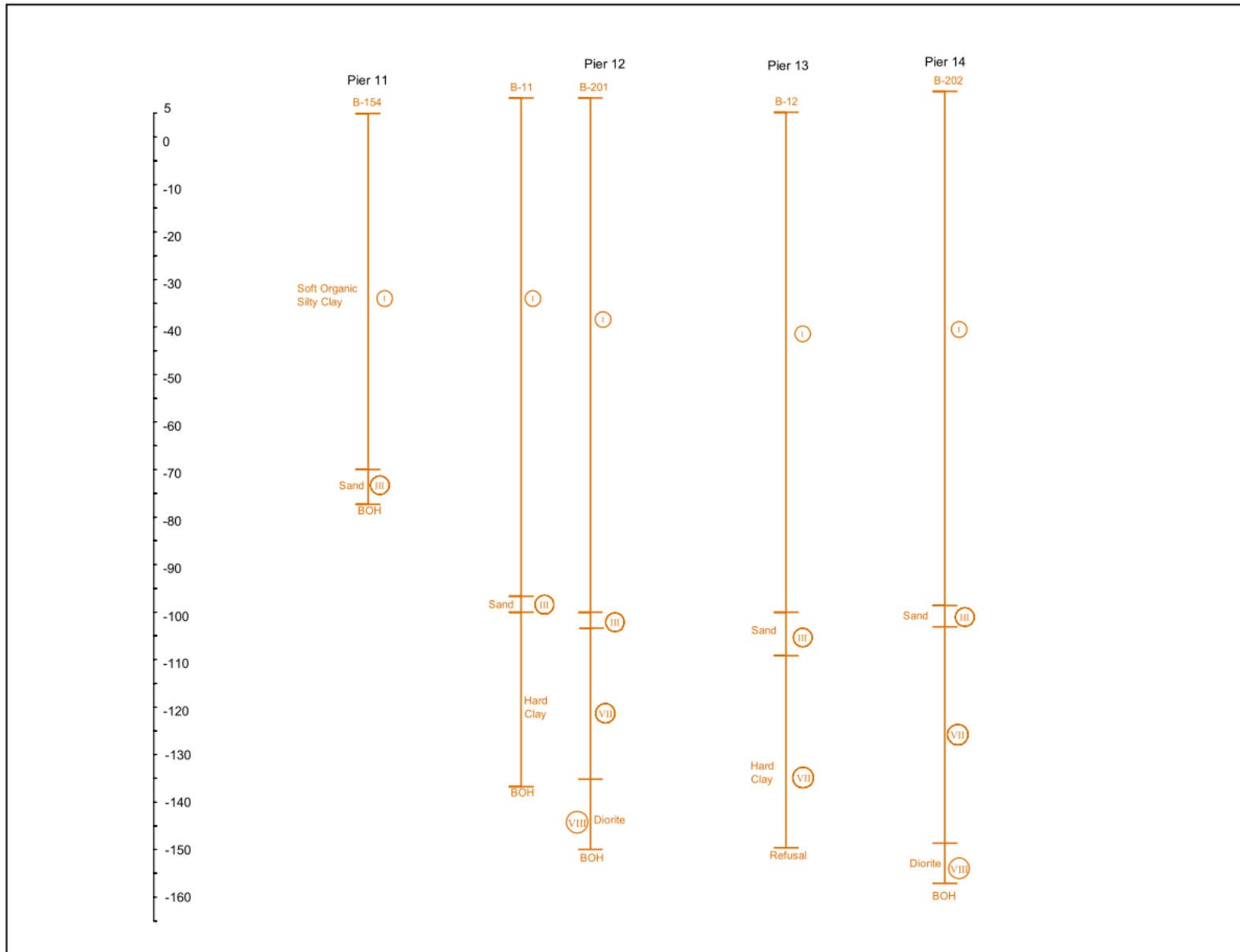
# Response



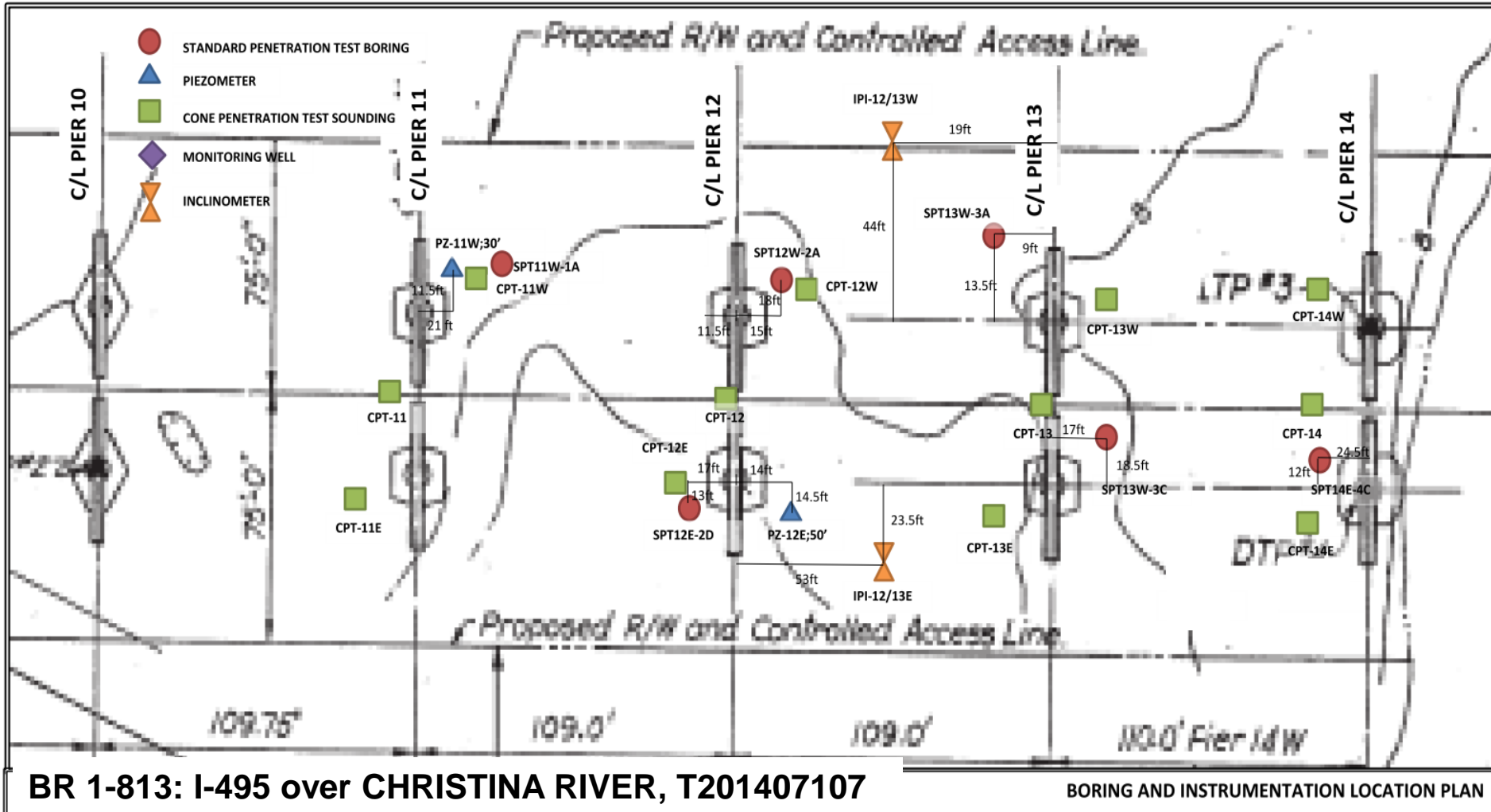
## LEGEND FOR STRATIFICATION

J.E.G. CO. & W.P.M. & R.	DELAWARE	SOIL DESCRIPTION
DESIGNATION	DESIGNATION	
I	A-7 & A-8	SOFT DARK GRAY ORGANIC SILTY CLAY, TRACE TO SOME VEGETATION AND TRACE PEAT LAYERS.
II	A-4	LOOSE TO MEDIUM COMPACT BROWN AND GRAY FINE TO MEDIUM SANDY SILT TO SILTY FINE SAND.
III	A-1	COMPACT TO VERY COMPACT BROWN COARSE TO FINE SAND, SOME GRAVEL, TRACE SILT AND MICA.
IV	A-6	MEDIUM TO STIFF GRAY AND BROWN SILTY CLAY AND CLAYEY SILT WITH GRAY FINE SAND LAYERS.
V	A-6	STIFF MOTTLED RED WITH GRAY SILTY CLAY, TRACE TO SOME SAND AND GRAVEL, LENSES OF GRAY FINE SANDY SILT.
VI	A-4	COMPACT TO VERY COMPACT RED, BROWN AND GRAY FINE SANDY SILT TO SILTY FINE SAND, SOME CLAY.
VII	A-6	STIFF TO HARD VARICOLORED SILTY CLAY TO CLAYEY FINE SAND AND FINE SAND.
VIII	—	BEDROCK - RELATIVELY SOUND FRACTURED DARK GRAY QUARTZ DIORITE.

# Response



# Response



# Response

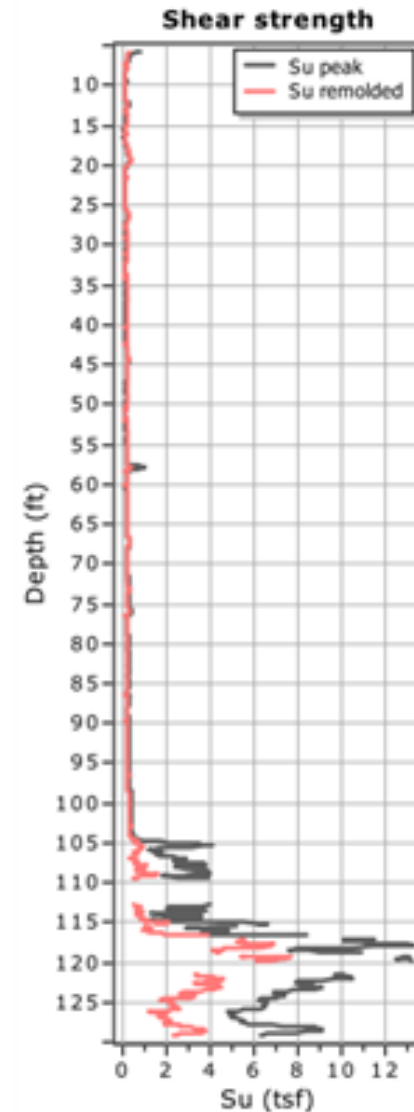
STATE OF DELAWARE  
DEPARTMENT OF TRANSPORTATION  
MATERIALS AND RESEARCH

PAGE 3 OF 7

Project Name: BR1-813 on I-495 over Christina River  
State Contract: T201407107

Boring No.: 12E-2D

Depth (ft.)	Water Level	No.	Sample Depth	Blows/6"	Sample Description	AASHTO Class.	Remarks
			41.0'		20" RECOVERY		
42.88		16	43.0'	WH WH WH 1	Saturated soft gray organic clay w/some silt, trace of fine to coarse sand.	A-7-5(27)	
45.56		U-4	45.0'		20" RECOVERY		Shelby Tube - Press Sample
			47.0'		24" RECOVERY		
48.24		17	47.0'	WH WH WH	Saturated soft gray organic clay w/some silt, trace of fine to coarse sand.	A-7-5(28)	
		18	49.0'	WH WH	20" RECOVERY Saturated soft gray organic clay w/some silt, trace of fine sand.	A-7-5(22)	
50.92			51.0'		24" RECOVERY		
53.6							
56.28		19	54.0'	WR WH WH WH	Saturated soft gray organic clay w/some silt.	A-7-5(27)	
			56.0'		24" RECOVERY		
58.96		20	59.0'	WR WR	Saturated soft gray organic clay w/some silt, trace of fine sand.	A-7-5(31)	
61.64		U-5	61.0'		24" RECOVERY		Shelby Tube - Press Sample
			63.0'		24" RECOVERY		
64.32		21	63.0'	WH WH WH WH	Saturated soft gray organic clay w/some silt, trace of fine sand.	A-7-5(27)	
			65.0'		24" RECOVERY		
		22	65.0'	WH WH	Saturated soft gray organic clay w/some silt,	A-7-5(37)	



# Foundation Design

CPT: C-12E

Total depth: 112.47 ft, Date: 6/8/2014

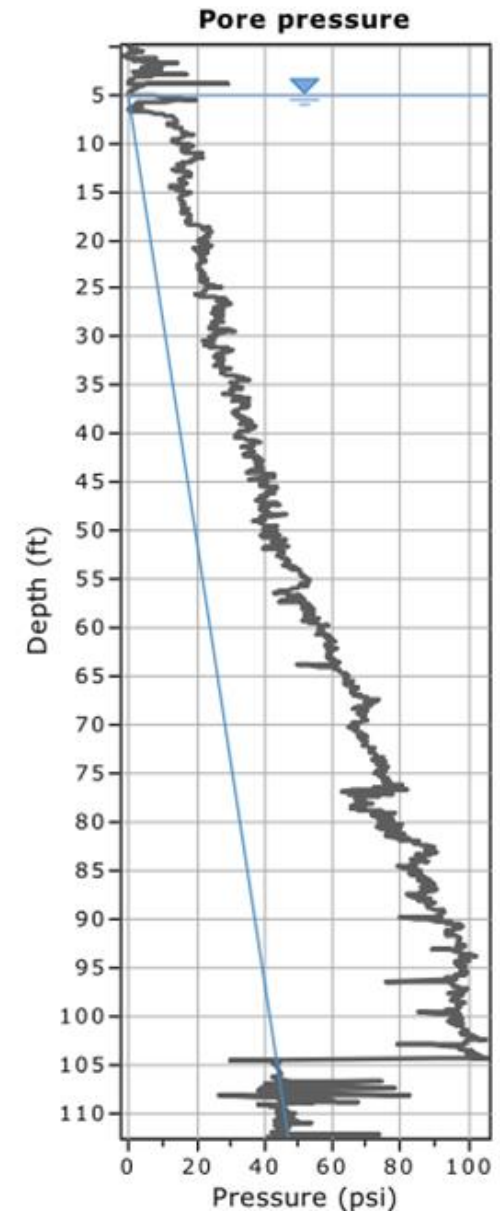
Surface Elevation: 7.00 ft

Cone Type: Hogentogler

Cone Operator: D. Krahl

- Cone Penetrometer  
Pore Pressure Readings

- Increased Pore Water Pressure  $\geq$  action level of 1.0 psi/ ft of depth.
- In-situ testing in the form of Cone Penetrometer Tests with piezometric readings indicated excess pore water pressure at or above the 1.0 psi/ft action level



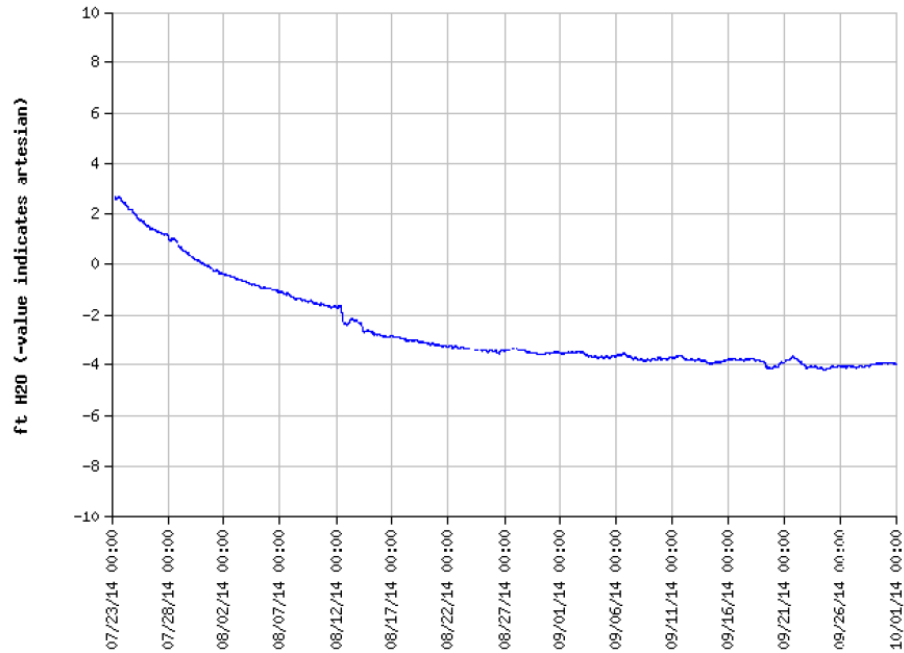
# Foundation Design

- Piezometer Readings
  - Subsequent piezometer readings indicated that the excess pore water was very slow to drain
  - This was confirmed by the Laboratory Consolidation Tests conducted on undisturbed samples ( $C_v = 0.01$  to  $0.02$  ft<sup>2</sup>/day).

READINGS PZ-12E	
Date	Pore Pressure (FT of Water)
6/11/2014	12.00
6/18/2014	11.78
6/25/2014	11.83
7/2/2014	11.09

# Foundation Design

PLOT OF PRESSURE HEAD IN FEET  
VS. TIME  
JULY 15 THROUGH OCTOBER 1, 2014



Y-AXIS ZERO REPRESENTS GROUND SURFACE, +/- EL 10



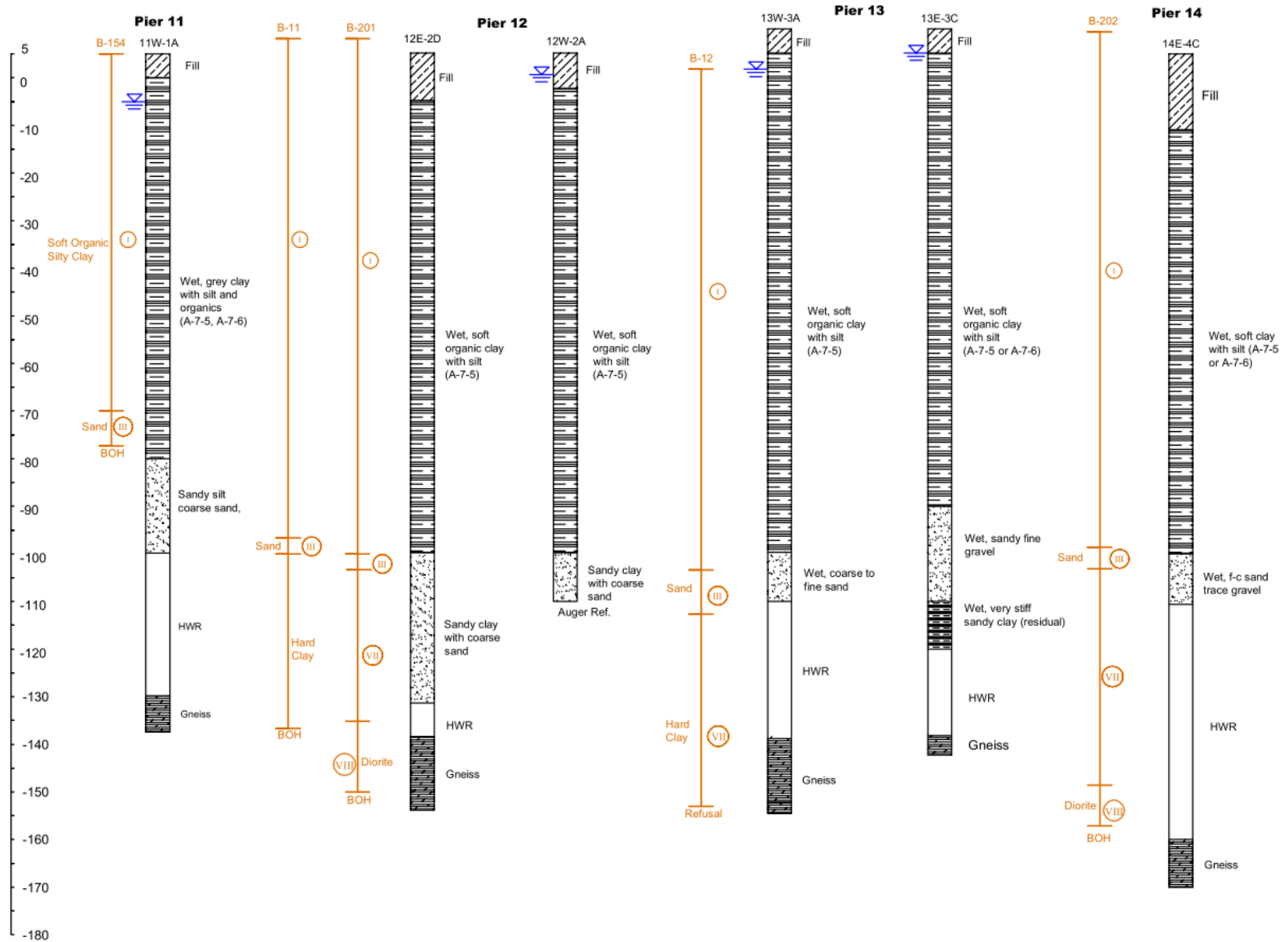
GEO-TECHNOLOGY ASSOCIATES, INC.  
*Geotechnical and Environmental Consultants*  
18 Boulden Circle, Suite 36  
New Castle, Delaware 19720  
(302) 326-2100  
Fax (302) 326-2399

BR1-183 ON I-495 OVER

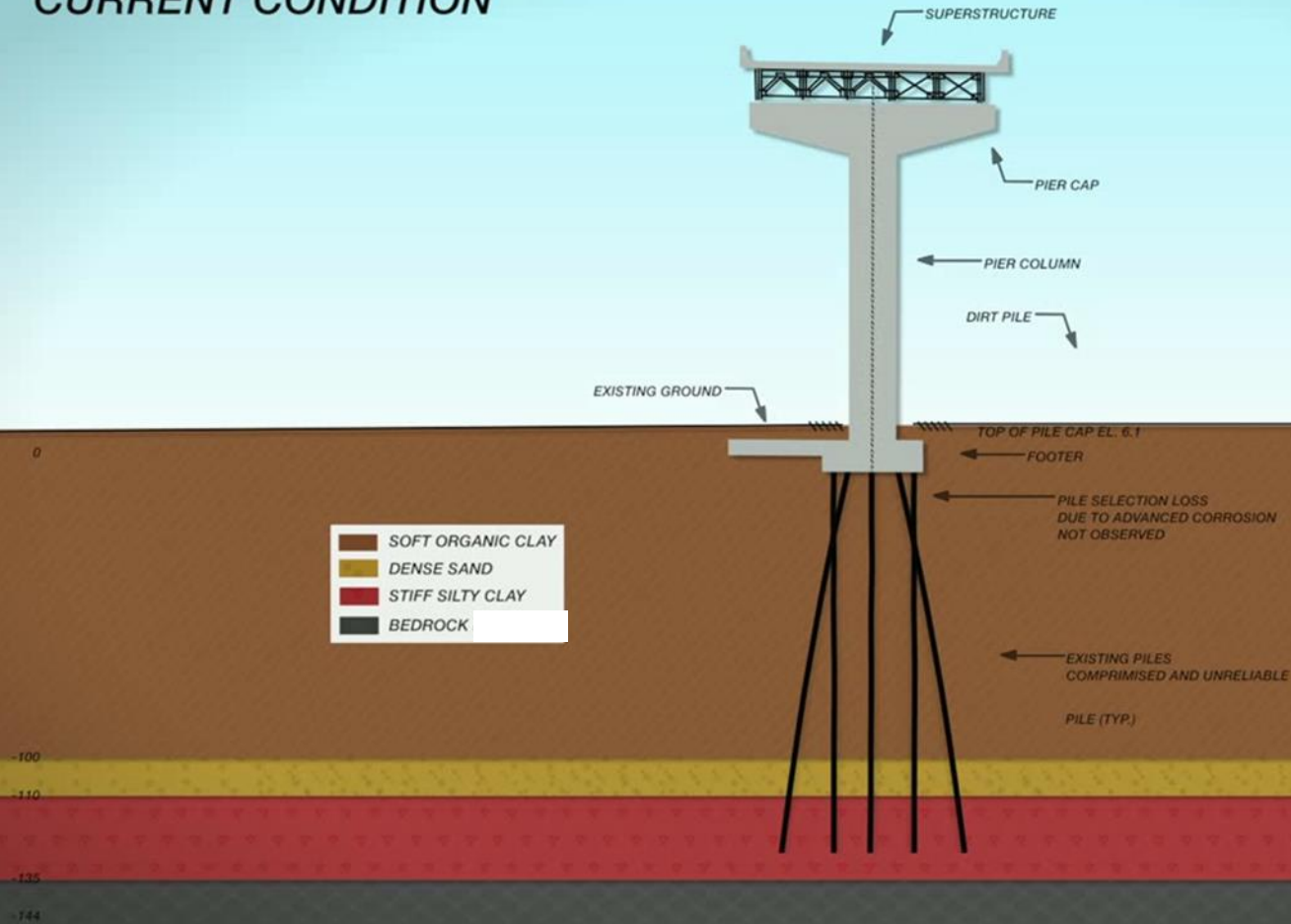
CHRISTINA RIVER

VW PIEZOMETER PZ-11E

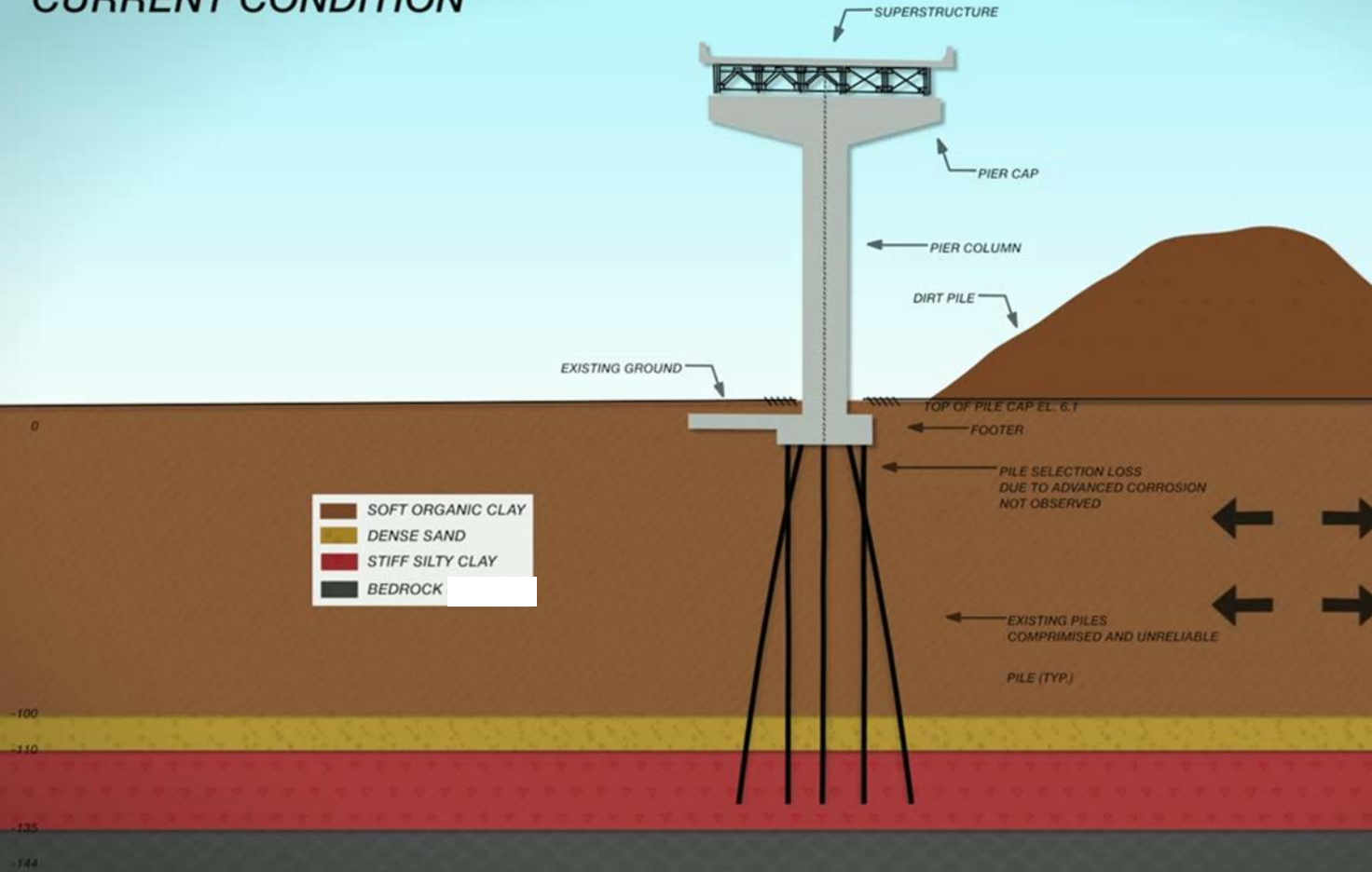
# Foundation Design



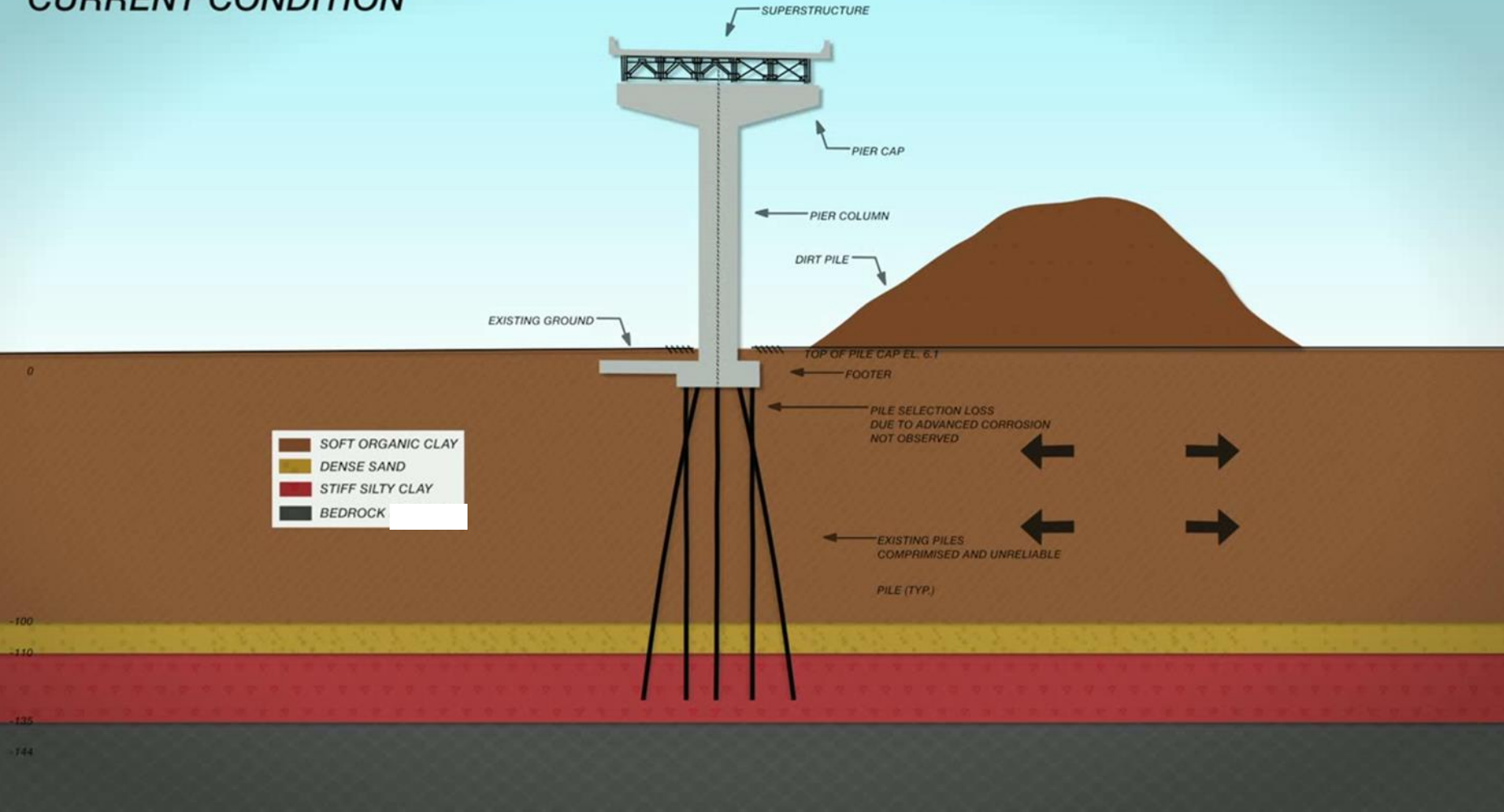
# CURRENT CONDITION



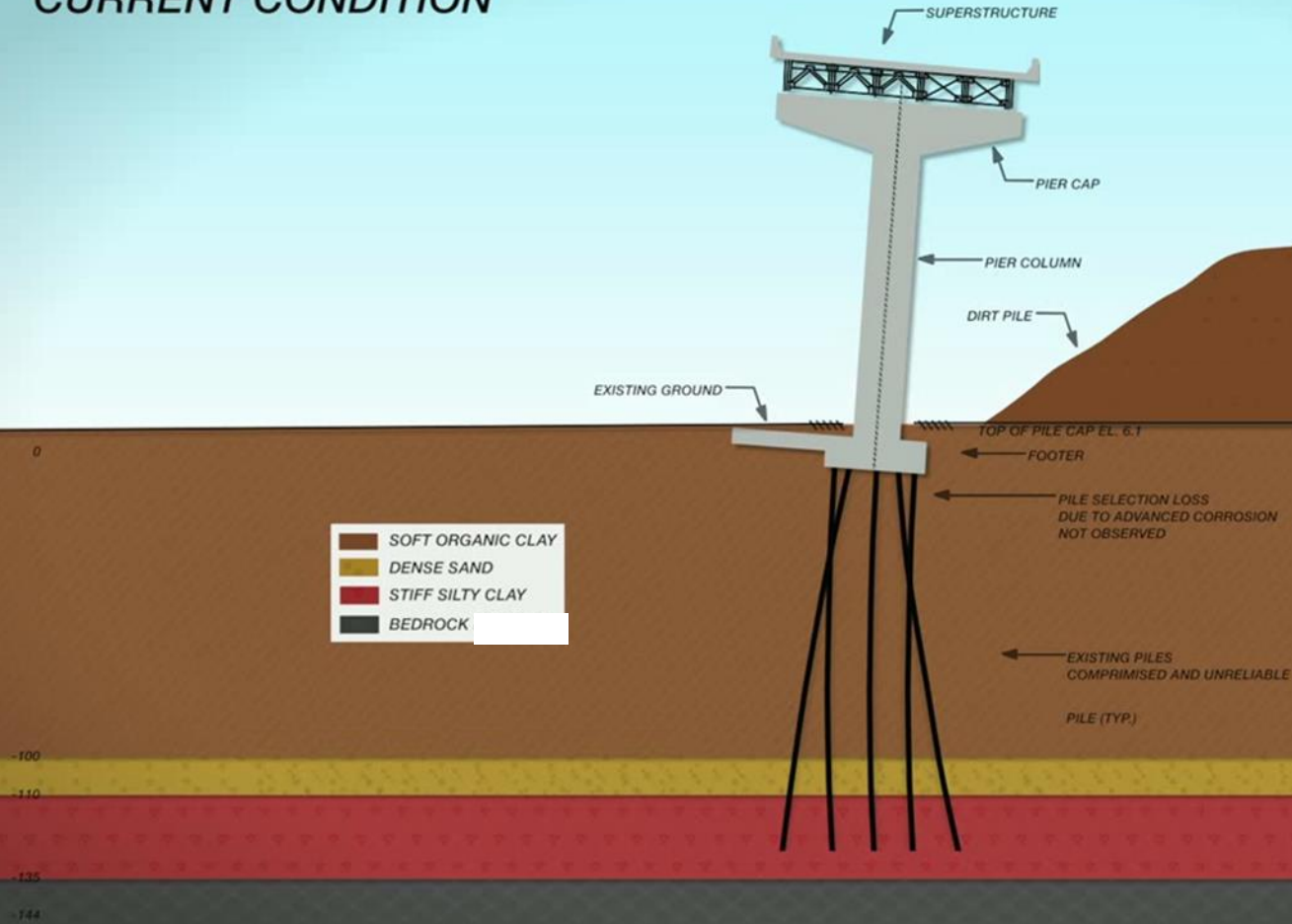
# CURRENT CONDITION



# CURRENT CONDITION



# CURRENT CONDITION



# Foundation Design

## Base Resistance ( $R_p$ ) for 'End Bearing' drilled shaft founded on Gneiss bedrock:

Initial, preliminary, base resistance calculation used presumptive values using empirical method from FHWA-NHI-10-016, Drilled Shafts Manual.

Final calculation of drilled shaft base resistance using AASHTO-method from AASHTO LRFD Bridge Design Specification, 6<sup>th</sup> Edition 2012 uses Canadian Geotechnical Society Method (1985) which accounts for spacing and aperture of discontinuities in the rock, in addition to, representative  $q_u$  values from rock core recovered from the project.

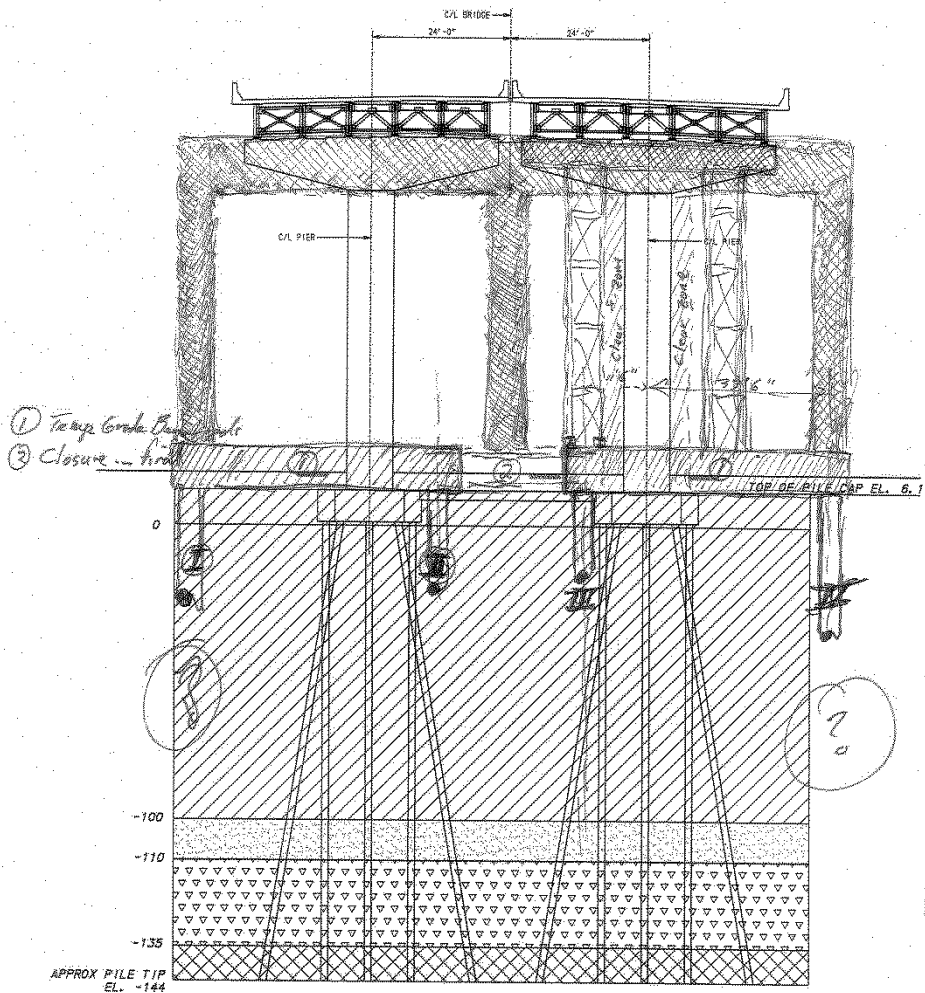
Using the AASHTO-method resulted in a refined Base Resistance ( $R_p$ ) of:

$$q_{BN} = 3 q_u K_{sp} d = 678 \text{ ksf}$$

$$\text{Base Resistance, } R_p = 4261 \text{ kips}$$

$R_p > 3183$  kip factored axial loading based on worst-case load condition, OK

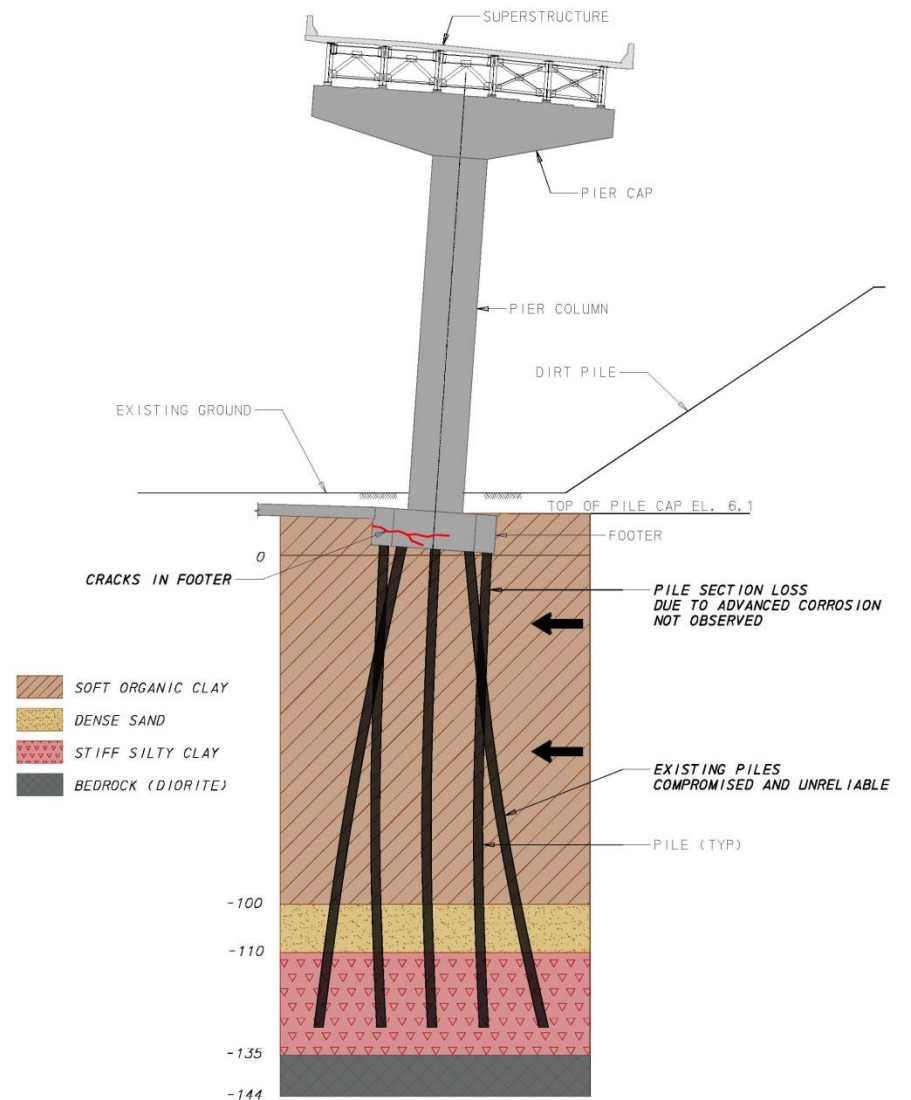
# Construction

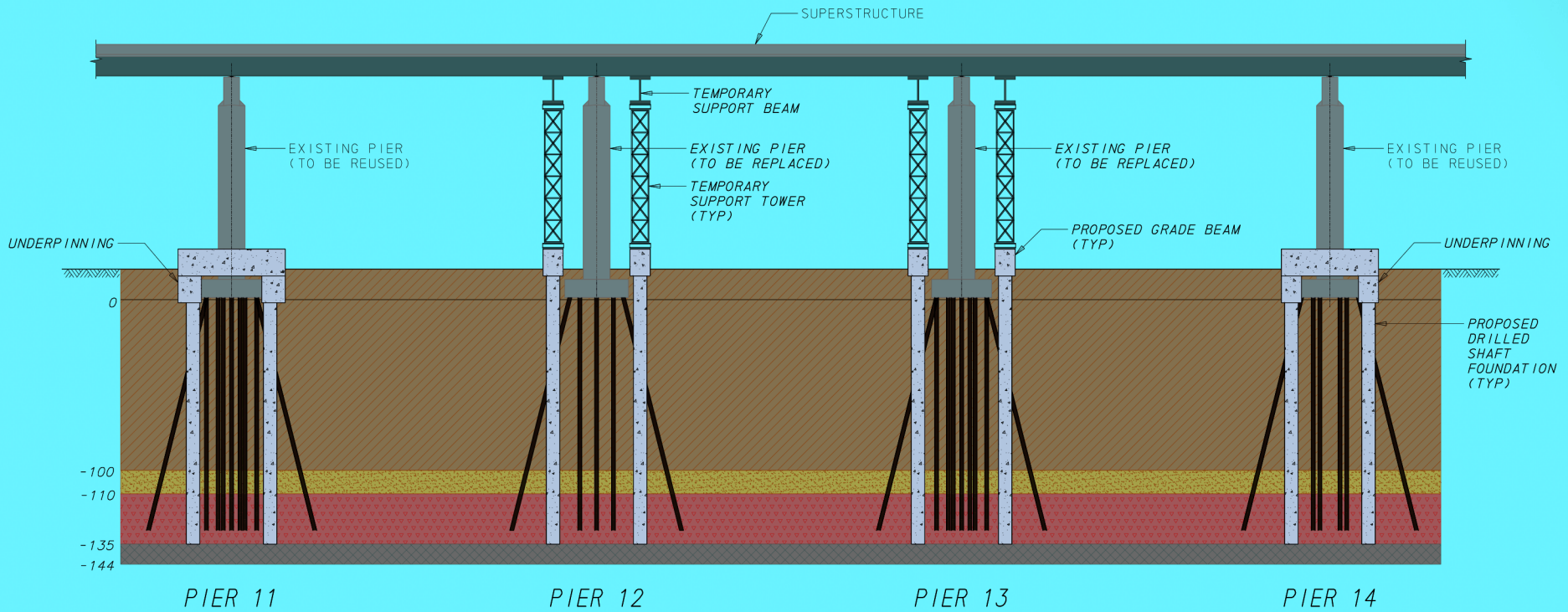


- Replace Piers 12 and 13
  - Pile cap cracked
  - Column insufficient for eccentric loading
  - Cannot rely on capacity of existing piles
- Drilled Shafts w/ Grade Beam
  - 4-ft diameter
  - Casing to bedrock
  - 130-ft to 160-ft below grade
  - **Rebar from Tappan Zee**
  - Support Temporary and Permanent Repairs
  - **Geotechnical Design**

# Construction

- Excess pore water pressures within the influence zone of the impacted piers made advancing borings extremely difficult
- Although dissipated during drilled shaft construction the overstressed subsoil continued to cause problems.





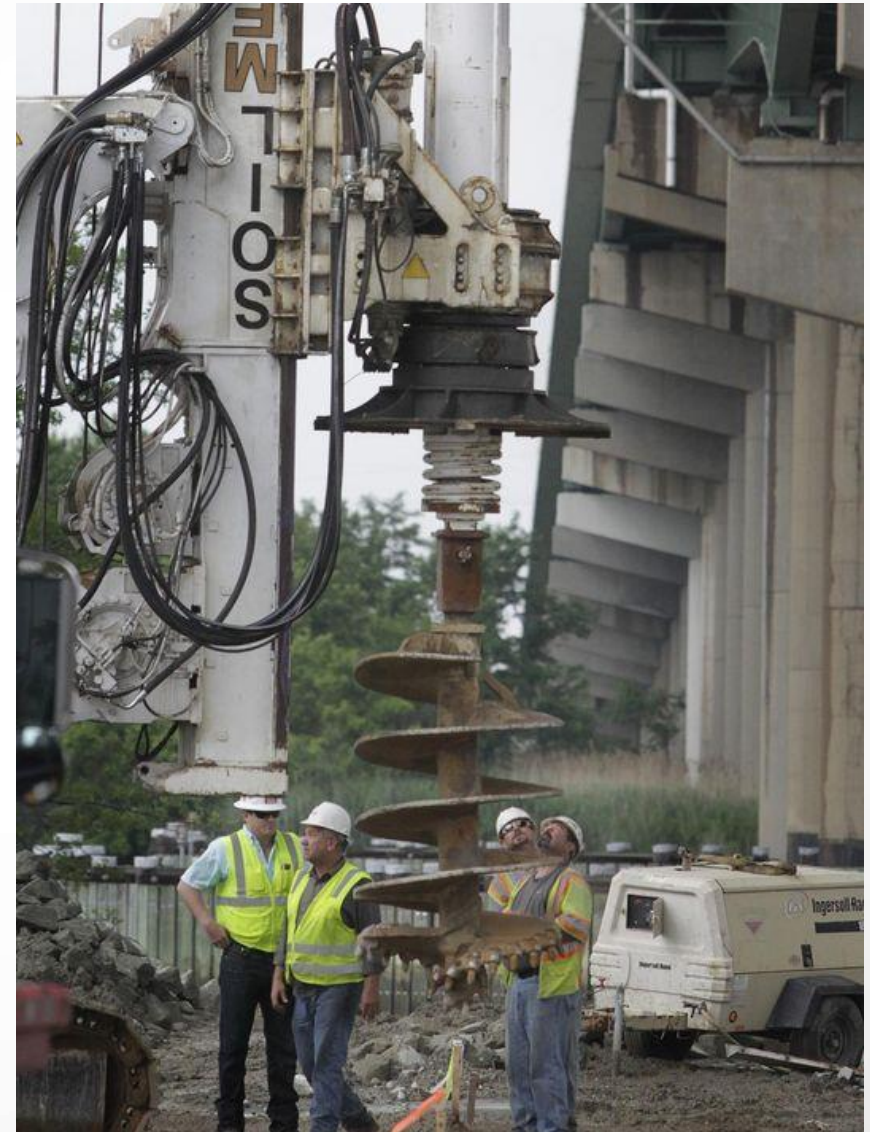
-  SOFT ORGANIC CLAY
-  DENSE SAND
-  STIFF SILTY CLAY
-  BEDROCK (DIORITE)

PROPOSED FOUNDATION REPAIR / TEMPORARY SUPPORT ELEVATION

# Construction

- **Construction**

- Began 6/5/2014
  - Site access
  - Causeway
  - Pier ties
- **Drilling Began 6/13/2014**
- **32 of 32 drilled shafts installed by 7/16/2014**
- Grade Beams Constructed
  - 12 and 13 SB North & South – 7/8/14
  - 12 and 13 NB North & South – 7/25/14
- Shoring Towers
  - Pier 12 and 13 SB– **7/22/14**



# Construction



First Delivery of Casing 6/12/2014



Cutting Teeth Welded to Casing

# Construction



First Drill Rig on Site 6/13/2014



Rebar Cage from Tappan Zee project  
6/16/2014

# Construction

Began oscillating in casings on 6/13/2014

Vibratory hammer used on 6/15/2014



# Construction

Right: Lifting 160 foot long Rebar Cage  
Below: Splicing of Rebar Cages in Yard



# Construction

Access Holes in Bridge Deck for Placement of Drilled Shaft Rebar



First Drilled Shaft Reinforcing Cage Placed 6/21/2014



# Construction



# Construction

- Drilled Shafts – Pouring PCC
  - Casings went to bedrock and were filled with a slurry.
  - SCC concrete was tremie poured from the bottom and slurry was pumped out and recycled.



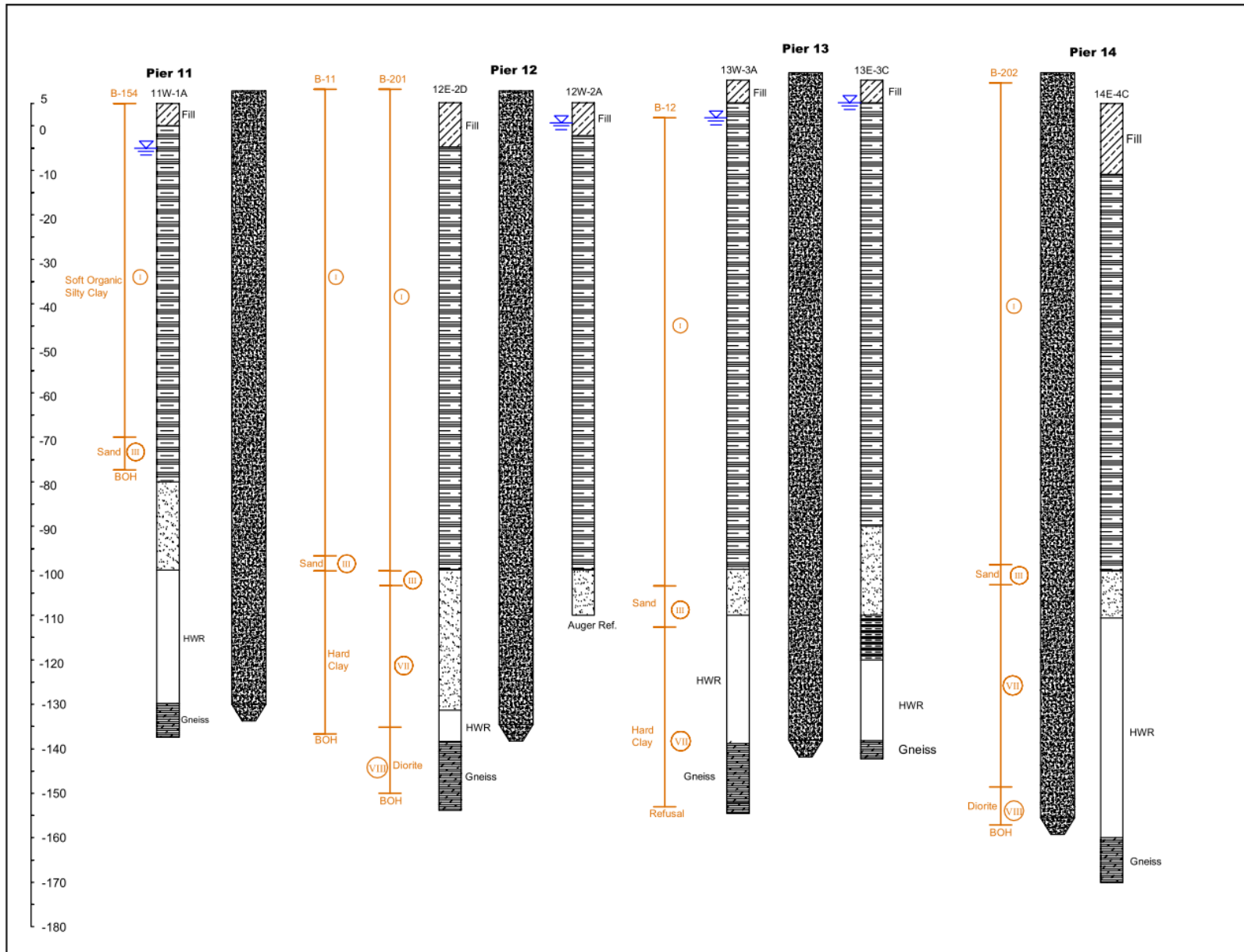
# Construction



# Construction



# Response



# Conclusions

- **Estimation of Lateral Loads Imposed by a Surcharge on Soft Clay**
  - **Modeling Techniques**
  - **Insitu Testing Options**
  - **Instrumentation**
  - **Methodologies**
- **Lessons Learned for Addressing Lateral Squeeze on Deep Foundations**
  - **Validity of Original Design**
  - **Battered Piles?**
  - **Control of ROW**
  - **Effectiveness of Drilled Shafts**

# Acknowledgements

- DeIDOT
  - Barry Benton, PE
  - Jason Hastings, PE
  - Tristan Siegel, PE
- FHWA
  - Dennis O’Shea, PE
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  - Neil Shemo, PE
  - Harry Roecker, PE
  - Aly Mohammad, PE
  - Anthony Crincoli, PE
  - Jim Bellenoit, PE
  - John Milius, PE
  - Jon Eberle, EIT
  - Gergis William, PE
- GTA, Inc
  - Meghan Lester, PE
- Duffield Associates, Inc.
  - R. David Charles, PE
- R K & K, Inc.
  - Eric Klein, PE
- AH Beck
  - Ian Kolda

# QUESTIONS?

