Using the Cone Penetrometer to Supplement Subsurface Exploration Programs

Presented by Meghan Lester, PE
Geo-Technology Associates, Inc.

Using the Cone Penetrometer to Supplement Subsurface Exploration Programs

- Review Purpose of Geotechnical Site Characterization
- Review Standard Penetration Test Procedures
- Introduce Cone Penetrometer Test and Benefits of Tool

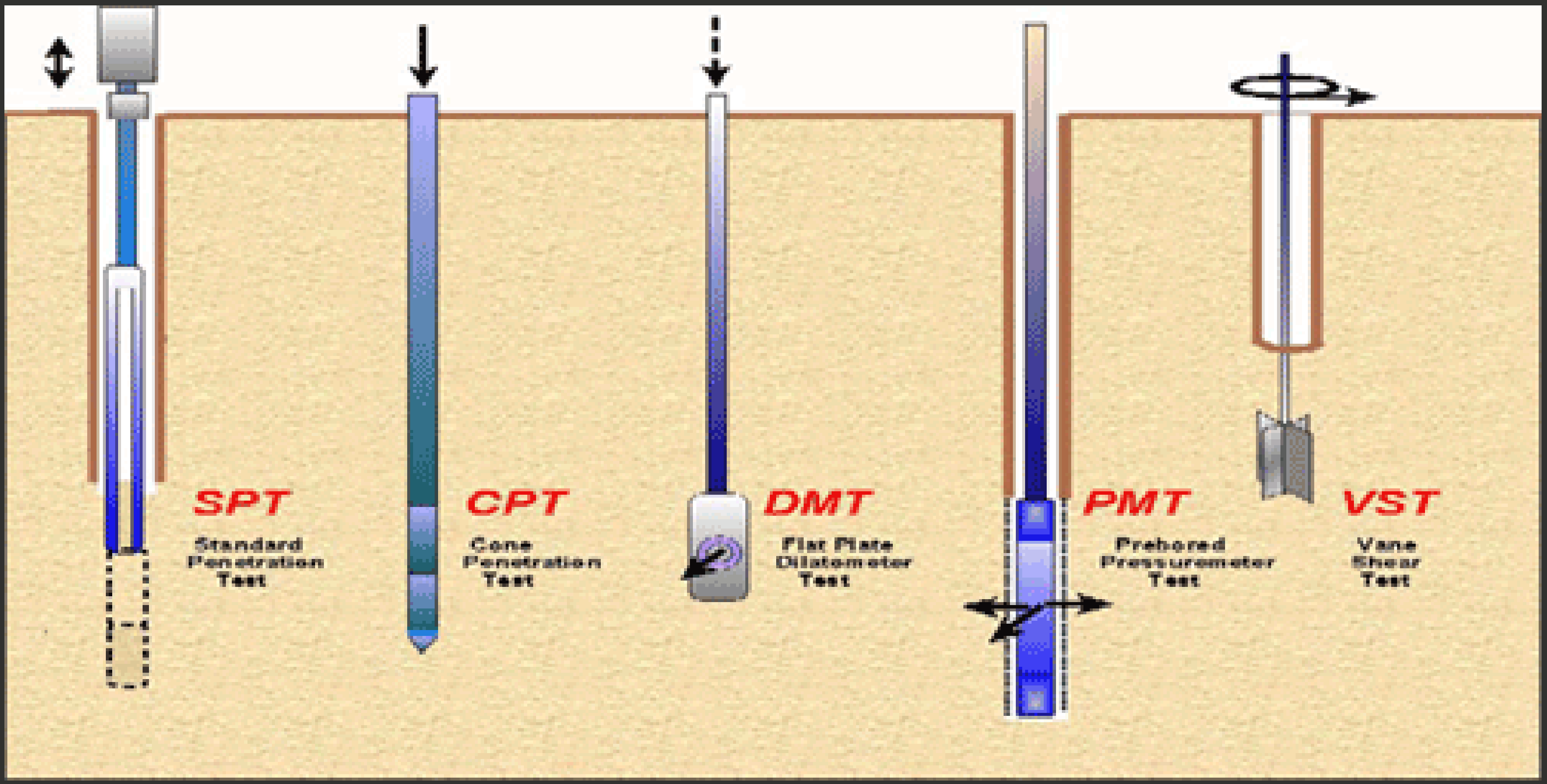
Purpose of Geotechnical Site Characterization

- Characterize the stratigraphy and general characteristics of soil and rock, including how these characteristics vary across the site
- Establish appropriate and reliable values for required design parameters and characterize groundwater conditions for design
- Identify and characterize hazards that may impact design, construction and performance

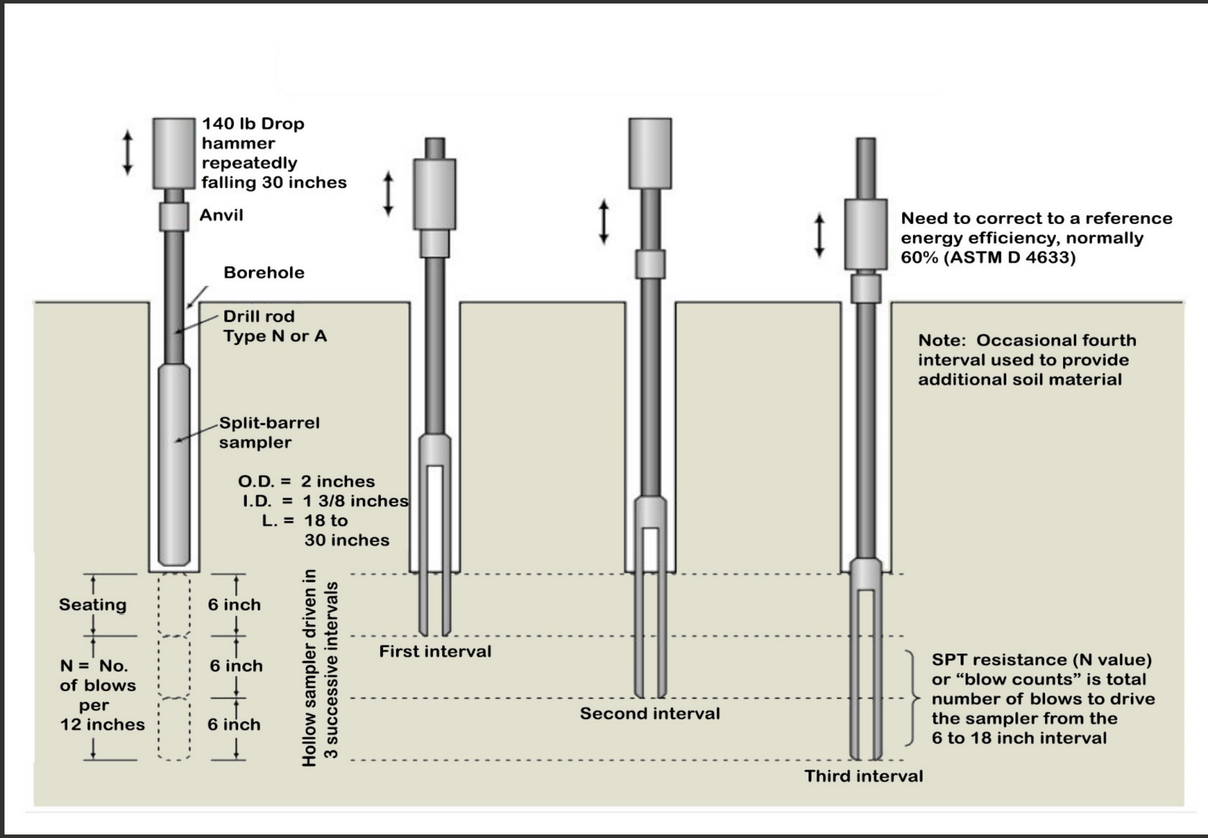
AASHTO Exploration Guidelines Table 3-2

	Minimum Number and Location of Exploration Points	Minimum Depth of Exploration
Retaining Walls	• Minimum of one exploration point • Exploration points every 100-200 ft. • Additional exploration points behind walls for anchored structures	• Depth below bottom of wall where stress increase becomes less than 10 percent of existing effective over burden stress • Depth should extend below any soft, compressible soils into competent bearing material
Shallow Foundations	• Minimum of one exploration point per substructure • For substructures with plan dimensions greater than 100 ft, a minimum of two exploration points • Additional exploration points for erratic conditions	• Depths below footing elevation where stress increase is less than 10 percent of existing overburden stress • Depth should extend below any soft, compressible soils into competent rock if encountered prior to meeting other depth criteria • In formations with highly variable and/or boulders, greater than 10-ft penetration into rock may be required.
Deep Foundations	• Minimum of one exploration point per embankment • For substructures with plan dimensions greater than 100 ft, a minimum of two exploration points • Additional exploration points for erratic subsurface conditions	• Depth below anticipated tip of foundation that is the greater of 20 ft or two times the maximum foundation group dimensions • Depth should extend below any soft, compressible soils to reach competent materials • Minimum 10 ft penetration into competent rock for piles bearing on rock • Minimum penetration into competent rock should be 10 ft for piles tipped on rock and greater of 10 ft, three times the shaft diameter for individual drilled shafts, or two times the maximum group dimensions below the anticipated tip elevation for drilled shafts
Embankment Foundations	• Minimum of one exploration point per embankment • Minimum of one exploration point at each bridge abutment location • Minimum of one exploration point per 300 ft of embankment, locations staggered in transverse direction • Additional exploration points for erratic subsurface conditions	• Minimum depth is greater of: ○ Depth where induces vertical stress is less than 10 percent of applied stress at base of embankment, or ○ Depth equal to twice embankment height below base of embankment unless competent hard stratum is encountered at shallower depth
Excavated Slopes	• Minimum of one exploration point per 300 ft of slope length • Minimum of three exploration points in transverse direction • Additional exploration points for erratic subsurface conditions	• Minimum depth is depth equal to the maximum slope height below the minimum excavation elevation unless competent hard stratum encountered at shallower depth • Exploration depth should extend below potential soft or weak strata that might impact instability

METHODS OF GEOTECHNICAL EVALUATION



STANDARD PENETRATION TEST BASICS ASTM D-1586 and AASHTO T-206

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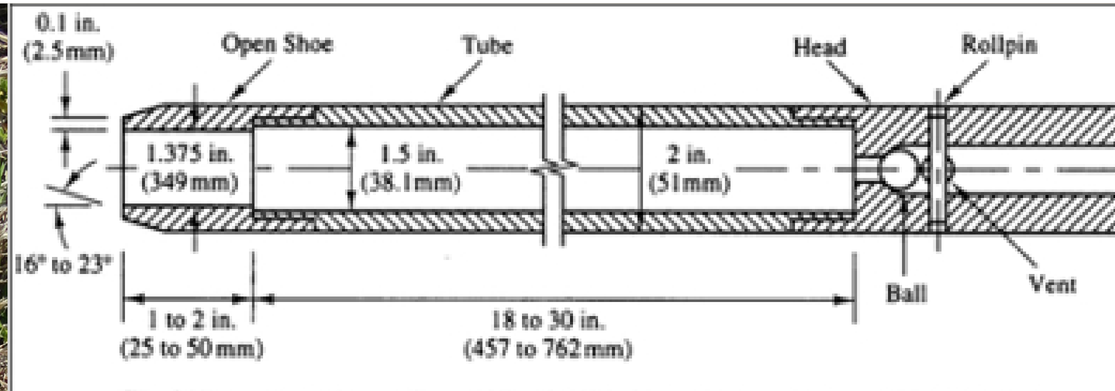

The SPT sampler (Adapted from ASTM D1586; Copyright ASTM, used with permission)

Reporting Criteria

Typical Exploration Log

LOG OF BORING NO. BH-12

Sheet 1 of 1

PROJECT: **Bayhealth New Health Campus**
PROJECT NO.: **150531**
PROJECT LOCATION: **Milford, Delaware**

WATER LEVEL (ft):	10.0	9.8	BOC
DATE:	4/10/15	4/10/15	
CAVED (ft):	In Augers	13.0	

DATE STARTED: **4/10/2015**
DATE COMPLETED: **4/10/2015**
DRILLING CONTRACTOR: **GTA**
DRILLER: **D. Hans**
DRILLING METHOD: **Hollow Stem Auger**
SAMPLING METHOD: **Split Spoon**

WATER ENCOUNTERED DURING DRILLING (ft) **10.0**
GROUND SURFACE ELEVATION: **32**
DATUM: **Google Earth**
EQUIPMENT: **CME550X**
LOGGED BY: **T. Hill**
CHECKED BY: **M. Lester**

SAMPLE NUMBER	SAMPLE DEPTH (ft.)	SAMPLE RECOVERY (in.)	SAMPLE BLOWS/6 inches	N (blows/ft.)
S-1	0.0	20	1-2-3-2	5
S-2	2.0	17	2-1-2-2	3
S-3	4.0	18	1-2-3-6	5
S-4	6.0	20	5-8-10-10	18
S-5	8.0	18	1-2-2-4	4
S-6	13.0	17	2-3-2-3	5
S-7	18.0	16	2-2-2-2	4
S-8	23.0	15	2-2-3-4	5
S-9	28.0	14	2-3-3-5	6
S-10	33.0	20	1-3-6-7	9
S-11	38.0	16	1-5-6-8	11
S-12	43.0	16	1-3-3-4	6
S-13	48.0	15	2-3-5-6	8

DEPTH (ft.): 0, 9, 18, 27, 36, 45

ELEVATION (ft.)	USCS	DESCRIPTION	REMARKS
32.0		Tilled agricultural land +/- 8 inches	
31.3	SM	Brown, moist, very loose, Silty SAND Same, very loose Light brown, moist, loose, Silty SAND Same, trace clay lenses	
24.0	CL	Gray, wet, soft, Sandy Lean CLAY	
22.5	SM	Orange, wet, loose, Silty SAND	
18.0	CL	Gray, wet, medium stiff, Lean CLAY with Sand Gray, wet, soft, Sandy Lean CLAY	
9.0	SM	Light brown, wet, loose, Silty SAND	
4.0	SP-SM	Light brown, wet, loose, Poorly-graded SAND with Silt Same, orange and brown, contains gravel Same, medium dense Same, loose, trace gravel Same, some gravel	
-18.0		Boring terminated at 50.0 feet	

NOTES: **Location and elevation should be considered approximate.**

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New Castle, DE 19720

LOG OF BORING NO. BH-12

Sheet 1 of 1

FACTORS THAT CAN AFFECT THE SPT RESULTS

Is this list too long?

TABLE 2.5 Factors that can Affect the Standard Penetration Test Results

Factors that can affect the standard penetration test results	Comments
Inadequate cleaning of the borehole	SPT is only partially made in original soil. Sludge may be trapped in the sampler and compressed as the sampler is driven, increasing the blow count. This may also prevent sample recovery.
Not seating the sampler spoon on undisturbed material	Incorrect *N* value is obtained.
Driving of the sampler spoon above the bottom of the casing	The *N* value is increased in sands and reduced in cohesive soil.
Failure to maintain sufficient hydrostatic head in boring	The water table in the borehole must be at least equal to the piezometric level in the sand; otherwise the sand at the bottom of the borehole may be transformed to a loose state.
Attitude of operators	Blow counts for the same soil using the same rig can vary, depending on who is operating the rig and perhaps the mood of operator and time of drilling.
Overdriven sample	Higher blow counts usually result from overdriven sampler.
Sampler plugged by gravel	Higher blow counts result when gravel plugs the sampler. The resistance of loose sand could be highly overestimated.
Plugged casing	High *N* values may be recorded for loose sand when sampling below the groundwater table. Hydrostatic pressure causes sand to rise and plug the casing.
Overwashing ahead of casing	Low blow count may result for dense sand since sand is loosened by overwashing.
Drilling method	Drilling technique (e.g., cased holes versus mud-stabilized holes) may result in different *N* values for the same soil.
Not using the standard hammer drop	Energy delivered per blow is not uniform. European countries have adopted an automatic trip hammer not currently in use in North America.
Free fall of the drive weight is not attained	Using more than 1.5 turns of rope around the drum and/or using wire cable will restrict the fall of the drive weight.
Not using the correct weight	Driller frequently supplies drive hammers with weights varying from the standard by as much as 10 lb.
Weight does not strike the drive cap concentrically	Impact energy is reduced, increasing the *N* value.
Not using a guide rod	Incorrect *N* value is obtained.
Not using a good tip on the sampling spoon	If the tip is damaged and reduces the opening or increases the end area, the *N* value can be increased.
Use of drill rods heavier than standard	With heavier rods, more energy is absorbed by the rods, causing an increase in the blow count.
Not recording blow counts and penetration accurately	Incorrect *N* values are obtained.
Incorrect drilling	The standard penetration test was originally developed from wash boring techniques. Drilling procedures which seriously disturb the soil will affect the *N* value, for example, drilling with cable tool equipment.

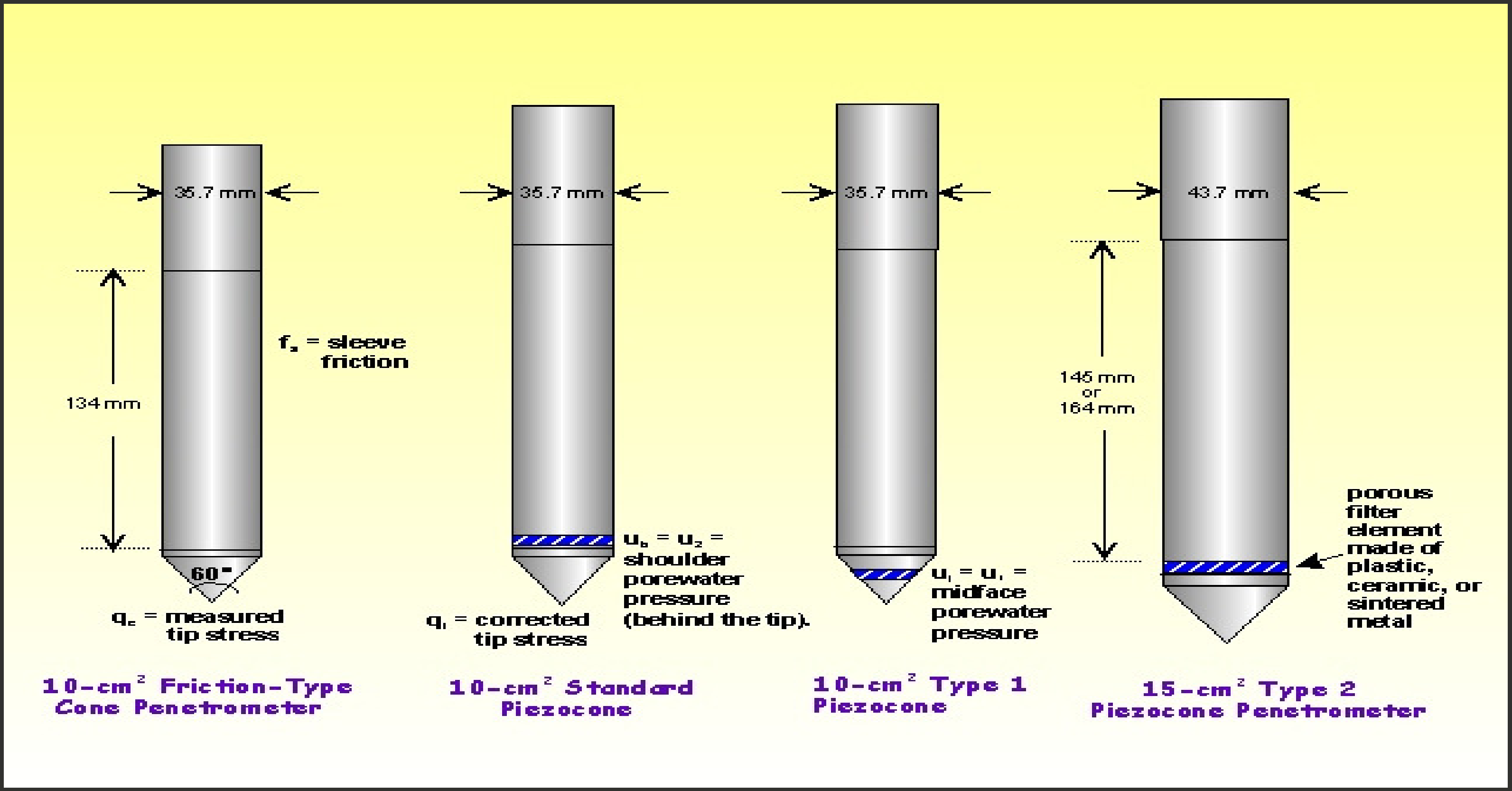
CONE PENETROMETER TEST

ASTM D-3341 & ASTM D-5778

CPT Soundings

Electronic Friction Cone and Piezocone commercially available and use with increased regularity because of flexibility, speed and continuous profile

TYPES OF CONES



Preparing the Cone for a Push

Pushing the Cone

- Rate of push is approximately 1 to 2 cm/sec
- 3-foot long rods are added and pushing is continued
- Data acquisition system allows for real time viewing

Sleeve and Tip Resistance

- Sleeve Friction
  - Load cells in sleeve about four inches from tip
  - Measure average skin friction as tip and sleeve are advanced
  - Sleeve Resistance is related to friction of the horizon being penetrated
- Tip Resistance
  - Load cells located directly behind tip
  - Cone forces passive failure when pushed and the cone can sense soil resistance about 8 inches ahead of advancing tip
  - Tip Resistance is related to undrained shear strength of saturated cohesive materials

Additional Cone Parameters

- Friction Ratio
  - Skin Friction/Tip Resistance
  - Used in classifying soil by its reaction to the cone being pushed through soil
  - Low Ratios tend to indicate granular soils
  - High Ratios indicate clayey soils

- Pore Pressure
  - Measure in-situ pore pressure
  - Measured in static or dynamic modes
  - Differential pore pressure also used in classifying soils
  - Dissipation test can be performed at any required depth

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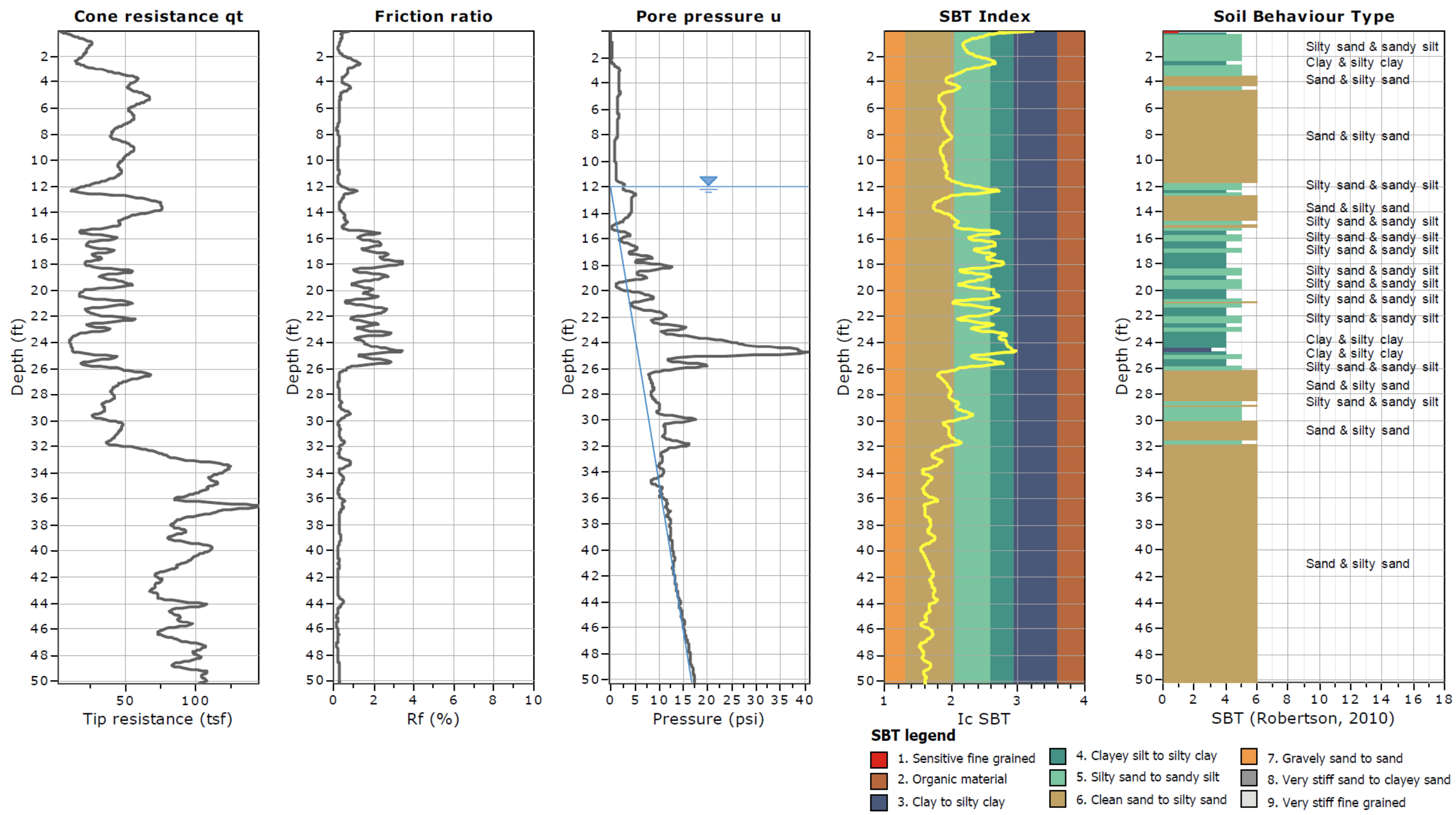
(302) 326-2100 Fax (302) 326-2399

CPT: BH-11
Total depth: 50.20 ft
Surface Elevation: 30.00 ft
Cone Type: Hogentogler
Cone Operator: K. Kozak/ D. Hans

Project:
Location:



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PROJECT:	**Bayhealth New Health Campus**	WATER LEVEL (ft):	10.0	9.8	BOC
PROJECT NO.:	**150531**	DATE:	4/10/15	4/10/15	
PROJECT LOCATION:	**Milford, Delaware**	CAVED (ft):	In Augers	13.0	

DATE STARTED:	**4/10/2015**	WATER ENCOUNTERED DURING DRILLING (ft)	**10.0**
DATE COMPLETED:	**4/10/2015**	GROUND SURFACE ELEVATION:	**32**
DRILLING CONTRACTOR:	**GTA**	DATUM:	**Google Earth**
DRILLER:	**D. Hans**	EQUIPMENT:	**CME550X**
DRILLING METHOD:	**Hollow Stem Auger**	LOGGED BY:	**T. Hill**
SAMPLING METHOD:	**Split Spoon**	CHECKED BY:	**M. Lester**

SAMPLE NUMBER	SAMPLE DEPTH (ft.)	SAMPLE RECOVERY (in.)	SAMPLE BLOWS/6 inches	N (blows/ft.)	ELEVATION (ft.)	DEPTH (ft.)	USCS	GRAPHIC SYMBOL	DESCRIPTION	REMARKS
S-1	0.0	20	1-2-3-2	5	32.0 31.3	0	SM		Tilled agricultural land +/- 8 inches Brown, moist, very loose, Silty SAND	
S-2	2.0	17	2-1-2-2	3					Same, very loose	
S-3	4.0	18	1-2-3-6	5					Light brown, moist, loose, Silty SAND	
S-4	6.0	20	5-8-10-10	18					Same, trace clay lenses	
S-5	8.0	18	1-2-2-4	4	24.0 22.5	9	CL SM		Gray, wet, soft, Sandy Lean CLAY Orange, wet, loose, Silty SAND	
S-6	13.0	17	2-3-2-3	5	18.0		CL		Gray, wet, medium stiff, Lean CLAY with Sand	
						18				
S-7	18.0	16	2-2-2-2	4					Gray, wet, soft, Sandy Lean CLAY	
					9.0					
S-8	23.0	15	2-2-3-4	5			SM		Light brown, wet, loose, Silty SAND	
					4.0	27				
S-9	28.0	14	2-3-3-5	6			SP-SM		Light brown, wet, loose, Poorly-graded SAND with Silt	
S-10	33.0	20	1-3-6-7	9					Same, orange and brown, contains gravel	
						36				
S-11	38.0	16	1-5-6-8	11					Same, medium dense	
S-12	43.0	16	1-3-3-4	6					Same, loose, trace gravel	
						45				
S-13	48.0	15	2-3-5-6	8					Same, some gravel	
					-18.0				Boring terminated at 50.0 feet	

NOTES: **Location and elevation should be considered approximate.**

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New Castle, Delaware
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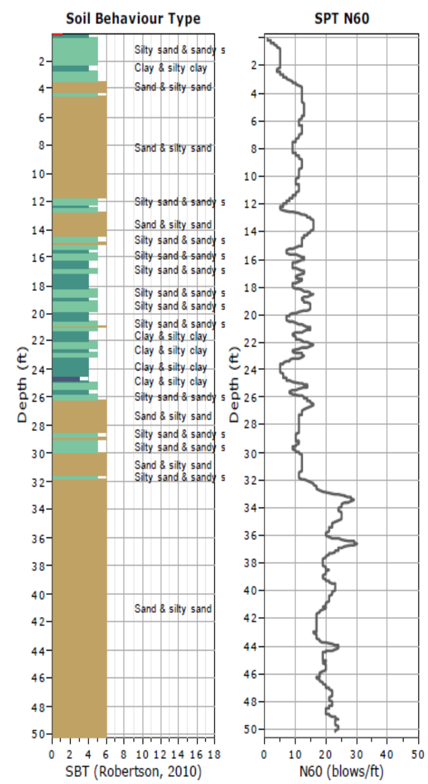
CPT: BH-11

Total depth: 50.20 ft, Date: 4/9/2015
Surface Elevation: 30.00 ft
Cone Type: Hogentogler
Cone Operator: K. Kozak/ D. Hans

Project: Bayhealth New Health Campus
Location: Milford, Delaware

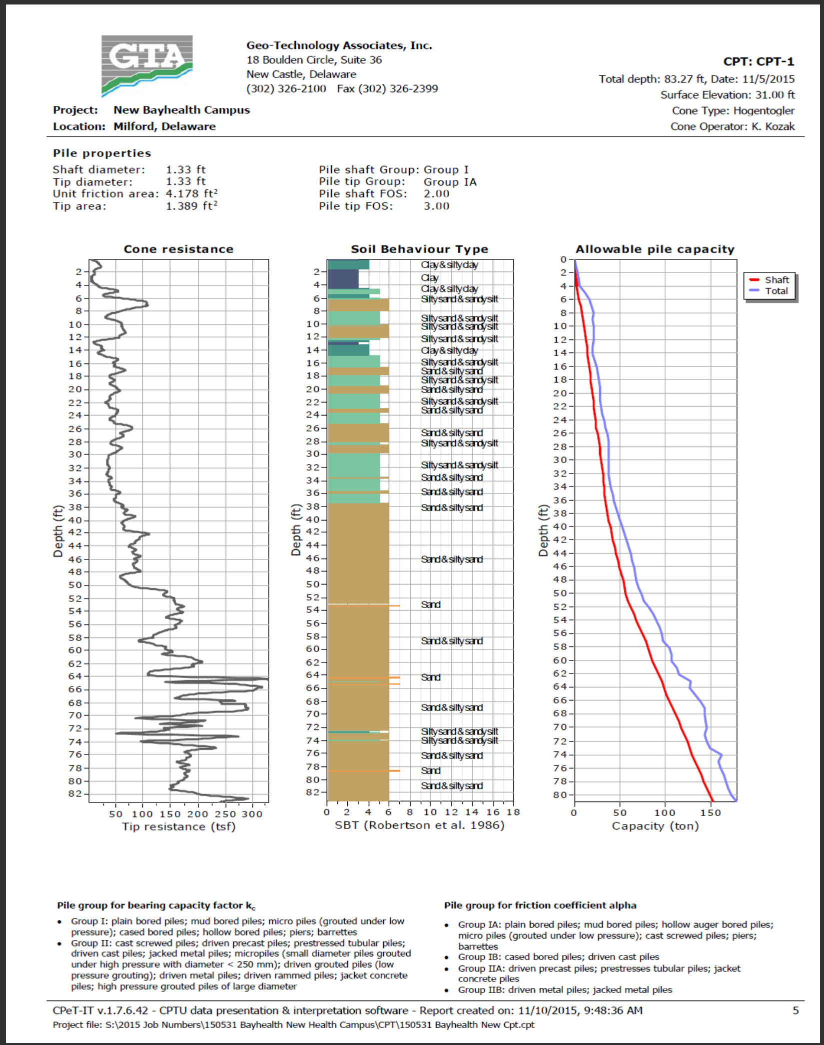


Benefit of Using CPT for Subsurface Explorations

- Continuous or near continuous data
- Repeatable and reliable penetration data
- Potential Cost Savings
- Environmental Applications
  - No direct human contact with contaminated materials

Benefit of Using CPT for Subsurface Explorations

- Determine subsurface stratigraphy and identify materials present using SBT
  - Capable of detecting discrete horizons or layers associated
    - Soft or loose materials
    - Discontinuous lenses
    - Peat and other organic materials
- Estimate Geotechnical Parameters
  - Determination of Pile Capacity
- Identification of Liquefiable Soils



Shear Wave Velocity Testing

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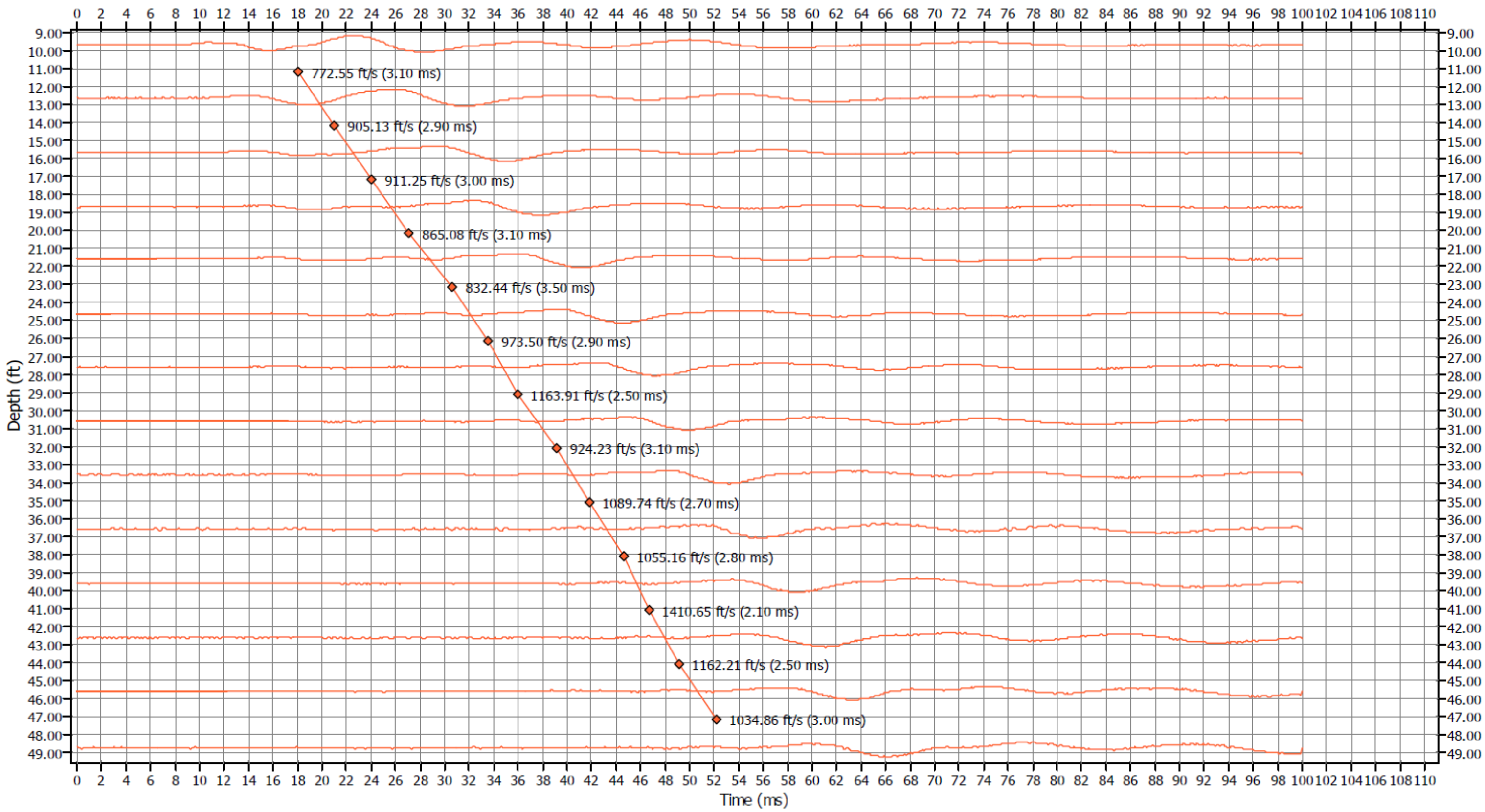
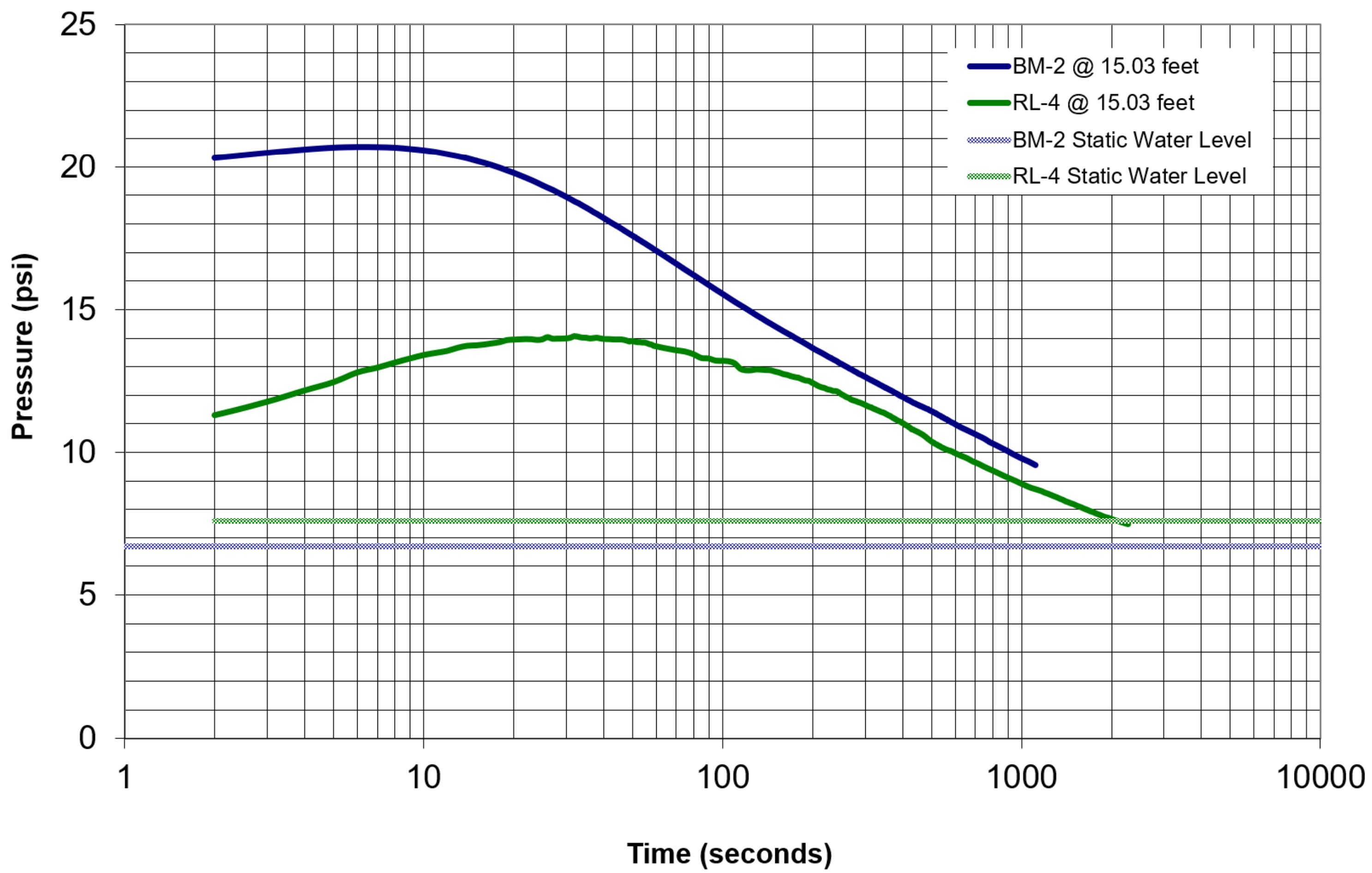
Project: Bayhealth New Health Campus **Borehole ID: BH-8**

Average S signals full graph (L signals)



Delaware Bay Dikes Repair and Prevention Project
CPTU Pore Pressure Dissipation Tests



Considerations

Standard Penetration Test

- Physical samples obtained
- Results operator dependent
- Requires a competent engineer to coordinate field exploration
- Not particularly suited to evaluate soft soils and cohesive soils

Cone Penetration Test

- No "ground-truthing" unless done in combination with test pits or borings
- Desiccated soils may be interpreted as sand or silt
- Less irregularity, results not operator dependent
- In compacted fills and ground improvement, CPT can identify density gradients and variances in stiffness and shear strength
- Useful in estimating dynamic properties and shear modulus

Both tools are best when used in combination, and when a prescriptive geotechnical program is not employed

Thank You!

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