FOUNDATION ANALYSIS AND DESIGN REPORT

TO: Mark Bishop, PE, Kimley-Horn and Associates, Inc.

FROM: Jeffery K. Voyen, PE, American Engineering Testing, Inc.

DATE: June 26, 2014

SUBJECT: Penn Avenue Retaining Wall and Pedestrian Bridge
Southwest Light Rail Transit Project
Minnepolis, Minnesota
AET No. 01-05697.10

1.0 PROJECT INFORMATION

This report provides preliminary foundation recommendations for the retaining wall planned on the south side of the Penn Station Kiss and Ride and the associated pedestrian bridge which will cross over the freight rail tracks to the Penn Station, where a vertical circulation structure will provide access to the platform. The current layout addressed in this report is presented on attached Figure 1. The current plan and profile sheet associated with this wall and bridge is also attached to this report. The estimated bottom of foundation elevation for the retaining wall is shown on the profile. The estimated bottom of foundation elevation for the pedestrian bridge is assumed to be about 5 feet below current grade.

2.0 SUBSURFACE EXPLORATION SUMMARY

2.1 Field Scope

Five standard penetration test (SPT) borings have been conducted specific to this wall and bridge, as follows:

- Pedestrian bridge/vertical circulation: 1019 SB, 1250 SV
- Retaining wall: 1018 SB, 1252 SW, 1253 SW

The locations of the above listed borings appear on attached Figure 1.

2.2 Laboratory Scope

During laboratory classification logging, water content tests were conducted on cohesive soil samples. In addition, three unconfined compression tests were performed on undisturbed thinwall tube samples. The test results appear on the individual boring logs, opposite the samples upon which they were performed.

2.3 Methods

2.3.1 Standard Penetration Test Borings

Logs of the noted borings are attached. The SPT borings were drilled with 3.25 inch diameter hollow stem augers and mud rotary drilling methods. Standard penetration test samples were taken with split-barrel samplers per ASTM: D1586, with the exception that the hammers were calibrated to near N_{60} values, consistent with MnDOT requirements. Additional details of the methods used appear on the attached sheet entitled *Exploration/Classification Methods*.

The soils were classified per the Unified Soil Classification System. The Soil Group category per the AASHTO Soil Classification System is also noted. The attached boring logs contain information concerning soil layering, soil classification, geologic description, and moisture condition. Relative density or consistency is also noted for the natural soils, which is based on the standard penetration resistance (N-value).

2.4 Geology/Soils Review

The generalized geologic profile consists of mixed fill over water-deposited (alluvial) soils, with glacial till deposits often interlayered at depth.

The Penn Avenue roadway area (where Borings 1252 SW and 1253 SW were drilled), is about 15 feet to 20 feet higher than the planned bridge area to the south, where the remaining test borings were drilled. Accordingly, the fill thickness varies; about 1 foot to 4 feet in the low elevation area to about 21½ feet to 29 feet in the Penn embankment area. The thicker fill area is mostly sands with silt to silty sands, with some clayey sand, ashes/cinders, and pieces of concrete.

The upper zone of alluvium at the lower elevation borings is predominantly lean clay and fat clay. Otherwise, the alluvium is mostly sand and sand with silt, sometimes having significant gravel content. Most of the clay is soft, and is located below planned foundation grades. The clay alluvium below the thicker Penn Avenue fill embankment is absent, suggesting either the sands rise to the north or the soft clay was removed prior to roadway filling. Regardless, the soft clays are expected below foundation grade in both bridge and wall areas.

The glacial till layers are interbedded within the alluvium, and are more prevalent at some locations than others. The till is mostly clayey sand, silty sand, and sandy lean clay.

Bedrock was not reached with boring depths up to 101 feet (approximate elevation 752).

2.5 Ground Water

Water levels appeared in the boreholes at elevations ranging from about 846 feet to 847½ feet, which is only about 4 feet to 6½ feet deep in the lower elevation area. As the levels were measured in granular soils, or after penetrating into granular soils and given some time to

stabilize, they should reasonably represent the hydrostatic ground-water level for that time and location. Ground-water levels should be expected to fluctuate both seasonally and annually.

3.0 FOUNDATION REVIEW

3.1 Foundation Type

It is anticipated the soft alluvial clays will be present below foundation grade in the bridge and wall foundation areas. In the bridge pier and Penn Station vertical circulation structure area, this soft clay depth is excessive, and soil excavate/refill correction is not feasible. The thickness of clay is less in the wall area, although the embankment proximity and space issues may complicate soil correction. Therefore, we are recommending all foundations be supported on a deep foundation system of driven piling.

The borings did not reach bedrock or obvious highly resistant material within the bored depth. In this case, it is preferred to gain pile capacity through a combination of end bearing and side skin friction. Based on typical resistance needs for this type of bridge, the use of 12-inch diameter CIP steel pipe pile is commonly used and was the pile type analyzed. Per normal MnDOT limits, this pile can be designed for a Factored Pile Bearing Resistance value (φR_n) of up to 100 tons, assuming a pile wall thickness of 0.250 inches.

The current design places the center pier of the pedestrian bridge beneath overhead power lines which may then preclude the use of driven piles. Alternatives which can be considered include the use of helical piles which can be installed in limited headroom areas or the use of special ground improvement techniques such as rammed aggregate piers, thereby allowing spread foundation support. Design of these systems is typically performed by the specialty contractor.

3.2 Pile Foundation Analysis

Pile bearing resistance versus pile length was analyzed using *DRIVEN* software (FHWA). This program uses the Nordlund method for granular soils and the Tomlinson method for cohesive soils. The granular soil internal friction angle used was based on its relationship to standard penetration test values as presented by Peck, Hanson, and Thorburn (1974), with the N-values being corrected for the influence of the effective overburden pressure. For cohesive soils, we estimated undrained shear strength based on correlations with the SPT data. The "ultimate capacity" determined from this *DRIVEN* analysis is considered the Nominal Resistance of Single Pile in Axial Compression (R_n) using LRFD terminology.

The nominal resistance (ultimate capacity) needed to be demonstrated in the field depends on the Resistance Factor allowed by the "Condition/Resistance Determination Method" used. A Resistance Factor (φ) of 0.65 can be used when dynamic analysis (High Strain Dynamic Pile Testing) is employed and a Resistance Factor (φ) of 0.50 should be used when field evaluation of steel pipe pile is based on the MPF12 driving formula (MnDOT's new formula). We recommend using dynamic analysis for pile evaluation on these bridges. In this case, a nominal resistance of

308 kips would then need to be demonstrated.

The *DRIVEN* results for 12-inch diameter CIP steel pipe pile, based on Borings 1018 SB, 1019 SB, 1250 SV, and 1253 SW are shown on attached Figures 2 to 5.

The lengths predicted by the computer analyses in order to attain a nominal resistance of 308 kips are shown in Table 3.2. This assumes a design φR_n = 100 tons and the use of dynamic analysis for the field evaluation method (allowing φ = 0.65).

Table 3.2 – Estimated Pile Lengths from DRIVEN Analyses

Boring No.	Assumed Bottom of Footing Elevation, ft	Estimated Tip Elevation, ft	Estimated Pile Length, ft
1018 SB	844	798	46
1019 SB	845	775	70
1250 SV	848	775	73
1253 SW	856*	810	46

*steps down to south, up to north

4.0 FOUNDATION RECOMMENDATIONS

4.1 12-inch Diameter CIP Steel Pipe Pile

The pedestrian bridge and retaining wall foundations can be supported with 12-inch diameter CIP steel pipe piles. The piles can be designed based on a Factored Pile Bearing Resistance (φR_n) value of up to 100 tons. The pipe piles should have a minimum yield strength (f_y) of 45 ksi and a minimum wall thickness of 0.250 inches. The pipe should be driven with a flat plate welded to the pile tip (closed end). The plate should have a minimum thickness of 0.75 inches and a diameter no greater than the pile diameter. The pipe piles should be inspected and concrete filled in accordance with MnDOT Specification 2452.D6. The minimum compressive strength of the concrete should be 3000 psi at 28-days.

The nominal resistance of the piles should be evaluated using high strain dynamic (PDA) testing, which will allow the Resistance Factor of 0.65. The dynamic testing should meet the minimum requirements listed in Section 10.5.5 of the *AASHTO LRFD Bridge Design Specifications, 2012*. This approach includes Quality Control of non-tested pile by calibrated wave equation analyses.

We refer you to previous Table 3.2 for the pile lengths predicted to achieve a nominal resistance of 308 kips. The pile lengths shown are based on the analysis methods discussed with assumed soil parameters. It is common for actual pile resistance to differ from the "theoretical" resistance.

The actual pile lengths must be confirmed at the time of driving, and lengths may be more or less than that shown. It should be recognized that pile lengths would be greater if the MRF12 formula is used, as a higher nominal resistance needs to be demonstrated.

Grade is not expected to be raised in the vicinity of the center pier and vertical circulation structure area where the soft clays are thicker, accordingly settlement is not expected around the piles. It is our opinion that down drag (DD) loads do not need to be considered in the design for these areas.

Minor down drag could be associated with the retaining wall piles, which should be reviewed further during advanced design when cross-sections are developed. As the clay thickness is less in this area and may already be at least partially pre-compressed by the existing fill embankment, these DD loads should be low or possibly non-existent.

A reduction factor for group effects does not need to be applied provided the pile arrangement maintains a center-to-center spacing of 3 times the diameter.

All foundations should have five or more piles for redundancy purposes. With five or more piles, a reduction factor for a lack of redundancy does not need to be applied.

Boulders or rock slabs may potentially be present within the profile. If pile penetration appears to be obstructed at abnormally variable depths (due to apparent boulders/slabs), additional pile and foundation review may be needed.

4.4 Retaining Wall Backfilling

The retaining wall should be designed to properly resist the lateral pressures exerted. The backfill material should consist of Select Granular Borrow (MnDOT 3149.2B2), which is modified to containing less than 10% by weight passing the #200 sieve. The "Select Granular Borrow 10% Modified" geometry should be maintained per the requirements shown on attached MnDOT *Diagram F-1*. However, all excavation backsloping must also meet OSHA requirements and the need for frost zone tapering below the approach pavement. The backfill should be compacted per the Specified Density Method (MnDOT 2105.3F1). The wall design can be based on lateral pressures presented in MnDOT design charts.

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under Minnesota Statute Section 326.02 to 326.15

Name: Jeffery K. Voyen
Jeffery K. Voyen

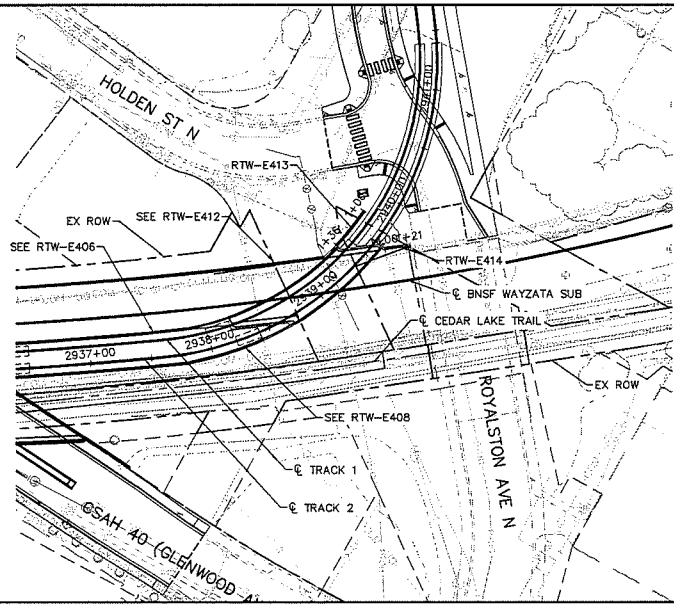
Date: 3-26-14 **License #: 15928**

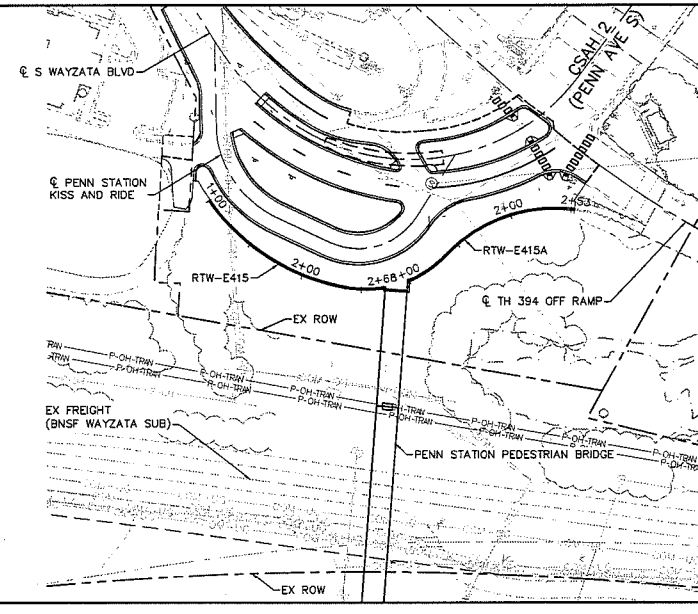
Report Reviewed By: _____

Gregory R. Reuter, PE

Attachments:

- Preliminary Plan-Profile Sheet
- Figure 1 – Boring Locations
- Subsurface Boring Logs
- Figures 2 to 5 – DRIVEN Analyses
- Exploration/Classification Methods
- Boring Log Notes
- Unified Soil Classification System
- AASHTO Soil Classification System
- MnDOT Diagram F-1





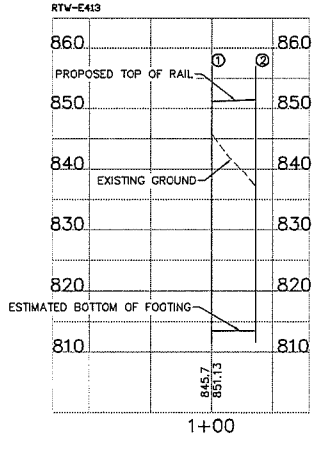
NOTE:
RTW-E413 TO RTW-E415 AND RTW-E415A ARE ANTICIPATED TO BE A CAST-IN-PLACE RETAINING WALLS ON PILING.

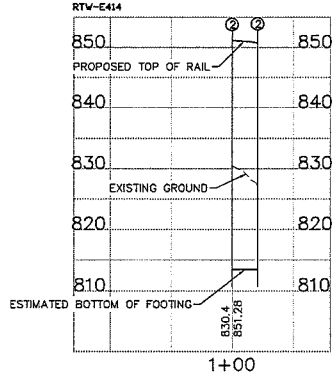
BEGIN/END OF RETAINING WALL AND END OF BRIDGE SUBSTRUCTURE TO BE COORDINATED DURING ADVANCED DESIGN.

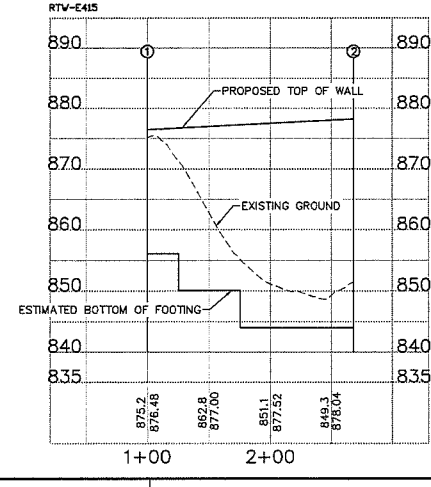
① PROPOSED GROUND LINE AT 2H:1V MAXIMUM SLOPE AT WALL TERMINATION NOT SHOWN.

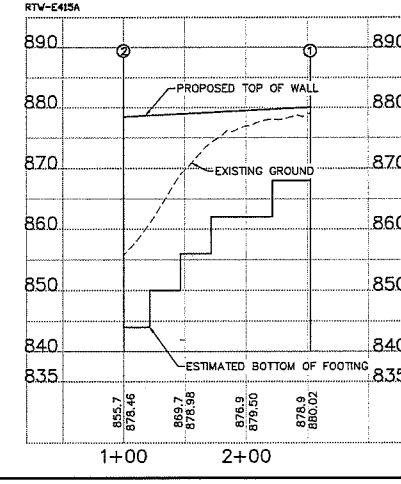
② JOINT LOCATION BETWEEN RETAINING WALL AND BRIDGE WINGWALL.

0 5.0 10 20
VERTICAL
0 25 50 100
HORIZONTAL
SCALE IN FEET









NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
RTW-E413 TO RTW-E415, & RTW-E415A
PLAN AND PROFILES

DISCIPLINE: STRUCTURES

SHEET NAME: E4-STU-RTW-PPFL - 005

SHEET 265 OF 277

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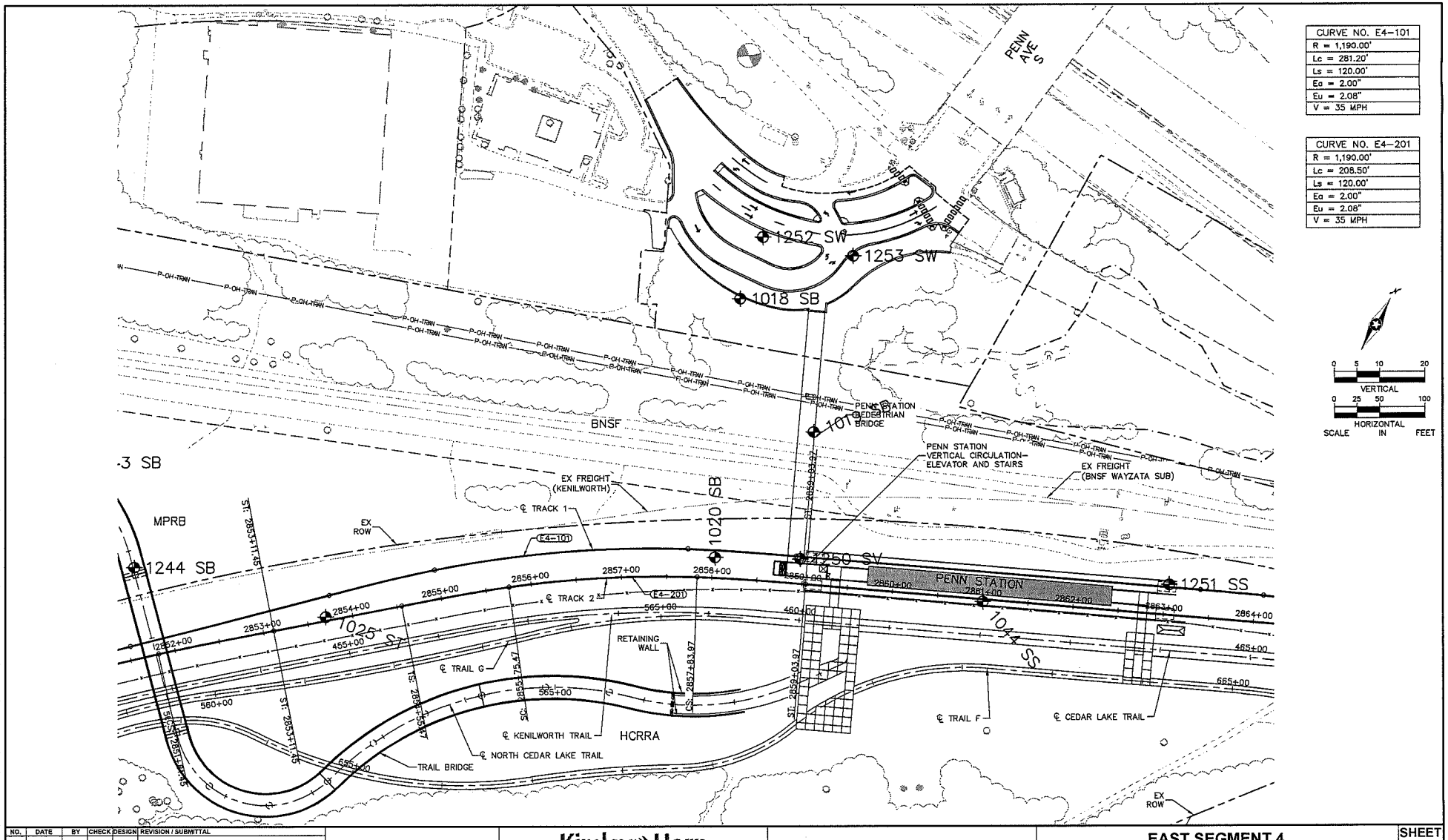

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn
SYSTRA
PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL
SOUTHWEST Green Line LRT Extension

EAST SEGMENT 4
SOIL BORINGS
PLANS
PENN STATION KISS AND RIDE

DISCIPLINE: CIVIL
SHEET NAME: E4-BRDG-SB - 004

SHEET 33 OF 42

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Figure 1 – Boring Locations

AET No. 01-05697.10

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1018 SB**	**852.1** (Surveyed)

Location , , **ft. LT**

Co. Coordinate: X=519134 Y=164842 (ft.)

Latitude (North)=44.9689248 Longitude (West)=-93.3094095

Drill Machine **69C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **4/29/13**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	1.0 851.1		Clayey sand with organic fines, trace roots, dark brown (A-6) fill		8	16				Hammer Calibration: 65% efficiency with 105 lb. hammer, 10/4/13
	4.0 848.1		LEAN CLAY, trace roots, brownish gray, brown and gray, firm, laminations of sand with silt (CL) (A-4, A-6) alluvium or fill		6	22				
5	6.5 845.6		LEAN CLAY WITH SAND, gray and brown mottled, soft, lenses and laminations of sand (CL) (A-4) alluvium		4	25				
	9.5 842.6		FAT CLAY, grayish brown, a little gray and brown, soft, laminations of lean clay and silt (CH) (A-7-6) alluvium		2	51				
10	11.5 840.6		LEAN CLAY, trace roots, gray, a little brown, stiff, laminations of sand (CL) (A-6) alluvium		10	29				
15	16.5 835.6		SAND, a little gravel, medium grained, brownish gray, waterbearing, loose, a lens of fine grained sand with silt (SP) (A-1-b) alluvium		5					No recovery
	19.0 833.1		SAND WITH SILT, fine to medium grained, brownish gray, waterbearing, loose, a lens of fine grained sand with silt (SP-SM) (A-3) alluvium	PD	10					
20	21.5 830.6		SILTY SAND, brownish gray, loose, a lens of clayey sand (SM) (A-2-4) till	PD	7					
25	28.0 824.1		SILTY SAND WITH GRAVEL, brownish gray, medium dense (SM) (A-2-4) till	PD PD PD	14 16					
	31.5 820.6		SAND WITH SILT AND GRAVEL, medium to fine grained, brownish gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD	19 25					
35	39.0 813.1		SILTY SAND, a little gravel, brownish gray, medium dense to dense, a lens of waterbearing sand with silt at 33', laminations of sand around 38' (SM) (A-2-4) alluvium	PD PD PD	27 28 37					
40	41.5		SANDY LEAN CLAY, a little gravel, dark brownish gray, hard (CL) (A-7-6) till	PD	38	23				

Index Sheet Code

(Continued Next Page)

Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1018 SB**	**852.1** (Surveyed)

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	810.6		SAND, a little gravel, medium grained, grayish brown, waterbearing, medium dense (SP) (A-1-b) alluvium							
	44.0		*(continued)*	PD	15					
45	808.1		SAND WITH GRAVEL, medium grained, brownish gray, waterbearing, medium dense to dense (SP) (A-1-b) alluvium	PD	27					
	49.0			PD	33					
	803.1		SAND, a little gravel, medium to fine grained, brownish gray, waterbearing, dense, a lens of sand with silt (SP) (A-1-b) alluvium	PD	50					
	53.0									
	799.1		SAND WITH GRAVEL, medium grained, brownish gray, waterbearing, dense (SP) (A-1-b) alluvium							
55				PD	32					
	58.0									
	794.1		GRAVEL WITH SAND, gray, waterbearing, dense (GP) (A-1-a) alluvium							
60				PD	41					
				PD	50					
65										
	67.5			PD						
	784.6		CLAYEY SAND, a little gravel, brown, hard (SC) (A-6) till		66	10				
70				PD						
					47	11				
75				PD						
	77.7				100/.2					
	774.4		Small rock chips recovered from drilling mud *							
	77.9		**END OF BORING**							
	774.2		**Based on Boring 1020 and Minnesota Geological Survey Maps, bedrock not anticipated, but is possible. Could also be a boulder or cobble in the till deposit.*							

Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn RR Overpass	**Southwest LRT, PEC East**	**1019 SB**	**850.0** (Surveyed)

Location , , **ft. LT**

Co. Coordinate: X=519278 Y=164753 (ft.)

Latitude (North)=44.9685517 Longitude (West)=-93.3091782

Drill Machine **27C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 3

Drilling Completed **11/10/13**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	0.0		Silty sand, a little gravel, brown (A-2-4, A-1-b) fill		12					Hammer Calibration: 65% efficiency with 105 lb. hammer, 11/1/12
	4.0				9					
5	846.0		CLAYEY SAND, with organic fines, trace roots, black, stiff (SC) (A-6) topsoil		13	14				
	6.5									
	843.5		SAND, a little gravel, medium grained, grayish brown, waterbearing, loose (SP) (A-1-b) alluvium		5					
	9.0									
10	841.0		LEAN CLAY, gray, a little dark gray and light gray, firm, laminations of fat clay and silt (CL) (A-7-6) alluvium		7	39				
	11.5									
	838.5		FAT CLAY, grayish brown, a little gray, dark brownish gray and light grayish brown, very soft, laminations of silt (CH) (A-7-6) alluvium			52	460	105		
15					1	91				
						92	285	98		
	19.0									
20	831.0		LEAN CLAY, gray, a little black, soft, laminations of waterbearing sand (CL) (A-6) alluvium		2	32				
	23.0				9					No recovery
	827.0		SAND WITH GRAVEL, medium grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD						
25					14					
	26.5			PD						
	823.5		GRAVEL WITH SAND, gray, waterbearing, medium dense (GP) (A-1-a) alluvium		12					
	28.0					17				
	822.0		CLAYEY SAND, a little gravel, gray, stiff (SC) (A-6) till	PD						
	29.0									
30	821.0		GRAVELLY SILTY SAND, gray, medium dense, lenses of clayey sand (SM) (A-1-b) till		21					
	31.5			PD						
	818.5		SILTY SAND WITH GRAVEL, gray, medium dense, lenses of clayey sand (SM) (A-1-b) till		22					
				PD						
35					19					
	36.5			PD						
	813.5		GRAVELLY SAND WITH SILT, medium grained, gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium		22					
	39.0			PD						
	811.0		SAND WITH GRAVEL, medium grained, gray, waterbearing, dense, lenses of clayey sand (SP) (A-1-b) alluvium		42					
40				PD						

Index Sheet Code

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn RR Overpass	**Southwest LRT, PEC East**	**1019 SB**	**850.0** (Surveyed)

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	44.0 806.0			PD	47					
45	46.5 803.5		CLAYEY SAND WITH GRAVEL, gray, hard (SC) (A-6) till	PD	48	10				
	48.5 801.5		SANDY LEAN CLAY, a little gravel, gray, very stiff (CL) (A-6) till	PD	25	25				
50	53.0 797.0		CLAYEY SAND WITH GRAVEL, gray, hard (SC) (A-6) till	PD	40	12				
55	58.0 792.0		SILTY SAND, a little gravel, gray, dense, a lens of clayey sand (SM) (A-2-4) till	PD	41					
60	63.0 787.0		SILTY SAND WITH GRAVEL, gray, dense, a lens of lean clay (SM) (A-2-4) till	PD	41					
	65.0 785.0		LEAN CLAY, gray, hard (CL) (A-7-6) alluvium	PD	31	35				
65	68.0 782.0		SAND WITH SILT AND GRAVEL, medium to fine grained, gray, waterbearing, dense (SP-SM) (A-1-b) alluvium	PD						
70	75.0 775.0		SAND, a little gravel, medium grained, gray, waterbearing, dense (SP) (A-1-b) alluvium	PD	37					
75				PD	36					
80			CLAYEY SAND, a little gravel, brown, hard (SC/SM) (A-2-6) till	PD	57	11				

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Soil Class: Rock Class: Edit: Date: 8/25/14

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn RR Overpass	**Southwest LRT, PEC East**	**1019 SB**	**850.0** *(Surveyed)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60} / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
85			CLAYEY SAND, a little gravel, brown, hard (SC/SM) (A-2-6) till *(continued)*	PD	62	12				
	88.0 / 762.0			PD						
90			SAND, fine to medium grained, brown, waterbearing, very dense (SP) (A-3) alluvium		57					
	93.0 / 757.0			PD						
95			SAND, a little gravel, medium grained, grayish brown, waterbearing, very dense (SP) (A-1-b) alluvium		51					
	96.0 / 754.0		**END OF BORING**							

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn RR Overpass	**Southwest LRT, PEC East**	**1250 SV**	**853.3** (Surveyed)

Location , , **ft. LT**

Co. Coordinate: X=519335 Y=164623 (ft.)

Latitude (North)=44.9683237 Longitude (West)=-93.3086337

Drill Machine **68C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 3

Drilling Completed **6/9/14**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Soil / Rock	Other Tests Or Remarks / Formation or Member
					REC (%)	RQD (%)	ACL (ft)	Core Breaks		
	2.0 / 851.3		Clayey sand with organic fines, a little gravel and sand with silt, trace roots, dark brown, a little light brown (A-2-4, A-1-b) fill		22	17				Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
	4.0 / 849.3		Sand with silt, a little gravel, light brown (A-1-b) fill		15					
▼ 5	6.5 / 846.8		SANDY LEAN CLAY, slightly organic, a little gravel, trace roots, black, a little grayish brown, firm, a lens of clayey sand (CL) (A-6) till		8	21				
			FAT CLAY, slightly organic, trace roots, gray to dark gray, a little light gray, firm, laminations of silt (CH) (A-7-6) till		5	55				Organic Content = 2.7%
10	12.0 / 841.3					55	545	107		LL=89%, PL=28%, PI=61%
	14.0 / 839.3		LEAN CLAY, gray, firm, laminations of waterbearing sand (CL) (A-6) till		8	27				
15			GRAVEL WITH SILT AND SAND, brownish gray, waterbearing, medium dense (GP) (A-1-b) alluvium	PD	14					Water level measured at 5.6' deep with HSA to 14.5' deep
	19.0 / 834.3		GRAVELLY SAND WITH SILT, medium grained, brownish gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD	18					
20	23.0 / 830.3		GRAVEL WITH SILT AND SAND, brownish gray, waterbearing, medium dense (GP) (A-1-b) alluvium	PD	21					No recovery
25	26.5 / 826.8		SAND WITH GRAVEL, medium grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	15					
				PD	13					
30	31.5 / 821.8		SAND WITH GRAVEL, medium to fine grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	15					
				PD	13					
35	36.5 / 816.8		SAND, a little gravel, medium to fine grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	16					
				PD	22					No recovery
40				PD	21					

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

SHEET 2 of 3

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn RR Overpass	**Southwest LRT, PEC East**	**1250 SV**	**853.3** (Surveyed)

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60} / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	44.0 809.3		SAND, a little gravel, medium to fine grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium *(continued)*		16					
45			GRAVELLY SAND WITH SILT, medium to fine grained, brownish gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD PD	22					
	48.0 805.3			PD	22					No recovery
50			SAND WITH GRAVEL, medium grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	20					
	53.0 800.3			PD						
55			SAND WITH GRAVEL, medium to fine grained, grayish brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	22					
60				PD	15					
	62.0 791.3			PD						
65			SILTY CLAY, brown, very stiff (CL-ML) (A-4)	PD	18	23				
	68.0 785.3			PD						
70			LEAN CLAY, brown, hard, laminations of wet silt (CL) (A-4) alluvium	PD	54	21				
75				PD	55	19				
	78.0 775.3			PD						
80			SAND, a little gravel, medium to fine grained, brown, waterbearing, dense (SP) (A-1-b) alluvium	PD	43					
	83.0 770.3			PD						

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn RR Overpass	**Southwest LRT, PEC East**	**1250 SV**	**853.3** *(Surveyed)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60} / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
85			SILTY SAND, a little gravel, brown, very dense (SM) (A-2-4) alluvium *(continued)*	PD	76					
	88.0 / 765.3			PD						
90			SAND, fine grained, brown, waterbearing, very dense (SP) (A-3) alluvium		53					
	93.0 / 760.3			PD						
95			SAND, a little gravel, fine to medium grained, brown, waterbearing, dense (SP) (A-1-b) alluvium		36					
	98.0 / 755.3			PD						
100			SAND WITH SILT AND GRAVEL, medium to fine grained, brown, waterbearing, very dense, laminations of silty sand (SP-SM) (A-1-b) alluvium		117					
	101.0 / 752.3		**END OF BORING**							

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1252 SW**	**878.1** (Surveyed)

Location , , **ft. LT**

Co. Coordinate: X=519122 Y=164914 (ft.)

Latitude (North)=44.9691223 Longitude (West)=-93.3094556

Drill Machine **91C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **6/16/14**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	1.0 877.1		Clayey sand with organic fines, a little gravel, trace roots, dark brown (A-6) fill		10					Hammer Calibration: 68% efficiency with 110 lb. hammer, 5/27/14
	4.0 874.1		Sand with silt, a little gravel, lean clay and silty sand, pieces of concrete, trace roots, brown, a little dark brown and gray (A-2-4) fill		11					
5	6.5 871.6		Sand with silt, a little gravel and silty sand, brown (A-2-4) fill		42					
10			Silty sand, a little gravel and ashes/cinders, pieces of concrete, brown and dark brown (A-2-4) fill		29 53 18					
15	16.5 861.6		Sand with silt, a little clayey sand, brown (A-3) fill		24 21					
20	21.5 856.6		SAND WITH SILT AND GRAVEL, fine to medium grained, brown, moist, dense (SP-SM) (A-1-b) alluvium or fill		10 33					
	24.0 854.1		SAND WITH SILT, a little gravel, medium to fine grained, brown, moist, medium dense (SP-SM) (A-1-b) alluvium		15					
25	26.5 851.6		SAND WITH SILT, a little gravel, fine to medium grained, brown, moist, medium dense, lenses of silty sand (SP-SM) (A-2-4) alluvium		14					
	29.0 849.1		SAND WITH SILT, a little gravel, brown, moist, medium dense (SP-SM) (A-3) alluvium		20					
30 ▼	31.5 846.6		SAND, a little gravel, medium grained, light brown, waterbearing, medium dense (SP) (A-1-b) alluvium		13					Water level measured at 31.7' deep with HSA to 32' deep
	34.0 844.1		SAND WITH SILT, a little gravel, fine to medium grained, brown, waterbearing, loose (SP-SM) (A-3) alluvium		9					
35	36.5 841.6		SAND WITH SILT, a little gravel, medium to fine grained, brown, waterbearing, loose, a lens of clayey sand (SP-SM) (A-1-b) alluvium		10					
	39.0 839.1		SAND WITH SILT, a little gravel, fine to medium grained, brownish gray, a little brown, waterbearing, loose, lenses of clayey sand and sand (SP-SM) (A-2-4) alluvium		8					
40	41.5			PD						

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1252 SW**	**878.1** *(Surveyed)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	836.6									No recovery
45			CLAYEY SAND WITH GRAVEL, grayish brown, very stiff, a lens of silty sand (SC) (A-2-4) till *(continued)*	PD	16 / 24	12				
	46.0 / 832.1		**END OF BORING**							

Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1253 SW**	**879.1** (Surveyed)

Location , , **ft. LT**

Co. Coordinate: X=519217 Y=164949 (ft.)

Latitude (North)=44.9692181 Longitude (West)=-93.3090884

Drill Machine **91C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 3

Drilling Completed **6/17/14**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	1.0 878.1		Mixture of silty sand and clayey sand, with organic fines, a little gravel, trace roots, black (A-2-4, A-6) fill		6					Hammer Calibration: 68% efficiency with 110 lb. hammer, 5/27/14
	2.0 877.1		Mixture of silty sand, sand with silt and gravel, a little clayey sand, trace roots, brown (A-2-4) fill		14					
5			Sand with silt and gravel, a little clayey sand, brown (A-1-b) fill		18					
	9.0 870.1				178					
10			Sand with silt, a little gravel, clayey sand and silty sand, pieces of concrete, brown, a little dark brown (A-3) fill		34					
	14.0 865.1				36					
15			Sand with silt and gravel, a little silty sand, brown (A-1-b) fill		30					
	19.0 860.1				34					
20			Silty sand, a little gravel and sand with silt, dark brown and brown (A-2-4) fill		31					
	24.0 855.1				33					
25			Clayey sand, a little gravel, brown (A-6) fill		18	11				
	26.5 852.6		Silty sand, a little gravel, dark brown and brown (A-2-4) fill		47					
	29.0 850.1		SAND, a little gravel, fine to medium grained, light brown, a little brown, moist, medium dense, a lens of sand with silt (SP) (A-3) alluvium		23					
30	31.5 847.6		SAND WITH SILT, a little gravel, fine to medium grained, brown, moist, medium dense, a lens of silty sand (SP-SM) (A-2-4) alluvium		23					
▼	34.0 845.1									Water level measured at 33' deep with HSA to 37' deep
35			SAND, a little gravel, medium to fine grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium		22					
	39.0 840.1		SAND, a little gravel, fine to medium grained, gray, waterbearing, medium dense, a lens of clayey sand (A-3) alluvium		14					
40	41.5			PD	21					

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1253 SW**	**879.1** *(Surveyed)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N_{60} / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
	837.6		SILTY SAND, fine grained, gray, wet, medium dense, a lens of lean clay (SM) (A-2-4) alluvium *(continued)*							
	44.0			PD	17					
45	835.1		CLAYEY SAND WITH GRAVEL, gray, very stiff (SC/SM) (A-2-4) alluvium		28	13				
	47.0			PD						
	832.1		SILTY SAND WITH GRAVEL, fine to medium grained, gray, moist, dense (SM) (A-1-b) alluvium		35					
	49.0			PD						
50	830.1				28					
				PD						
55			SAND WITH SILT AND GRAVEL, medium to fine grained, gray, waterbearing, dense (SP-SM) (A-1-b) alluvium		20					No recovery
				PD						
60					11					
	63.0			PD						
	816.1		SILTY SAND, fine grained, gray, wet, medium dense (SM) (A-4) alluvium							
65					16					
	66.0			PD						
	813.1									
			SAND, a little gravel, medium grained, gray, waterbearing, dense, lens of clayey sand (SP) (A-1-b) alluvium		36					
70				PD						
	75.0			PD						
75	804.1				82					
			SAND WITH GRAVEL, medium to fine grained, gray, waterbearing, very dense, a lens of silty sand (SP) (A-1-b) alluvium							
				PD						
80					52					
	83.0			PD						
	796.1									

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Penn Retaining Wall	**Southwest LRT, PEC East**	**1253 SW**	**879.1** *(Surveyed)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 (%) REC	MC (%) RQD	COH (psf) ACL (ft)	γ (pcf) Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
85			SAND, medium grained, gray, waterbearing, dense (SP) (A-1-b) alluvium *(continued)*	PD	49					
	88.0 / 791.1			PD						
90			GRAVELLY SAND WITH SILT, possible cobble around 92' to 93.5', medium to fine grained, gray, waterbearing (SP-SM) (A-1-b) alluvium		78					
	93.5 / 785.6			PD						
95			SAND, a little gravel, fine grained, grayish brown, waterbearing, very dense to dense, a lens of clayey sand at 94½' (SP) (A-3) alluvium		83/.5					
				PD						
100	101.0 / 778.1		**END OF BORING**		46					

Soil Class: Rock Class: Edit: Date: 8/25/14

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Figure 2 – DRIVEN Analysis, 12-inch dia. CIP Steel Pipe Pile, Boring 1018 SB

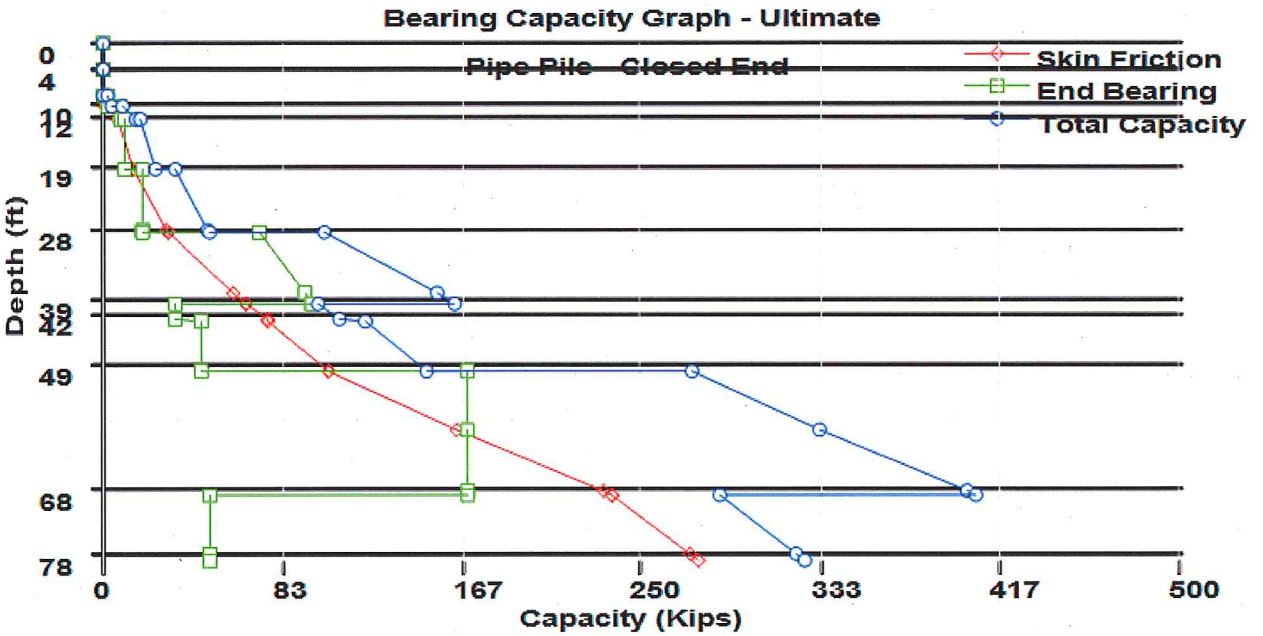


Figure 3 – DRIVEN Analysis, 12-inch dia. CIP Steel Pipe Pile, Boring 1019 SB

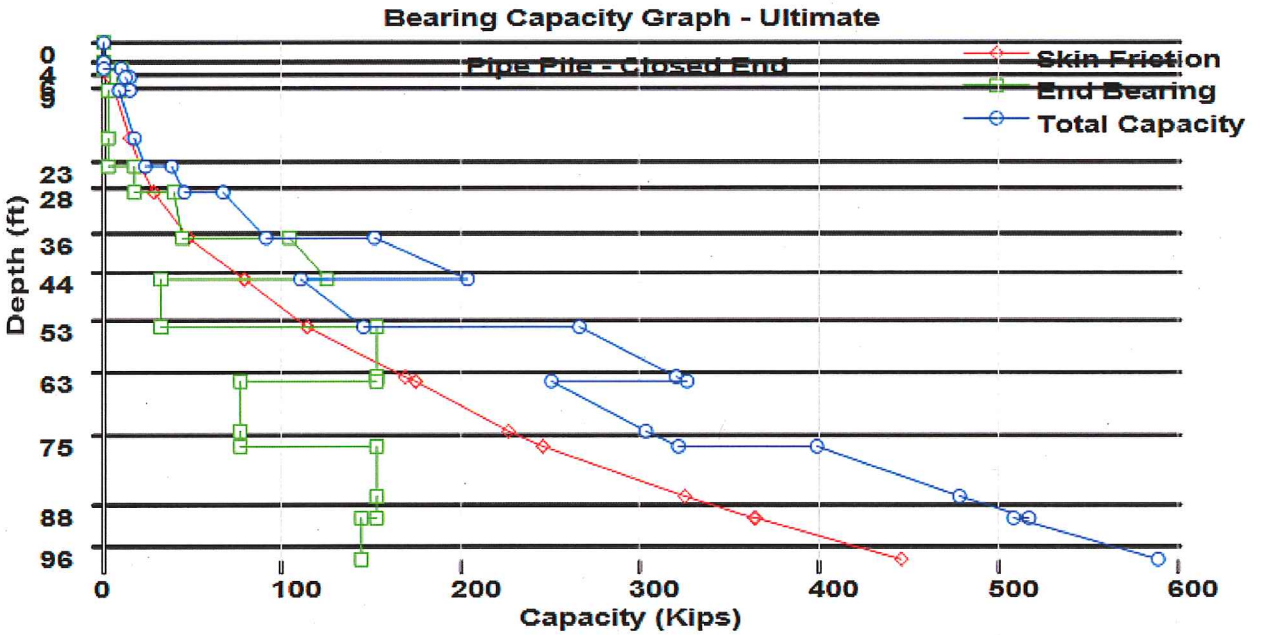


Figure 4 – DRIVEN Analysis, 12-inch dia. CIP Steel Pipe Pile, Boring 1250 SV

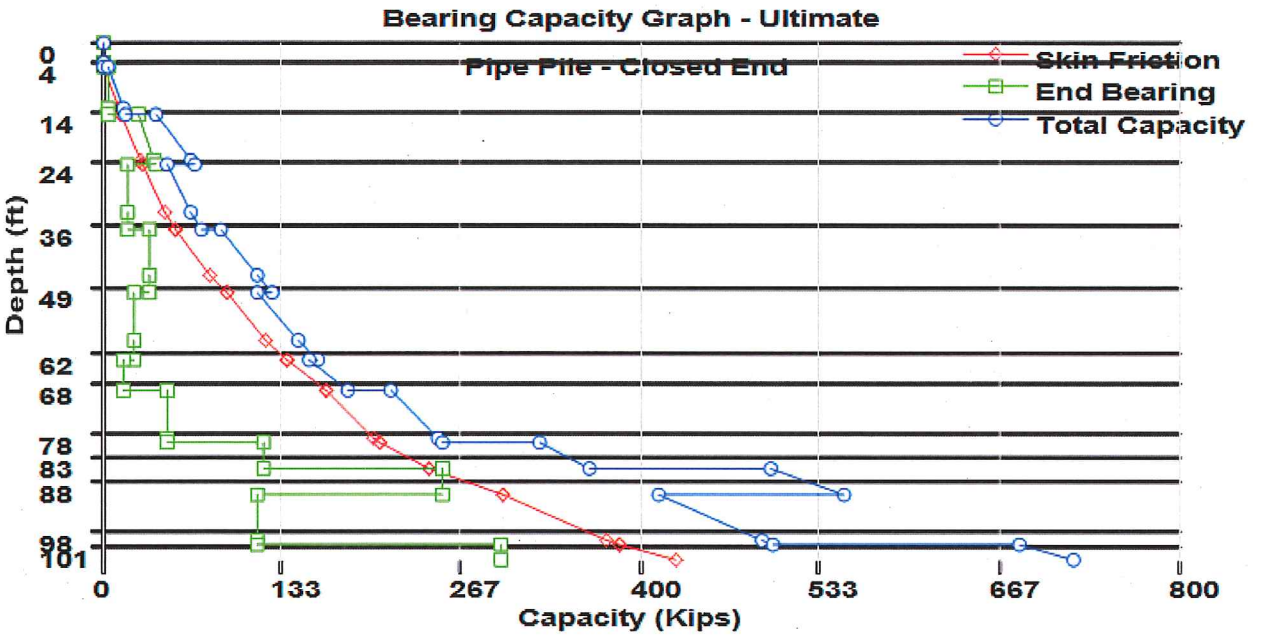
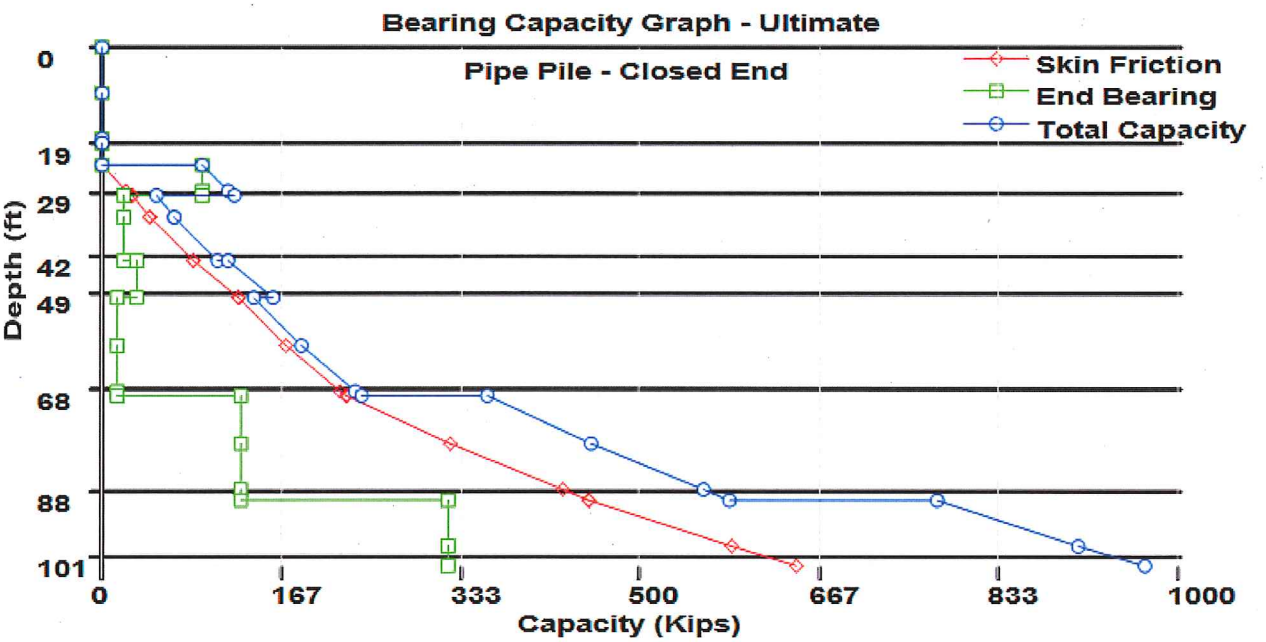


Figure 5 – DRIVEN Analysis, 12-inch dia. CIP Steel Pipe Pile, Boring 1253 SW



SAMPLING METHODS

Split-Spoon Samples (SS) - Calibrated to N_{60} Values

Standard penetration (split-spoon) samples were collected in general accordance with ASTM: D1586 with one primary modification. The ASTM test method consists of driving a 2" O.D. split-barrel sampler into the in-situ soil with a 140-pound hammer dropped from a height of 30". The sampler is driven a total of 18" into the soil. After an initial set of 6", the number of hammer blows to drive the sampler the final 12" is known as the standard penetration resistance or N-value. Our method uses a modified hammer weight, which is determined by measuring the system energy using a Pile Driving Analyzer (PDA) and an instrumented rod.

In the past, standard penetration N-value tests were performed using a rope and cathead for the lift and drop system. The energy transferred to the split-spoon sampler was typically limited to about 60% of its potential energy due to the friction inherent in this system. This converted energy then provides what is known as an N_{60} blow count.

Most of today's drill rigs incorporate an automatic hammer lift and drop system, which has higher energy efficiency and subsequently results in lower N-values than the traditional N_{60} values. By using the PDA energy measurement equipment, we are able to determine actual energy generated by the drop hammer. With the various hammer systems available, we have found highly variable energies ranging from 55% to over 100%. Therefore, the intent of AET's hammer calibrations is to vary the hammer weight such that hammer energies lie within about 60% to 65% of the theoretical energy of a 140-pound weight falling 30". The current ASTM procedure acknowledges the wide variation in N-values, stating that N-values of 100% or more have been observed. Although we have not yet determined the statistical measurement uncertainty of our calibrated method to date, we can state that the accuracy deviations of the N-values using this method are significantly better than the standard ASTM Method.

Sampling Limitations

Unless actually observed in a sample, contacts between soil layers are estimated based on the spacing of samples and the action of drilling tools. Cobbles, boulders, and other large objects generally cannot be recovered from test borings, and they may be present in the ground even if they are not noted on the boring logs.

CLASSIFICATION METHODS

Soil classifications shown on the boring logs are based on the Unified Soil Classification (USC) system. The USC system is described in ASTM: D2487 and D2488. Where laboratory classification tests (sieve analysis or Atterberg Limits) have been performed, accurate classifications per ASTM: D2487 are possible. Otherwise, soil classifications shown on the boring logs are visual-manual judgments. Charts are attached which provide information on the USC system, the descriptive terminology, and the symbols used on the boring logs.

Visual-manual judgment of the AASHTO Soil Group is also noted as a part of the soil description. A chart presenting details of the AASHTO Soil Classification System is also attached.

The boring logs include descriptions of apparent geology. The geologic depositional origin of each soil layer is interpreted primarily by observation of the soil samples, which can be limited. Observations of the surrounding topography, vegetation, and development can sometimes aid this judgment.

WATER LEVEL MEASUREMENTS

The ground-water level measurements/comments are shown on the boring logs in the remarks section. The true location of the water table at the boring locations may be different than the water levels measured in the boreholes. This is possible because there are several factors that can affect the water level measurements in the borehole. Some of these factors include: permeability of each soil layer in profile, presence of perched water, amount of time between water level readings, presence of drilling fluid, weather conditions, and use of borehole casing.

SAMPLE STORAGE

Unless notified to do otherwise, we routinely retain representative samples of the soils recovered from the borings for a period of 30 days.

BORING LOG NOTES

DRILLING AND SAMPLING SYMBOLS

Symbol	Definition
AR:	Sample of material obtained from cuttings blown out the top of the borehole during air rotary procedure.
B, H, N:	Size of flush-joint casing
CAS:	Pipe casing, number indicates nominal diameter in inches
COT:	Clean-out tube
DC:	Drive casing; number indicates diameter in inches
DM:	Drilling mud or bentonite slurry
DR:	Driller (initials)
DS:	Disturbed sample from auger flights
DP:	Direct push drilling; a 2.125 inch OD outer casing with an inner 1½ inch ID plastic tube is driven continuously into the ground.
FA:	Flight auger; number indicates outside diameter in inches
HA:	Hand auger; number indicates outside diameter
HSA:	Hollow stem auger; number indicates inside diameter in inches
LG:	Field logger (initials)
MC:	Column used to describe moisture condition of samples and for the ground water level symbols
N (BPF):	Standard penetration resistance (N-value) in blows per foot (see notes)
NQ:	NQ wireline core barrel
PD:	Plug Drilling (same as RDF)
PQ:	PQ wireline core barrel
RDA:	Rotary drilling with compressed air and roller or drag bit.
RDF:	Rotary drilling with drilling fluid and roller or drag bit
REC:	In split-spoon (see notes), direct push and thin-walled tube sampling, the recovered length (in inches) of sample. In rock coring, the length of core recovered (expressed as percent of the total core run). Zero indicates no sample recovered.
SS:	Standard split-spoon sampler (steel; 1.5" is inside diameter; 2" outside diameter); unless indicated otherwise
SU	Spin-up sample from hollow stem auger
TW:	Thin-walled tube; number indicates inside diameter in inches
WASH:	Sample of material obtained by screening returning rotary drilling fluid or by which has collected inside the borehole after "falling" through drilling fluid
WH:	Sampler advanced by static weight of drill rod and hammer
WR:	Sampler advanced by static weight of drill rod
94mm:	94 millimeter wireline core barrel
▼:	Water level directly measured in boring
▽:	Estimated water level based solely on sample appearance

TEST SYMBOLS

Symbol	Definition
COH:	Cohesion, psf (0.5 x q_u)
CONS:	One-dimensional consolidation test
γ:	Wet density, pcf
DST:	Direct shear test
E:	Pressuremeter Modulus, tsf
HYD:	Hydrometer analysis
LL:	Liquid Limit, %
LP:	Pressuremeter Limit Pressure, tsf
MC:	Moisture Content, %
OC:	Organic Content, %
PERM:	Coefficient of permeability (K) test; F - Field; L - Laboratory
PL:	Plastic Limit, %
q_p:	Pocket Penetrometer strength, tsf (approximate)
q_c:	Static cone bearing pressure, tsf
q_u:	Unconfined compressive strength, psf
R:	Electrical Resistivity, ohm-cms
RQD:	Rock Quality Designation of Rock Core, in percent (aggregate length of core pieces 4" or more in length as a percent of total core run)
SA:	Sieve analysis
TRX:	Triaxial compression test
VSR:	Vane shear strength, remolded (field), psf
VSU:	Vane shear strength, undisturbed (field), psf
%-200:	Percent of material finer than #200 sieve

STANDARD PENETRATION TEST NOTES

(Calibrated Hammer Weight)

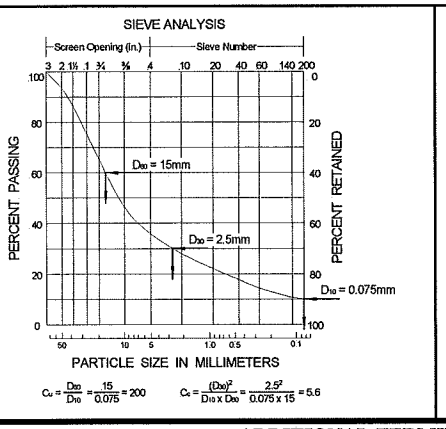
The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide N_{60} values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), permitted in ASTM: D1586, the blows for each complete 6" increment and for each partial increment is on the boring log. For partial increments, the number of blows is shown to the nearest 0.1' below the slash.

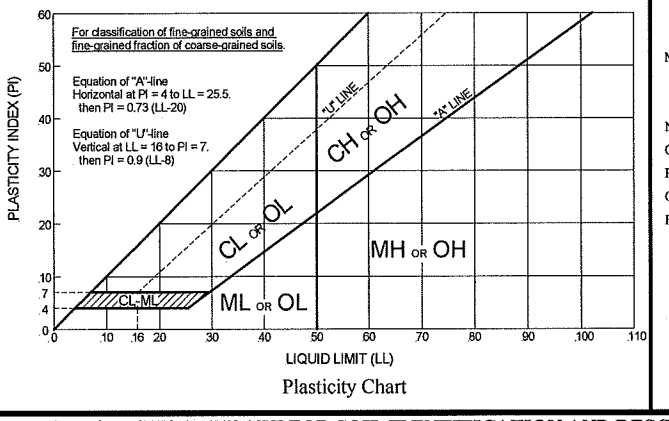
The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM: D1586 is encountered) whereas the length of sample recovered is for the entire sampler drive (which may even extend more than 18").

UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

AMERICAN ENGINEERING TESTING, INC.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	Cu≥4 and 1≤Cc≤3[E]	GW	Well graded gravel[F]
			Cu<4 and/or 1>Cc>3[E]	GP	Poorly graded gravel[F]
		Gravels with Fines more than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel[F,G,H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	Cu≥6 and 1≤Cc≤3[E]	SW	Well-graded sand[I]
			Cu<6 and/or 1>Cc>3[E]	SP	Poorly-graded sand[I]
		Sands with Fines more than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G,H,I]
			Fines classify as CL or CH	SC	Clayey sand[G,H,I]
Fine-Grained Soils 50% or more passes the No. 200 sieve (see Plasticity Chart below)	Silts and Clays Liquid limit less than 50	inorganic	PI>7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI<4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	Liquid limit–oven dried / Liquid limit – not dried <0.75	OL	Organic clay[K,L,M,N] / Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	Liquid limit–oven dried / Liquid limit – not dried <0.75	OH	Organic clay[K,L,M,P] / Organic silt[K,L,M,Q]
Highly organic soil			Primarily organic matter, dark in color, and organic in odor	PT	Peat[R]





Plasticity Chart

Notes

[A]Based on the material passing the 3-in (75-mm) sieve.

[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C]Gravels with 5 to 12% fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

[D]Sands with 5 to 12% fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

[E]$Cu = D_{60}/D_{10}$, $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains ≥15% sand, add "with sand" to group name.

[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H]If fines are organic, add "with organic fines" to group name.

[I]If soil contains ≥15% gravel, add "with gravel" to group name.

[J]If Atterberg limits plot is hatched area, soils is a CL-ML silty clay.

[K]If soil contains 15 to 29% plus No. 200 add "with sand" or "with gravel", whichever is predominant.

[L]If soil contains ≥30% plus No. 200, predominantly sand, add "sandy" to group name.

[M]If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N]PI≥4 and plots on or above "A" line.

[O]PI<4 or plots below "A" line.

[P]PI plots on or above "A" line.

[Q]PI plots below "A" line.

[R]Fiber Content description shown below.

ADDITIONAL TERMINOLOGY NOTES USED BY AET FOR SOIL IDENTIFICATION AND DESCRIPTION

Grain Size

Term	Particle Size
Boulders	Over 12"
Cobbles	3" to 12"
Gravel	#4 sieve to 3"
Sand	#200 to #4 sieve
Fines (silt & clay)	Pass #200 sieve

Gravel Percentages

Term	Percent
A Little Gravel	3% - 14%
With Gravel	15% - 29%
Gravelly	30% - 50%

Consistency of Plastic Soils

Term	N-Value, BPF
Very Soft	less than 2
Soft	2 - 4
Firm	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	Greater than 30

Relative Density of Non-Plastic Soils

Term	N-Value, BPF
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	Greater than 50

Moisture/Frost Condition

(MC Column)

D (Dry): Absence of moisture, dusty, dry to touch.

M (Moist): Damp, although free water not visible. Soil may still have a high water content (over "optimum").

W (Wet/ Waterbearing): Free water visible intended to describe non-plastic soils. Waterbearing usually relates to sands and sand with silt.

F (Frozen): Soil frozen

Layering Notes

Laminations: Layers less than ½" thick of differing material or color.

Lenses: Pockets or layers greater than ½" thick of differing material or color.

Peat Description

Term	Fiber Content (Visual Estimate)
Fibric Peat:	Greater than 67%
Hemic Peat:	33 – 67%
Sapric Peat:	Less than 33%

Organic Description (if no lab tests)

Soils are described as *organic*, if soil is not peat and is judged to have sufficient organic fines content to influence the Liquid Limit properties. *Slightly organic* used for borderline cases.

Root Inclusions

With roots: Judged to have sufficient quantity of roots to influence the soil properties.

Trace roots: Small roots present, but not judged to be in sufficient quantity to significantly affect soil properties.

AASHTO SOIL CLASSIFICATION SYSTEM

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

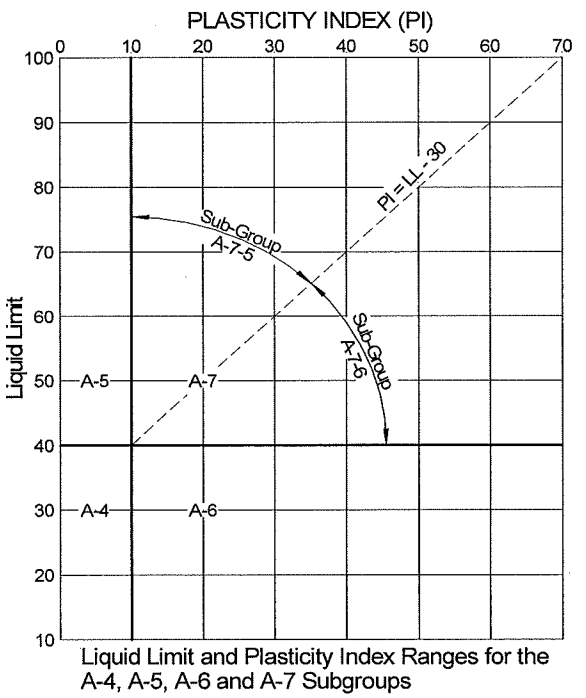
Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35% or less passing No. 200 sieve)							Silt-Clay Materials (More than 35% passing No. 200 sieve)			
Group Classification	A-1			A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, Percent passing:											
No. 10 (2.00 mm)	50 max.	....	....	....	....	....	....	....	....	....	....
No. 40 (0.425 mm)	30 max.	50 max.	51 min.	....	....	....	....	....	....	....	....
No. 200 (0.075 mm)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of Fraction Passing No. 40 (0.425 mm)											
Liquid limit	....		....	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Ratings as Subgrade	Excellent to Good							Fair to Poor			

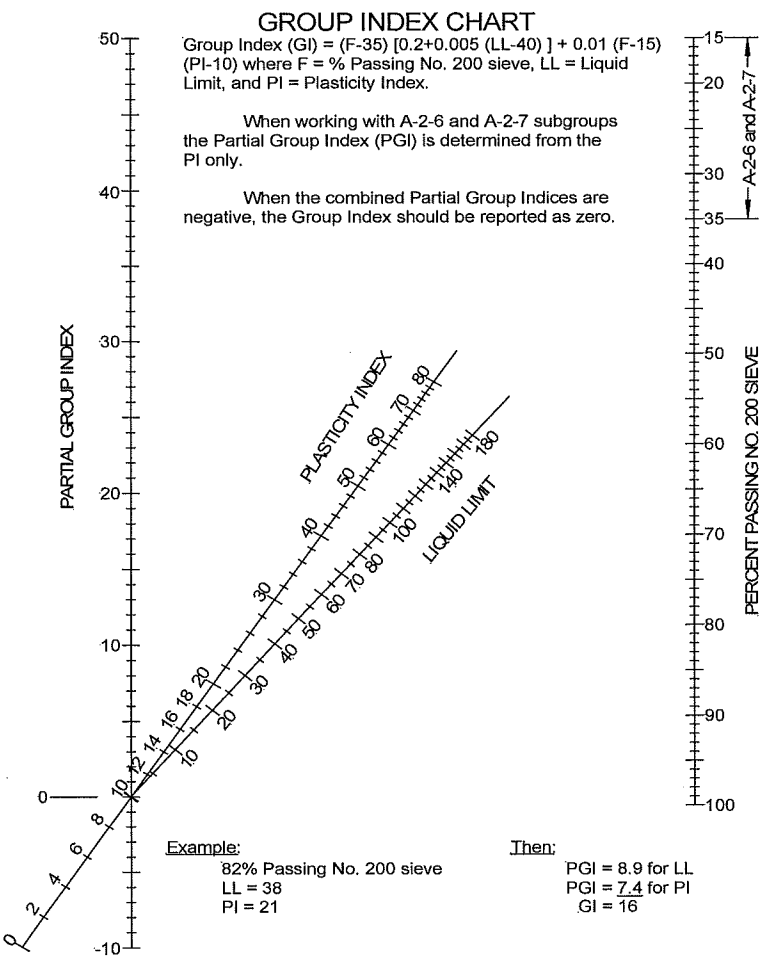
The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.

Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.

Group A-8 soils are organic clays or peat with organic content >5%.



Liquid Limit and Plasticity Index Ranges for the A-4, A-5, A-6 and A-7 Subgroups



Example:
82% Passing No. 200 sieve
LL = 38
PI = 21

Then:
PGI = 8.9 for LL
PGI = 7.4 for PI
GI = 16

Definitions of Gravel, Sand and Silt-Clay

The terms "gravel", "coarse sand", "fine sand" and "silt-clay", as determinable from the minimum test data required in this classification arrangement and as used in subsequent word descriptions are defined as follows:

GRAVEL - Material passing sieve with 3-in. square openings and retained on the No. 10 sieve.

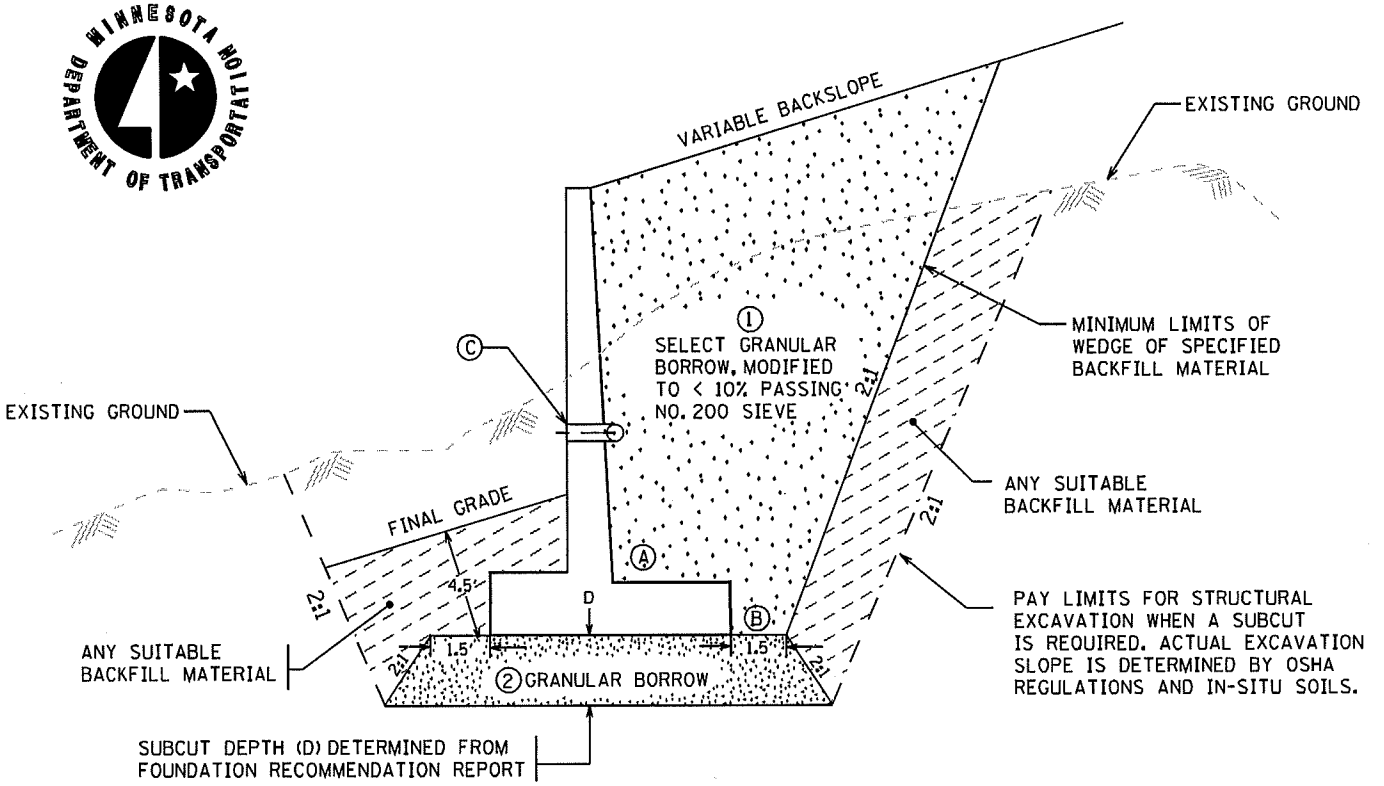
COARSE SAND - Material passing the No. 10 sieve and retained on the No. 40 sieve.

FINE SAND - Material passing the No. 40 sieve and retained on the No. 200 sieve.

COMBINED SILT AND CLAY - Material passing the No. 200 sieve

BOULDERS (retained on 3-in. sieve) should be excluded from the portion of the sample to which the classificaiton is applied, but the percentage of such material, if any, in the sample should be recorded.

The term "silty" is applied to fine material having plasticity index of 10 or less and the term "clayey" is applied to fine material having plasticity index of 11 or greater.



All slope dimensions shown as V:H

THE RECOMMENDATIONS MAY BE MODIFIED AS PER THE ATTACHED FOUNDATIONS INVESTIGATION AND RECOMMENDATION REPORT

EXCAVATION AND BACKFILL NOTES:

① Mn/DOT SPEC. 3149.2B2 MODIFIED TO 10% PASSING THE NO. 200 SIEVE COMPACT BACKFILL TO SPECIFIED DENSITY METHOD Mn/DOT SPEC. 2105.3F1

② IF SUBCUT IS REQUIRED, BACKFILL WITH GRANLAR BORROW, Mn/DOT SPEC. 3149.2B1. COMPACT BACKFILL TO 100% OF STANDARD PROCTOR (T-99). REFER TO FOUNDATION RECOMMENDATION LETTER FOR SUBCUT DEPTHS.

DRAINAGE SYSTEM NOTES:

PROVIDE WALL DRAINAGE SYSTEM A, B OR C

Ⓐ Ⓑ PLACE A 6 IN. I.D. NON-STEEL PERFORATED PIPE(Mn/DOT SPEC. 3245) WRAPPED WITH A TYPE I GEOTEXTILE FABRIC (Mn/DOT SPEC. 3733) RUNNING THE ENTIRE LENGTH OF THE WALL AND LAID A MINIMUM OF 2 IN. ABOVE THE TOP OF FOOTING (OPTION A) OR BOTTOM ELEVATION OF THE FOOTING (OPTION B). STRUCTURAL BACKFILL MATERIALS SHALL COMPLETELY SURROUND THE PIPE. AT ALL TIMES, THE SLOPE OF THE PIPE SHALL BE CHECKED TO ENSURE POSITIVE DRAINAGE. FREQUENT TIES (SPACED APPROXIMATELY 200 FT. APART) SHALL BE MADE FROM THE PIPE TO THE INPLACE OR PROPOSED DRAINAGE SYSTEM.

Ⓒ PROVIDE WEEP HOLES AS SPECFIED IN THE BRIDGE STANDARD PLANS MANUAL, STANDARD SHEET 5-297.621 TO 5-297.623.

STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION
STRUCTURAL BACKFILL, FOOTING SUBCUT & DRAINAGE SYSTEM TREATMENT
(STANDARD CANTILEVER RETAINING WALL DESIGN)

DIAGRAM NO.

F–1

November 2005

PREPARED BY THE FOUNDATIONS UNIT

GEOTECHNICAL ENGINEERING SECTION – OFFICE OF MATERIALS