FOUNDATION ANALYSIS AND DESIGN REPORT

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

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

DATE: August 28, 2014

SUBJECT: South Connector Freight Rail Bridges
Southwest Light Rail Transit Project
St. Louis Park, Minnesota
AET No. 01-05697.09

1.0 PROJECT INFORMATION

This report provides foundation analysis and recommendations for the South Connector bridges which will carry the realigned freight rail track over the LRT tracks and Oxford Street in St. Louis Park, Minnesota. Bridge designations in this report are SOCO for the bridge over the LRT and SCOX for the bridge over Oxford Street.

1.1 Bridge Information

The bridges will have ballasted reinforced concrete decks on 4 lines of welded steel plate girders and parapet abutments. Bridge widths are both planned at 14'-10" out-to-out of bridge deck and and 19'-8" out-to-out of bridge (top). The SOCO bridge over LRT will have two spans and an out-to-out bridge length of 199'-0½". The SCOX bridge over Oxford Street will have one span with an out-to-out length of 96'-6".

The preliminary bottom of foundation elevations are shown in Table 1.1.

Table 1.1 – Bottom of Footing Elevations

Bridge	Substructure	Elevation, ft
SOCO	West Abutment	888.5
	Center Pier	886.0
	East Abutment	888.5
SCOX	West Abutment	893.5
	East Abutment	895.0

The plan and profile sheets from the preliminary bridge plans are attached to this report.

1.2 Approach Information

The approaches to the east and west of the bridges will be parallel retained wall embankments, having a width consistent with the top of the bridges (about 20 feet). This same retained system will also be used in the gap between the bridges. The exposed wall height near and between the bridges will range from about 22 feet to 25 feet.

2.0 SUBSURFACE EXPLORATION AND TESTING SUMMARY

2.1 Field Exploration Scope

The exploratory test program performed specific to these bridges consisted of four standard penetration test (SPT) "foundation" borings. Two foundation borings relative to the east retained wall approaches were also drilled and contained herein. The locations of the borings drilled appear on attached Figure 1. The County coordinates also appear on the logs.

2.2 Laboratory Scope

During laboratory classification logging, water content tests were conducted on cohesive soil samples. The test results appear on the individual boring logs, opposite the samples upon which they were performed.

2.3 Methods

Logs of the SPT borings are attached. The borings were drilled using 3.25 inch diameter hollow stem augers and mud rotary drilling (plug drilling) techniques. 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 per MnDOT requirements.

The soils were visually-manually classified per the Unified Soil Classification System. The soil group category per the AASHTO Soil Classification System is also noted on the logs. Please refer to the attachments entitled *Exploration/Classification Methods, Boring Log Notes, Unified Soil Classification System,* and *AASHTO Soil Classification System* for additional details.

Field and laboratory testing is done in general conformance with the described procedures. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

2.4 Geology/Soils Review

The generalized geologic profile consists of fill overlying water-deposited (alluvium), with glacially-deposited till at depth. Organic soils are buried beneath the fill at the SOCO bridge; the layers being 2½ feet of hemic peat swamp deposits on the west side and one foot of less organic clay topsoil on the east side. The swamp deposit is known to increase in thickness to the west towards Louisiana Avenue. Bedrock is about 69 feet to 75 feet deep.

2.4.1 Bedrock

The bedrock at the six boring locations ranges in depth from 69 feet to 75 feet (corresponding to elevation 825.7 feet to 830.4 feet). The bedrock is limestone of the Platteville Formation.

2.4.2 Natural Overburden Soils

The natural soil beneath the fill and buried organic layer is alluvium (water-deposited soil). The alluvium is mostly sand, with lesser amounts of sand with silt, clayey sand, silty clay, sandy silt, and silt. These soils contain varying gravel content. Upper zones of the alluvium are sometimes loose, based on N-values of 5 to 9. Glacially-deposited till soils are found at depth, both as thinner layers within the alluvium (Boring 1216 SB) and more substantially thick deposits (more at depth at the remaining locations). The till is clayey sand to silty sand, often containing significant gravel content. Very dense granular alluvium often appears beneath the till just above the limestone bedrock.

2.4.3 Upper Fill

The fill thickness at the SOCO bridge is about 6½ to 9 feet thick. The fill is primarily a mixture of sandy soils (sands to silty sands and clayey sands). At Boring 1223 SB in Oxford Street, it is difficult to ascertain whether the soils from 2 feet to 11½ feet are fill or natural alluvium. If the soil is fill, it is relatively compact based on N-values of 17 to 27. Borings 1224 SB, 1225 SW, and 1226 SW indicate lesser fill thicknesses of 4 feet to 2 feet.

2.5 Ground Water

Ground-water levels were encountered in the boreholes at depths ranging from 11.7 feet to 20.8 feet; corresponding to elevation 885.3 feet to 882.2 feet. These levels were measured in granular soils and were allowed to stabilize for 10 minutes prior to the final measurement. Therefore, they should provide a good indication of the steady-state water level for that time and location. Water levels are expected to fluctuate both seasonally and annually.

3.0 FOUNDATION ANALYSIS

The following analysis uses Load and Resistance Factor Design (LRFD) methodology. In the future, it may be determined that freight rail bridge foundation analyses needs to follow AREMA standards which use Allowable Stress Design (ASD) methodology. If this is determined to be the case, the report will need to be modified using the preferred methodology during advanced design.

3.1 Foundation Analysis

3.1.1 Foundation Type

The presence of the buried organic soils coupled the looseness of the underlying sands precludes the feasibility of spread foundation support, particularly for the SOCO bridge. It is possible that the SCOX bridge could be founded on spread footings, although the sand looseness at limiting Boring 1223 SB may result in a large foundation, which may limit spread footing support feasibility. This could be analyzed further during advanced design using seismic CPT soundings to refine sand modulus parameters. At this time, supporting the bridge on driven piles is considered the appropriate approach, and is the foundation type analyzed and recommended on a preliminary basis.

It would be possible to consider either CIP steel pipe pile or H-pile for bridge support. A typical pipe pile type for this case is a 12-inch diameter CIP steel pipe pile having a wall thickness of 0.250 inches. As demonstrated later, this pile type is expected to approach or even reach the bedrock, so the use of H-pile may be preferred. We conducted analyses for pipe pile to predict lengths, although specific analysis for the H-pile was not done, as it is expected that they would be driven to "refusal" on the bedrock.

3.1.2 Pile Foundation Analysis Methods

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.

DRIVEN does not specifically address bedrock resistance (other than allowing input of very high values of cohesion). However, it is expected that if nominal resistance needs are not met prior to reaching the bedrock, high tip resistance will be gained with minimal penetration into the bedrock. Therefore, the *DRIVEN* analysis performed only evaluates whether resistance is met before reaching the highly resistant bedrock.

3.1.3 Analysis Results

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 is employed. Assuming a design φR_n of 100 tons for the 12-inch diameter CIP steel pipe pile, a nominal resistance of 308 kips would need to be demonstrated in the field.

The *DRIVEN* results for 12-inch diameter CIP steel pipe pile (0.250" wall) based on the three borings is presented on the following figures.

Figure 3.1.3a – DRIVEN Results, 12-inch dia. CIP Steel Pipe Pile, Boring 1216 SB

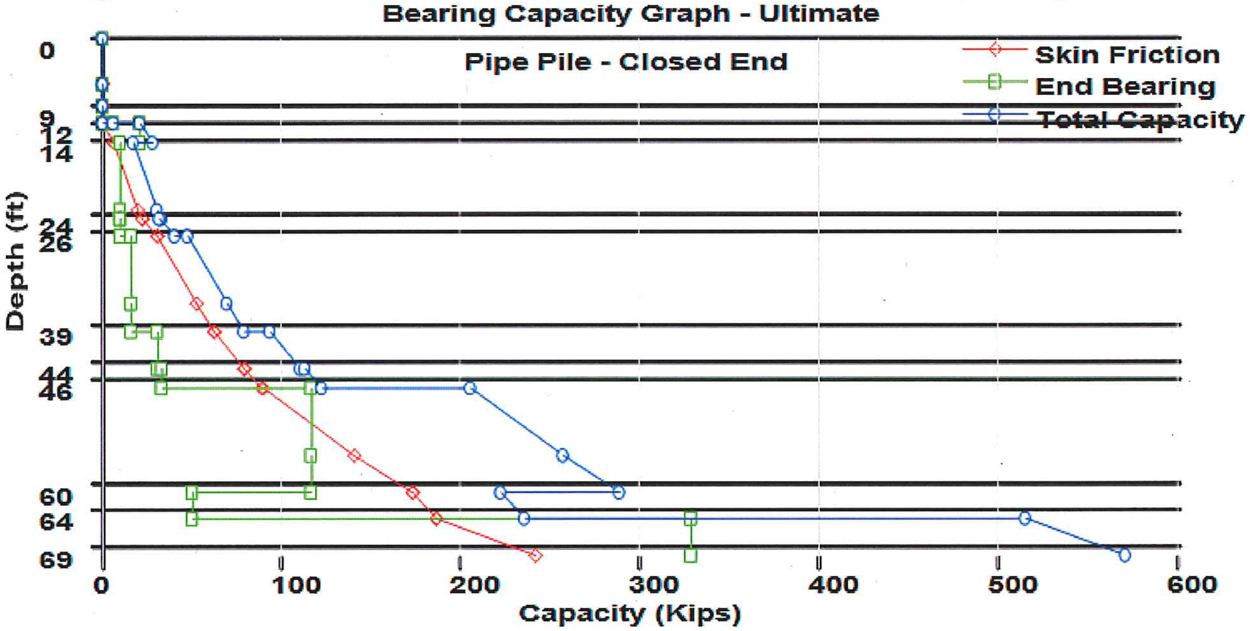


Figure 3.1.3b – DRIVEN Results, 12-inch dia. CIP Steel Pipe Pile, Boring 1217 SB

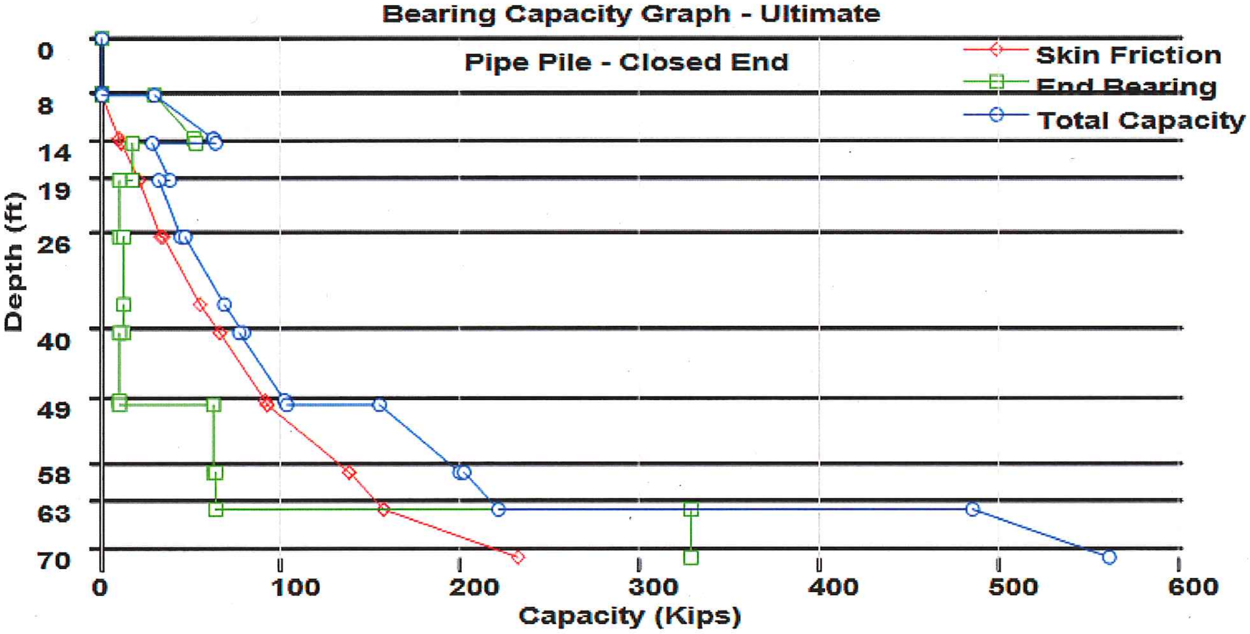


Figure 3.1.3c – DRIVEN Results, 12-inch dia. CIP Steel Pipe Pile, Boring 1223 SB

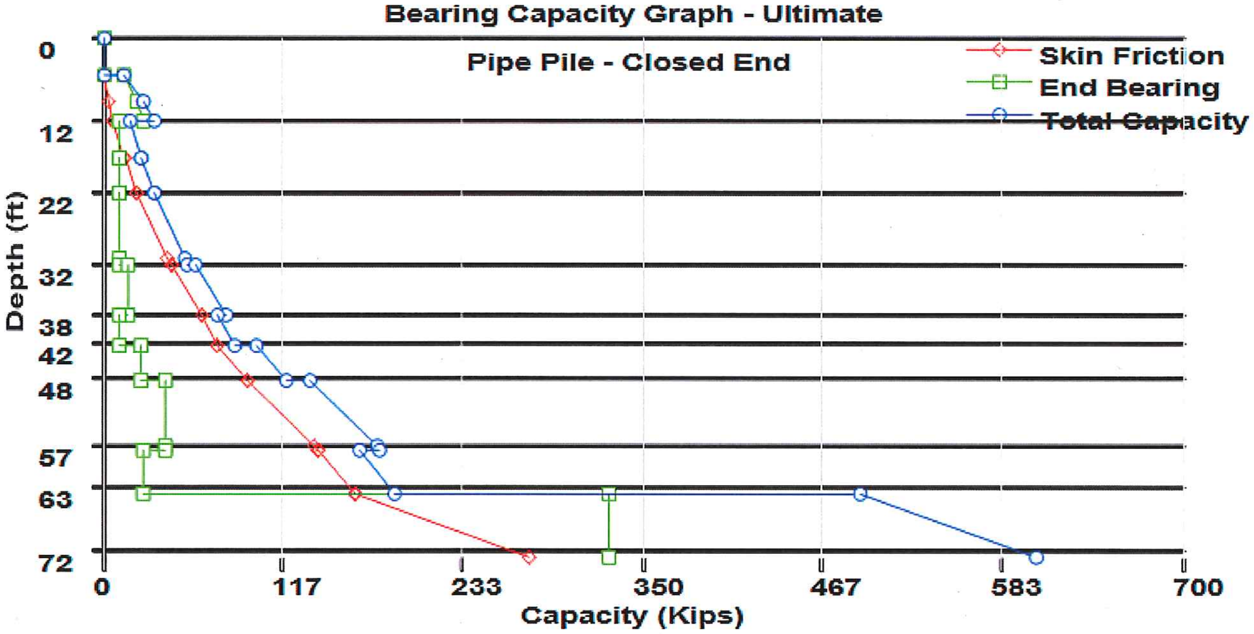
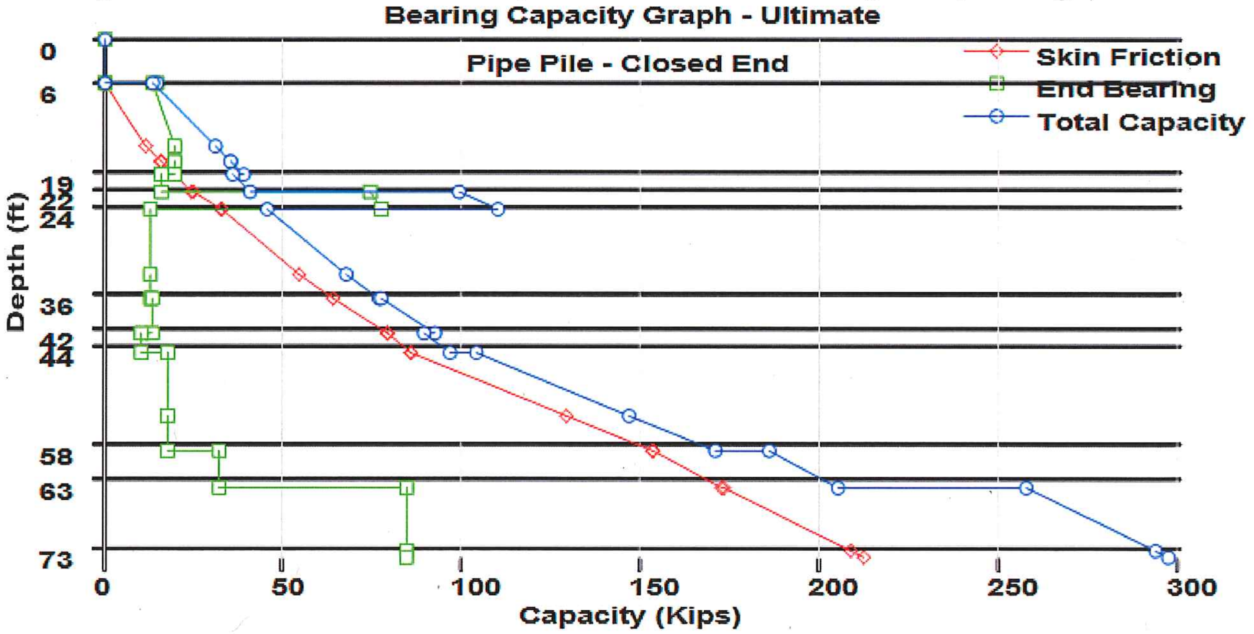


Figure 3.1.3d – DRIVEN Results, 12-inch dia. CIP Steel Pipe Pile, Boring 1224 SB



As shown, nominal resistance needs were met within the very dense granular alluvial/till layer just above the bedrock. The lengths predicted are shown in Table 3.1.3a.

Table 3.1.3a – Estimated Pile Lengths - 12" dia. CIP Steel Pipe

Bridge	Substructure	Boring No.	Proposed Bottom of Footing Elevation, ft	Estimated Tip Elevation, ft	Estimated Pile Length, ft
SOCO	West Abutment	1216 SB	888.5	830	58
	Pier	1216 SB	886.0	830	56
	East Abutment	1217 SB	888.5	833	56
SCOX	West Abutment	1223 SB	893.5	836	58
	East Abutment	1224 SB	895.0	828	67

As demonstrated, resistance increases significantly upon reaching the very dense layer due to the greatly increased tip resistance. Therefore, increased design resistance values can be used by increasing the pile wall thickness. Our recommendations will address these greater wall thicknesses.

If H-pile is used, it is expected that they will meet reasonable design resistance with "refusal" on the bedrock. Therefore, lengths predicted are shown in Table 3.1.3b.

Table 3.1.3b – Estimated Pile Lengths – H-pile

Bridge	Substructure	Boring No.	Proposed Bottom of Footing Elevation, ft	Estimated Tip Elevation, ft	Estimated Pile Length, ft
SOCO	West Abutment	1216 SB	888.5	825.5	63
	Pier	1216 SB	886.0	825.5	61
	East Abutment	1217 SB	888.5	825.5	63
SCOX	West Abutment	1223 SB	893.5	827	67
	East Abutment	1224 SB	895.0	828	67

3.2 Retained Wall Approach Review

Unless the swamp deposits represented by Boring 1216 SB are completely removed and replaced with engineered fill, the retained wall approach on the west side of the SOCO bridge will need to be supported on piles. This includes support of the fill soils contained within the retaining walls. Structures to the west of this wall will also be supported by piles, so this system will be a continuation of the support system for those structures.

Based on the Borings 1224 SB, 1225 SW, and 1226 SW, it is anticipated that the retained wall system to the east of the SCOX bridge can be supported on spread footings. There is also potential for this for the wall system between the bridges, although some local correction may be needed (e.g., removal of buried topsoil at Boring 1217 SB). Foundation support of the retaining walls will need to be further analyzed during advanced design, and may be influenced by the potential additional testing and analysis for the SCOX bridge.

4.0 FOUNDATION RECOMMENDATIONS

4.1 HP12x53 Piles

The bridge foundations can be supported on H-piles, meeting ASTM A572, Grade 50 ($f_y = 50$ ksi). The piles should be equipped with rock points. Various sizes of H-piles can be considered, as listed below. These piles can be designed based on the maximum Factored Pile Bearing Resistance (φR_n) values shown for each size.

- HP12x53, 140 tons
- HP14x73, 190 tons
- HP14x89, 225 tons
- HP14x102, 260 tons
- HP14x117, 300 tons

The nominal resistance of the piles can be evaluated using either high strain dynamic (PDA) testing or the MnDOT MPF12 driving formula, although dynamic analysis allows for better evaluation of whether or not damage is occurring. 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. Resistance Factors of 0.65 or 0.60 should be employed for PDA or MPF12 field analysis methods, respectively. It is anticipated that all H-piles sizes would establish required resistance with "refusal" upon the bedrock. Estimated tip elevations are shown in Table 3.1.3b.

If the approach fill was allowed to impose loads on the swamp in the vicinity of the abutments such that settlement occurred around the piles, downdrag (DD) loads would need to be considered in the foundation design. However, settlement will need to be mitigated to meet differential settlement requirements between the approach and the pile supported bridge (likely though supporting the approach on piles), and assuming this occurs, the settlement needed to create the DD loads are not expected to occur. In this case, it is our opinion that downdrag (DD) loads would not need to be considered in the pile design.

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 flange length.

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.

4.2 12-inch Diameter CIP Steel Pipe Piles

The bridge foundations can be supported with 12-inch diameter CIP steel pipe piles. The piles can be designed based on the following Factored Pile Bearing Resistance (φR_n) values, pending the pipe wall thickness used.

- 0.2500 wall thickness, 100 tons
- 0.3125 wall thickness, 125 tons
- 0.3750 wall thickness, 150 tons

The pipe piles should have a minimum yield strength (f_y) of 45 ksi. 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 3.1.3a for the pile lengths predicted to achieve required nominal resistance values. Note that with each increase in resistance needs due to increasing wall thickness, greater penetration may be needed, but this is expected to be somewhat minor considering the apparent high density. The actual pile lengths must be confirmed at the time of driving, and lengths may be more or less than that shown.

Pending mitigation of settlement around the piles, it is our opinion that down drag (DD) loads do not need to be considered in the design. This should be studied further during advanced design.

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 Approach/Retaining Wall Foundation Support

We recommend that the approach retaining walls on the west side of the SOCO bridge be structurally supported on a pile foundation system, consistent with that recommended for the bridge and the structures to the west. The foundation support needs for the remaining retained wall systems should be evaluated during advance design. Lightweight fill could be considered for either reducing settlement or reducing loads on piles.

4.5 Abutment/Retaining Wall Backfilling

The imbalanced abutment walls and retaining walls must be designed to resist the lateral pressures exerted. Where lightweight fill is not used, 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. Typical "Select Granular Borrow 10% Modified" geometry is shown on attached MnDOT *Diagram F-1*. However, all excavation backsloping must also meet OSHA requirements. For proper track approach performance, frost tapering of the Select Granular Borrow over frost susceptible soils should be maintained at no steeper than 1V:20H within the frost zone (assume a frost zone of 4.5 feet). The backfill should be compacted per the Specified Density Method (MnDOT 2105.3F1).

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

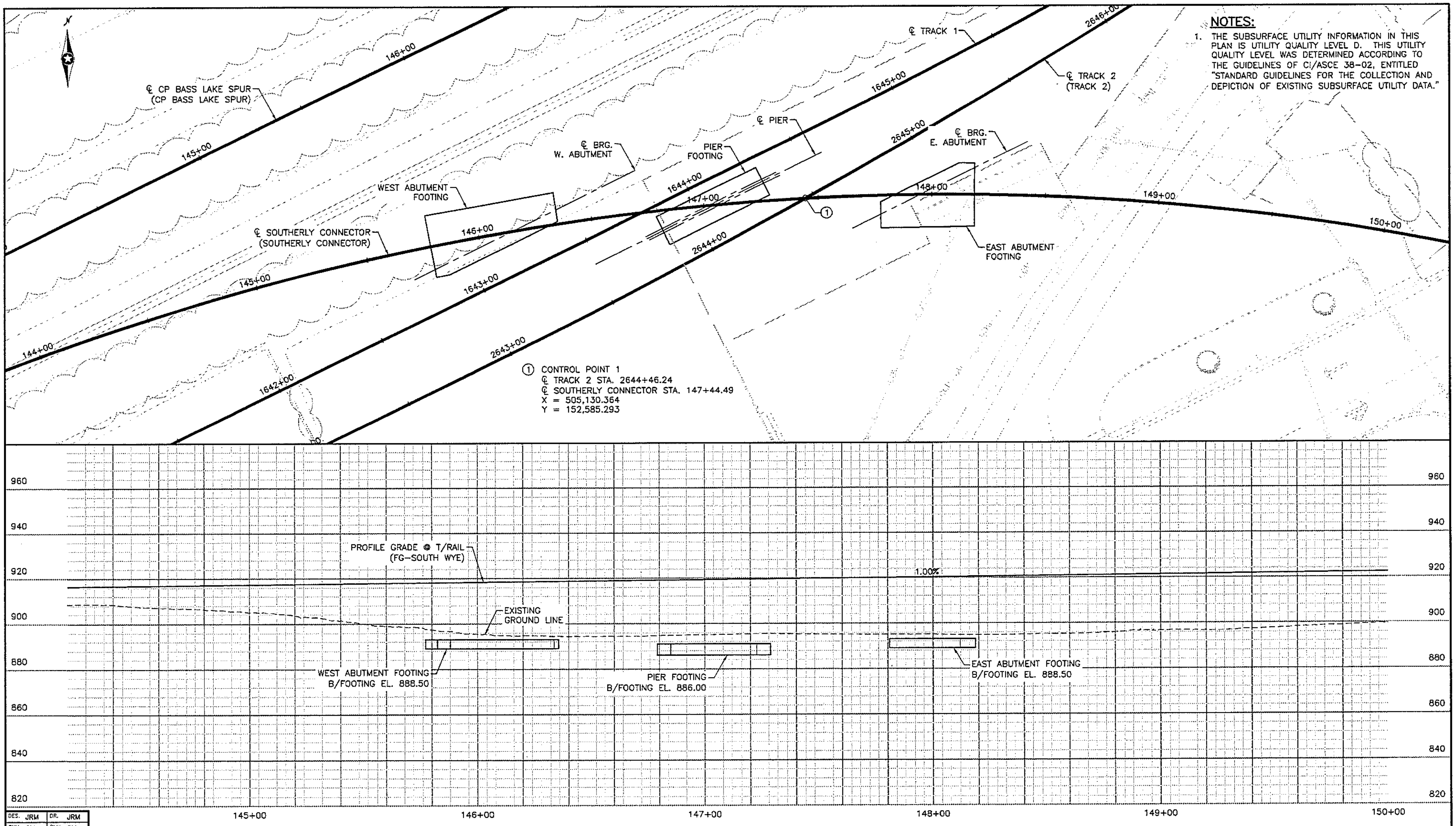
Date: 8/28/14 **License #: 15928**

Report Reviewed By: ______________________
Gregory R. Reuter, PE, PG, Principal Engineer

Attachments:
- Preliminary Bridge Plan-Profile Sheets
- Figure 1 – Boring Locations
- Subsurface Boring Logs
- Exploration/Classification Methods
- Boring Log Notes
- Unified Soil Classification System
- AASHTO Soil Classification System
- MnDOT Diagram F-1

NOTES:

1. THE SUBSURFACE UTILITY INFORMATION IN THIS PLAN IS UTILITY QUALITY LEVEL D. THIS UTILITY QUALITY LEVEL WAS DETERMINED ACCORDING TO THE GUIDELINES OF CI/ASCE 38-02, ENTITLED "STANDARD GUIDELINES FOR THE COLLECTION AND DEPICTION OF EXISTING SUBSURFACE UTILITY DATA."



DES. JRM	DR. JRM
CHK. GM	CHK. GM

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

TKDA

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
SOUTHERLY CONNECTOR OVER LRT
BRIDGE XXXXX (FRT)
BORINGS

DISCIPLINE: STRUCTURES

SHEET NAME: E2-STU-BRG-SOCO-FRT-SUR-002

SHEET 85 OF 277

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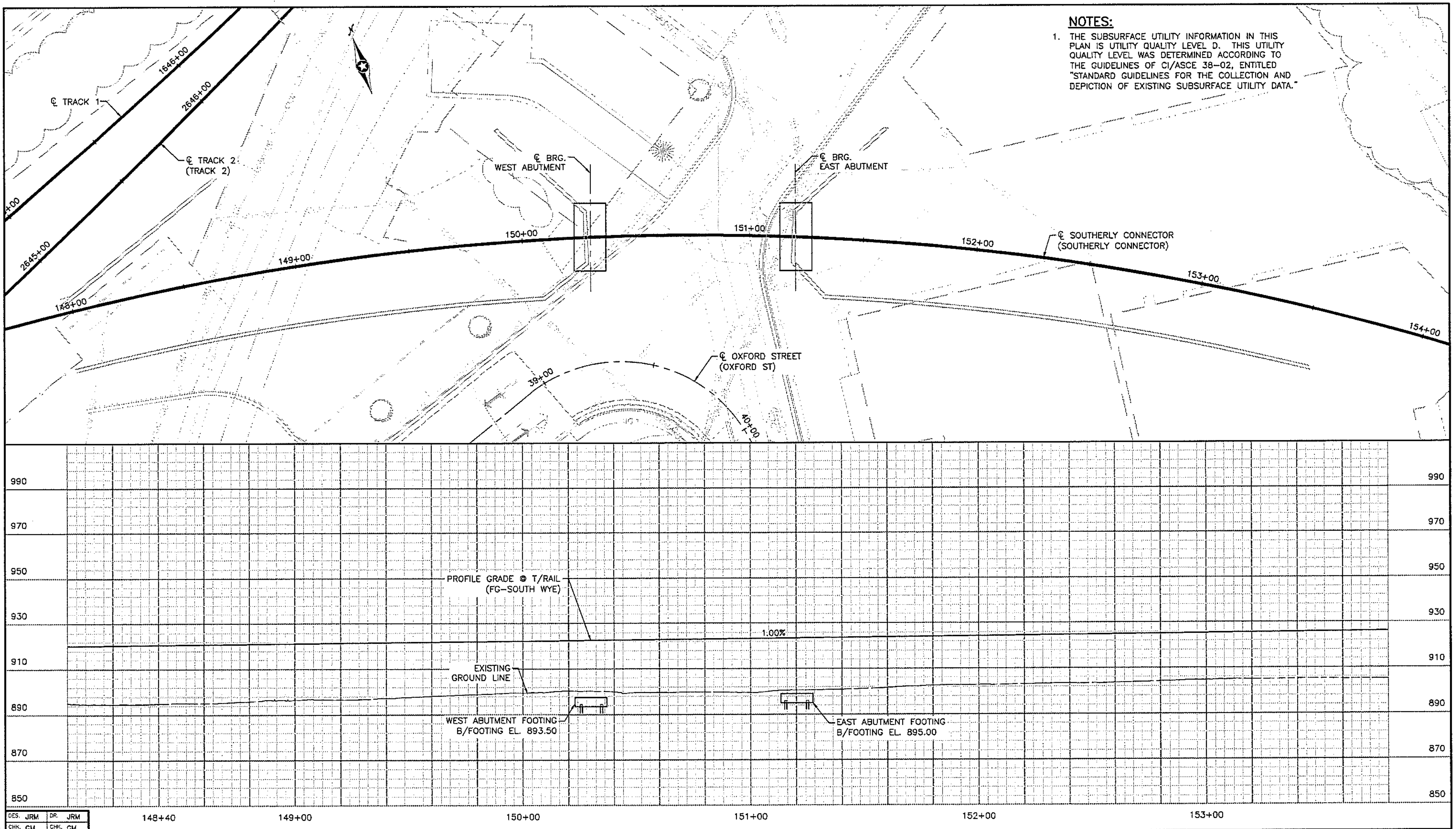

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DES. JRM	DR. JRM
CHK. GM	CHK. GM

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

TKDA

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
SOUTHERLY CONNECTOR AT OXFORD
BRIDGE XXXXX (FRT)
BORINGS

DISCIPLINE: STRUCTURES

SHEET NAME: E2-STU-BRG-SCOX-FRT-SUR-002

SHEET 90 OF 277

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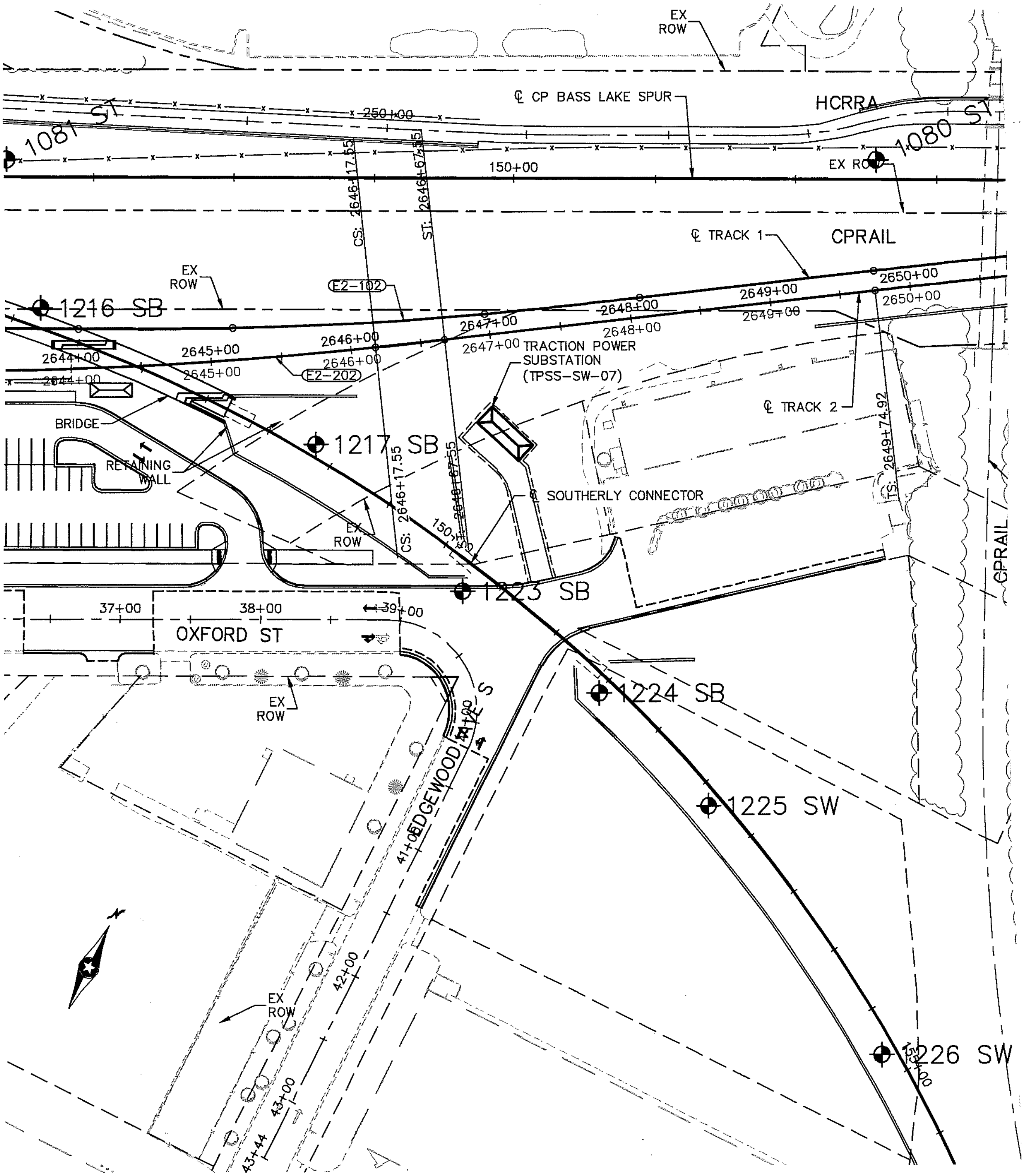

AMERICAN ENGINEERING TESTING, INC.

PROJECT
South Connector Freight Rail Bridges, SWLRT Project

AET NO.
01-05697

SUBJECT
Boring Locations

DATE
August 12, 2014

SCALE
1" = 103'±

DRAWN BY
KHA

CHECKED BY
JV

FIGURE 1

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.: **SOCO-FRT**
Trunk Highway/Location: **Southwest LRT, PEC East**
Boring No.: **1216 SB**
Ground Elevation: **894.7** (Surveyed)

Location: **, , ft. LT**
Co. Coordinate: X=505051 Y=152593 (ft.)
Latitude (North)=44.9353530 Longitude (West)=-93.3638303
Drill Machine: **91C**
Hammer: **CME Automatic Calibrated**
SHEET 1 of 2
Drilling Completed: **5/28/14**

Depth / Elev.	Classification	SPT N60	MC (%)	Other Tests Or Remarks
2.0 892.7	Clayey sand with gravel, trace roots, dark brown (A-6) fill	17	9	Hammer Calibration: 68% efficiency with 110 lb. hammer, 5/27/14
4.0 890.7	Sand with silt, a little gravel, dark brown (A-1-b) fill	33		
9.0 885.7	Clayey sand with gravel, a little sand, dark brown, a little light brown (A-6, A-1-b) fill	17 6	11 13	
11.5 883.2	HEMIC PEAT, black (PT) (A-8) swamp deposit	9	76	
14.0 880.7	CLAYEY SAND WITH GRAVEL, gray, hard, laminations of sand (SC) (A-6) alluvium (petroleum-type odor)	33	10	Water level measured at 11.7' deep with HSA to 14.5' deep (rose from 12.3' deep 10 minutes earlier)
16.5 878.2	SAND, a little gravel, medium to fine grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	11		
19.0 875.7	SAND WITH GRAVEL, medium grained, gray, waterbearing, loose (SP) (A-1-b) alluvium	9		
21.5 873.2	SAND, a little gravel, fine to medium grained, gray, waterbearing, loose (SP) (A-3) alluvium	8		
24.0 870.7	SAND, a little gravel, medium grained, gray, waterbearing, loose (SP) (A-1-b) alluvium	9		
26.5 868.2	CLAYEY SAND, a little gravel, brownish gray, stiff (SC) (A-6) till	11	23	
31.5 863.2	SAND WITH GRAVEL, medium to fine grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium	15 17		
34.0 860.7	SAND, a little gravel, medium grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	18		
41.5	SAND WITH GRAVEL, medium grained, gray, waterbearing, loose to medium dense (SP) (A-1-b) alluvium	10 13 19		

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

METROPOLITAN COUNCIL

SHEET 2 of 2

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	SOCO-FRT	**Southwest LRT, PEC East**	**1216 SB**	**894.7** *(Surveyed)*

Depth / Elev.	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil: Other Tests Or Remarks / Rock: Formation or Member
853.2	SAND WITH GRAVEL, medium to fine grained, waterbearing, medium dense (SP) (A-1-b) alluvium *(continued)*	☒ PD	23				
44.0 850.7	CLAYEY SAND, a little gravel, brown, hard (SC) (A-6) till	☒	38	10			
46.5 848.2	SAND WITH SILT, a little gravel, fine grained, brown, wet, dense, a lens of sand (SP-SM) (A-3) alluvium	PD ☒	42				
48.0 846.7	SAND, fine to medium grained, brown, waterbearing, dense to medium dense, lenses of sand with silt (SP) (A-3) alluvium	PD ☒ PD ☒	44 26				
57.5 837.2	GRAVELLY SAND WITH SILT, medium to fine grained, grayish brown, waterbearing, very dense (SP-SM) (A-1-b) alluvium	PD ☒	58	12			
60.5 834.2	CLAYEY SAND, a little gravel, brown, hard, a lens of lean clay (SC) (A-6) till	PD					
64.0 830.7	GRAVELLY SAND WITH SILT, fine to medium grained, brown, waterbearing, very dense (SP-SM) (A-1-b) alluvium Top of Bedrock	☒ PD	170/.5				
69.0 825.7	LIMESTONE, weathered to generally fresh, gray	☒ PD	200/.4 100/0				PLATTEVILLE FORMATION
74.5 820.2	END OF BORING						

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
	SOCO-FRT	**Southwest LRT, PEC East**	**1217 SB**	**896.3** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=505270 Y=152591 (ft.)

Latitude (North)=44.9353473 Longitude (West)=-93.3629847

Drill Machine **91C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **5/27/14**

Depth / Elev.	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Other Tests Or Remarks / Formation or Member
0.3 896.0	3.5" Bituminous pavement						Hammer Calibration: 68% efficiency with 110 lb. hammer, 5/27/14
1.3 895.0	Silty sand with gravel, a little clayey sand, brown (A-1-b) fill		45				
5.5 890.8	Mixture of silty sand and clayey sand, a little gravel, sand with silt and sandy lean clay, pieces of bituminous, black, a little brown (A-2-4, A-6) fill		11 11	19			
6.5 889.8	Sand with gravel, a little silty sand, light brown (A-1-b) fill						
7.5 888.8	SANDY LEAN CLAY, black, firm (CL) (A-6) topsoil						
9.0 887.3	SILTY SAND, a little gravel, fine to medium grained, dark brown, moist, loose (SM) (A-2-4) alluvium		8	19			
14.0 882.3	CLAYEY SAND WITH GRAVEL, brownish gray, very stiff, laminations of silty sand (SC) (A-2-6) alluvium		21 50/.2	10			
19.0 877.3	GRAVELLY SAND WITH SILT, medium to fine grained, grayish brown, a little light gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium		12 16				Water level measured at 13.6' deep with HSA to 14.5' deep (maintained same level for 10 minutes)
24.0 872.3	SAND, a little gravel, medium grained, gray, very loose to loose (SP) (A-1-b) alluvium		3 6				
30.5 865.8	GRAVELLY SAND, medium grained, gray, waterbearing, loose to medium dense (SP) (A-1-b) alluvium	PD PD	7 13				
39.5 856.8	SAND, a little gravel, medium to fine grained, gray, waterbearing, loose to medium dense (SP) (A-1-b) alluvium	PD PD PD PD	9 7 17 16				
	SAND WITH GRAVEL, medium to fine grained, brownish gray to gray, waterbearing, loose (SP) (A-1-b) alluvium	PD	10				

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

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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SHEET 2 of 2

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	SOCO-FRT	**Southwest LRT, PEC East**	**1217 SB**	**896.3** *(Surveyed)*

DEPTH	*Depth* *Elev.*	*Lithology*	*Classification*	*Drilling Operation*	*SPT N60* *REC (%)*	*MC (%)* *RQD (%)*	*COH (psf)* *ACL (ft)*	*γ (pcf)* *Core Breaks*	*Soil: Other Tests Or Remarks* *Rock: Formation or Member*
	44.5 851.8		SAND WITH GRAVEL, medium to fine grained, brownish gray to gray, waterbearing, loose (SP) (A-1-b) alluvium *(continued)*	PD	8				
45	47.0 849.3		SAND WITH GRAVEL, fine to medium grained, grayish brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	12				
	48.5 847.8		GRAVELLY SAND, medium grained, gray, a little light tan, waterbearing, medium dense, laminations of sand with silt (SP) (A-1-b) alluvium	PD	11	9			
50	49.5 846.8		CLAYEY SAND, a little gravel, grayish brown, stiff to hard (SC) (A-6) till		34				
55	58.0 838.3		GRAVEL WITH CLAY AND SAND, brownish gray to brown, dense to medium dense (GP-GC) (A-1-b) till	PD PD	27				
60	63.0 833.3		CLAYEY SAND WITH GRAVEL, grayish brown and gray, hard, laminations of silty sand (SC/SM) (A-2-4) till	PD	96				
65	69.5 826.8		SAND WITH SILT AND GRAVEL, fine grained, brownish gray, a little gray, waterbearing, very dense, laminations of sand (SP-SM) (A-3) alluvium	PD	81				
70	70.5 825.8		GRAVEL WITH CLAY AND SAND, gray (GP-GC) colluvium Top of Bedrock		50/.3				PLATTEVILLE FORMATION
	73.1 823.2		LIMESTONE, weathered, gray	WS	100/.05				
			END OF BORING						

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State Project	*Bridge No. or Job Desc.* **SCOX-FRT**	*Trunk Highway/Location* **Southwest LRT, PEC East**	*Boring No.* **1223 SB**	*Ground Elevation* **898.9** *(Surveyed)*
Location **, , ft. LT**		*Drill Machine* **33C**		SHEET 1 of 2
Co. Coordinate: X=505410 Y=152543 (ft.)		*Hammer* **CME Automatic Calibrated**		*Drilling Completed* **5/8/14**
Latitude (North)=44.9352156 *Longitude (West)=-93.3624441*				

DEPTH	*Depth* *Elev.*	*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*
	0.8 898.2	9" Bituminous pavement						Hammer Calibration: 69% efficiency with 105 lb. hammer, 9/17/13
	2.0 896.9	Sand with silt and gravel, light brown (A-1-b) fill		29				
5	9.0 889.9	GRAVELLY SAND, medium to fine grained, light brown and brown, moist, medium dense (SP) (A-1-b) alluvium or fill		19 23 17				
10	11.5 887.4	GRAVELLY SAND WITH SILT, medium to fine grained, brown, moist, medium dense (SP-SM) (A-1-b) alluvium or fill		27				
15	16.5 882.4	SAND WITH SILT, a little gravel, medium to fine grained, light brown, a little light tan, moist, loose, laminations of lean clay below 14' (SP-SM) (A-1-b) alluvium		8 8				
▼	19.0 879.9	SAND, a little gravel, fine to medium grained, light grayish brown, waterbearing, loose (SP) (A-3) alluvium		7				Water level measured at 16.7' deep with HSA to 17' deep (rose from 16.9' deep 10 minutes earlier)
20	24.0 874.9	SAND , a little gravel, medium to fine grained, light grayish brown to light brown, waterbearing, loose to medium dense (SP) (A-1-b) alluvium		5 13				
25 30	34.0 864.9	SAND, a little gravel, medium to coarse grained, gray, waterbearing, loose to medium dense (SP) (A-1-b) alluvium	PD	6 16 8 18				
35	38.5 860.4	SAND, a little gravel, medium to fine grained, grayish brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD PD	14 13				
40		SAND WITH GRAVEL, medium to coarse grained, gray, waterbearing, loose (SP) (A-1-b) alluvium	PD	9				

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	SCOX-FRT	**Southwest LRT, PEC East**	**1223 SB**	**898.9** (Surveyed)

Depth / Elev.	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Other Tests Or Remarks / Formation or Member
42.5 856.4	CLAYEY SAND, a little gravel, grayish brown, very stiff (SC) (A-6) till	PD ☒ PD	28	10			
47.5 851.4	CLAYEY SAND, a little gravel, brown, very stiff to hard (SC/SM) (A-2-6) till	☒ PD ☒ PD	20 33	11 11			
57.0 841.9	CLAYEY SAND, a little gravel, grayish brown, very stiff (SC) (A-6) till	☒	30	12			
61.0 837.9	SILTY SAND, a little gravel, grayish brown, very dense, lenses and laminations of clayey sand (SM) (A-2-4) till	PD ☒ PD	50/.4				
68.0 830.9	SAND WITH SILT, a little gravel, fine grained, light grayish brown, moist, very dense (SP-SM) (A-3) alluvium Top of Bedrock	☒	74				
71.8 827.1	LIMESTONE, weathered, gray	PD	100/.05				PLATTEVILLE FORMATION
74.1 824.8	END OF BORING						

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	SCOX-FRT	**Southwest LRT, PEC East**	**1224 SB**	**901.2** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=505525 Y=152529 (ft.)

Latitude (North)=44.9351771 Longitude (West)=-93.3620001

Drill Machine **85C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **7/29/14**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil: Other Tests Or Remarks / Rock: Formation or Member
	0.2 901.0		2.25" Bituminous pavement Sand with silt and gravel, a little lean clay and clayey sand, brown (A-1-b) fill		36 20				Hammer Calibration: 66% efficiency with 105 lb hammer, 10/31/12
5	4.0 897.2		SAND, a little gravel, fine to medium grained, light brown, a little brown, moist, medium dense (SP) (A-3) alluvium		15				
	6.5 894.7		SAND WITH GRAVEL, medium grained, light brown, moist, medium dense (SP) (A-1-b) alluvium		11				
10	9.0 892.2		SAND, a little gravel, medium to fine grained, light brown, moist, medium dense (SP) (A-1-b) alluvium		12 17				
15	14.0 887.2		SAND WITH SILT, fine to medium grained, light brown, a little brown, moist, medium dense, laminations of silty sand (SP-SM) (A-1-b) alluvium		16				
▼	16.5 884.7		SAND , fine grained, brown, waterbearing, medium dense (SP) (A-3) alluvium		12				Water level measured at 17.4' deep with HSA to 19.5' deep (rose from 18.9' deep 10 minutes earlier)
20	19.0 882.2		SILT, gray, a little brown, wet, medium dense, lenses and laminations of sand (ML) (A-4) alluvium	PD	20	21			
	21.5 879.7		CLAYEY SAND, a little gravel, grayish brown, very stiff (SC) (A-2-6) till	PD	27	11			
25	24.0 877.2		SAND, fine grained, brown, waterbearing, medium dense (SP) (A-3) alluvium	PD PD	14 11				
30	29.0 872.2		SAND, medium to fine grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	11				
35	31.5 869.7		SAND, fine grained, brown, waterbearing, medium dense (SP) (A-3) alluvium	PD PD	13 14				
	36.5 864.7		SILTY CLAY, brown, stiff (CL-ML) (A-4) alluvium	PD	16	27			
40	39.0 862.2		SILT WITH SAND, brown, wet, medium dense (ML) (A-4) alluvium	PD	16	28			
	41.5								

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SHEET 2 of 2

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	SCOX-FRT	**Southwest LRT, PEC East**	**1224 SB**	**901.2** *(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*
	859.7		SAND, a little gravel, medium grained, brownish gray, waterbearing, loose (SP) (A-1-b) alluvium *(continued)*	☒	10					
	44.0 857.2			PD						
45			CLAYEY SAND WITH GRAVEL, brown, very stiff (SC) (A-6) till	☒	25					
	46.5 854.7			PD						
				☒	20	11				
				PD						
50				☒	23	13				
			CLAYEY SAND, a little gravel, brown, very stiff to stiff (SC) (A-2-6) till	PD						
55				☒	15	13				
	58.0 843.2			PD						
60				☒	37	13				
				PD						
65			CLAYEY SAND, a little gravel, grayish brown, a little brown, hard, laminations of waterbearing sand (SC) (A-6) till	☒	97	11				
				PD						
70				☒	100/.4	12				
	73.0 828.2		Top of Bedrock	PD						PLATTEVILLE FORMATION
75	75.7 825.5		LIMESTONE, highly weathered to weathered, gray till *38/.5 + 49/.5 + 100/.2	☒	*	12				
			END OF BORING							

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	SCOX-FRT WALL	**Southwest LRT, PEC East**	**1225 SW**	**904.1** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=505649 Y=152488 (ft.)

Latitude (North)=44.9350646 Longitude (West)=-93.3615214

Drill Machine **85C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **7/30/14**

Depth / Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
0.2 903.9	2.5" Bituminous pavement						Hammer Calibration: 66% efficiency with 105 lb hammer, 10/31/12
0.5 903.6	3.5" Silty sand with gravel, brown (A-2-4) fill		46				
2.0 902.1	Gravelly sand with silt, brown (A-1-b) fill						
4.0 900.1	Gravel with sand, light brown (A-1-b) fill		25				
16.5 887.6	SAND WITH GRAVEL, medium to fine grained, light grayish brown to light brown, moist, loose to dense (SP) (A-1-b) alluvium		8 41 42 40 31				
19.0 885.1	SAND, fine to medium grained, light brown, moist, loose to dense (SP) (A-3) alluvium		39				
21.5 882.6	SAND, medium to fine grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium		18				
24.0 880.1	SAND, a little gravel, fine to medium grained, brown, waterbearing, medium dense, a lens of silt (SP) (A-3) alluvium		19				Water level measured at 20.8' deep with HSA to 22' deep (maintained level for 10 minutes)
26.5 877.6	CLAYEY SAND, a little gravel, grayish brown, very stiff (SC) (A-6) till	PD	19	10			
29.0 875.1	SAND, medium to fine grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	17				
31.5 872.6	CLAYEY SAND, brown, stiff, laminations of lean clay (SC/SM) (A-2-6) till	PD	14	15			
39.0 865.1	SILTY SAND WITH GRAVEL, brownish gray to brown, medium dense (SM) (A-2-4) till	PD PD PD	14 21 17				
42.0	CLAYEY SAND, a little gravel, brown, very stiff (SC/SM) (A-2-6) till	PD PD	24	13			

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	SCOX-FRT WALL	**Southwest LRT, PEC East**	**1225 SW**	**904.1** *(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
	862.1		CLAYEY SAND WITH GRAVEL, brown, hard, lenses of silty sand and sand with silt (SC/SM) (A-2-6) till	☒	37	12				
				PD						
45				☒	39	13				
	46.5 857.6		CLAYEY SAND, a little gravel, brown, very stiff (SC/SM) (A-2-6) till	PD						
				☒	26	13				
				PD						
50				☒	22	12				
				PD						
55				☒	22	12				
	58.0 846.1		SAND WITH SILT, a little gravel, fine to medium grained, brownish gray, waterbearing, very dense (SP-SM) (A-3) alluvium	PD						
60				☒	92					
				PD						
65				☒	137					
	68.0 836.1		SAND WITH SILT, medium to fine grained, brownish gray, waterbearing, very dense (SP-SM) (A-1-b) alluvium	PD						
70				☒	91					
				PD						
	73.0 831.1		CLAYEY SAND, a little gravel, brown, hard (SC) (A-6) till							
75	75.0 829.1		Top of Bedrock LIMESTONE, weathered, gray	☒	*	10				PLATTEVILLE FORMATION
	75.3 828.8		END OF BORING *55/.5 + 100/.3							

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	SCOX-FRT WALL	**Southwest LRT, PEC East**	**1226 SW**	**903.4** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=505833 Y=152349 (ft.)

Latitude (North)=44.9346832 Longitude (West)=-93.3608111

Drill Machine **85C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **7/30/14**

Depth / Elev.	Classification	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
0.3 / 903.2	3" Bituminous pavement					Hammer Calibration: 66% efficiency with 105 lb hammer, 10/31/12
0.5 / 902.9	3" Crushed limestone base, light brown (A-1-b) fill					
2.0 / 901.4	Sand with silt, a little silty sand, light grayish brown (A-3) fill	17				
4.0 / 899.4	Sand, a little gravel, trace roots, light grayish brown (A-1-b) fill	10				
6.5 / 896.9	SAND, a little gravel, trace roots, medium to fine grained, light brown, moist, medium dense (SP) (A-1-b) alluvium	11				
11.5 / 891.9	SAND, fine grained, light brownish gray, moist, medium dense (SP) (A-3) alluvium	15 25				
14.0 / 889.4	SAND WITH SILT, a little gravel, medium to fine grained, brown, moist, medium dense (SP-SM) (A-1-b) alluvium	30				
▼ 18.5 / 884.9	SAND WITH SILT, fine grained, light grayish brown to brown, moist to waterbearing, medium dense (SP-SM) (A-3) alluvium	24 18				Water level measured at 18.1' deep with SS to 18.5' deep (maintained level for 10 minutes)
24.0 / 879.4	CLAYEY SAND, a little gravel, brown, very stiff, laminations of sand with silt (SC/SM) (A-2-6) till	24 17	11			
36.5 / 866.9	SAND, fine grained, grayish brown to brownish gray, waterbearing, medium dense (SP) (A-3) alluvium	22 20 20 25 28				
39.0 / 864.4	SAND, fine to medium grained, grayish brown, waterbearing, medium dense (SP) (A-3) alluvium	22				
41.5	SAND, a little gravel, medium to fine grained, grayish brown, waterbearing, medium dense (SP) (A-1-b) alluvium	27				

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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	SCOX-FRT WALL	**Southwest LRT, PEC East**	**1226 SW**	**903.4** *(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
	861.9		GRAVELLY SAND, fine to medium grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium *(continued)*	☒	25					
	44.0 859.4		CLAYEY SAND, a little gravel, brown, very stiff (SC/SM) (A-2-6) till	PD						
45				☒	24	11				
				PD						
				☒	27	11				
				PD						
50				☒	27	12				
				PD						
55				☒	30	11				
				PD						
60				☒	29					No recovery
	63.0 840.4		GRAVELLY SAND WITH SILT, fine to medium grained, grayish brown, very dense, a lens of clayey sand (SP-SM) (A-1-b) alluvium *50/.5 + 100/.1	PD						
65				☒	*					
				PD						
	68.0 835.4		CLAYEY SAND, a little gravel, brownish gray, hard, a lens of silty sand (SC/M) (A-2-6) till Top of Bedrock							
70				☒	68	15				
	73.0 830.4		LIMESTONE, weathered, gray	PD						PLATTEVILLE FORMATION
75				☒	119					
	76.0 827.4		END OF BORING							

EXPLORATION/CLASSIFICATION METHODS

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)

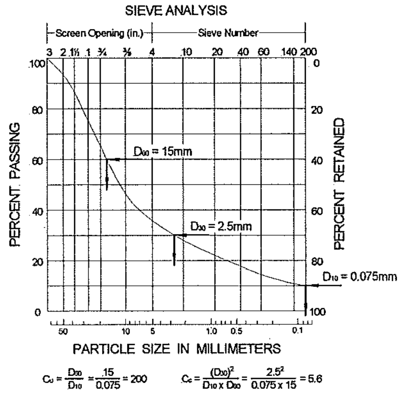
The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide N_{60} values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), 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.

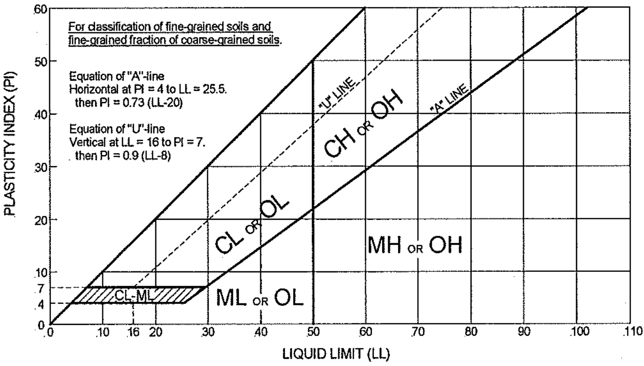
The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM: D1586 is encountered) whereas the length of sample recovered 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	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]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[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]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[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	$\frac{\text{Liquid limit–oven dried}}{\text{Liquid limit – not dried}} < 0.75$	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	$\frac{\text{Liquid limit–oven dried}}{\text{Liquid limit – not dried}} < 0.75$	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

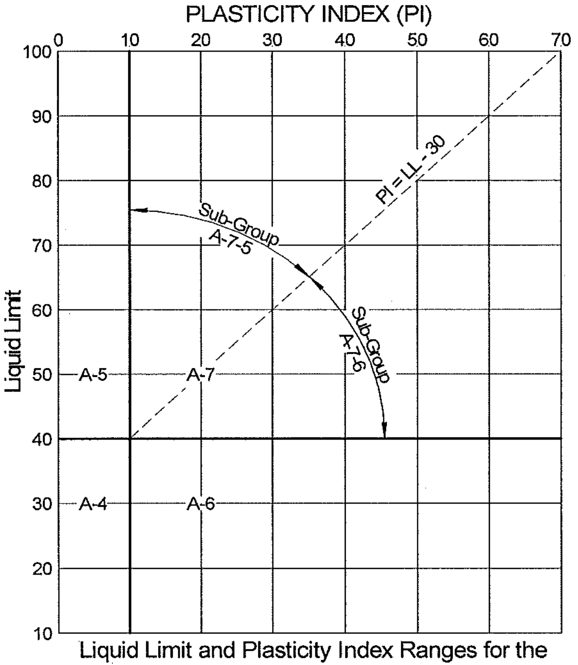
Classification of Soils and Soil-Aggregate Mixtures

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-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	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

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.

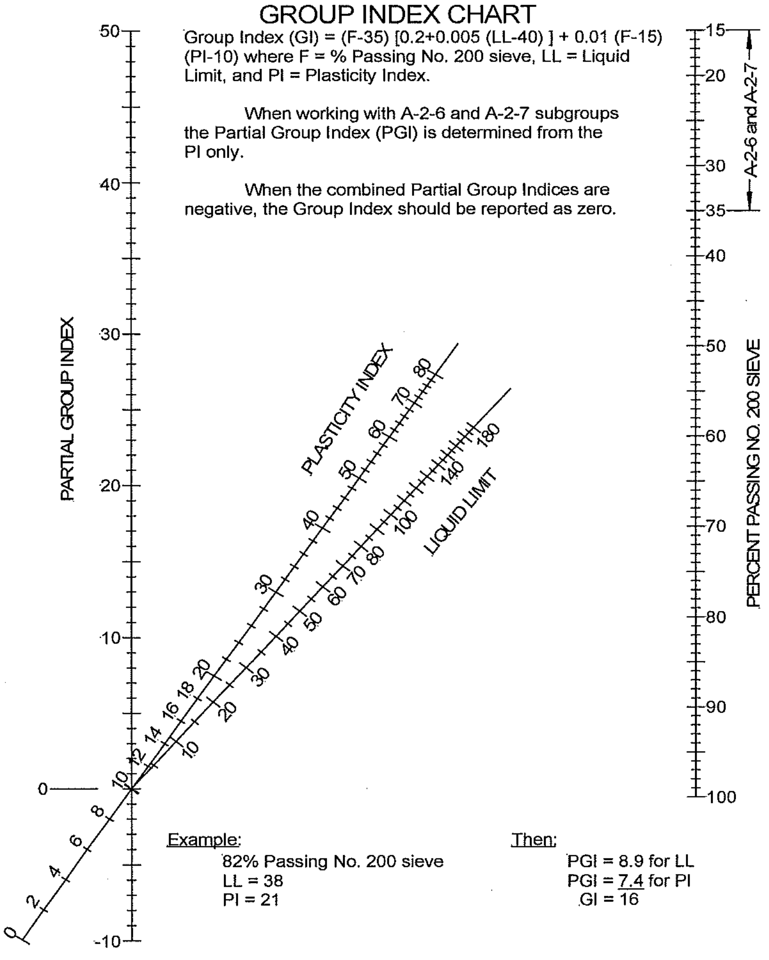
FINE SAND - Material passing the No. 40 sieve and retained on the No. 200 sieve.

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.

GROUP INDEX CHART



Group Index (GI) = (F-35) [0.2+0.005 (LL-40)] + 0.01 (F-15) (PI-10) where F = % Passing No. 200 sieve, LL = Liquid Limit, and PI = Plasticity Index.

When working with A-2-6 and A-2-7 subgroups the Partial Group Index (PGI) is determined from the PI only.

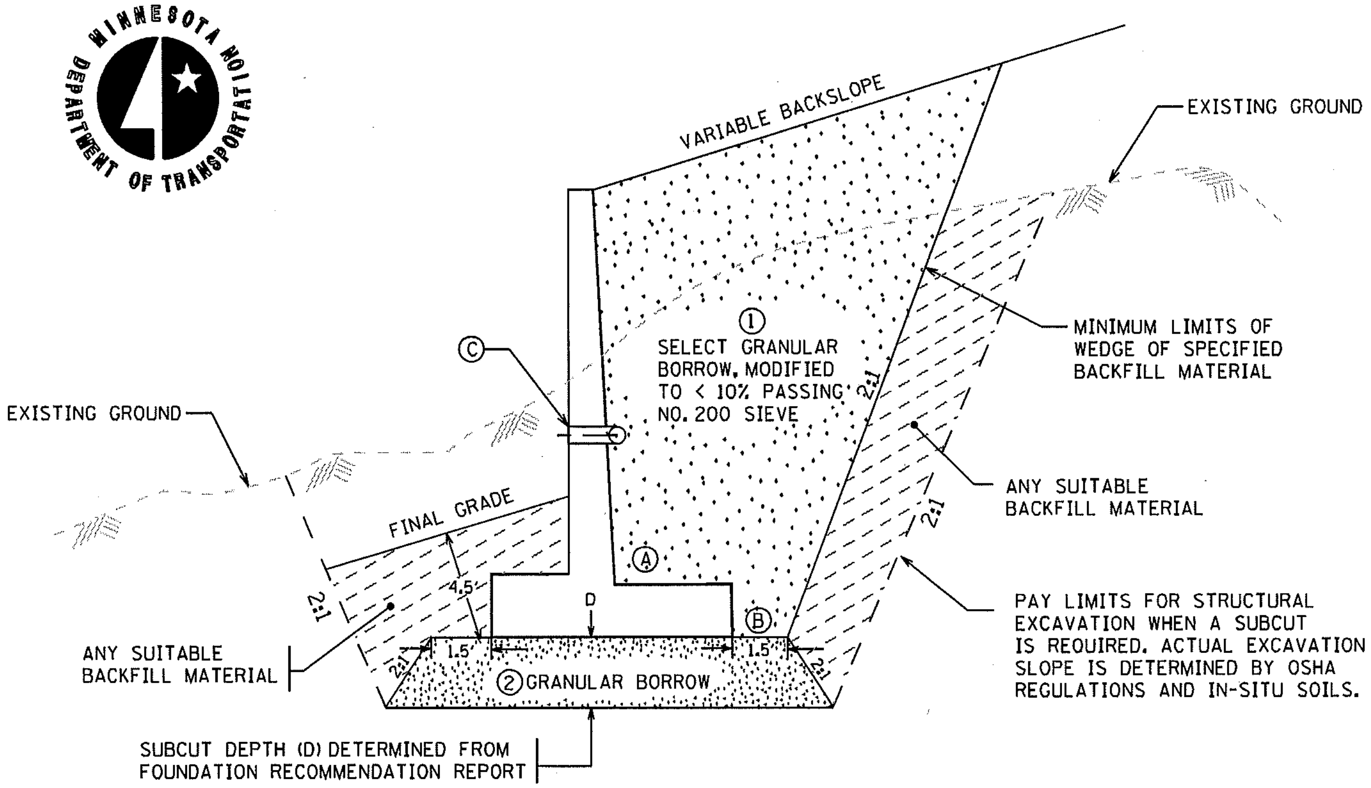
When the combined Partial Group Indices are negative, the Group Index should be reported as zero.

Example:

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

Then:

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



NOT TO SCALE

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)

November 2005
PREPARED BY THE FOUNDATIONS UNIT
GEOTECHNICAL ENGINEERING SECTION – OFFICE OF MATERIALS

DIAGRAM NO.

F–1