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: LRT, Freight Rail, and Pedestrian Bridges over Minnehaha Creek
Southwest Light Rail Transit Project
Minneapolis, Minnesota
AET No. 01-05697.06

1.0 PROJECT INFORMATION

This report provides foundation analysis and recommendations for the bridges which will carry the light rail transit (LRT) tracks, the re-aligned freight rail tracks, and the pedestrian trail over Minnehaha Creek in St. Louis Park. Separate one-span bridges are planned for each of the three described crossings. The bridges will be 94'-8" long, intended to span Minnehaha Creek and a future trail. The existing bridge foundations and a portion of the abutment front faces are planned to remain in-place. The trail will then be located between the new and old foundations on the west side. Concrete slope paving will be used between the new and old foundations on the east side. With the planned configuration, we understand foundation scour will not be an issue.

Out-to-out bridge widths and deck structure types are planned as follows:

- LRT bridge: 30'-6", prestressed concrete beams
- Freight bridge: 19'-8", steel welded plate girders
- Trail bridge: 18'-6", prestressed concrete beams

The preliminary bottom of foundation elevation is 889.0 feet for the west abutment. The foundation at the east abutment could be placed as high as elevation 895.0 feet, although we are recommending a bottom at elevation 892.0 feet for geotechnical reasons (to penetrate a clay layer).

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

Based on preliminary plans, the proposed approaches on both sides will be very near or slightly cut into existing grade. The exception is at the freight bridge where the approaches are shown to have a grade raise of about two feet.

2.0 SUBSURFACE EXPLORATION SUMMARY

2.1 Scope

The exploratory test program performed and included in this report consisted of the following:

- Trail/Freight West Abutment: CPT 1258 CB, Boring 1009 SB
- Trail/Freight East Abutment: CPT 1259 CB, Boring 1010 SB
- LRT West Abutment: Boring 1260 SB
- LRT East Abutment: Boring 1261 SB

Boring 1010 SB also included rock coring once bedrock was reached. 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, two sieve analysis tests (-#200) were performed. 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 above 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*. Rock coring was performed in general accordance with ASTM:D2113, using an NQ size wireline system.

The soils were classified per the Unified Soil Classification System, although 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).

2.3.2 Piezocone Penetration Test Soundings

CPT_u testing was conducted in general accordance with ASTM:D5778; with the user notes, abbreviations, and definitions appearing on the attachment *Cone Penetration Test Index Sheet*.

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 about 9 feet to 16½ feet of fill overlying water-deposited (alluvium) granular soils to about elevation 876 feet to 881 feet, which is then mostly underlain by glacially deposited (till) soils. A 2½-foot layer of organic clay appears above the alluvium (below 16½ feet of fill) at Boring 1260 SB. Bedrock is about 86 feet to 91 feet below the surface.

2.4.1 Bedrock

The bedrock depth at Borings 1009 SB and 1010 SB is 88.8 feet and 91.0 feet, respectively (corresponding to elevation 824.0 feet and 821.9 feet). Borings 1260 SB and 1261 SB were obstructed, and pieces of the bedrock were not retrieved. We expect that the obstruction at Boring 1260 SB (75.3 feet deep) was caused by a cobble or boulder. However, the obstruction at 1261 SB may have been the bedrock based on the elevation proximity to the known bedrock elevations. The bedrock is limestone of the Platteville Formation. The rock coring performed at Boring 1010 SB indicates the limestone to be only slightly weathered. RQD values were 92% to 95%.

2.4.2 Natural Overburden Soils

The natural soil profile predominantly consists of alluvium (water-deposited soils) over glacially-deposited till soils. The alluvium is mostly granular, mainly consisting of sand to silty sand having varying gravel content (at times, mostly gravel). The till mostly consists of clayey sand and silty sand, again having varying gravel content. The upper portion of the till is noticeably looser/softer than the lower zone.

2.4.3 Upper Fill

The borings were drilled on the existing raised embankment. At the boring locations, the fill was 9 feet to 16½ feet thick. The fill is primarily a mixture of sandy soils (sands to silty sands and clayey sands). The N-values indicate relatively high levels of compaction in the existing trail area (based on Borings 1009 SB and 1010 SB) and moderate levels of compaction in the existing freight area (based on Borings 1260 SB and 1261 SB).

2.5 Ground Water

Borings 1009 SB and 1010 SB were drilled in March of 2013. Ground-water levels measured in the boreholes at that time indicated ground-water level elevations of 889.5 feet and 888.7 feet. Borings 1260 SB and 1261 SB were drilled in the spring of 2014. The elevations of the levels measured at that time were 893.2 feet and 893.1 feet, which corresponded well with the creek level at that time. As these levels were measured in granular soils, 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, which was evidenced from the 2013 to 2014 levels measured.

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 planned foundations are expected to penetrate through the upper fill and organic clay layers and extend into the natural alluvium. The soils exposed are expected to be the natural sands, with one qualification. CPT 1259 CB (Freight/Trail east abutment) indicates the presence of a marginal clay layer to about elevation 893½ feet. If bottom of footing elevations on the east side are established at elevation 892 feet, the limiting soils should be penetrated and natural sands exposed. Based on support upon the sands, it is our opinion that a spread footing foundation can be considered for support of these bridges.

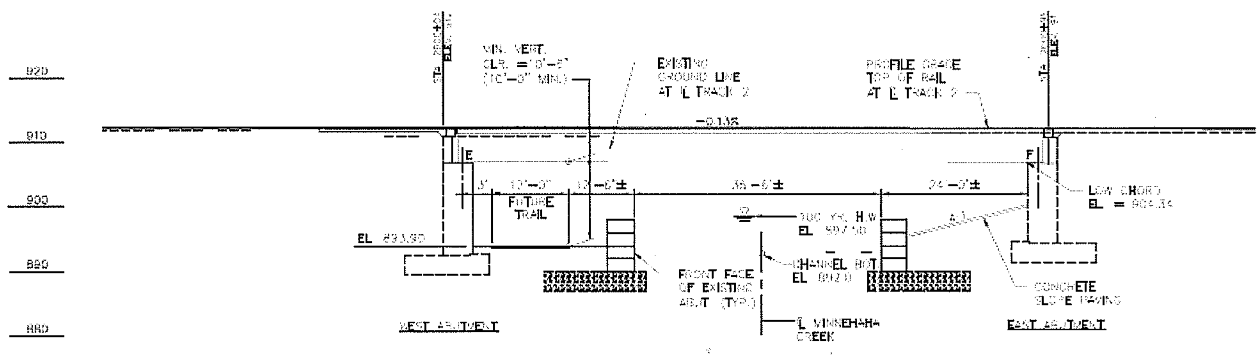
It should be recognized that the foundations are expected to extend below the ground-water level, and local ground water control will be needed to construct the footings. However, similar ground water control would likely be needed for a pile foundation approach, based on foundation bottom elevations.

The alternate to a spread foundation approach would be to support the bridge on H-piles which are driven to the bedrock around elevation 822 feet to 824 feet. This preliminary report, however, presents the spread foundation support only.

3.2 Design Assumptions

The profile/elevation view for the LRT bridge is shown on Figure 3.2. The profile views pertaining to the freight and trail bridges are generally similar to this, so are not shown.

Figure 3.2 – Profile/Elevation View



Foundation data used in our analysis was determined from the preliminary plans and information provided by Kimley-Horn and Associates, Inc. (KHA), as shown in Table 3.2.

Table 3.2 –Foundation Data

Substructure	Bottom of Footing Elevation, ft	Footing Width, ft	Footing Length, ft	Max. Service Loads (nominal), ksf	Maximum Strength Loads (factored), ksf
Trail West Abutment	889.0	11.0	20	2.73	3.55
Trail East Abutment	892.0*	11.0	20	2.73	3.55
Freight West Abutment	889.0	13.0	21.3	5.42	7.95
Freight East Abutment	892.0*	13.0	21.3	5.42	7.95
LRT West Abutment	889.0	11.0	32	3.98	5.11
LRT East Abutment	892.0*	11.0	32	3.98	5.11

*recommended to penetrate clay layer (and keep side-by-side footings at same elevation)

3.3 Foundation Analysis

3.3.1 Discussion

The natural granular soils are judged capable of supporting a spread footing foundation system for the new bridges. If clays happen to be present in the excavation bottom, the analysis assumed they will be subcut and replaced with sand/gravel as discussed later.

3.3.2 Nominal Bearing Resistance – Strength Limit State

The nominal (ultimate) bearing resistance of the spread footing foundations was evaluated using the bearing resistance formula presented in Section 10 of the *AASHTO LRFD Bridge Design Specifications, 2012.* The internal friction angle of the granular bearing soils was correlated to SPT N-values obtained in the borings.

The results of our foundation analyses for varying footing widths pertaining to the Strength Limit State appear on Figures 2 to 5, attached to this report.

3.3.3 Nominal Bearing Resistance – Service Limit State

Footing settlement was estimated by computing Young's modulus values using the shear wave velocities determined from the CPT_u soundings and an assumed Poisson's ratio of 0.2, with reduction factors applied to the dynamic (i.e. small-strain moduli) to account for the variation of modulus with strain level under static loading. Changes in total vertical stress due to foundation loading from the footings were evaluated by Boussinesq equations.
The results of our foundation analyses for varying footing widths pertaining to the Service Limit State appear on Figures 2 to 5, attached to this report.

3.3.4 Sliding Resistance of Abutment Footings

We assume that the concrete for the footing will be poured directly onto the sandy foundation soils. It is also assumed that the passive resistance in front of the footings will be ignored.

3.3.5 Global Stability Analysis

The global stability of the abutments was checked using Bishop's Modified method of slices using the computer program SLOPE/W 2012. It is assumed that a minimum factor of safety of 1.5 would be acceptable. The footing was modeled as a very strong material, thus forcing the critical failure surface behind the heel of the footing. Based on information from KHA, we evaluated a live load surcharge of either 250 psf (for the pedestrian and LRT bridges) or 500 psf (for the freight rail bridge).

For the west abutments, we analyzed geometry including an 11-foot wide footing, with the 500 psf live load, and a representative soil profile. We found a factor of safety of 1.51, which meets the minimum required value. For the east abutments, we first analyzed an 11-foot wide footing, with the 250 psf live load associated with the pedestrian and LRT bridges, for which we found a factor of safety of 1.56. We also analyzed a 13-foot wide footing with the 500 psf live load surcharge associated with the freight bridge, and we found a factor of safety of 1.55.

The results of our global stability analyses appear on Figures 6 to 8, attached to this report.

4.0 FOUNDATION RECOMMENDATIONS

4.1 Foundation Type and Depth

Based on our interpretation of the subsurface conditions, the bridges can be supported on conventional spread footing foundations. Footings should be supported at least 4.5 feet below final grade for frost protection. The planned footing depths do exceed this minimum cover depth.

4.2 Footing Design

4.2.1 Nominal Bearing Resistance – Strength Limit State

The maximum factored bearing pressure should be maintained below the factored bearing resistance (nominal bearing resistance provided at the effective footing width times a Resistance Factor of 0.45). Based on the preliminary information, it appears this requirement will be satisfied, but should be re-evaluated once loads based on the effective footing width are established. If the maximum factored bearing pressure exceeds the factored bearing resistance provided at the effective footing width, the footing should be widened until the criterion is met.

4.2.2 Nominal Bearing Resistance – Service Limit State

To maintain settlements within the 1-inch criteria, the nominal bearing resistance should be maintained below the limits established in Figures 2 to 5. The final nominal bearing resistance will need to be met using the effective footing width. The preliminary data suggests this requirement should be met, but should be re-evaluated once loads based on the effective footing width are established.

4.2.3 Sliding Resistance

The shear resistance of the sandy soils along the base of the footing should be able to resist the computed lateral loads. This will allow the passive resistance from the soils in front of the footing to be ignored. This evaluation can be based on the following recommended parameters:

- a friction angle of 32 degrees for cast-in-place concrete on the sandy foundation soils,
- a Nominal Sliding Resistance of 0.60 times the applied vertical force, and
- a Resistance Factor of 0.8.

4.2.4 Global Stability of Abutments

The calculated factors of safety for the critical surfaces developed for the West and East Abutment analyses are about 1.5 and 1.55, respectively. Both meet or exceed 1.5, and are acceptable.

4.3 Dewatering and Excavation/Filling Needs

4.3.1 Dewatering

The excavation to bottom of footing elevation is expected to extend up to 4 feet below the most recent water level measurements, although this is expected to fluctuate with time. Accordingly, dewatering will be needed to properly construct the foundations. This will likely need to be in the form of a local cofferdam, wherein the direct inflow of water from the bottom and sides can be controlled. The till soils below about elevation 875 feet to 880 feet offers a less permeable deposit than the upper sands for at least a partial "seal" using this approach.

4.3.2 Potential Over-Excavation

The bearing soils exposed during construction should be observed, probed with hand auger borings, and evaluated for suitability by a geotechnical engineer/technician. If clayey, organic, or excessively soft/loose soils are encountered, they should be subcut further and replaced with compacted granular fill. The excavation should continue to extend out horizontally from the edge of foundations a distance at least equal to the depth of fill required to establish grade, forming a 1:1 oversizing.

4.3.3 Engineered Fill Soil Type and Compaction below Foundations

Based on the borings/CPTs, it is not expected that over-excavation is needed. However, if it is needed, engineered fill would need to be placed. Engineered fill placed to establish foundation grade should at least meet the requirements of MnDOT Specification 3149.2B2, Select Granular Borrow. This granular fill should be placed and compacted in accordance with MnDOT Specification 2105. Compaction should meet the Specified Density Method, with the modification that the entire thickness of the new fill below the footing be compacted to a minimum of 100% of the Standard Proctor density.

If excess water is present, open-graded gravel (such as Coarse Filter Aggregate per MnDOT 3149.2H) could be used. Open-graded gravels must be separated from surrounding soils with a geotextile separation fabric (Type V geotextile per MnDOT 3733) to prevent internal erosion of fines into the open void space.

4.4 Abutment Backfilling

The imbalanced abutment walls must be designed to 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 roadway. For proper track/trail approach performance, frost tapering of the Select Granular Borrow below the tracks/trail of 1V:20H should be maintained 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). The wall design can be based on lateral pressures presented in MnDOT design charts.

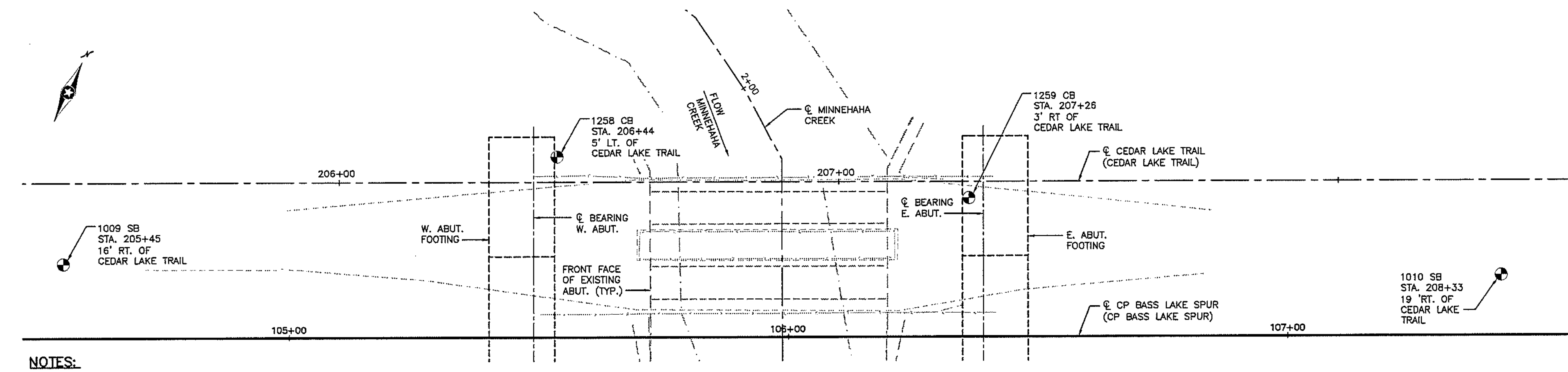
I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under Minnesota Statute Section 326.02 to 326.15

Name: Jeffery K. Voyen
Jeffery K. Voyen

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

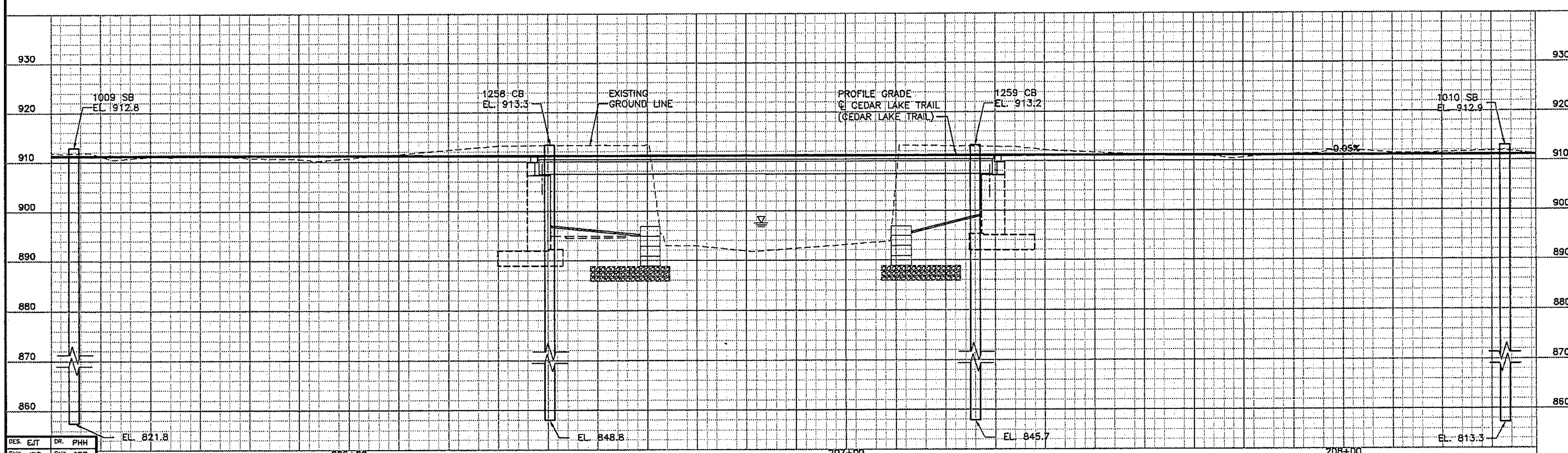
Report Reviewed By: Joseph G. Bentler
Joseph G. Bentler, PE

Attachments:
- Preliminary Bridge Plan-Profile Sheets
- Figure 1 – Boring and CPT Locations
- Subsurface Boring Logs
- Cone Penetration Test Logs
- Figures 2 to 5 – LRFD Bearing Graphs
- Figures 6 to 8 – Global Stability Analysis
- Exploration/Classification Methods
- Boring Log Notes
- Unified Soil Classification System
- AASHTO Soil Classification System
- Cone Penetration Test Index Sheet
- MnDOT Diagram F-1



NOTES:

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



DES. EJT	DR. PHH
CHK. JDP	CHK. CPE

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

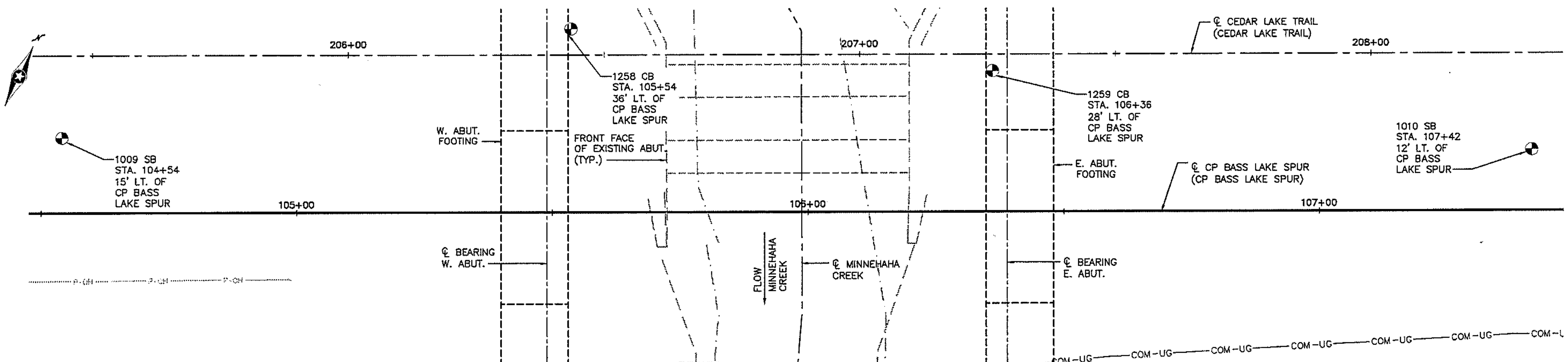
EAST - VOLUME 2 (STRUCTURES)
MINNEHAHA CREEK
BRIDGE XXXXX (TRL)
BORINGS (1 OF 3)

DISCIPLINE: STRUCTURES

SHEET NAME: E2-STU-BRG-MNHA-TRL-BOR-001

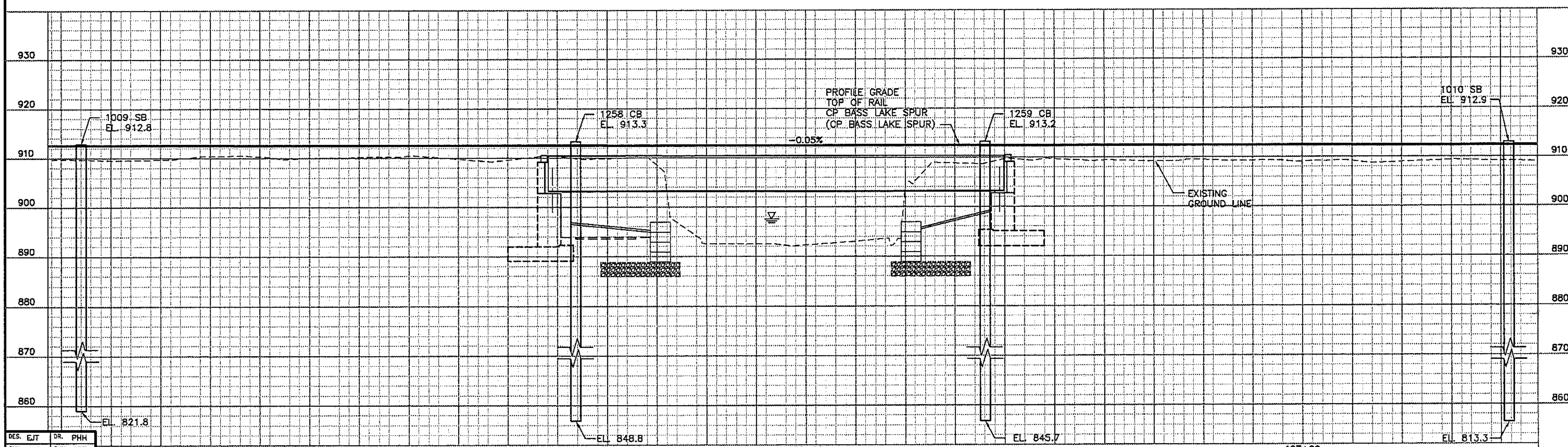
SHEET 37 OF 277

Jun. 20 2014 10:48 am V:\3300_pec-e\CAD\segment e2\plan sheets\structures\E2-STU-BRG-MNHA-TRL-SUR-002.dwg By: Katie.Ellis



NOTES:

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



DES. EJT	DR. PHH
CHK. JDP	CHK. CPE

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

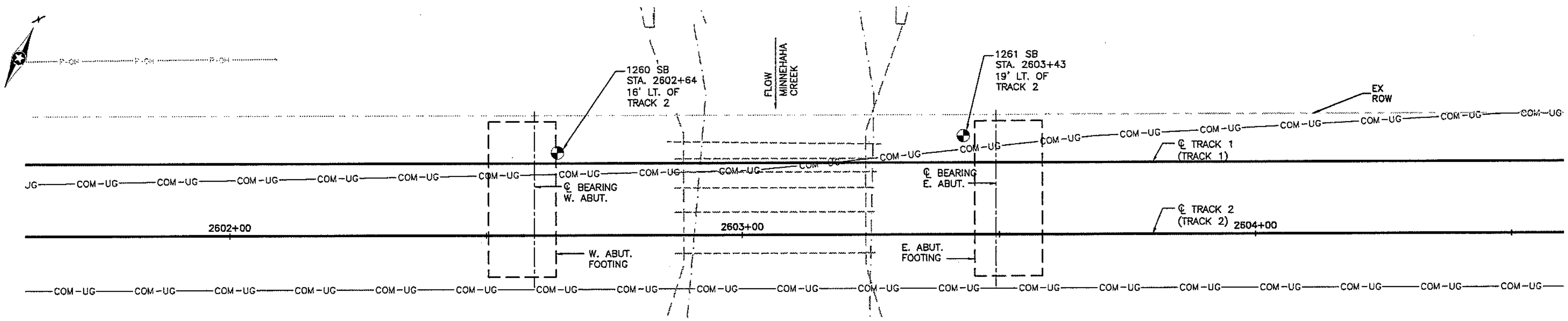
EAST - VOLUME 2 (STRUCTURES)
MINNEHAHA CREEK
BRIDGE XXXXX (FRT)
BORINGS (1 OF 3)

DISCIPLINE: STRUCTURES

SHEET NAME: E2-STU-BRG-MNHA-FRT-BOR-001

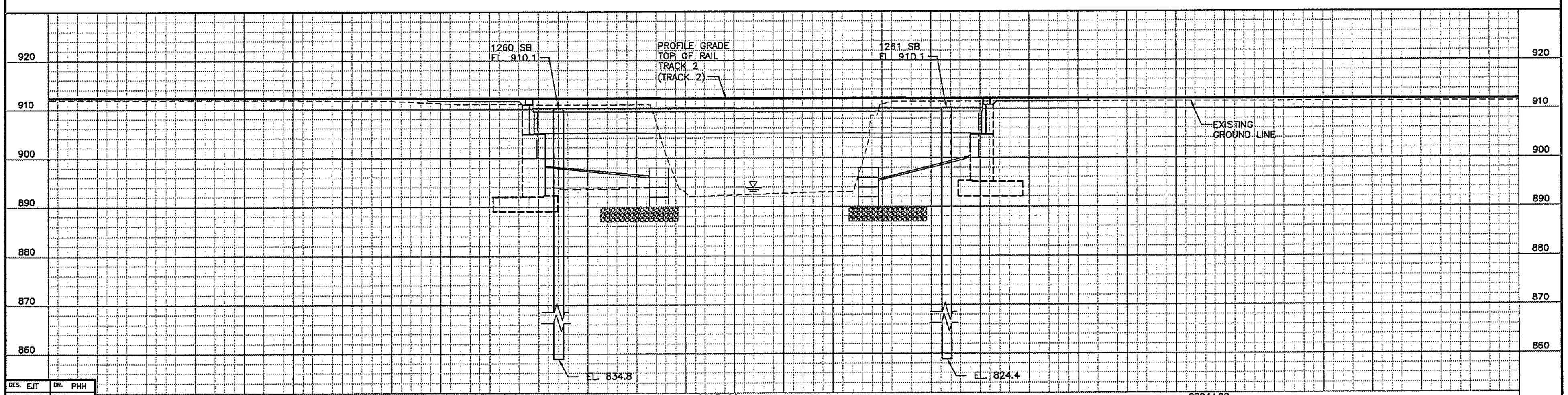
SHEET 46 OF 277

Jun, 20 2014 11:03 am V:\3300_pec-e\CAD\segment e2\plan sheets\structures\E2-STU-BRG-MNHA-FRT-SUR-002.dwg By: Katie.Ellis



NOTES:

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



DES. EJT	DR. PHH
CHK. CPE	CHK. JDP

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

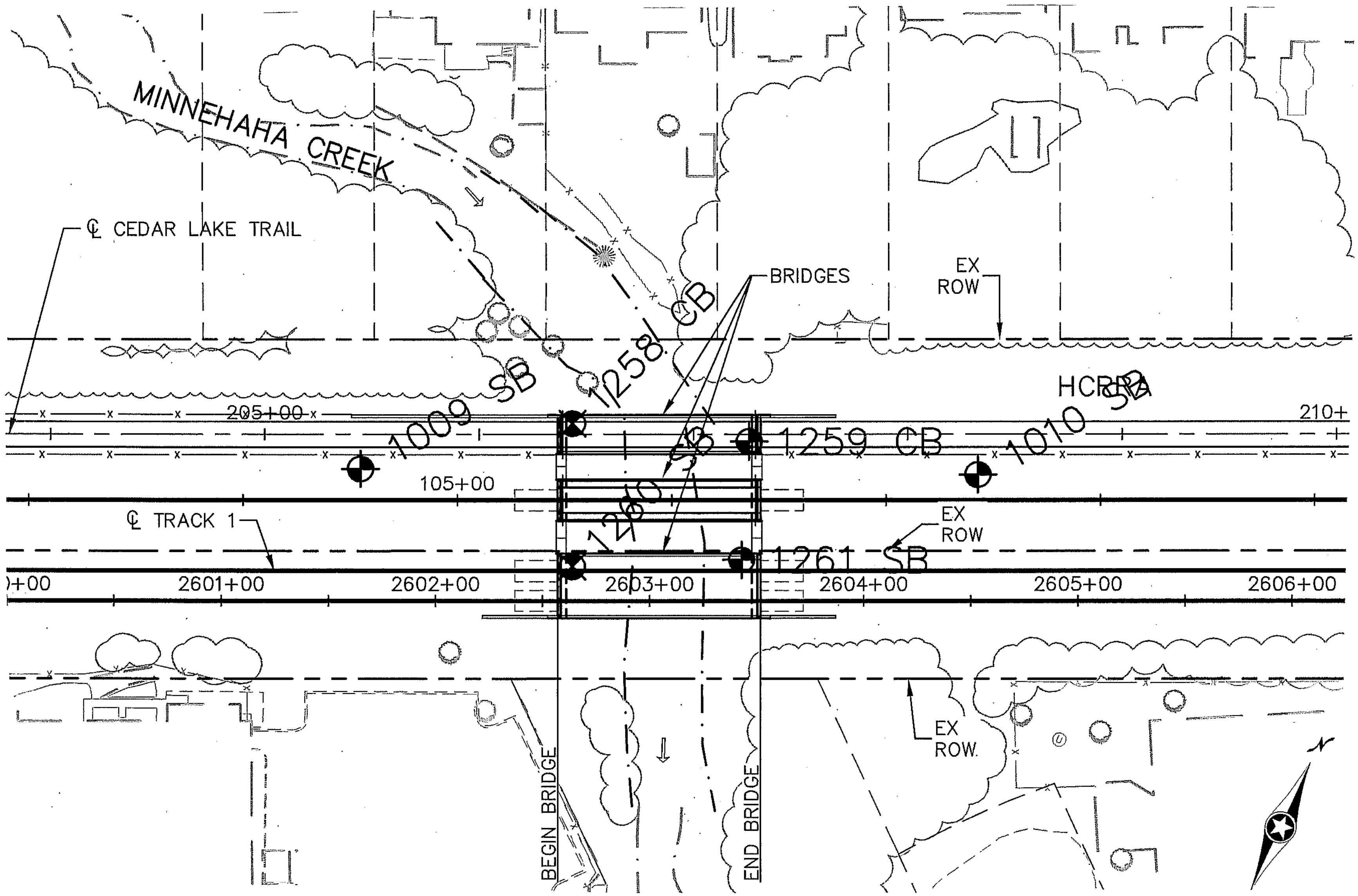
EAST - VOLUME 2 (STRUCTURES)
MINNEHAHA CREEK
BRIDGE XXXXX (LRT)
BORINGS (1 OF 3)

DISCIPLINE: STRUCTURES

SHEET NAME: E2-STU-BRG-MNHA-LRT-BOR-001

SHEET 53 OF 277

Jun, 20 2014 11:26 am V:\3300_pec-e\CAD\segment e2\plan sheets\structures\E2-STU-BRG-MNHA-LRT-SUR-002.dwg By: Katie.Ellis



AMERICAN ENGINEERING TESTING, INC.	PROJECT LRT, Freight, and Trail Bridges over Minnehaha Creek			AET NO. 01-05697.06
	SUBJECT Boring and CPT Locations			DATE June 27, 2014
	SCALE 1" = 71'±	PREPARED 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

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1009 SB**	**912.8** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=501210 Y=150872 (ft.)

Latitude (North)=44.9306345 Longitude (West)=-93.3786616

Drill Machine **1C**

Hammer **CME Automatic Calibrated**

Drilling Completed **3/25/13**

DEPTH	Depth / Elev.	Classification	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
	2.0 / 910.8	Gravelly silty sand, pieces of brick, trace roots, dark brown and brown, frozen (A-2-4) fill					Hammer Calibration: 66% efficiency with 105 lb. hammer, 9/18/13
	11.5 / 901.3	Silty sand with gravel, a little clayey sand, brown and dark brown, a little black (A-1-b, A-2-4) fill	45	4			-#200 = 13%
5			20				
			32				
10			23				
	14.0 / 898.8	SAND WITH SILT AND GRAVEL, medium to fine grained, light brown, moist, medium dense (SP-SM) (A-1-b) alluvium	19				
15	19.0 / 893.8	SAND WITH GRAVEL, medium to fine grained, light grayish brown, a little brownish gray, moist, medium dense, laminations of clayey sand (SP) (A-1-b) alluvium	13				
			11				
20	21.5 / 891.3	SAND WITH SILT AND GRAVEL, fine to medium grained, brown and light brown, moist, medium dense (SP-SM) (A-1-b) alluvium	13				
▼	29.0 / 883.8	SAND WITH GRAVEL, medium to fine grained, brown and brownish gray, moist to waterbearing, medium dense (SP) (A-1-b) alluvium	13				Water level measured at 23.3' deep with HSA to 24.5' deep (rose from 23.7' deep 27 minutes earlier)
25			20				
			20				
30	31.5 / 881.3	GRAVELLY SILTY SAND, brownish gray, dense, a lens of clayey sand (SM/SC) (A-2-4) till	32				
	34.0 / 878.8	SAND WITH GRAVEL, medium grained, brownish gray, a little brown, waterbearing, very dense, a lens of gravel with silt and sand (SP) (A-1-b) alluvium	72				
35	36.5 / 876.3	LEAN CLAY WITH SAND, dark grayish brown, very stiff (CL) (A-6) alluvium	30	12			
	40.0 / 872.8	CLAYEY SAND WITH GRAVEL, brown, stiff (SC) (A-6) till	10	12			
40		SILTY SAND, a little gravel, grayish brown, very loose to medium dense (SM/SC) (A-2-4) till					No recovery

Index Sheet Code

(Continued Next Page)

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

X:\01-GEO\GINTW\1 GINT PROJECTS\01-05697 MNDOT TEMPLATE.GPJ

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

MINNESOTA DEPARTMENT OF TRANSPORTATION

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1009 SB**	**912.8** (Surveyed)

Depth / Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
	SILTY SAND, a little gravel, grayish brown, very loose to medium dense (SM/SC) (A-2-4) till *(continued)*		5				
			7				
			4				
			5				
		PD					
			6				
		PD					
60.5 / 852.3			*				*10/0.5 + 36/0.5 + 50/0.4
63.0 / 849.8	GRAVEL WITH CLAY AND SAND, possible cobbles, grayish brown, very dense (GP-GC) (A-1-b) alluvium	PD					
	CLAYEY SAND WITH GRAVEL, possible cobbles, grayish brown, hard (SC) (A-6) till		55				
		PD					
			**				**40/0.5 + 50/0.1
		PD					
			35	10			
78.0 / 834.8		PD					
	GRAVEL WITH CLAY AND SAND, brown, very dense (GP-GC) (A-1-b) till		80	13			
83.0 / 829.8		PD					

(Continued Next Page)

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
	Minnehaha Creek	Southwest LRT, PEC East	1009 SB	912.8 (Surveyed)

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Other Tests Or Remarks (Soil) / Formation or Member (Rock)
85			CLAYEY SAND, a little gravel, brown, very stiff (SC) (A-6) till *(continued)*	PD	20				
	88.8 / 824.0		Top of Bedrock	PD					
90	91.0 / 821.8		LIMESTONE, gray	PD	100/.1				PLATTEVILLE FORMATION
			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
	Minnehaha Creek	Southwest LRT, PEC East	1010 SB	912.9 (Surveyed)

Location , , ft. LT

Co. Coordinate: X=501471 Y=150994 (ft.)

Latitude (North)=44.9309690 Longitude (West)=-93.3776539

Drill Machine 1C

Hammer CME Automatic Calibrated

Drilling Completed 4/1/13

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
2.0 / 910.9	Silty sand with gravel and organic fines, trace roots, dark brown, frozen (A-2-4) fill						Hammer Calibration: 66% efficiency with 105 lb. hammer, 9/18/13
6.5 / 906.4	Gravelly sand with silt, a little silty sand and clayey sand, brown and light brown (A-1-b) fill		55; 53	2			-#200=10%
9.0 / 903.9	Silty sand, a little gravel, dark brown (A-2-4) fill		14				
11.5 / 901.4	SAND WITH SILT, a little gravel, fine to medium grained, light brown, moist, medium dense (SP-SM) (A-3) alluvium		24				
14.0 / 898.9	SAND WITH SILT AND GRAVEL, medium to fine grained, light brown, moist, medium dense (SP-SM) (A-1-b) alluvium		19				
16.5 / 896.4	GRAVELLY SAND WITH SILT, fine to medium grained, brown, moist, dense (SP-SM) (A-1-b) alluvium		50				
19.0 / 893.9	SAND WITH SILT, a little gravel, fine grained, light brown, moist, medium dense (SP-SM) (A-3) alluvium		18				
22.5 / 890.4	SAND WITH SILT AND GRAVEL, medium to fine grained, brown, moist, medium dense, a lens of medium to fine grained sand with gravel (SP-SM) (A-1-b) alluvium		11				
24.0 / 888.9	SAND, medium grained, light brown, moist, loose (SP) (A-1-b) alluvium		6				
26.5 / 886.4	SAND WITH GRAVEL, medium grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium		15				Water level measured at 24.2' deep with HSA to 24.5' deep (same level 5 minutes earlier)
29.0 / 883.9	SAND WITH SILT AND GRAVEL, medium grained, brownish gray, waterbearing, medium dense, a lens of fine to medium grained sand (SP-SM) (A-1-b) alluvium		25				
36.5 / 876.4	GRAVELLY SILTY SAND, fine to medium grained, grayish brown, wet, dense to very dense (SM) (A-1-b) alluvium	PD; PD; PD	45; 35; 70				
39.0 / 873.9	CLAYEY SAND WITH GRAVEL, brown, stiff (SC) (A-6) till	PD	11	9			
	SILTY SAND, a little gravel, brown, loose (SM/SC) (A-2-4) till	PD	8				

Index Sheet Code

(Continued Next Page)

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

MINNESOTA DEPARTMENT OF TRANSPORTATION

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	Southwest LRT, PEC East	1010 SB	912.9 (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
	43.0 / 869.9				6					
45			SILTY SAND WITH GRAVEL, grayish brown, very loose (SM) (A-2-4) till	PD	4					
				PD	3					
50				PD	4					
	53.0 / 859.9			PD						
55			SILTY SAND, a little gravel, brown, loose (SM/SC) (A-2-4) till		6					
				PD						
60					7					
				PD						
65					10					
	67.5 / 845.4			PD						
70			CLAYEY SAND, a little gravel, brown, hard to very stiff (SC) (A-6) till		40	11				
				PD						
75					26	11				
				PD						
80					26	10				
	83.0 / 829.9			PD						

(Continued Next Page)

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1010 SB**	**912.9** (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
85–90			CLAYEY SAND WITH GRAVEL, brown, hard (SC/SM) (A-2-4) till *(continued)*	PD	34	10			
				PD					
90	91.0 / 821.9		Top of Bedrock		56	14			
95			LIMESTONE, light gray and gray, crinkley bedded Weathering: Slightly weathered Fracturing: Very to moderately fractured Stratification: Very thinly bedded Hardness: Hard		100	95			PLATTEVILLE FORMATION
	99.6 / 813.3				100	92			
			END OF BORING						

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

X:\01-GEO\GINTW\1 GINT PROJECTS\01-05697 MNDOT TEMPLATE.GPJ

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1260 SB**	**910.1** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=501319 Y=150873 (ft.)

Latitude (North)=44.9306372 Longitude (West)=-93.3782408

Drill Machine **68C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **5/27/14**

DEPTH	Depth / Elev.	Classification	SPT N60 (REC %)	MC (%) (RQD %)	COH (psf) (ACL ft)	γ (pcf) (Core Breaks)	Other Tests Or Remarks / Formation or Member
		Mixture of sand with silt and silty sand, a little gravel, light brown and black (A-1-b) fill	15				Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
			15				
5	4.0 / 906.1	Clayey sand, a little gravel and sand, grayish brown, a little light brown and dark brown (A-6) fill	6	19			
			8	14			
10	9.0 / 901.1	Sand with silt and gravel, a little clayey sand, light brown and dark brown (A-1-b, A-6) fill	9				
			10	17			
15			26				
	16.5 / 893.6	ORGANIC CLAY, a little gravel and sand, trace roots, black, very stiff (OH) (A-8) swamp deposit or fill	17	144			Water level measured at 16.9' deep with HSA to 19.5' deep (rose from 17.9' deep 10 minutes earlier)
20	19.0 / 891.1	SAND WITH SILT, a little gravel, fine to medium grained, gray and brown, waterbearing, medium dense to dense (SP-SM) (A-1-b) alluvium	25				
			31				
25	24.0 / 886.1	GRAVELLY SAND WITH SILT, fine to medium grained, grayish brown, waterbearing, very dense (SP-SM) (A-1-b) alluvium	71				
	26.5 / 883.6	SAND WITH SILT AND GRAVEL, fine to medium grained, dark brownish gray, waterbearing, very dense (SP-SM) (A-1-b) alluvium	56				
30	29.0 / 881.1	CLAYEY SAND, a little gravel, brown to grayish brown, hard to stiff, a lens of waterbearing sand with silt (SC) (A-6, A-1-b) till	42	10			
			14	14			
35	34.0 / 876.1	CLAYEY SAND, a little gravel, grayish brown, soft to stiff (SC/SM) (A-2-4) till	4	13			
			5				No recovery
40			8				No recovery

Index Sheet Code

(Continued Next Page)

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

MINNESOTA DEPARTMENT OF TRANSPORTATION

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1260 SB**	**910.1** *(Surveyed)*

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Other Tests Or Remarks / Formation or Member
			CLAYEY SAND, a little gravel, grayish brown, soft to stiff (SC/SM) (A-2-4) till *(continued)*	X	4	15			
				PD					
45				X	15				No recovery
				PD					
				X	5	12			
				PD					
50				X	7	12			
	53.0 / 857.1			PD					
55			CLAYEY SAND WITH GRAVEL, brownish gray, hard (SC) (A-6) till	X	64	10			
				PD					
60				X	98	9			
				PD					
65				X	103	11			
				PD					
70				X	69	10			
				PD					
75	75.3 / 834.8			X	100/.3	8			

END OF BORING

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1261 SB**	**910.1** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=501389 Y=150910 (ft.)

Latitude (North)=44.9307387 Longitude (West)=-93.3779705

Drill Machine **68C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 3

Drilling Completed **5/28/14**

Depth / Elev.	Classification	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
4.0 / 906.1	Mixture of sand with silt and clayey sand, a little gravel, dark brown and brown (A-2-4) fill	7, 9				Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
11.5 / 898.6	Sand, a little gravel and clayey sand, light brown and brown, a little dark brown (A-1-b) fill	14, 15, 5				
14.0 / 896.1	SAND WITH GRAVEL, fine to medium grained, light brown, a little brown, moist, very dense, laminations of clayey sand (SP) (A-1-b) alluvium or fill	56				
16.5 / 893.6	SAND WITH SILT AND GRAVEL, medium to fine grained, light brown, moist, medium dense (SP-SM) (A-1-b) alluvium	19				
19.0 / 891.1	SAND, a little gravel, medium grained, light brown, waterbearing, loose (SP) (A-1-b) alluvium	10				Water level measured at 17' deep with HSA to 19.5' deep (rose from 18.5' deep 10 minutes earlier)
21.5 / 888.6	SAND WITH SILT AND GRAVEL, medium to fine grained, dark brown, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	30				
24.0 / 886.1	SILTY SAND WITH GRAVEL, fine to medium grained, gray, wet, dense (SM) (A-2-4) alluvium	32				
26.5 / 883.6	SAND WITH SILT AND GRAVEL, fine to medium grained, dark brown, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	29				
31.5 / 878.6	GRAVEL WITH SILT AND SAND, dark brown, waterbearing, very dense (GP-GM) (A-1-a) alluvium	69, 123				
34.0 / 876.1	SILTY SAND, a little gravel, brown, wet, very dense, lens of clayey sand, lens of sand with silt (SM) (A-2-4) till	56				
	CLAYEY SAND, a little gravel, brown to grayish brown, firm to soft, lenses of silty sand (SC/SM) (A-2-4) till	7	13			
		6	14			
		4	14			

Index Sheet Code

(Continued Next Page)

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

MINNESOTA DEPARTMENT OF TRANSPORTATION

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1261 SB**	**910.1** (Surveyed)

DEPTH	Depth / Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
		CLAYEY SAND, a little gravel, brown to grayish brown, firm to soft, lenses of silty sand (SC/SM) (A-2-4) till *(continued)*		4	13			
			PD					
45				4				No recovery
			PD					
				5	15			
			PD					
50				4	13			
			PD					
55				7	15			
			PD					
60				5	13			
	62.5 / 847.6		PD					
65		CLAYEY SAND, a little gravel, grayish brown, very stiff (SC) (A-6) till		19	10			
	66.5 / 843.6		PD					
		CLAYEY SAND WITH GRAVEL, grayish brown, hard (SC/SM) (A-2-4) till		97	11			
			PD					
70				38	11			
			PD					
75				40	12			
			PD					
80				116	8			
	83.0 / 827.1		PD					

(Continued Next Page)

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Minnehaha Creek	**Southwest LRT, PEC East**	**1261 SB**	**910.1** *(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	85.7 / 824.4		SANDY LEAN CLAY, a little gravel, brown, hard (CL/SC) (A-6) till *(continued)* END OF BORING	PD	88/.7	16				23/.5 + 38/.5 + 50/.2

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

X:\01-GEO\GINTW\1 GINT PROJECTS\01-05697 MNDOT TEMPLATE.GPJ

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing.

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER

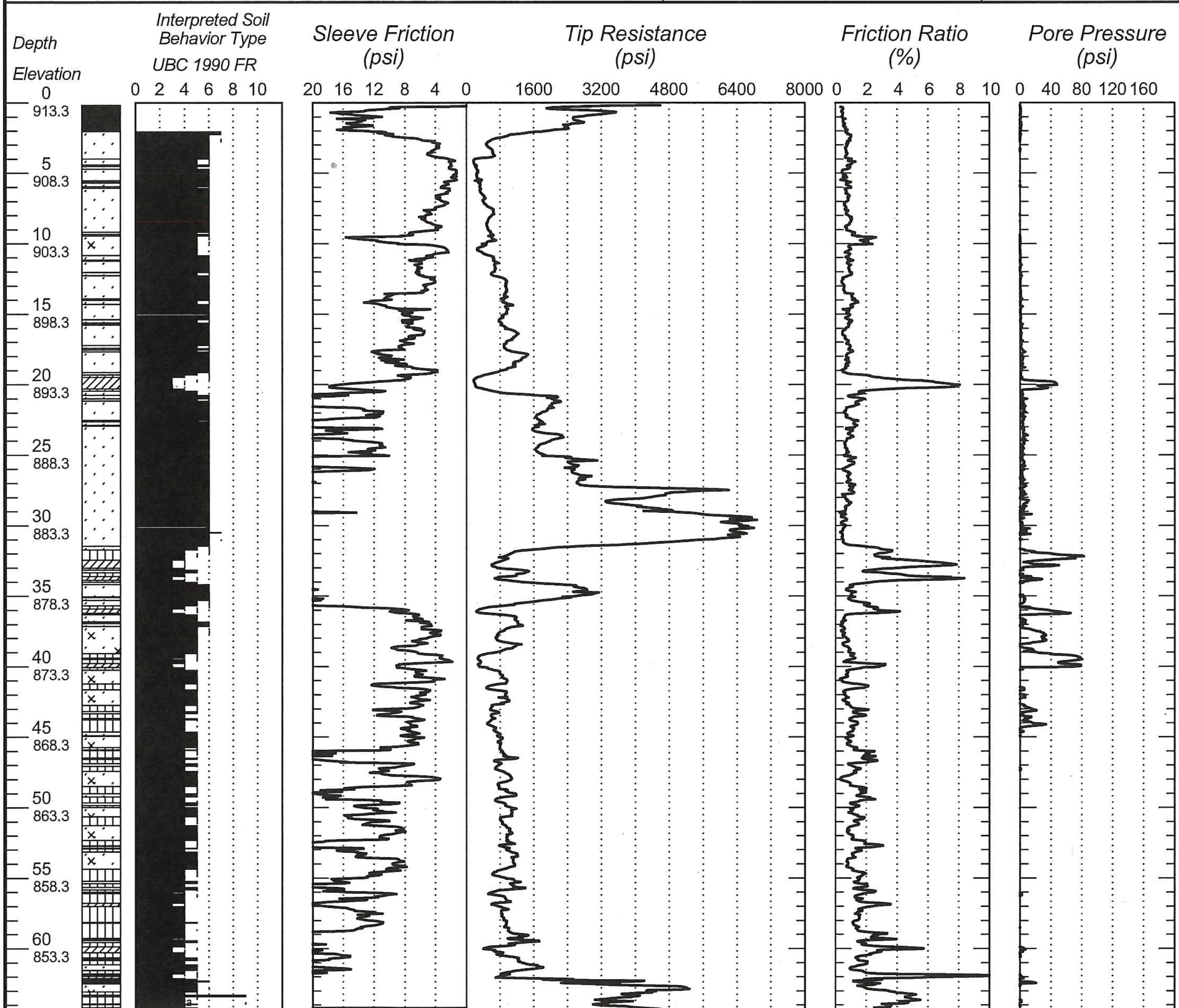
U.S. Customary Units

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
AET 01-05697	**Minnehaha Creek**	**Southwest LRT, PEC East**	**1258CB**	**913.3** (Surveyed)

Location **Hennepin Co. Coordinate: X=501290 Y=150934** (ft.)	CPT Machine **20**	SHEET 1 of 1
Latitude (North)= Longitude (West)=	CPT Operator **Adams**	Date Completed
No Station-Offset Information Available	Hole Type **CPT-SEISMIC**	**5/15/14**



Bottom of Hole 64.53

Index Sheet Code 2015Y1401C.ECP Soil Class: Rock Class: Edit: Date: 8/25/14

X:\01-GEO\GINTW\1 GINT PROJECTS\01-05697_RAPID CPT.GPJ

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing.

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER

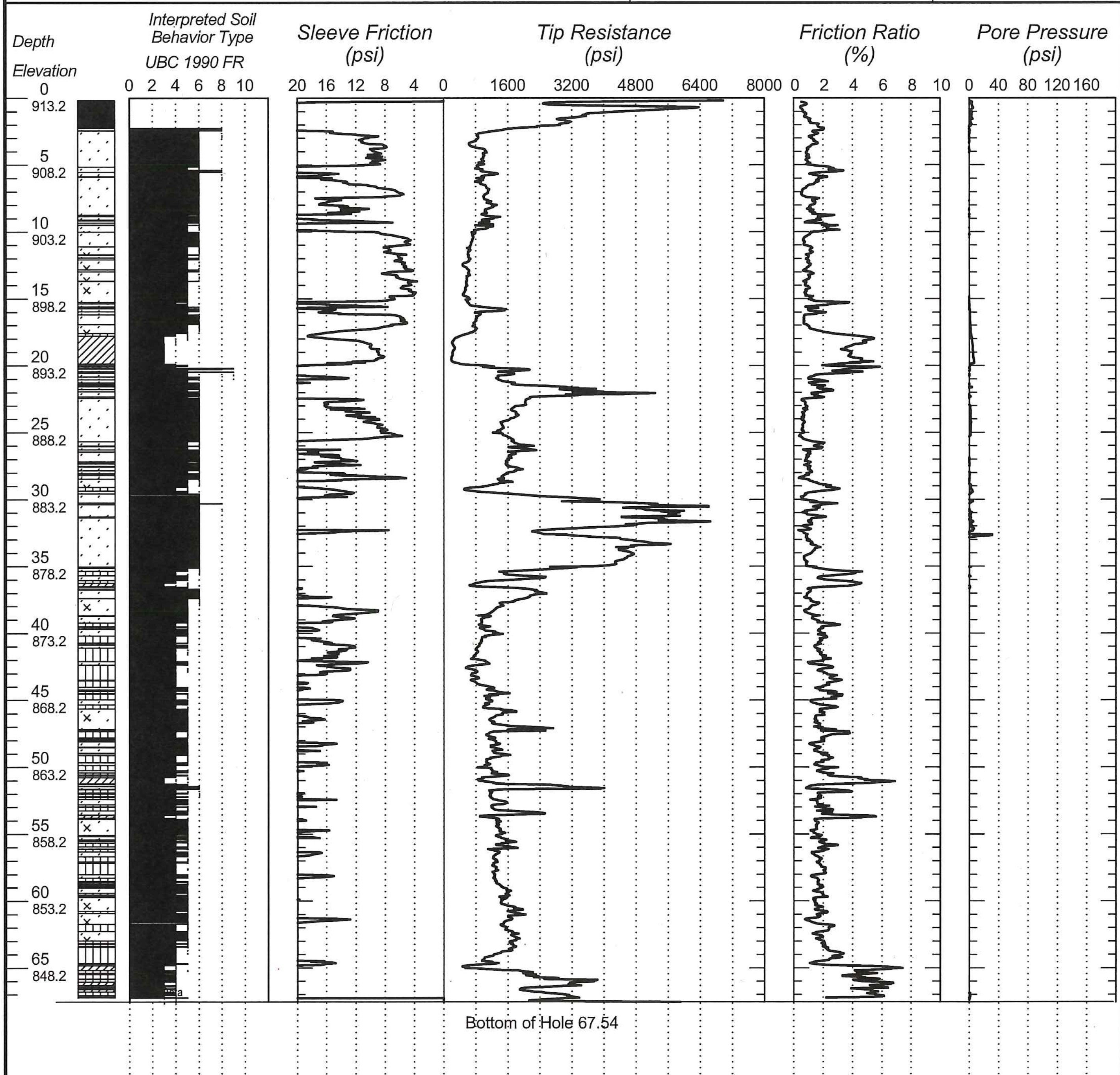
U.S. Customary Units

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
AET 01-05697	**Minnehaha Creek**	**Southwest LRT, PEC East**	**1259CB**	**913.2** (Surveyed)

Location **Hennepin Co. Coordinate: X=501368 Y=150962** (ft.)	CPT Machine **20**	SHEET 1 of 1
Latitude (North)= Longitude (West)=	CPT Operator **Adams**	Date Completed
No Station-Offset Information Available	Hole Type **CPT-SEISMIC**	**5/15/14**



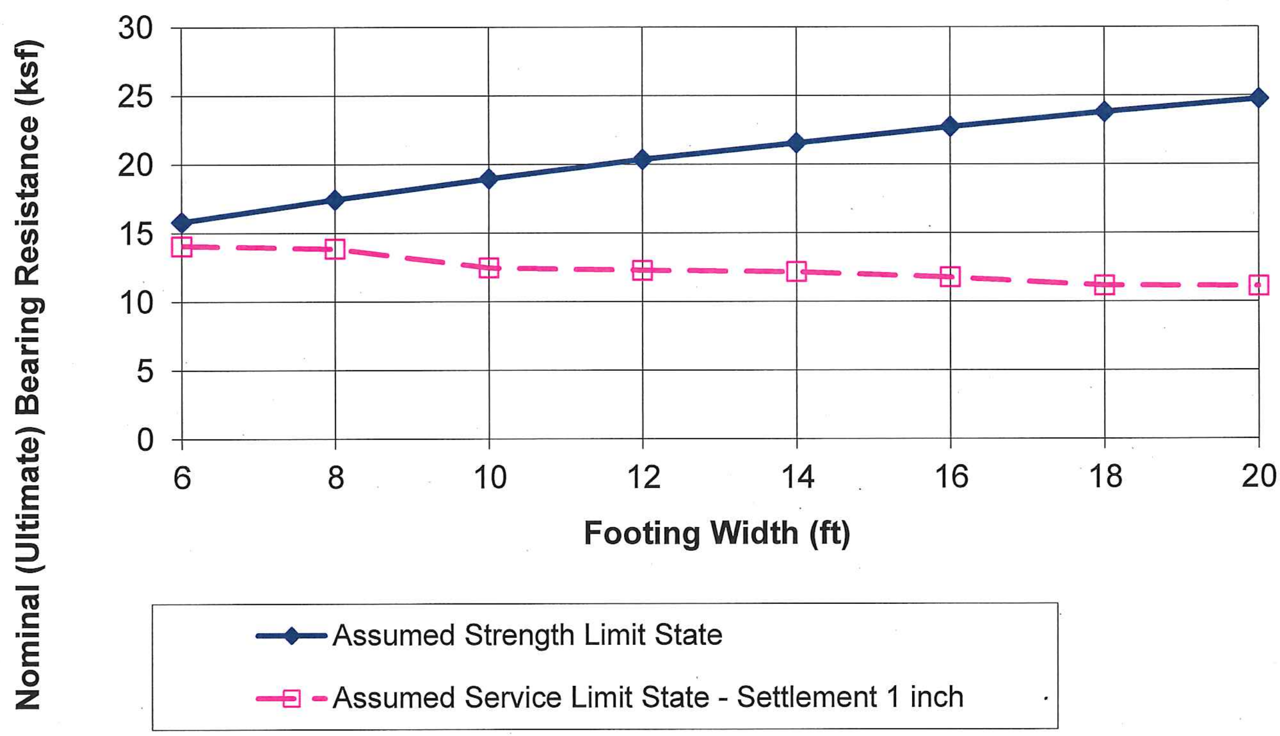
Bottom of Hole 67.54

Index Sheet Code 2015Y1402C.ECP Soil Class: Rock Class: Edit: Date: 8/25/14

X:\01-GEO\GINTW\1 GINT PROJECTS\01-05697_RAPID CPT.GPJ

B (ft)	assumed e (ft)	B' (ft)	q_n	$q_{settle*}$	$\phi_b\ q_n$
6.0	0	6.0	15.806	14.063	7.113
8.0	0	8.0	17.435	13.863	7.846
10.0	0	10.0	18.952	12.463	8.528
12.0	0	12.0	20.357	12.263	9.161
14.0	0	14.0	21.546	12.163	9.696
16.0	0	16.0	22.727	11.763	10.227
18.0	0	18.0	23.796	11.163	10.708
20.0	0	20.0	24.753	11.113	11.139

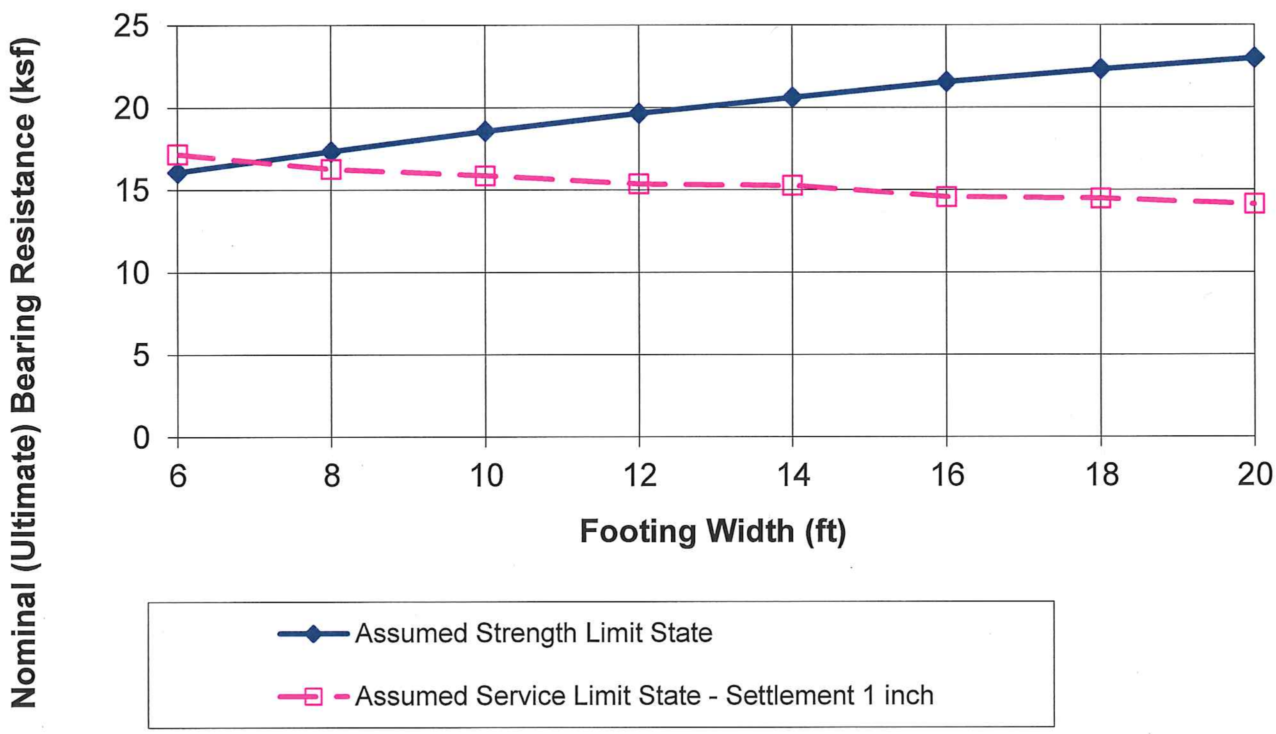
Figure 2. LRFD Spread Footing Bearing Graph for West Abutment
Freight Rail and Trail Bridge over Minnehaha Creek; St. Louis Park, MN
(AET No. 01-05697)



NOTES: Assumed Length of Footing is Approximately 20 feet
Bearing pressures shown are based on CPT 1258 CB, in units of ksf.

B (ft)	assumed e (ft)	B' (ft)	q_n	$q_{settle*}$	$\phi_b\ q_n$
6.0	0	6.0	16.079	17.163	7.236
8.0	0	8.0	17.335	16.263	7.801
10.0	0	10.0	18.563	15.863	8.353
12.0	0	12.0	19.640	15.363	8.838
14.0	0	14.0	20.605	15.263	9.272
16.0	0	16.0	21.552	14.563	9.698
18.0	0	18.0	22.315	14.463	10.042
20.0	0	20.0	22.984	14.123	10.343

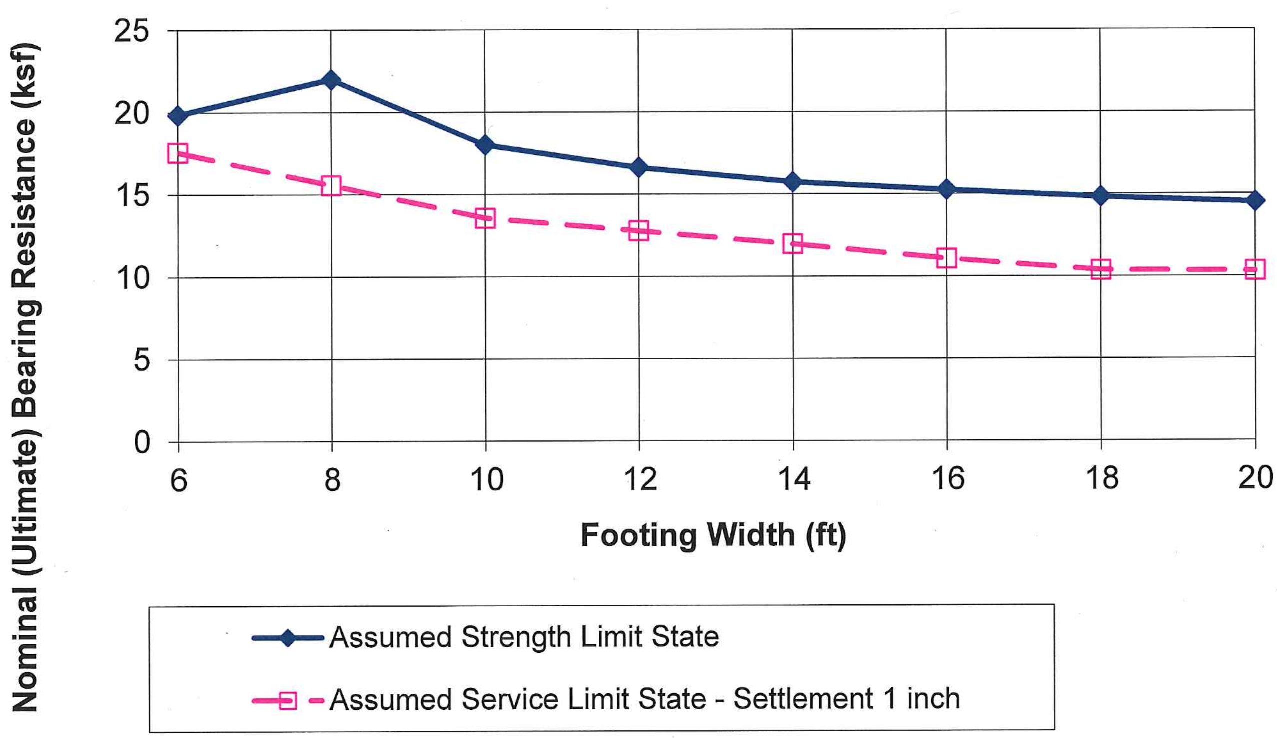
Figure 3. LRFD Spread Footing Bearing Graph for East Abutment
Freight Rail and Trail Bridge over Minnehaha Creek; St. Louis Park, MN
(AET No. 01-05697)



NOTES: Assumed Length of Footing is Approximately 20 feet
Bearing pressures shown are based on CPT 1259 CB, in units of ksf.

B (ft)	assumed e (ft)	B' (ft)	q_n	$q_{settle*}$	ϕ_b q_n
6.0	0	6.0	19.826	17.563	8.922
8.0	0	8.0	21.989	15.563	9.895
10.0	0	10.0	18.009	13.563	8.104
12.0	0	12.0	16.614	12.763	7.476
14.0	0	14.0	15.722	11.963	7.075
16.0	0	16.0	15.245	11.063	6.860
18.0	0	18.0	14.812	10.363	6.665
20.0	0	20.0	14.498	10.313	6.524

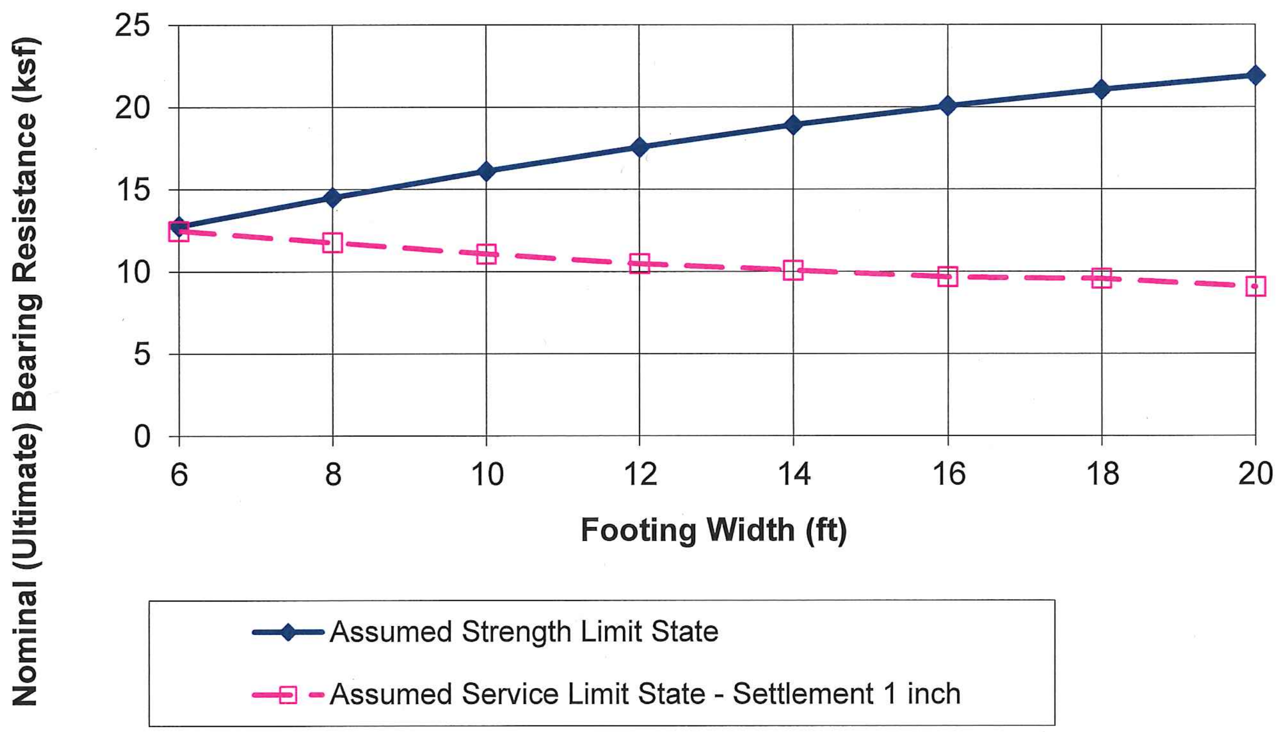
Figure 4. LRFD Spread Footing Bearing Graph for West Abutment
SWLRT Bridge over Minnehaha Creek; St. Louis Park, MN
(AET No. 01-05697)



NOTES: Assumed Length of Footing is Approximately 30 feet
Bearing pressures shown are based on Boring 1260 SB, in units of ksf.

B (ft)	assumed e (ft)	B' (ft)	q_n	$q_{settle*}$	$\phi_b\ q_n$
6.0	0	6.0	12.748	12.463	5.737
8.0	0	8.0	14.498	11.763	6.524
10.0	0	10.0	16.098	11.063	7.244
12.0	0	12.0	17.546	10.463	7.896
14.0	0	14.0	18.909	10.063	8.509
16.0	0	16.0	20.056	9.663	9.025
18.0	0	18.0	21.051	9.563	9.473
20.0	0	20.0	21.896	9.063	9.853

Figure 5. LRFD Spread Footing Bearing Graph for East Abutment
SWLRT Bridge over Minnehaha Creek; St. Louis Park, MN
(AET No. 01-05697)



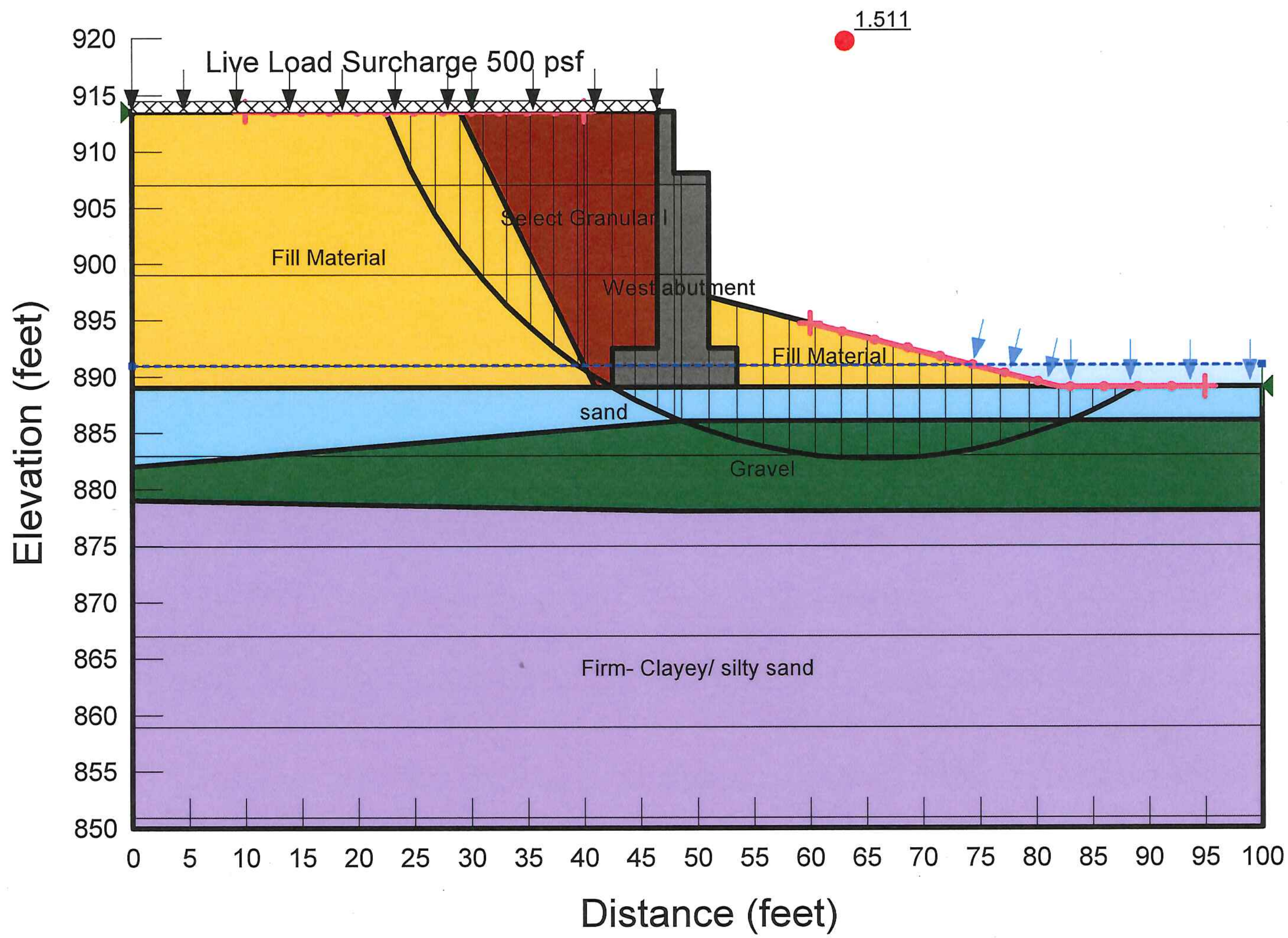
NOTES: Assumed Length of Footing is Approximately 30 feet
Bearing pressures shown are based on Boring 1261 SB, in units of ksf.

SLOPE/W 2012
Method: Bishop
AET No. 01-05697
Ramdhan, Neil
Date: 6/27/2014

Figure 6

SWLRT
Minnehaha Creek Bridges
West Abutment
Effective Stress (Drained) Global Stability Analysis

Name: West abutment Model: Mohr-Coulomb Unit Weight: 150 pcf Cohesion': 10,000 psf Phi': 55 °
Name: Fill Material Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °
Name: sand Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 33 °
Name: Gravel Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 38 °
Name: Firm- Clayey/ silty sand Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 28 °
Name: Select Granular I Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °



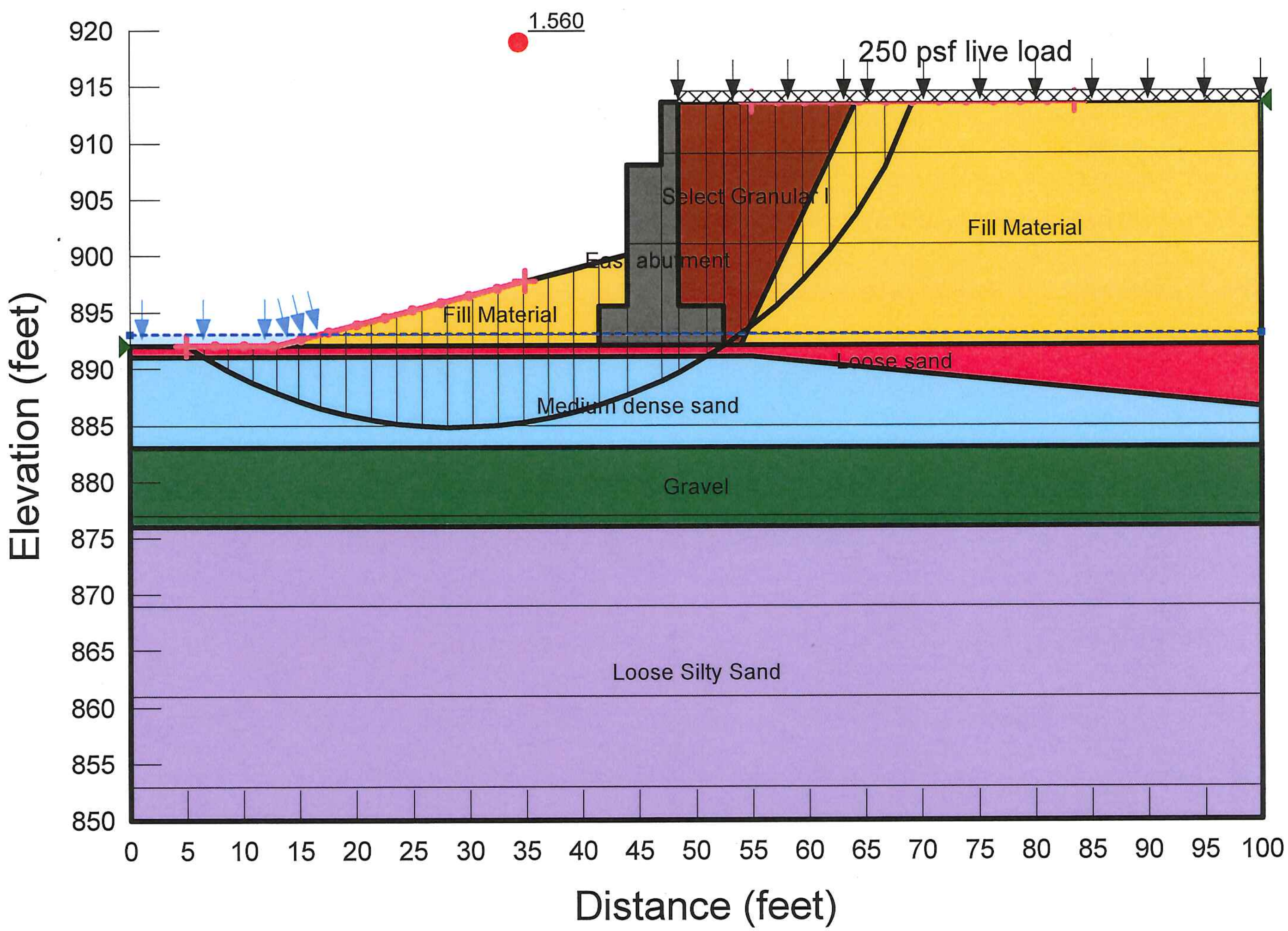
\\stp-fileserv1\Data\01-GEO\Projects\Neil\JB\01-05697 SW LRT\SB 1258 (West Abutment)\West abutment global_with actual footing size.gsz

SLOPE/W 2012
Method: Bishop
AET No. 01-05697
Ramdhan, Neil
Date: 6/27/2014

Figure 7

SWLRT
Minnehaha Creek Bridges
East Abutment
Effective Stress (Drained) Global Stability Analysis

Name: East abutment Model: Mohr-Coulomb Unit Weight: 150 pcf Cohesion': 10,000 psf Phi': 45 °
Name: Fill Material Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °
Name: Medium dense sand Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 33 °
Name: Gravel Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 38 °
Name: Loose Silty Sand Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 28 °
Name: Select Granular I Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °
Name: Loose sand Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 30 °



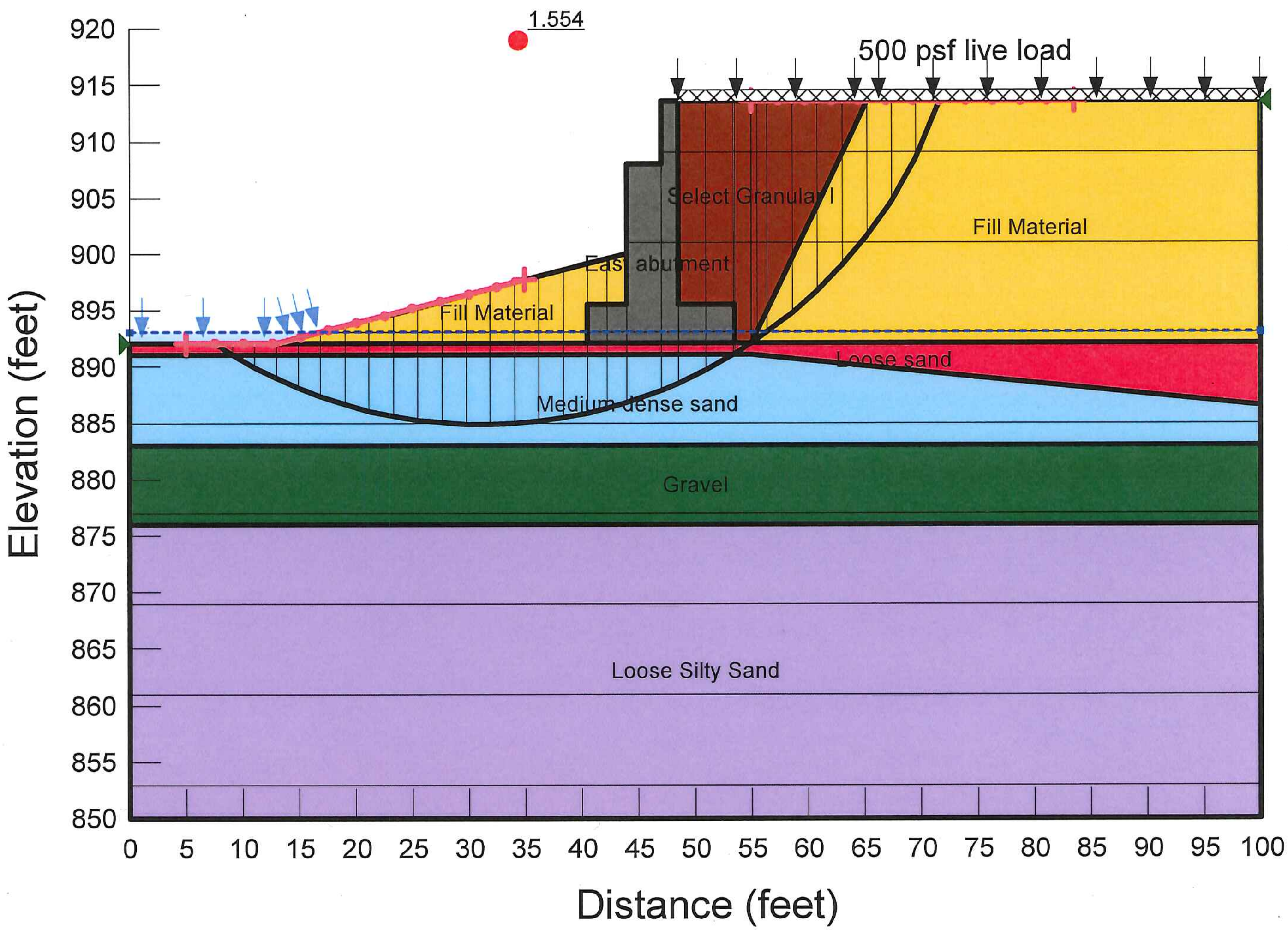
\\stp-fileserv1\Data\01-GEO\Projects\Neil\JB\01-05697 SW LRT\SB 1259 (East Abutment)\East abutment global_with 11 ft footing.gsz

SLOPE/W 2012
Method: Bishop
AET No. 01-05697
Ramdhan, Neil
Date: 6/27/2014

Figure 8

SWLRT
Minnehaha Creek Bridges
East Abutment
Effective Stress (Drained) Global Stability Analysis

Name: East abutment Model: Mohr-Coulomb Unit Weight: 150 pcf Cohesion': 10,000 psf Phi': 45 °
Name: Fill Material Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °
Name: Medium dense sand Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 33 °
Name: Gravel Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 38 °
Name: Loose Silty Sand Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 28 °
Name: Select Granular I Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °
Name: Loose sand Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 30 °



\\stp-fileserv1\Data\01-GEO\Projects\Neil\JB\01-05697 SW LRT\SB 1259 (East Abutment)\East abutment global_with 13 ft footing.gsz

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)

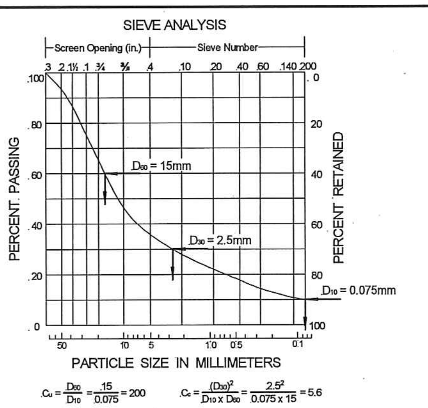
The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide N_{60} values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material),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

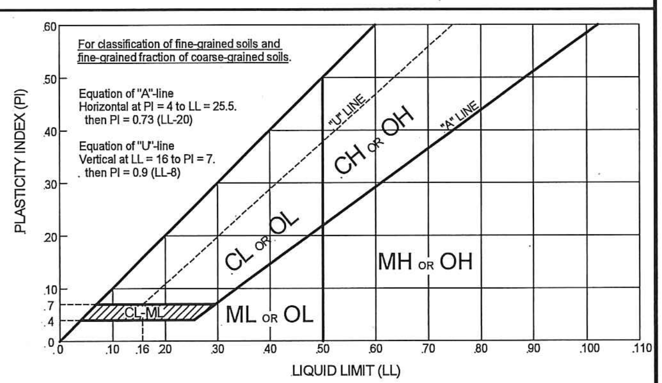
The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM: D1586 is encountered) whereas the length of sample recovered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

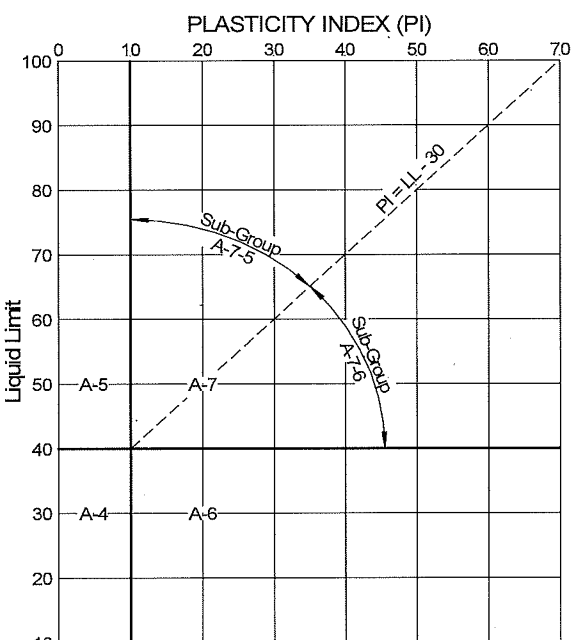
Classification of Soils and Soil-Aggregate Mixtures

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.

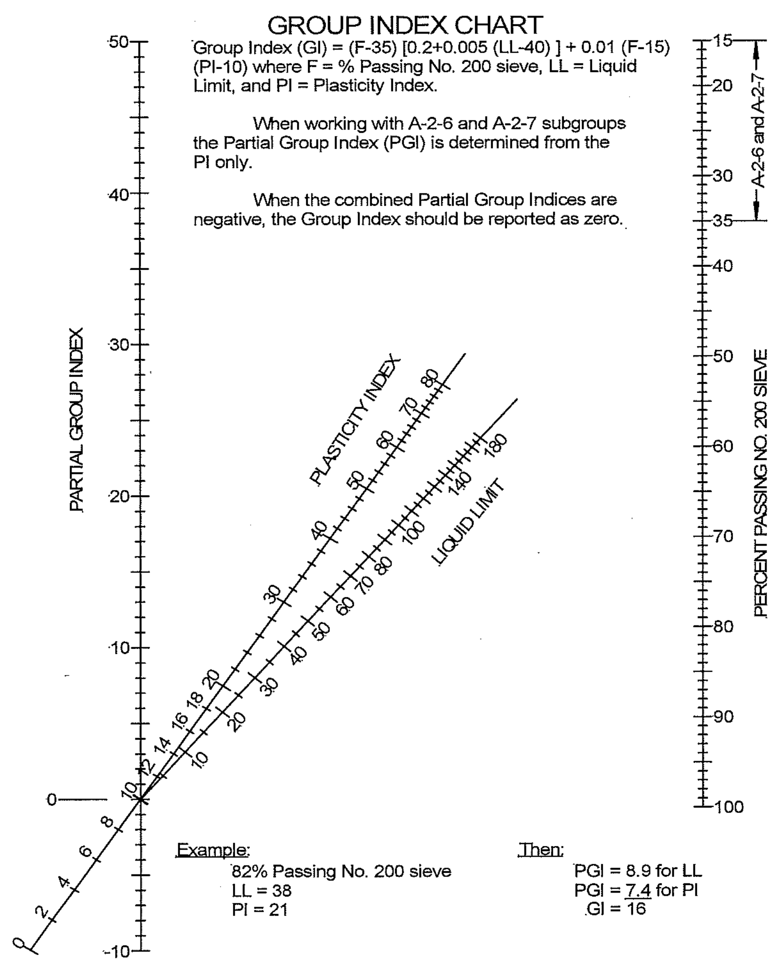
FINE SAND - Material passing the No. 40 sieve and retained on the No. 200 sieve.

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

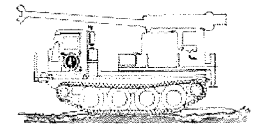
BOULDERS (retained on 3-in. sieve) should be excluded from the portion of the sample to which the classificaiton is applied, but the percentage of such material, if any, in the sample should be recorded.

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



Minnesota Department of Transportation
Geotechnical Section
Cone Penetration Test Index Sheet 1.0 (CPT 1.0)



USER NOTES, ABBREVIATIONS AND DEFINITIONS

This Index sheet accompanies Cone Penetration Test Data. Please refer to the Boring Log Descriptive Terminology Sheet for information relevant to conventional boring logs.

This Cone Penetration Test (CPT) Sounding follows ASTM D 5778 and was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this sounding was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the conditions and materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this sounding.

Since subsurface conditions outside each CPT Sounding are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this sounding will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water pressure measurements and subsequent interpreted water levels shown on this log should be used with discretion since they represent dynamic conditions. Dynamic Pore water pressure measurements may deviate substantially from hydrostatic conditions, especially in cohesive soils. In cohesive soils, water pressures often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

CPT Terminology

CPT ....Cone Penetration Test
CPTU...........Cone Penetration Test with Pore Pressure measurements
SCPTU.........Cone Penetration Test with Pore Pressure and Seismic measurements
Piezocone...Common name for CPTU test

(Note: This test is not related to the Dynamic Cone Penetrometer DCP)

q_T TIP RESISTANCE

The resistance at the cone corrected for water pressure. Data is from cone with 60 degree apex angle and a 10 cm² end area.

f_s SLEEVE FRICTION RESISTANCE

The resistance along the sleeve of the penetrometer.

FR Friction Ratio

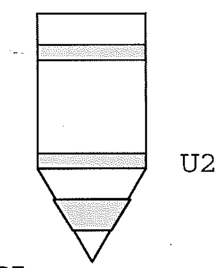
Ratio of sleeve friction over corrected tip resistance.
FR = fs/qt

V_s Shear Wave Velocity

A measure of the speed at which a siesmic wave travels through soil/rock.

PORE WATER MEASUREMENTS

Pore water measurements reported on CPT Log are representative of water pressures measured at the U2 location, just behind the cone tip, prior to the sleeve, as shown in the figure below. These measurements are considered to be dynamic water pressures due to the local disturbance caused by the cone tip. Dynamic water pressure decay and Static water pressure measurements are reported on a Pore Water Pressure Dissipation Graph.



SBT SOIL BEHAVIOR TYPE

Soil Classification methods for the Cone Penetration Test are based on correlation charts developed from observations of CPT data and conventional borings. Please note that these classification charts are meant to provide a guide to Soil Behavior Type and should not be used to infer a soil classification based on grain size distribution.

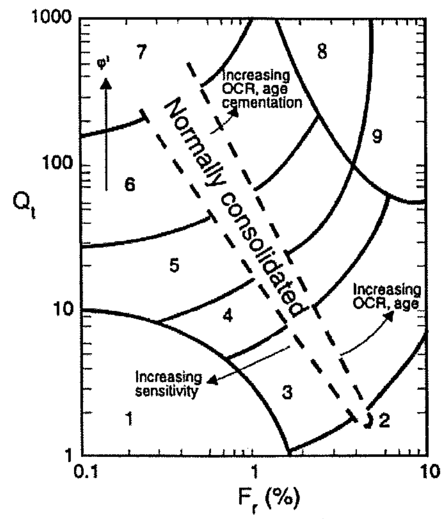
The numbers corresponding to different regions on the charts represent the following soil behavior types:

1. Sensitive, Fine Grained
2. Organic Soils - Peats
3. Clays - Clay to Silty Clay
4. Silt Mixtures - Clayey Silt to Silty Clay
5. Sand Mixtures - Silty Sand to Sandy Silt
6. Sands - Clean Sand to Silty Sand
7. Gravelly Sand to Sand
8. Very Stiff Sand to Clayey Sand
9. Very Stiff, Fine Grained

Note that engineering judgment, and comparison with conventional borings is especially important in the proper interpretation of CPT data in certain geo-materials.

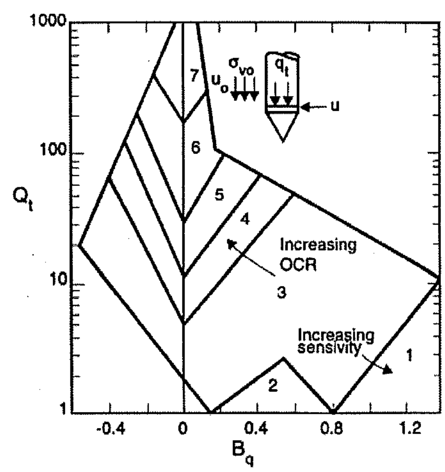
The following charts are used to provide a Soil Behavior Type for the CPT Data.

Robertson CPT 1990
Soil Behavior type based on friction ratio



$$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

Robertson CPTU 1990
Soil Behavior type based on pore pressure

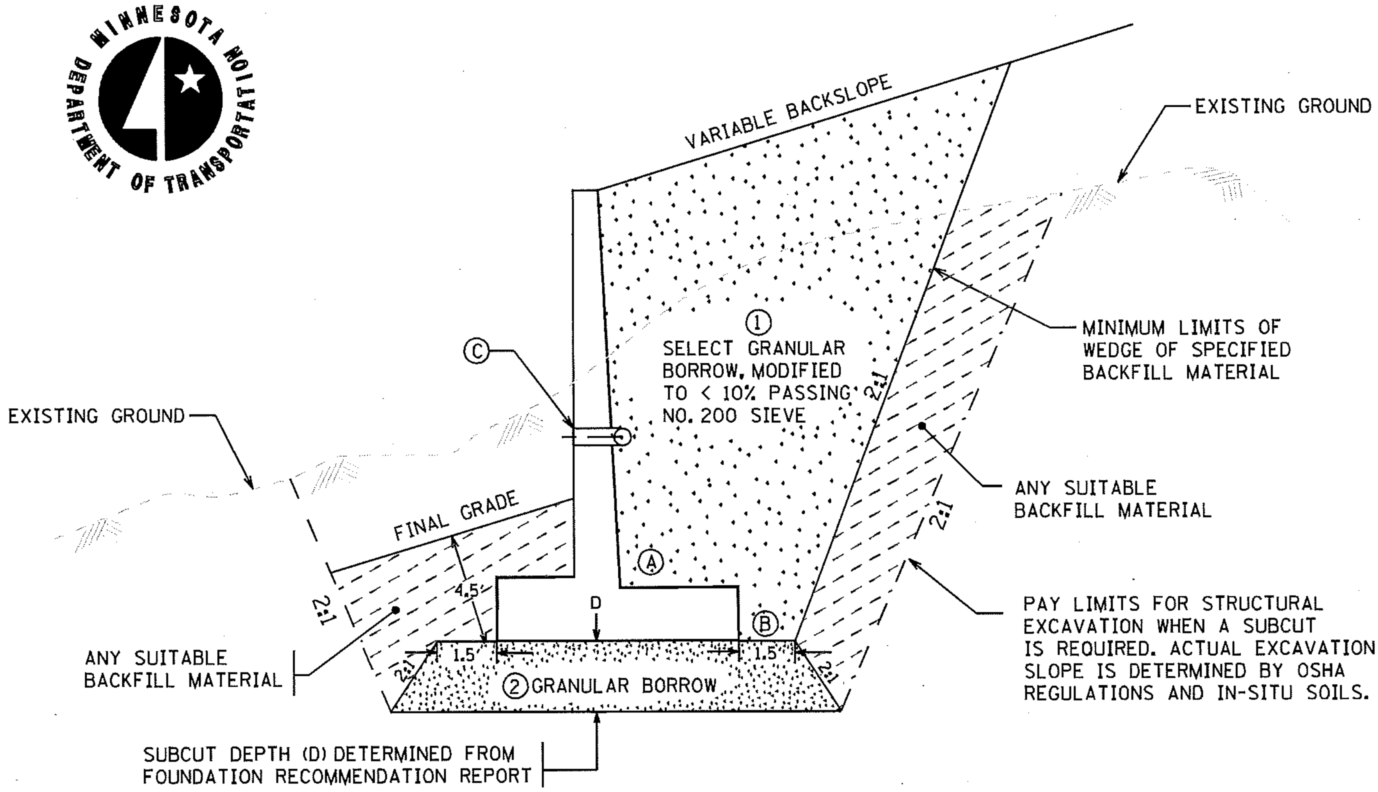


$$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \qquad B_q = \frac{u_2 - u_o}{q_t - \sigma_{vo}}$$

where ...

QT.......................... normalized cone resistance
Bq.......................... pore pressure ratio
Fr........................... Normalized friction ratio
σvo .... overburden pressure
σ'vo .... effective over burden pressure
U2.......................... measured pore pressure
U0.......................... equilibrium pore pressure

G:\GEOTECH\PUBLIC\FORMS\CPTINDEX.DOC January 30, 2002



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)	DIAGRAM NO. F–1
November 2005 PREPARED BY THE FOUNDATIONS UNIT GEOTECHNICAL ENGINEERING SECTION – OFFICE OF MATERIALS	