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 and Pedestrian Bridge over Channel in Kenilworth Corridor
Southwest Light Rail Transit Project
Minneapolis, Minnesota
AET No. 01-05697.03

1.0 PROJECT INFORMATION

This report provides foundation analysis and recommendations for the bridge which will carry the light rail transit (LRT) tracks and the pedestrian trail over the Lake of the Isles – Cedar Lake channel located within the Kenilworth Corridor in Minneapolis. The report does not specifically address the freight rail bridge planned to the northwest, as borings have not yet been performed in that alignment which is wooded and less accessible at this time. It is reasonable to assume that similar foundation recommendations may apply for the freight rail bridge, at least on a preliminary basis; although buried swamp conditions at the abutment locations could require the need for down drag considerations and/or approach correction/improvement.

The new bridge will be a four-span concrete slab structure. Current substructure data is presented in Table 1.0. Note that cofferdams will be installed to construct the pier foundations; therefore, pile resistance (whether axial or uplift) would need to be considered from the bottom of the concrete seal placed to resist buoyancy during construction.

Table 1.0 – Bridge Substructure Data

Substructure	Station	Bottom of Foundation Elevation
South Abutment	2801+96.05	853.0
Pier 1	2802+15.05	838.0*
Pier 2	2802+40.05	838.0*
Pier 3	2802+65.05	838.0*
North Abutment	2802+84.05	853.0

*denotes bottom of assumed 6-foot thick concrete seal

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

The south approach will be a portal trench from the shallow tunnel planned in the corridor, such that grade at the south end of the bridge deck will not be significantly different from the current grade. Grade on the north side of the bridge is planned to be several feet higher than current grade, before again lowering into a tunnel portal trench.

2.0 SUBSURFACE EXPLORATION SUMMARY

2.1 Scope

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

- South Abutment: Boring 1005 SB
- North Abutment: Boring 1006 SB
- Channel/Piers: No foundation borings, although shallow probes 1145 HC to 1147 HC were taken from a boat to explore channel bottom sediment conditions
- Approach considerations: Borings 1042 ST (south), 1041 ST (north)

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

2.2 Methods

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*.

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 Geology/Soils Review

2.3.1 Channel Historical Information

The channel over which the bridge will cross hydraulically connects Cedar Lake and Lake of the Isles. The channel was created by man in the early 1900's through excavation. Prior to channel excavation, the Cedar Lake level was typically a little higher in elevation than the Lake of the Isles level (which would have created a ground-water gradient to the east). However, creation of the channel has since allowed stabilization of a common lake level, and hence, minimized or eliminated the gradient between the lakes.

2.3.2 Geology/Soils Present

Borings 1005 SB and 1006 SB indicate about 16½ feet to 24 feet of fill is in-place in the abutment areas. This represents fill placed for the approaches to the current bridge. The fill is mostly silty sand, sand with silt, clayey sand, and sandy lean clay. The fill also has inclusions of wood, roots, brick, and ashes/cinders. Some zones are slightly organic, although the borings did not encounter highly organic soils which are normally found as swamp deposits. Boring 1042 ST located to the south does include peat swamp deposits buried below 14½ feet of fill, suggesting swamp deposits are present in the area, but were apparently removed in the existing bridge abutment area. The presence of buried swamp deposits may be an important issue to evaluate in the future for the adjacent freight rail bridge. The N-values in the fill are variable, including some zones of lower apparent compaction. However, they are not considered overly compressible due to the amount of time they have been in-place and provided future applied loads are not significantly increased.

The underlying natural soils are predominantly alluvial (water-deposited) sands and gravels to a depth of about 125 feet beneath the surface. Minor interlayering with sand with silt or silty sand is also present. Boring 1006 SB included an interbedded layer of lean clay with sand at a depth of 70 feet. The soils beneath this major alluvial deposit include hard silty clay/ lean clay or very dense sandy silt alluvium and clayey sand/sandy lean clay glacial till.

The borings extended to 141 feet and 181 feet deep and did not reach bedrock.

2.4 Ground Water

Ground-water levels through the Kenilworth Corridor have been monitored in piezometers on a weekly basis since mid-October, 2013. The monitoring has included measuring the channel water level, except when influenced by the ice and snow. During this time period, the channel elevation has ranged from elevation 852.13 feet (12/2/2013) to 853.30 feet (4/28/2014).

The piezometer water level data shows a ground-water level gradient from southwest to northeast in the general direction parallel to the corridor. The ground surface elevation along the corridor also generally follows this gradient.

The data shows that the channel and lakes feed the ground-water level rather than the ground-water level feeding the open water areas. The ground-water levels in the core of the corridor located between the lakes has hydrostatic levels deeper than the channel and lake levels. The piezometer to the south of the channel ("upgradient" side) shows an average ground-water level about 2½ feet lower than the channel level. The lakes and channel take on surface runoff, which then infiltrates into the granular alluvial deposit and migrates away from the channel.

3.0 FOUNDATION ANALYSIS

3.1 Foundation Analysis

3.1.1 Foundation Type

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

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.

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 (High Strain Dynamic Pile Testing) is employed and a Resistance Factor (φ) of 0.50 should be used when field evaluation of steel pipe pile is based on the MPF12 driving formula (MnDOT's new formula). We recommend using dynamic analysis for pile evaluation on these bridges. In this case, a nominal resistance of 308 kips would then need to be demonstrated.

The *DRIVEN* results for 12-inch diameter CIP steel pipe pile, based on Borings 1005 SB and 1006 SB are shown on the following figures:

Figure 3.1.3a – DRIVEN Results, Boring 1005 SB (South Abutment)

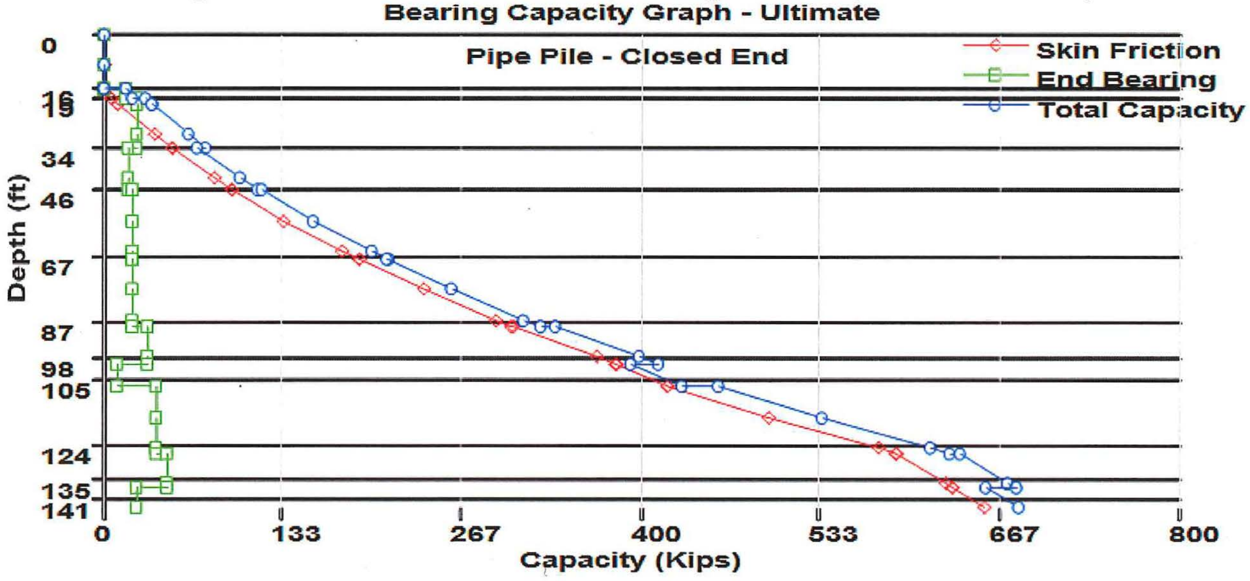
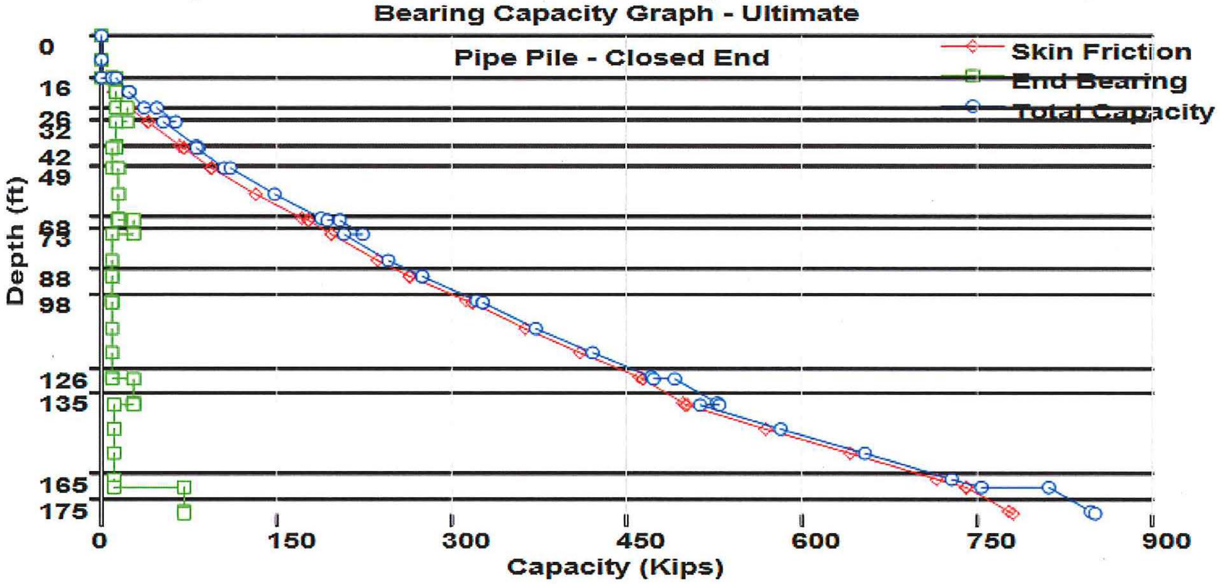
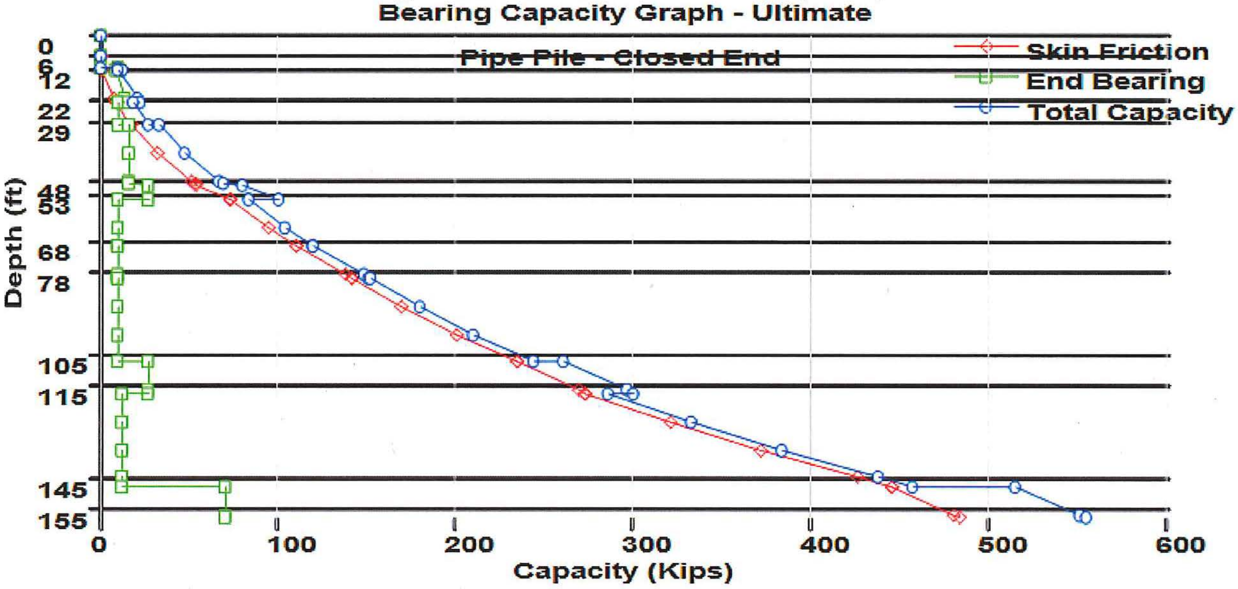


Figure 3.1.3b – DRIVEN Results, Boring 1006 SB (North Abutment)



A boring has not been performed in the channel area. To evaluate pile lengths for the piers, we used Boring 1006 SB soil parameter data below a depth of 20 feet (roughly the elevation between the mudline and the general bottom of the sediment where present). The top of pile for resistance purposes was then determined from the given assumed bottom of seal elevation. The results appear in Figure 3.1.3c.

Figure 3.1.3c – DRIVE Results (Piers)



The lengths predicted by the computer analyses in order to attain a nominal resistance of 308 kips are shown in Table 3.1.3a. This assumes a design $\varphi R_n = 100$ tons and the use of dynamic analysis for the field evaluation method (allowing $\varphi = 0.65$).

Table 3.1.3 – Estimated Pile Lengths from DRIVEN Analyses

Substructure	Proposed Bottom of Footing or Seal Elevation, ft	Estimated Tip Elevation, ft	Estimated Pile Length, ft
South Abutment	853.0	783	70
Piers	838.0	728	110
North Abutment	853.0	773	80

*from bottom of footing/seal

3.2 Pile Uplift Resistance

The piles for the piers in the channel will need to be driven prior to concrete seal placement within the cofferdams. To avoid excavation around the piles prior to seal placement, we assume that the excavation to bottom of seal will take place prior to pile driving. In addition to concrete seal and pile weight, buoyancy uplift resistance can be assisted with skin friction resistance of the piles. The nominal skin resistance from a single 12-inch diameter steel pipe pile driven to the depths required for a design $\varphi R_n = 100$ tons is 295 kips (most of the axial resistance is skin friction rather than end bearing resistance). The Nordlund method was used to determine the nominal unit skin friction, and accordingly, a Resistance Factor (φ_{up}) of 0.35 is considered appropriate. Therefore, a factored skin friction resistance value of 100 kips should be assumed for design.

For shorter piles (or for sheet pile resistance contribution), the unit nominal skin resistance can be assumed to be 0.85 ksf. A Resistance Factor (φ_{up}) of 0.35 is again considered appropriate for use with this unit value.

3.3 Approach Settlement Review

3.3.1 LRT/Pedestrian Bridge

The borings near the abutments indicate that buried organic swamp deposits are not present. Grade raise is only planned for the north approach, and that grade raise is no more than 2½ feet. In our opinion, approach settlement should be negligible, to the extent that settlement criteria for track performance will be satisfied and that down drag (DD) loads do not need to be considered in the pile foundation design.

4.0 FOUNDATION RECOMMENDATIONS

4.1 12-inch Diameter CIP Steel Pipe Pile

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

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

We refer you to previous Table 3.1.3 for the pile lengths predicted to achieve a nominal resistance of 308 kips. The pile lengths shown are based on the analysis methods discussed with assumed soil parameters. It is common for actual pile resistance to differ from the "theoretical" resistance. The actual pile lengths must be confirmed at the time of driving, and lengths may be more or less than that shown.

It is our opinion that down drag (DD) loads do not need to be considered in the 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.

4.2 Abutment/Wingwall Backfilling

Imbalanced abutment walls and wingwalls 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 track/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.

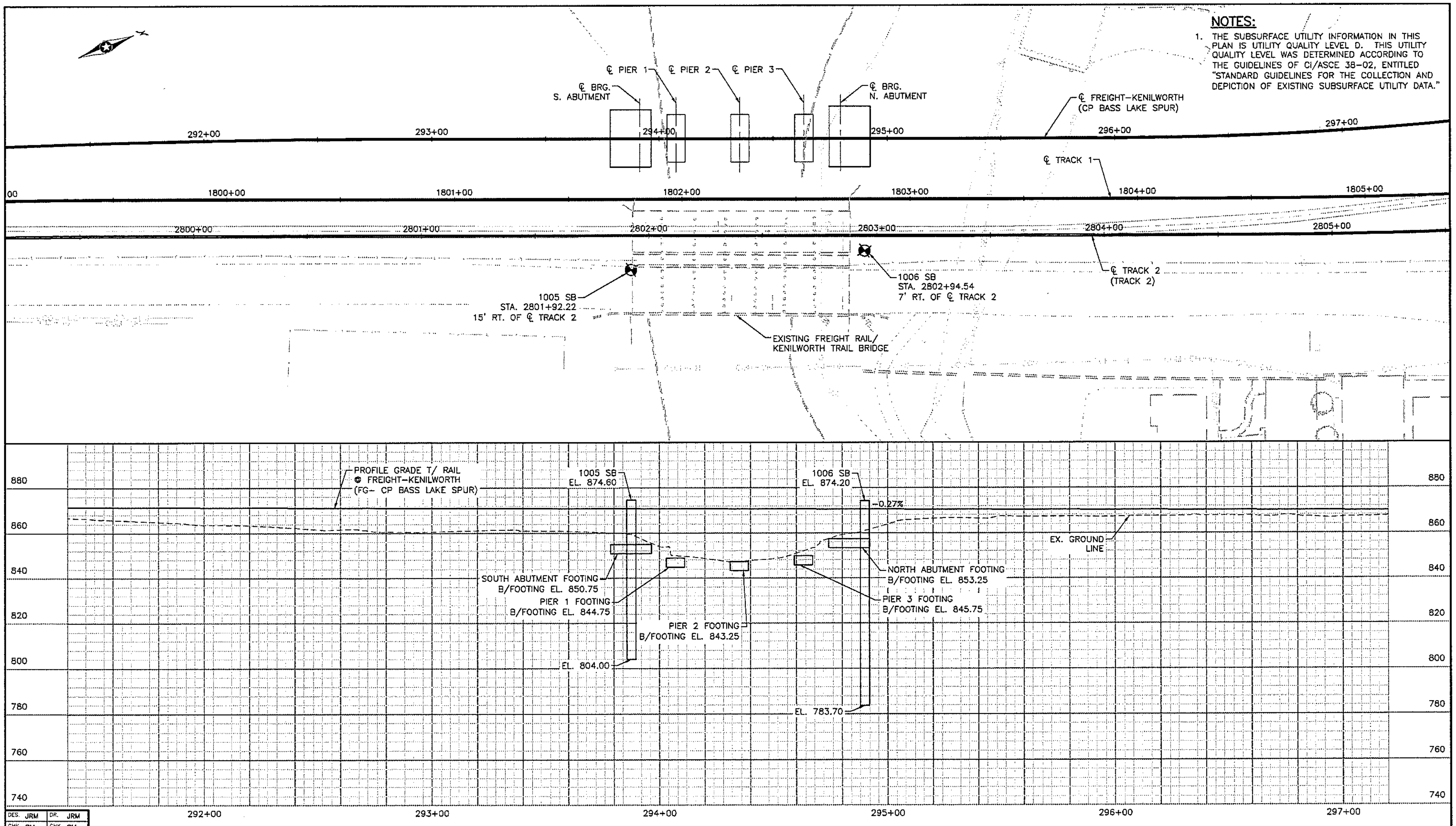
I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under Minnesota Statute Section 326.02 to 326.15

Name: Jeffery K. Voyen
Jeffery K. Voyen

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

Report Reviewed By:
Gregory R. Reuter, PE, PG

Attachments:
- Preliminary Bridge Plan-Profile Sheets
- Figure 1 – Boring Locations
- Subsurface Boring Logs
- Sieve/Hydrometer Test Results, Channel Bottom Sampling
- 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)
CEDAR LAKE CHANNEL RAILROAD BRIDGE
BRIDGE XXXXX (FRT)
BORINGS (1 OF 2)

DISCIPLINE: STRUCTURES

SHEET NAME: E3-STU-BRG-CLCH-FRT-SUR-002

SHEET 128 OF 277

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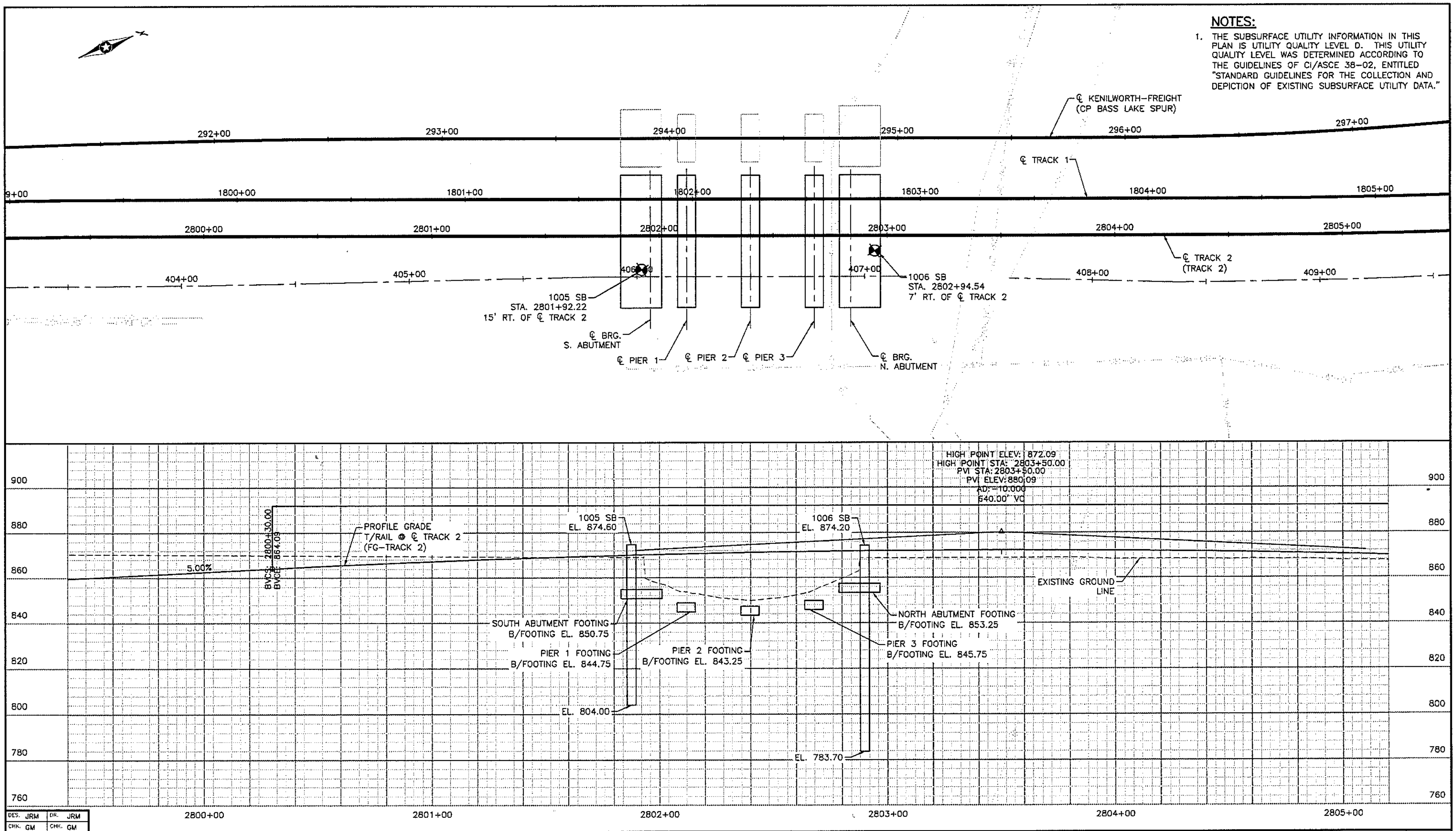

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DES. JRM	DR. JRM
CHK. GM	CHK. GM

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

TKDA

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
CEDAR LAKE CHANNEL LRT/TRAIL
BRIDGE XXXXX (LRT)
BORINGS (1 OF 2)

DISCIPLINE: STRUCTURES

SHEET NAME: E3-STU-BRG-CLCH-LRT-SUR-002

SHEET 135 OF 277

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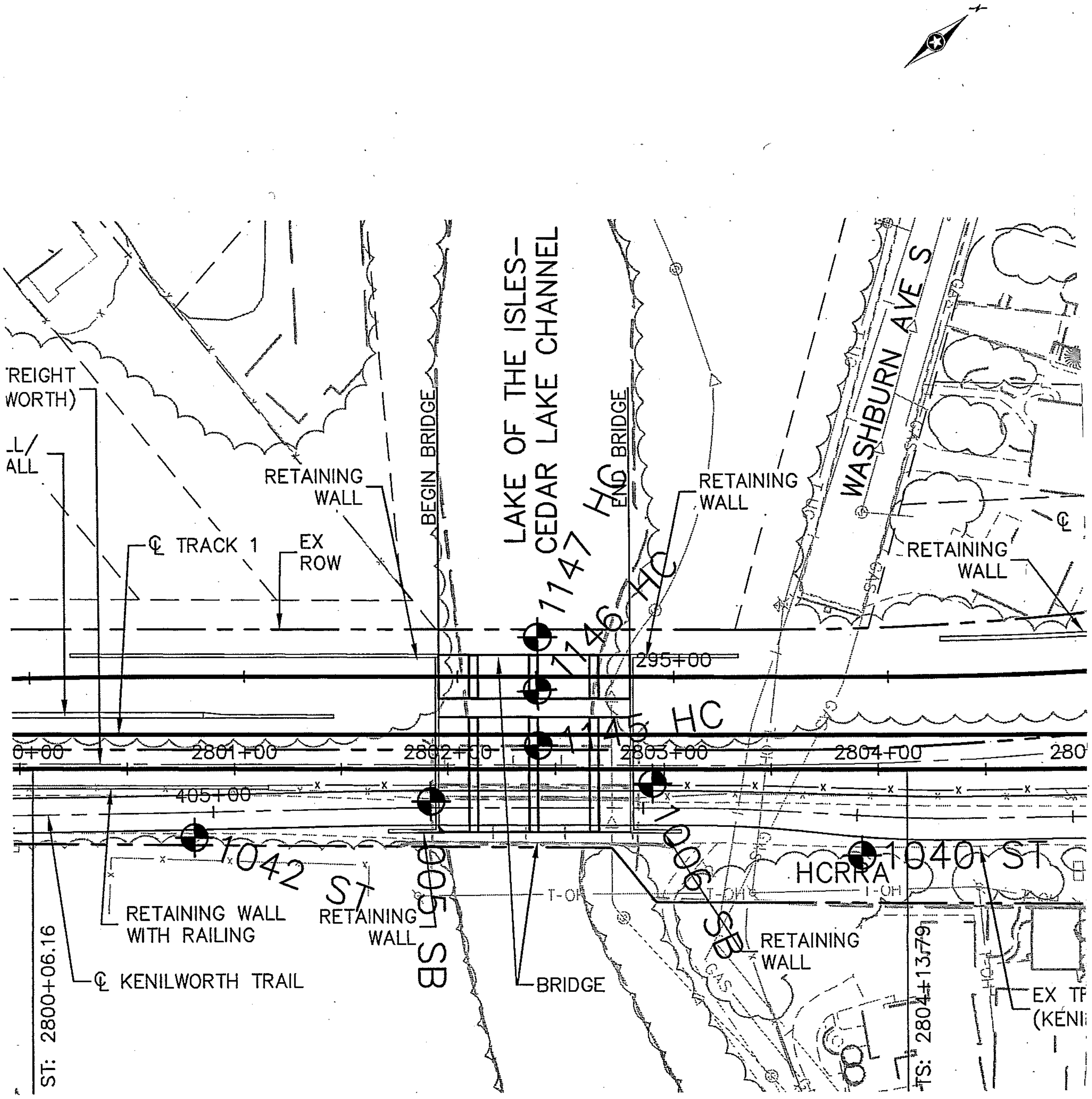

AMERICAN ENGINEERING TESTING, INC.

PROJECT
SWLRT Bridge over Channel

AET NO.
01-05697

SUBJECT
Boring Locations

DATE
April 29, 2014

SCALE
1" =75'±

PROVIDED BY
KHA

CHECKED BY
JV

FIGURE 1

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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MINNESOTA DEPARTMENT OF TRANSPORTATION

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
	Kenilworth Channel	**Southwest LRT, PEC East**	**1005 SB**	**869.1** *(Surveyed)*

Location **, , ft. LT**

Co. Coordinate: X=517230 Y=159918 (ft.)

Latitude (North)=44.9554248 *Longitude (West)=-93.3167812*

Drill Machine **68C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 4

Drilling Completed **3/27/13**

Depth / Elev.	Classification	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
0.6 868.5	Silty sand with gravel, trace roots, dark brown, frozen (A-2-4) fill					Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
2.0 867.1	Crushed limestone base, a little silty sand, light brown, a little brown, frozen (A-1-b) fill					
6.5 862.6	Silty sand with gravel and wood, brown and dark brown (A-1-b) fill	6	9			-#200 = 14%
16.5 852.6	Silty sand with gravel, a little sand with silt and clayey sand, possible cobbles below 11', pieces of wood, brown, a little light brown and dark brown (A-2-4) fill	15 5 7 21				
19.0 850.1	Gravelly silty sand, pieces of brick, brownish gray (A-1-b) fill	34				
24.0 845.1	Sand with silt and gravel, a little clayey sand, brownish gray, a little brown (A-1-b) fill	22 19				Water level measured at 21.1' deep with HSA to 22' deep (rose from 21.3' deep 10 minutes earlier)
27.0 842.1	SAND WITH SILT AND GRAVEL, medium to fine grained, gray, waterbearing, dense (SP-SM) (A-1-b) alluvium	34				
	SAND, fine grained, brown, waterbearing, medium dense (SP) (A-3) alluvium	18 15 18 17 19 21				

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40. Drilling Operation: PD at 24 to 41 ft.

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.

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U.S. Customary Units

SHEET 2 of 4

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1005 SB**	**869.1** (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
			SAND, fine grained, brown, waterbearing, medium dense (SP) (A-3) alluvium *(continued)*	☒	20					
	44.0 825.1		SAND, a little gravel, medium grained, grayish brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD						
45				☒	14					
	46.5 822.6		SAND, fine grained, grayish brown, waterbearing, medium dense (SP) (A-3) alluvium	PD						
				☒	21					
				PD						
50				☒	23					
				PD						
	53.0 816.1		SAND, a little gravel, fine to medium grained, brownish gray, waterbearing, medium dense, lenses of fine grained sand (SP) (A-3) alluvium							
55				☒	21					
				PD						
60				☒	19					
				PD						
65				☒	20					
				PD						
70				☒	23					
	72.5 796.6		SAND, fine to medium grained, brownish gray, waterbearing, medium dense (SP) (A-3) alluvium	PD						
75				☒	26					
				PD						
80				☒	29					
				PD						
	83.0 786.1									

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U.S. Customary Units

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SHEET 3 of 4

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	Kenilworth Channel	**Southwest LRT, PEC East**	**1005 SB**	**869.1** *(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	87.0 782.1		SAND, medium grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium *(continued)*	PD ☒	15					
90	93.0 776.1		SAND, a little gravel, medium grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD ☒ PD	27					
95	98.0 771.1		SAND, medium to fine grained, brownish gray, waterbearing, dense (SP) (A-1-b) alluvium	☒ PD	34					
100	105.0 764.1		GRAVEL WITH SAND, possible cobbles, brownish gray, waterbearing, medium dense (GP) (A-1-a) alluvium	☒	13					
105 110	115.0 754.1		SAND WITH GRAVEL, medium grained, dark grayish brown, waterbearing, dense, a lens of gravelly sand with silt (SP) (A-1-b) alluvium	PD ☒	39					
115 120	124.5 744.6		SAND, a little gravel, medium grained, brownish gray, waterbearing, dense (SP) (A-1-b) alluvium	PD ☒ PD	32					Lost mud circulation at 120 feet, hole collapsed at 40 feet, re-augered with HSA down to 50 feet and re-drilled with rotary methods to continue advancement.
125			LEAN CLAY WITH SAND, brown, hard (CL) (A-6) till or alluvium							

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

METROPOLITAN COUNCIL

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UNIQUE NUMBER

U.S. Customary Units

SHEET 4 of 4

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	Kenilworth Channel	**Southwest LRT, PEC East**	**1005 SB**	**869.1** *(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*
		▨		PD						
130		▨	LEAN CLAY WITH SAND, brown, hard (CL) (A-6) till or alluvium *(continued)*	☒	54	13				
135	135.0 734.1	▨		PD						
		▨	CLAYEY SAND, a little gravel, brown, very stiff (SC) (A-6) till							
140		▨		☒	29	11				
	141.0 728.1		**END OF BORING**							

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN
ENGINEERING
TESTING, INC.

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MINNESOTA DEPARTMENT OF TRANSPORTATION

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1006 SB**	**868.4** (Surveyed)

Location , , ft. LT

Co. Coordinate: X=517289 Y=160002 (ft.)

Latitude (North)=44.9556550 Longitude (West)=-93.3165530

Drill Machine 68C

Hammer CME Automatic Calibrated

SHEET 1 of 5

Drilling Completed 3/27/13

DEPTH	Depth Elev.	Lithology	Classification	Drilling Operation	SPT N60 REC (%)	MC (%) RQD (%)	COH (psf) ACL (ft)	γ (pcf) Core Breaks	Soil / Rock	Other Tests Or Remarks Formation or Member
	0.3 868.1		Silty sand with organic fines, a little gravel and clayey sand with organic fines, trace roots, dark brown (A-2-4) fill							Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
	2.0 866.4		Gravel with clay and sand, dark brown (A-1-b) fill							
	4.0 864.4		Mixture of silty sand and sand with silt, gravelly, dark brown and light brown, a little black (A-2-4) fill		30					
5	6.5 861.9		Sand with silt and gravel, a little clayey sand, brown (A-1-b) fill		24					
10	11.5 856.9		Clayey sand, a little gravel, slightly organic lean clay and silty sand, ashes/cinders, trace roots, dark brown and black (A-6, A-4) fill		13 9	10 16				
	14.0 854.4		Slightly organic sandy lean clay, a little gravel and sandy lean clay, trace roots, black and brownish gray (A-6) fill		6	20				
15	16.5 851.9		Silty sand with gravel, a little clayey sand, brownish gray (A-1-b) fill		30					
	19.0 849.4		SAND WITH SILT AND GRAVEL, fine to medium grained, brown, a little brownish gray, moist, medium dense, laminations of clayey sand (SP-SM) (A-2-4) alluvium		13					
20 ▼	21.5 846.9		GRAVELLY SILTY SAND, fine to medium grained, brown, wet, medium dense (SM) (A-1-b) alluvium		11					
	24.0 844.4		GRAVELLY SAND WITH SILT, medium to fine grained, light grayish brown, waterbearing, medium dense (SP-SM) (A-1-b) alluvium		11					Water level measured at 21.0' deep with HSA to 24.5' deep (rose from 22.3' deep 10 minutes earlier)
25	26.5 841.9		SAND WITH GRAVEL, possible cobbles, medium grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	14					
	29.0 839.4		GRAVELLY SAND, possible cobbles, medium to coarse grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	18					
30	31.5 836.9		SAND WITH SILT AND GRAVEL, possible cobbles, medium to fine grained, gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD	18					
	34.0 834.4		SAND, a little gravel, possible cobbles, medium grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	15					
35 40	41.5		SAND, a little gravel, possible cobbles above 36', fine to medium grained, brownish gray, waterbearing, medium dense, lenses of lean clay below 39' (SP) (A-3) alluvium	PD PD PD PD	13 14 15	23				

Index Sheet Code

(Continued Next Page)

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

METROPOLITAN
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U.S. Customary Units

SHEET 2 of 5

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	Kenilworth Channel	**Southwest LRT, PEC East**	**1006 SB**	**868.4** *(Surveyed)*

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*
826.9	SAND, medium to fine grained, brownish gray, waterbearing, loose (SP) (A--b) alluvium *(continued)*	☒ PD	10					
44.0 824.4	SAND, a little gravel, medium to fine grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium	☒ PD ☒ PD ☒ PD ☒	10 13 15 19					
58.0 810.4	SAND, fine to medium grained, brownish gray, waterbearing, medium dense (SP) (A-3) alluvium	PD ☒	20					
62.5 805.9	SAND WITH GRAVEL, medium to fine grained, brownish gray, a little dark brownish gray, waterbearing, medium dense, a lens of lean clay with sand (SP) (A-1-b) alluvium	PD ☒	18					
68.0 800.4	LEAN CLAY WITH SAND, brown, hard, laminations of waterbearing fine to medium grained sand (CL) (A-4) alluvium	PD ☒	31	17				
73.0 795.4	SAND, a little gravel, medium grained, brown, waterbearing, loose (SP) (A-1-b) alluvium	PD ☒	10					
78.0 790.4	SAND, a little gravel, fine to medium grained, brownish gray, waterbearing, medium dense, laminations of medium grained sand (SP) (A-3) alluvium	PD ☒	13					
82.5 785.9	SAND, medium grained, brownish gray, waterbearing, loose to medium dense (SP) (A-1-b) alluvium	PD						

DEPTH: 45, 50, 55, 60, 65, 70, 75, 80

(Continued Next Page)

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

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SHEET 3 of 5

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	Kenilworth Channel	**Southwest LRT, PEC East**	**1006 SB**	**868.4** *(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*
85				PD ☒	10					
			SAND, medium grained, brownish gray, waterbearing, loose to medium dense (SP) (A-1-b) alluvium *(continued)*	PD						
90				☒	14					
	93.0 775.4			PD						
			SAND, a little gravel, medium grained, brownish gray, waterbearing, medium dense, a lens of fine to medium grained sand (SP) (A-1-b) alluvium							
95				☒	19					
	98.0 770.4			PD						
100				☒	9					
105				PD						
			SAND WITH GRAVEL, possible cobbles, medium grained, brownish gray, waterbearing, loose (SP) (A-1-b) alluvium							
110				☒	9					
115	115.0 753.4			PD						
			SAND, a little gravel, medium grained, brownish gray, waterbearing, loose, a lens of medium to fine grained sand (SP) (A-1-b) alluvium							
120				☒	10					
				PD						
125	125.5									

(Continued Next Page)

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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SHEET 4 of 5

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1006 SB**	**868.4** (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
	742.9		SILTY CLAY, brown, hard (CL-ML) (A-4) alluvium	PD						
130				☒	31	27				
135	135.0 733.4		SAND WITH SILT, a little gravel, medium to fine grained, brown, waterbearing, medium dense, a lens of clayey sand at 140' (SP-SM) (A-1-b) alluvium	PD						
140				☒	26					
145	145.0 723.4		SAND WITH SILT, possible cobbles, fine to medium grained, grayish brown, waterbearing, medium dense (SP-SM) (A-3) alluvium	PD						
150				☒	17					
155				PD						
160				☒	23					
165	165.0 703.4		SANDY SILT, a little gravel, possible cobbles, brownish gray, wet, very dense (ML) (A-4) alluvium	PD						

(Continued Next Page)

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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SHEET 5 of 5

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	Kenilworth Channel	**Southwest LRT, PEC East**	**1006 SB**	**868.4** *(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*
				PD						
170			SANDY SILT, a little gravel, possible cobbles, brownish gray, wet, very dense (ML) (A-4) alluvium *(continued)*	⊠	81	24				
175	175.0 693.4		SANDY LEAN CLAY, a little gravel, dark brownish gray, hard (CL) (A-6) till	PD						
180				⊠	80	13				
	181.0 687.4		**END OF BORING**							

Soil Class: Rock Class: Edit: Date: 8/25/14
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State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1040 ST**	**867.9** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=517377 Y=160056 (ft.)

Latitude (North)=44.9558029 Longitude (West)=-93.3162129

Drill Machine **1C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 1

Drilling Completed **5/16/13**

Depth	Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
0–4.0	863.9	Silty sand, a little gravel and ashes/cinders, trace roots, dark brown (A-2-4) fill	☒ ☒	10 14				Hammer Calibration: 66% efficiency with 105 lb. hammer, 9/18/13
6.5	861.4	Clayey sand, a little gravel, brown (A-2-4) fill	☒	9	12			
9.0	858.9	Clayey sand, a little gravel, dark brown (A-6) fill	☒	2	22			
16.5	851.4	Mixture of silty sand and clayey sand, with gravel, brown (A-2-4) fill	☒ ☒ ☒	20 9 7	14 14 10			
19.0	848.9	Clayey sand, a little gravel, brown (A-2-4) fill	☒	13	26			Water level measured at 18.3' deep with HSA to 19.5' deep
21.5	846.4	Clayey sand with gravel, a little ashes/cinders, black (A-2-4) fill	☒	27	21			
24.0	843.9	SAND WITH SILT, fine grained, gray, waterbearing, medium dense (SP-SM) (A-3) alluvium	PD ☒	24				
26.0	841.9	SAND WITH SILT AND GRAVEL, fine to medium grained, gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD ☒	26				

END OF BORING

Index Sheet Code

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

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1042 ST**	**869.0** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=517172 Y=159822 (ft.)

Latitude (North)=44.9551616 Longitude (West)=-93.3170055

Drill Machine **1C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 1

Drilling Completed **5/8/13**

Depth / Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
2.0 867.0	Clayey sand with gravel, a little silty sand, brown (A-2-4) fill		14	16			Hammer Calibration: 66% efficiency with 105 lb. hammer, 9/18/13
4.5 864.5	Silty sand with gravel, a little sand with silt, trace roots, black, a little brown (A-2-4) fill		11				
7.0 862.0	Sand with silt, a little gravel, brown (A-3) fill		19				
9.5 859.5	Mixture of clayey sand and sand with silt, with gravel, brown (A-2-4) fill		13	7			
12.0 857.0	Gravelly silty sand, brown (A-1-b) fill		12				
14.5 854.5	Sand with silt and gravel, a little clayey sand, brown (A-1-b) fill		21				
19.5 849.5	HEMIC PEAT, brown to dark brown (PT) (A-8) swamp deposit		13 11	317 164			Water level measured at 14.5' deep with HSA to 14.5' deep
22.0 847.0	SAND WITH SILT AND GRAVEL, fine to medium grained, light brownish gray, waterbearing, loose, a lens of clayey sand (SP-SM) (A-1-b) alluvium		10				
27.0 842.0	SAND WITH GRAVEL, medium grained, brownish gray to gray, waterbearing, loose (SP) (A-1-b) alluvium	 PD	8 10				
29.5 839.5	GRAVELLY SAND WITH SILT, medium to fine grained, gray, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD	22				
34.5 834.5	GRAVEL WITH SAND, gray, waterbearing, medium dense (GP) (A-1-a) alluvium	PD PD	25 28				
37.0 832.0	SAND, a little gravel, medium to fine grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	22				
39.0 830.0	GRAVEL WITH SAND, gray, waterbearing, medium dense (GP) (A-1-a) alluvium		18				
	END OF BORING						

Index Sheet Code

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

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MINNESOTA DEPARTMENT OF TRANSPORTATION

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1145 HC**	**852.8** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=517242 Y=159973 (ft.)

Latitude (North)=44.9555756 Longitude (West)=-93.3167347

Drill Machine **HA/Tube**

Hammer **n/a**

SHEET 1 of 1

Drilling Completed **8/23/13**

DEPTH	Depth Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock: Other Tests Or Remarks / Formation or Member
	2.0 850.8		Water						
	3.0 849.8		SAND WITH GRAVEL, includes organics, medium to fine grained, black/dark brown (SP) alluvium			38			-#200 = 3.6%
5	4.0 848.8		SAND, a little gravel, includes organics, medium to fine grained, black/dark brown (SP) alluvium			39			-#200 = 3.7%
	7.0 845.8		SAND WITH SILT AND GRAVEL, medium to fine grained, dark brown (SP-SM) alluvium			15			-#200 = 7.0%

END OF BORING
Locations, elevations and depths should be considered approximate (samples taken below water from boat).

Index Sheet Code

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

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1146 HC**	**852.8** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=517222 Y=159989 (ft.)

Latitude (North)=44.9556195 Longitude (West)=-93.3168119

Drill Machine **HA**

Hammer **n/a**

SHEET 1 of 1

Drilling Completed **8/22/13**

DEPTH	Depth Elev.	Lithology	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Soil	Other Tests Or Remarks
					REC (%)	RQD (%)	ACL (ft)	Core Breaks	Rock	Formation or Member
	4.0 848.8		Water							
5	6.0 846.8		SILT WITH SAND, black/dark brown (OH) sediment, OC = 20%			372				-#200 = 75%
	7.0 845.8		SILTY SAND, with organic fines, fine grained, dark brown (SM/OH) sediment, OC = 15%			119				-#200 = 49.5%
	8.5 844.3		ORGANIC SILT WITH SAND, dark brown, encountered gravel at about 8½' (likely represents the top of the alluvium) (OH) sediment, OC = 13%			108				-#200 = 74%

END OF BORING

Locations, elevations and depths should be considered approximate (samples taken below water from boat).

Index Sheet Code

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

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	Kenilworth Channel	**Southwest LRT, PEC East**	**1147 HC**	**852.8** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=517203 Y=160005 (ft.)

Latitude (North)=44.9556635 Longitude (West)=-93.3168852

Drill Machine **HA**

Hammer **n/a**

SHEET 1 of 1

Drilling Completed **8/23/13**

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock: Other Tests Or Remarks / Formation or Member
			Water						
5	4.0 848.8		ORGANIC SANDY SILT, black/dark brown (OH) sediment						-#200 = 68%
	6.0 846.8		SILTY SAND, with organic fines, fine grained, black/dark brown (SM/OH) sediment						-#200 = 49%
	8.0 844.8		SILTY SAND WITH GRAVEL, medium to fine grained, dark brown (SM) alluvium			20			-#200 = 14%
	9.0 843.8		**END OF BORING** Locations, elevations and depths should be considered approximate (samples taken below water from boat).						

Index Sheet Code

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

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

SIEVE AND HYDROMETER ANALYSIS TEST RESULTS

PROJECT:
Southwest LRT – Kenilworth Channel
Minneapolis, Minnesota

AET NO.: 01-05697

DATE: April 29, 2014

TEST METHOD:

Sieve Analysis: General conformance with ASTM:D6913, Method A

RESULTS:

Boring Number	1145 HC	1145 HC	1145 HC
Sample Depth	2'-3'	3'-4'	4'-7'
Dry Sample Weight (gms)	662.14	277.97	262.22
Sieve Size or Number	**Percent Passing by Weight**		
1½"	100	100	100
1"	94	100	100
3/4"	93	100	94
5/8"	92	100	92
1/2"	91	100	86
3/8"	90	100	86
#4	84	96	80
#10	73	81	73
#20	57	63	58
#40	31	36	34
#100	5.7	6.6	10
#200	3.6	3.7	7.0
Silt %/Clay %	*	*	*
Geologic origin	alluvium	alluvium	alluvium

* *hydrometer analysis not performed*

Note: The small sample size limits the accuracy of the test, and the sample may not necessarily be representative of the entire layer shown on the boring log

SIEVE AND HYDROMETER ANALYSIS TEST RESULTS

PROJECT:
Southwest LRT – Kenilworth Channel
Minneapolis, Minnesota

AET NO.: 01-05697

DATE: April 29, 2014

TEST METHOD:

Sieve/Hydrometer Analysis: General conformance with ASTM:D422

RESULTS:

Boring Number	1146 HC	1146 HC	1146 HC
Sample Depth	4'-5'	5'-6'	6'-8½'
Dry Sample Weight (gms)	126.74	117.12	115.34
Sieve Size or Number	**Percent Passing by Weight**		
3/8"	100	100	100
#4	99	99	100
#10	99	98	99
#20	97	94	98
#40	94	89	97
#100	83	60	88
#200	75	50	74
Silt %/Clay %*	56.8/18.5	36.5/13.0	56.9/16.8
Geologic origin	sediment	sediment	sediment

* *Clay taken to be particles smaller than 0.005 mm*

Note: The small sample size limits the accuracy of the test, and the sample may not necessarily be representative of the entire layer shown on the boring log

SIEVE AND HYDROMETER ANALYSIS TEST RESULTS

PROJECT:
Southwest LRT – Kenilworth Channel
Minneapolis, Minnesota

AET NO.: 01-05697

DATE: April 29, 2014

TEST METHODS:

Sieve Analysis Only: General conformance with ASTM:D6913, Method A
Sieve/Hydrometer Analysis: General conformance with ASTM:D422

RESULTS:

Boring Number	1147 HC	1147 HC	1147 HC
Sample Depth	4'-6'	6'-8'	8'-9'
Dry Sample Weight (gms)	139.5	144.62	615.04
Sieve Size or Number	**Percent Passing by Weight**		
3/4"	100	100	100
5/8"	100	100	99
1/2"	100	100	97
3/8"	100	100	94
#4	100	100	85
#10	99	98	73
#20	97	95	57
#40	91	89	42
#100	75	60	20
#200	68	49	14
Silt %/Clay %*	52.1/16.1	37.5/11.8	**
Geologic origin	sediment	sediment	alluvium

** Clay taken to be particles smaller than 0.005 mm*

*** hydrometer analysis not performed*

Note: The small sample size limits the accuracy of the test, and the sample may not necessarily be representative of the entire layer shown on the boring log

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)

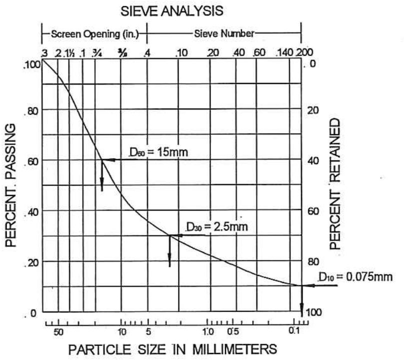
The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide N_{60} values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material),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

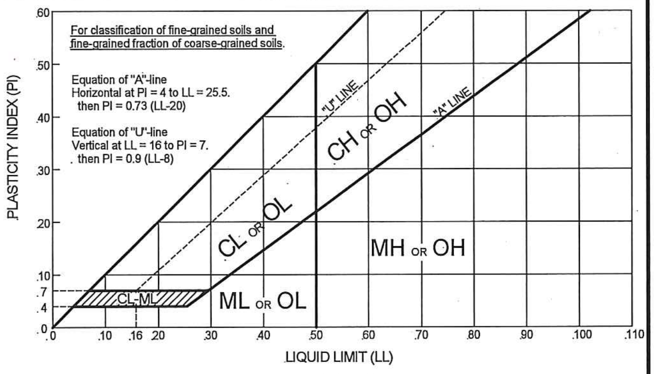
UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

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]



$Cu = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200$ $\quad$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{2.5^2}{0.075 \times 15} = 5.6$



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

[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

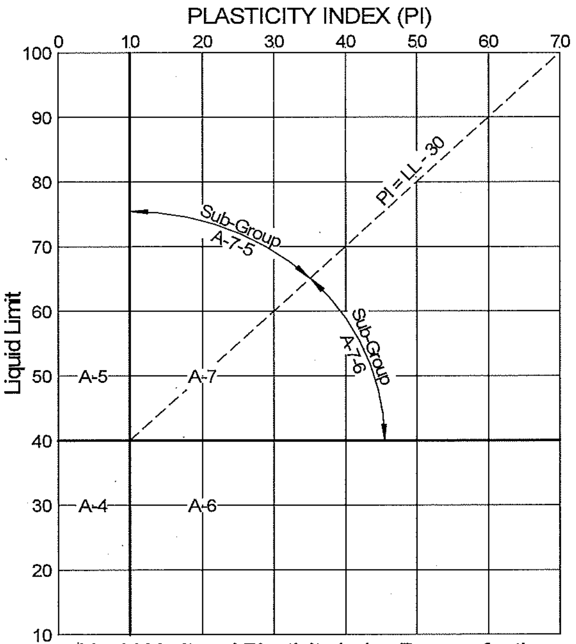
Classification of Soils and Soil-Aggregate Mixtures

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

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

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

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



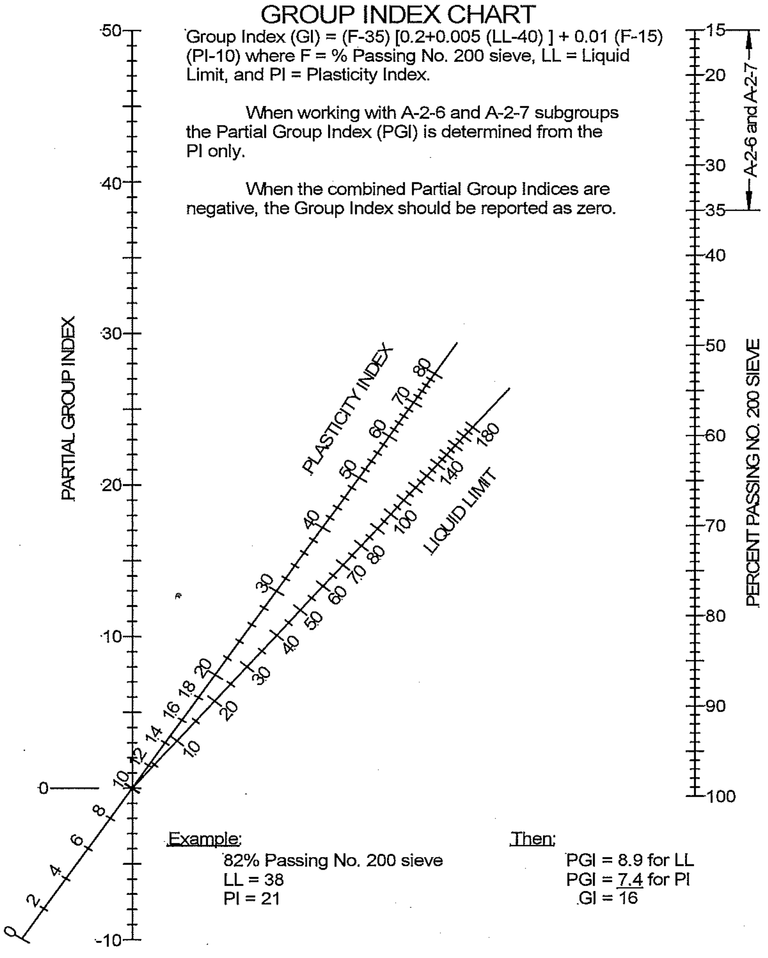
Liquid Limit and Plasticity Index Ranges for the A-4, A-5, A-6 and A-7 Subgroups

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

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.

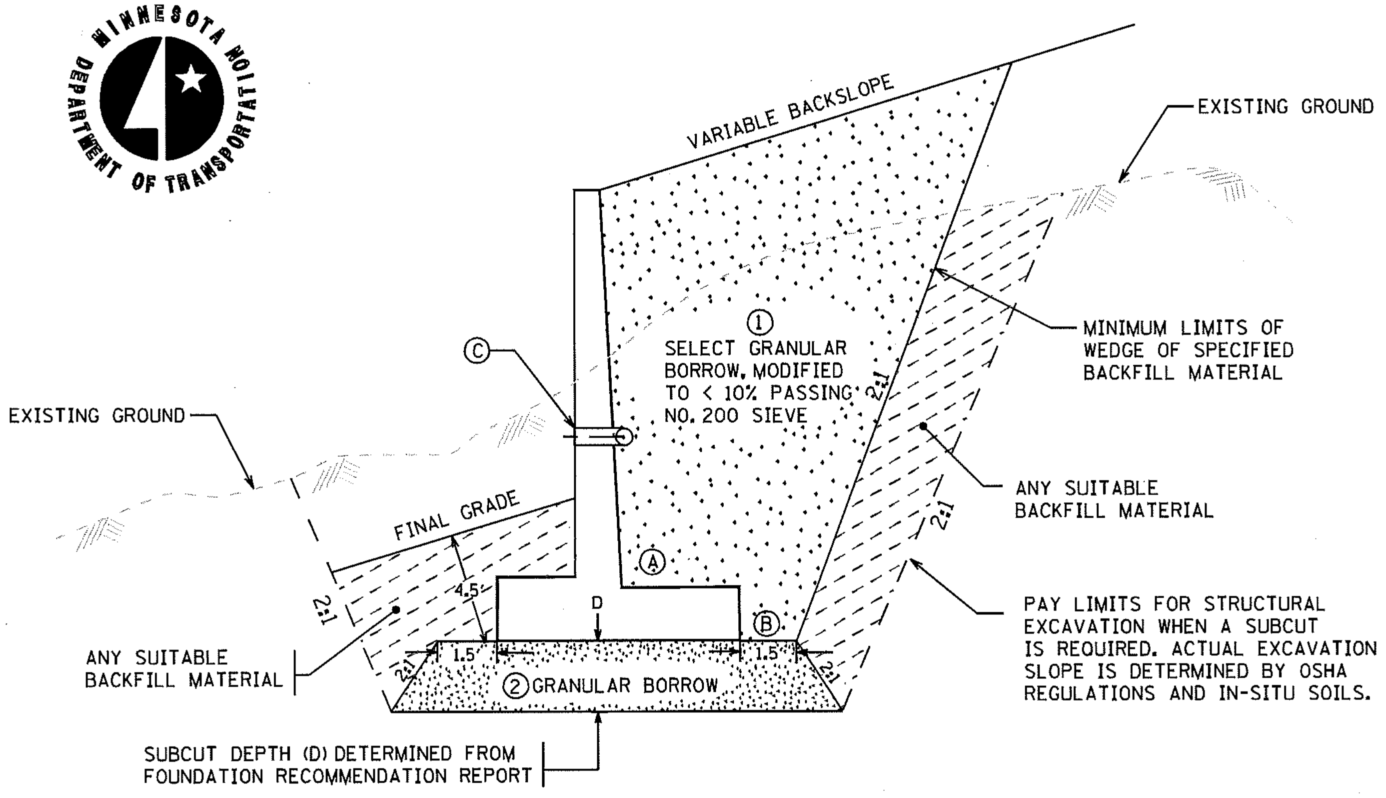
COARSE SAND - Material passing the No. 10 sieve and retained on the No. 40 sieve.

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.



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