



June 2012

DRAFT FOUNDATION INVESTIGATION AND DESIGN REPORT

High Mast Light Poles Highway 400-Highway 11 Interchange Simcoe County G.W.P. 2179-10-00

Submitted to:
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REPORT



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PART A

**FOUNDATION INVESTIGATION REPORT
HIGH MAST LIGHT POLES
HIGHWAY 400 NBL REHABILITATION
HIGHWAY 400-HIGHWAY 11 INTERCHANGE
SIMCOE COUNTY
G.W.P. 2179-10-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the rehabilitation of the Highway 400 northbound lanes (NBL) at the Highway 400-Highway 11 interchange in Simcoe County, Ontario.

This report addresses the foundation investigation carried out for five high mast light poles.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal (RFP) dated May 2008, in Section 6.8 of MH's *Technical Proposal* and in the scope change for foundation engineering services dated June 2010, for this assignment.

2.0 SITE DESCRIPTION

The proposed high mast light poles addressed in this report are located along the Highway 400 northbound lanes (NBL) and southbound lanes (SBL) near the Highway 400-Highway 11 interchange in Simcoe County, Ontario.

In general, the overall surface topography in the area is gently sloping. The natural ground surface within the area addressed by this report varies from approximately Elevation 230 m near the southern end of the site, to Elevation 238 m towards the northern extent of the site.

The Highway 400 embankments at this site vary in height from approximately 5 m to 9 m relative to the natural ground surface. The pavement surface of Highway 400 is at approximately Elevation 231 m at the southern end of the site and approximately Elevation 242 m at the north end of the site. The Highway 11 embankments are approximately 3 m above natural ground surface throughout the site, between Elevations 232 m and 234 m. The embankment side slopes are generally oriented at about 2 horizontal to 1 vertical (2H:1V), with the slope faces generally well vegetated.

3.0 INVESTIGATION PROCEDURES

A total of four boreholes (Boreholes 2007-45, 09-F-5, 09-F-7 and 11-HML-01) were advanced as part of the subsurface investigation at this site. Borehole 2007-45 was drilled as part of a previous assignment for Highway 400 SBL in November 2007. Boreholes 09-F-5 and 09-F-7 were drilled as part of the investigation for the Highway 400 NBL high fill embankment in August 2009. Borehole 11-HML-01 was drilled to provide additional coverage for the high mast light pole area in December 2011. The locations of these boreholes are shown on Drawing 1.

The boreholes were drilled using a track-mounted Diedrich D-50 Turbo drill rig, supplied and operated by Walker Drilling Ltd. of Utopia, Ontario, and a track-mounted CME-55 drill rig supplied and operated by Canadian Soil Drilling of Midhurst, Ontario. The boreholes were advanced using 200 mm internal diameter hollow stem augers, with soil samples obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure. In situ field vane testing was conducted using "N"-sized vanes where soft to stiff cohesive soils were encountered, to measure the undrained shear strength of the clayey silt to silty clay deposits at these locations.



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The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations. All boreholes were backfilled to ground surface using bentonite pellets in accordance with Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by a member of Golder's staff who located the boreholes in the field, directed the drilling, sampling and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratories in Mississauga and Cambridge for further examination and laboratory testing. Index and classification tests (water contents, Atterberg limits and grain size distributions) were carried out on selected soil samples. All geotechnical laboratory testing was completed to ASTM and MTO LS standards as applicable.

The borehole locations were measured by Golder personnel relative to the survey staking along the highway alignment and to fixed site features, and the ground surface elevations at the borehole locations were determined from the digital terrain model for this project. The borehole locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum, are summarized in the following table and are shown on Drawing 1.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation	Borehole Depth
2007-45	4,920,780.6	292,709.0	231.5 m	13.7 m
09-F-5	4,920,787.2	292,803.8	231.5 m	9.8 m + DCPT
09-F-7	4,920,910.4	292,856.7	233.5 m	16.8 m + DCPT
11-HML-01	4,920,520.4	292,605.4	229.5 m	11.3 m + DCPT

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 400 is located within the physiographic region known as the Simcoe Uplands, according to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984).

The general topography within the Simcoe Uplands consists of sloping till or moraine plains (Ontario Geological Society, 1991). The surficial soils in this region consist of sandy silt to sand and gravel, representing shoreline deposits of a former glacial lake that once flooded the area, overlying a glacial till deposit. Surficial deposits of clayey silt to silty clay are also present adjacent to current and former streams.

4.2 Site Stratigraphy

Four boreholes (Boreholes 2007-45, 09-F-5, 09-F-7 and 11-HML-01) were advanced at this site at the locations shown on Drawing 1. The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are summarized on the borehole records contained in Appendix A. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.



A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil

Approximately 100 mm to 700 mm of topsoil was encountered immediately below the existing ground surface in three of the boreholes (Boreholes 09-F-5, 09-F-7 and 11-HML-01) that were advanced for the high mast light pole foundation investigation.

4.2.2 Fill

Approximately 0.8 m to 1.0 m of fill was encountered in Boreholes 2007-45 and 09-F-7 which were advanced through the toe of the Highway 400 NBL and SBL embankments.

The fill encountered in these boreholes is generally cohesionless, varying in composition from sand and gravel containing trace to some silt, to silty sand containing trace clay.

The measured Standard Penetration Test (SPT) “N” values within the cohesionless fill range from 5 to 32 blows per 0.3 m of penetration, indicative of a loose to dense relative density.

4.2.3 Sand to Sandy Silt

An extensive deposit of cohesionless soil was encountered below the topsoil/fill in all of the boreholes advanced within the area of the high mast light pole foundation investigation. The deposit contains numerous clayey silt interlayers that are addressed separately in Section 4.2.4, below. The deposit was not fully penetrated in any of the boreholes; including the clayey silt interlayers, the overall thickness of the deposit ranges from more than 12.9 m to more than 15.7 m. The surface of the deposit was encountered between Elevation 228.8 m and 232.4 m and the deposit was penetrated to between Elevation 216.7 m and 221.8 m.

This deposit varies in composition, typically grading from sand containing trace to some silt, trace clay and gravel to sandy silt containing trace clay. Clayey silt seams, layers and/or lenses were observed within many of the recovered samples, as noted on the borehole records. The results of grain size distribution tests completed on eleven selected samples of this sand to sandy silt deposit are shown on Figures B1A and B1B in Appendix B.

The measured SPT “N” values in the sand to sandy silt deposit range from “weight of hammer” to 21 blows per 0.3 m of penetration, although many of the lower SPT “N” values are considered to be affected by sample disturbance due to groundwater inflow to the borehole during sampling, as indicated on the borehole records. These results indicate that the deposit typically has a loose to compact relative density.

4.2.4 Clayey Silt to Silty Clay Interlayers

Cohesive interlayers were encountered within the sand to sandy silt deposit in Boreholes 2007-45, 09-F-5 and 09-F-7, although the thickness and elevation of the interlayers varies from borehole to borehole. The depth and



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elevation of the surface/base of the interlayers and the interlayer thickness(es) as encountered in the boreholes are summarized in the table below:

Borehole No.	Depth to Surface	Interlayer Surface Elevation	Interlayer Thickness	Interlayer Base Elevation
2007-45	2.3 m	229.2 m	1.5 m	227.7 m
	4.6 m	226.9 m	1.5 m	225.4 m
09-F-5	0.7 m	230.8 m	0.8 m	230.0 m
	2.9 m	228.6 m	0.9 m	227.7 m
	4.7 m	226.8 m	0.9 m	225.9 m
09-F-7	2.1 m	231.4 m	6.5 m	224.9 m
	13.3 m	220.2 m	>3.5 m	Below 216.7 m

These cohesive interlayers vary in composition from clayey silt with sand containing trace gravel, to silty clay containing trace to some sand and trace gravel. Seams of sand or silt were observed in some of the recovered samples, as noted on the borehole records. The results of grain size distribution tests carried out on three selected samples of the clayey silt to silty clay interlayers are shown on Figure B2 contained in Appendix B.

Atterberg limits testing was conducted on five samples of the cohesive interlayers and measured plastic limits of 10 to 15 per cent, liquid limits of 14 to 29 per cent, and plasticity indices of 4 to 16 per cent. These test results, which are plotted on a plasticity chart on Figure B3 in Appendix B, confirm that the cohesive interlayers are generally clayey silt of low plasticity.

The measured SPT “N” values within the clayey silt to silty clay interlayers range from 1 to 18 blows per 0.3 m of penetration. Where lower SPT “N” values were measured, in situ vane shear strength testing was carried out and measured undrained shear strengths ranging from approximately 24 kPa to greater than 96 kPa. In general, the cohesive portion of this deposit is considered to have a soft to very stiff consistency.

Remoulded shear strengths were measured to assess the sensitivity of the clayey silt to silty clay interlayers. Based on these results, the sensitivity of the clay varies from approximately 1.2 to 3.0. These results indicate that the clay has a low sensitivity (CFEM, 2006).

4.3 Groundwater Conditions

Based on the observed soil moisture conditions, changes in colour from brown to grey and the observed water levels in the open boreholes following completion of drilling, the estimated groundwater depths and elevations at each of the boreholes are summarized as follows:



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Borehole No.	Estimated Groundwater Level During Drilling	
	Depth	Elevation
2007-45	3.0 m	228.5 m
09-F-5	1.5 m	230.0 m
09-F-7	6.1 m	227.4 m
11-HML-01	2.3 m	227.2 m

These measured water levels may not represent the stabilized groundwater level at the site, particularly where significant cohesive interlayers are present (such as in Borehole 09-F-7). The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring season.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Alexander Mayot, EIT and reviewed by Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Fin Heffernan, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.

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HIGHWAY 400 NBL REHABILITATION**

PART B

**FOUNDATION DESIGN REPORT
HIGH MAST LIGHT POLES
HIGHWAY 400 NBL REHABILITATION
HIGHWAY 400-HIGHWAY 11 INTERCHANGE
SIMCOE COUNTY
G.W.P. 2179-10-00**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations for the geotechnical design of the proposed high mast light pole foundations at the Highway 400-Highway 11 interchange in Simcoe County, Ontario. These recommendations are based on interpretation of the factual data obtained during the subsurface investigation. The interpretation and recommendations contained in this report are intended for use by the design engineer. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions or operational constraints may be required in the contract documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect the equipment selection, construction method and scheduling.

6.2 Design of High Mast Light Pole Foundations

The high mast light pole foundations should be designed in accordance with MTO's *Procedures for the Design of High Mast Light Poles*, dated May 2004. For each of the high mast light poles addressed in this report, it is anticipated that single caisson foundations will be used based on the subsurface conditions.

6.2.1 Lateral Geotechnical Resistance

The unfactored passive lateral earth pressure, P_p (kPa), distributed along the caisson foundations for each HML pole may be calculated using the following equations, based on the stratigraphy and geotechnical design parameters given in Table 1 following the text of this report.

$$P_p = K_p \gamma d + 2 s_u / K_p \quad \text{above the groundwater table}$$

$$P_p = K_p \gamma d_w + K_p \gamma' (d - d_w) + 2 s_u / K_p \quad \text{below the groundwater table}$$

Where K_p is the passive earth pressure coefficient;
 γ is the bulk unit weight (kN/m³);
 γ' is the effective unit weight below the groundwater level (kN/m³);
 d is the depth below the ground surface (m);
 d_w is the depth to the groundwater level (m); and
 s_u is the undrained shear strength (kPa).

In the design of the foundations, the passive resistance within the upper 1.6 m below ground surface should be neglected to account for frost action. The unfactored lateral resistance should be calculated assuming an equivalent pile width equal to three times the caisson diameter. A resistance factor of 0.5 should be applied to this calculated lateral resistance in order to obtain the factored lateral geotechnical resistance, in accordance with Section 6.6.2.1 of the *CHBDC*.

Where an undrained shear strength, s_u , is provided, the undrained capacity of the caisson should be checked to determine whether the drained or undrained case will govern. In this case, the lateral resistance for the length of the caisson within cohesive soil should be calculated assuming an internal angle of friction, $\phi' = 0$ degrees and



an unfactored passive lateral pressure distribution equivalent to nine times the undrained shear strength acting over the actual width of the caisson. A resistance factor of 0.5 should be applied to this calculated lateral resistance in order to obtain the factored lateral geotechnical resistance, as noted above.

6.3 Construction Considerations

6.3.1 Control of Soil and Groundwater

The water-bearing cohesionless soils at this site should be expected to run or flow into the caisson hole during or after the drilling for the caisson foundations. Therefore, appropriate equipment and procedures will be required to minimize ground loss during drilling and concrete placement. This could include the use of temporary or permanent caisson liners, and/or the use of drilling mud. It is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to warn the Contractor of this condition, which will affect the installation of the high mast light pole foundations at this site. A sample NSSP to address this condition is provided in Appendix C.

7.0 CLOSURE

This Foundation Design Report was prepared by Alexander Mayot, EIT., and reviewed by Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Fin Heffernan, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

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TABLE 1 – GEOTECHNICAL DESIGN PARAMETERS FOR HIGH MAST LIGHT POLE FOUNDATIONS G.W.P. 2179-10-00

HML Pole No(s)	Borehole No.	Stratum	Depth ¹ (m)	Elevation (m)	Groundwater Elevation (m)	Design Parameters				
						s_u (kPa)	ϕ ,	γ (kN/m ³)	γ' (kN/m ³)	K_p
1,2	11-HML-01	Topsoil	0.0 – 0.7	229.5 – 228.8	228.0	-	28°	18	8	2.8
		Compact Sand	0.7 – 1.4	228.8 – 228.1		-	30°	20	10	3.0
		Loose Silty Sand to Sand	1.4 – 11.3	228.1 – 218.4		-	28°	20	10	2.8
3	09-F-5	Topsoil / Loose Silty Sand	0.0 – 0.7	231.5 – 230.8	230.0	-	26°	20	10	2.6
		Firm Silty Clay	0.7 – 1.5	230.8 – 230.0		35	28°	19	9	2.8
		Compact Sand and Silt	1.5 – 2.9	230.0 – 228.6		-	30°	20	10	3.0
		Soft Clayey Silt	2.9 – 3.8	228.6 – 227.7		20	28°	19	9	2.8
		Loose Silty Sand	3.8 – 4.7	227.7 – 226.8		-	28°	20	10	2.8
		Soft Clayey Silt	4.7 – 5.6	226.8 – 225.9		20	28°	19	9	2.8
		Compact Sand	5.6 – 9.8	225.9 – 221.8		-	30°	20	10	3.0
4	2007-45	Loose Fill / Compact Sandy Silt	0.0 – 2.3	231.5 – 229.2	230.0	-	28°	20	10	2.8
		Soft to Firm Clayey Silt	2.3 – 3.8	229.2 – 227.7		25	28°	19	9	2.8
		Compact Sand and Silt	3.8 – 4.6	227.7 – 226.9		-	28°	20	10	2.8
		Firm Clayey Silt	4.6 – 6.1	226.9 – 225.4		30	27°	19	9	2.7
		Compact Sand and Silt to Sand	6.1 – 13.7	225.4 – 217.8		-	32°	20	10	3.3
5	09-F-7	Topsoil / Dense Fill	0.0 – 1.1	233.5 – 232.4	230.0	-	32°	21	11	3.3
		Loose Silty Sand	1.1 – 2.1	232.4 – 231.4		-	28°	20	10	2.8
		Stiff to Very Stiff Clayey Silt	2.1 – 4.5	231.4 – 229.0		60	32°	19	9	3.3
		Soft Clayey Silt	4.5 – 7.5	229.0 – 226.0		25	30°	19	9	3.0
		Very Stiff Clayey Silt / Loose to Compact Silty Sand	7.5 – 13.3	226.0 – 220.2		60	30°	20	10	3.0
		Firm to Stiff Clayey Silt	13.3 – 16.8	220.2 – 216.7		50	35°	19	9	3.7



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NOTES:

1. Depths are given at the borehole location relative to present (2012) estimated ground surface; the ground surface elevation at the borehole location should be compared to the ground surface elevation at the actual high mast light pole support location, and the depths of the soil strata adjusted accordingly.
2. Design Parameters:

s_u	= undrained shear strength (kPa)
ϕ'	= effective friction angle (degrees)
γ	= bulk unit weight (kN/m ³)
γ'	= effective unit weight below the groundwater level (kN/m ³), and
K_p	= passive earth pressure coefficient
3. Although the passive earth resistance in the upper 1.6 m is neglected to account for frost action, s_u , ϕ' and K_p parameters are given in the event that the ground surface elevation varies significantly between the borehole location and the actual high mast light pole support location.



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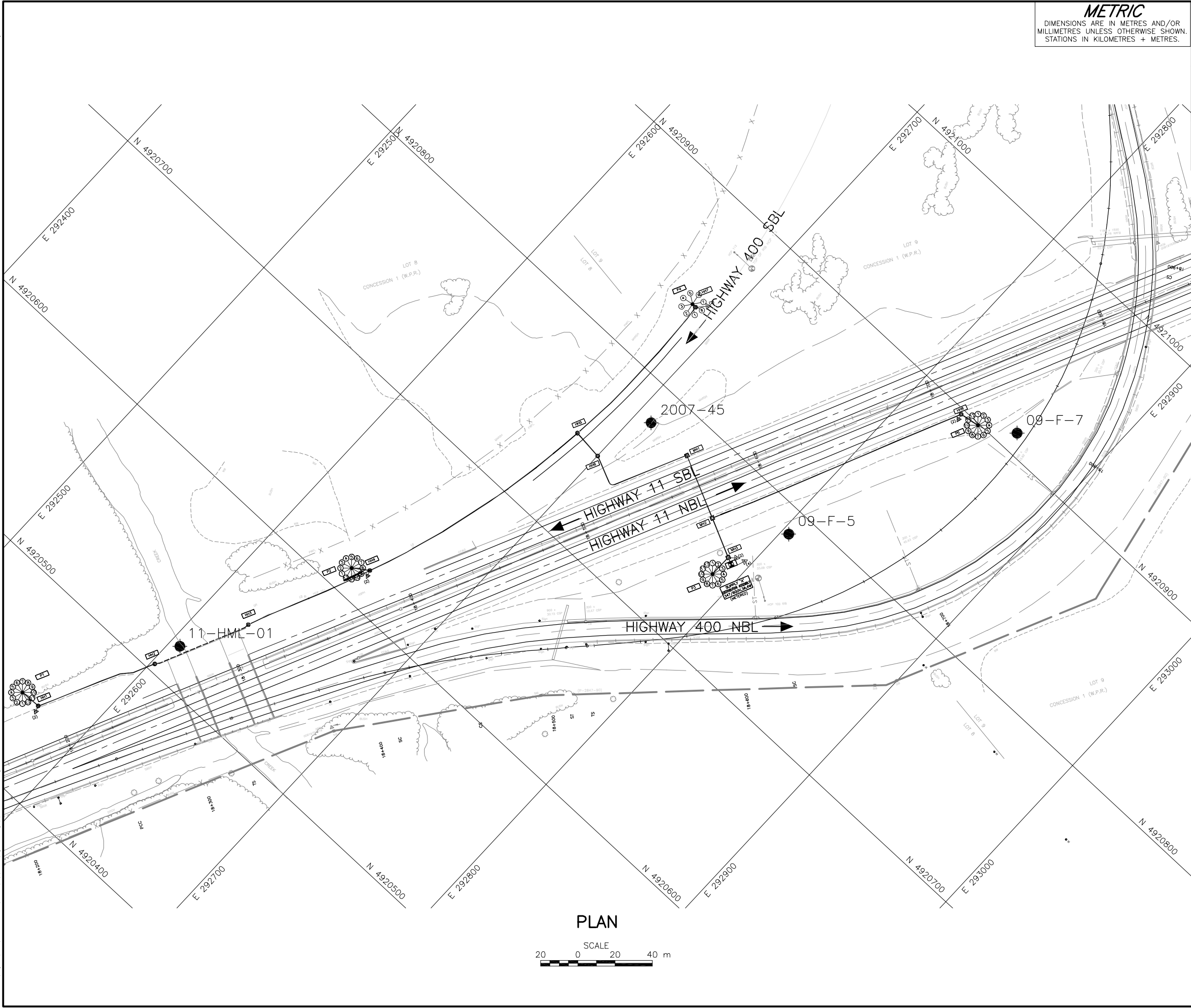
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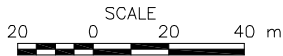
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Ontario Provincial Standard Drawings (OPSD)

OPSD 3400.011 Contours of Frost Depths for Southern Ontario



PLAN



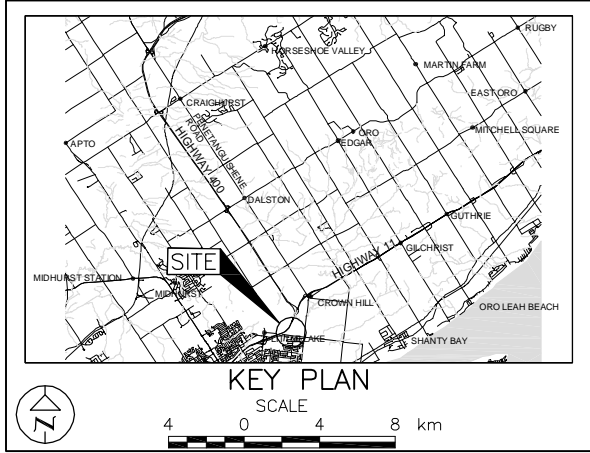
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2179-10-00

HIGHWAY 400-11 INTERCHANGE
HIGH MAST LIGHT POLES
BOREHOLE LOCATIONS

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND

Borehole Location

Approximate HML Pole Location

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
09-F-5	231.5	4920787.2	292803.8
09-F-7	233.5	4920910.4	292856.7
11-HML-01	229.5	4920520.4	292605.4
2007-45	231.5	4920780.6	292709.0

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plan provided in digital format by Morrison Hershfield drawing files X-x84117Base.dwg, X-x84117Align.dwg, X-1084117_LTG.dwg , received June 22, 2012.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 400		PROJECT NO. 09-1111-0022	DIST. CENTRAL
SUBM'D. AM	CHKD. LCC	DATE: 6/26/2012	SITE:
DRAWN: JFC	CHKD. AM	APPD. LCC	DWG. 1



APPENDIX A

Borehole Records



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	kPa	C_u, S_u	psf
Very soft	0 to 12		0 to 250
Soft	12 to 25		250 to 500
Firm	25 to 50		500 to 1,000
Stiff	50 to 100		1,000 to 2,000
Very stiff	100 to 200		2,000 to 4,000
Hard	over 200		over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Percent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength


τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

PROJECT		06-1111-011		RECORD OF BOREHOLE No 2007-45		1 OF 1 METRIC							
W.P.		167-99-00		LOCATION		N 4920780.6 :E 292709.0							
DIST		Central HWY 400		BOREHOLE TYPE		210 mm Diameter Hollow Stem Augers							
DATUM		Geodetic		DATE		November 27, 2007							
						ORIGINATED BY <u>PKS</u>							
						COMPILED BY <u>VO</u>							
						CHECKED BY <u>LCC</u>							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
231.5 0.0	GROUND SURFACE Silty sand, trace clay (FILL) Loose Black Moist		1	SS	5	▽	231						0 25 63 12
230.7 0.8	Sandy SILT, trace clay, containing clayey silt seams Loose to compact Brown Moist becoming wet below 1.5 m depth		2	SS	8		230						
229.2 2.3	CLAYEY SILT, trace to some sand Soft Brown Wet		3	SS	10		229						
227.7 3.8	SAND and SILT, trace clay Compact Brown Wet		4	SS	3		228						
226.9 4.6	CLAYEY SILT, trace sand, containing silty sand seams Firm Brown Wet		5	SS	4		227						
225.4 6.1	SAND and SILT, trace gravel, trace clay Compact Brown Wet		6	SS	13		226						
222.4 9.1	SAND, some silt, trace gravel and clay Compact Brown Wet		7	SS	5		225						
220.8 10.7	Silty SAND, trace gravel and clay Compact Brown Wet		8	SS	11		224						
217.8 13.7	END OF BOREHOLE		9	SS	21		223						
			10	SS	17		222						
			11	SS	14		221						
			12	SS	13		220						
					219								
					218								
NOTE: 1. Water level in open borehole at a depth of 3.0 m (Elevation 228.5 m) upon completion of drilling.													

MIS-MTO 001 06-1111-011.GPJ GAL-MISS.GDT 2/19/08 DD

PROJECT		09-1111-0022		RECORD OF BOREHOLE No 09-F-5		1 OF 1 METRIC											
G.W.P.		2039-06-00		LOCATION		N 4920787.2 ; E 292803.8											
DIST		Central HWY 400		BOREHOLE TYPE		CME 55 Track-Mount, 108 mm Diameter Hollow Stem Auger											
DATE		Geodetic		DATE		August 5, 2010											
ORIGINATED BY		AB		COMPILED BY		MS/NK											
CHECKED BY		LCC															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	γ	GR SA SI CL				
231.5	GROUND SURFACE																
0.0	TOPSOIL		1	SS	2		231										
230.8	Silty SAND Very loose Brown Moist																
0.7	SILTY CLAY, trace to some sand Firm to stiff Brown Moist		2	V	-		230	2.3									
230.0	SAND and SILT, containing clayey silt layers Compact Grey Wet		3	SS	16			2.5									
1.5			4	SS	18		229						0 43 50 7				
228.6	CLAYEY SILT, trace sand Soft Grey Moist		5	SS	1		228										
227.7	Silty SAND, trace clay Loose Grey Wet							3									
3.8							227										
226.8	CLAYEY SILT Very soft Brown Wet		6	SS	2												
4.7							226										
225.9	SAND, some silt to Silty SAND, trace clay, containing clayey silt layers Loose to compact Brown Wet		7	SS	3*		225						0 80 16 4				
5.6							224										
			8	SS	3*		223										
							222						0 68 27 5				
221.8	END OF BOREHOLE		9	SS	10		221										
9.8	Dynamic Cone Penetration Test						220										
							219										
218.7	END OF DCPT																
12.8	Notes: *SPT "N" value considered to be affected by sample disturbance due to groundwater inflow to borehole. 1. Water level in open borehole at a depth of 1.5 m (Elevation 230.0 m) on completion of drilling.																


MIS-MTO 001 09-1111-0022.GPJ GAL-MISS.GDT 22/11/10 DD/SAC

PROJECT		09-1111-0022		RECORD OF BOREHOLE No 09-F-7		1 OF 2 METRIC											
G.W.P.		2039-06-00		LOCATION		N 4920910.4 , E 292856.7											
DIST		Central HWY 400		BOREHOLE TYPE		CME 55 Track-Mount, 108 mm Diameter Hollow Stem Auger											
DATUM		Geodetic		DATE		August 4, 2010											
						ORIGINATED BY AB											
						COMPILED BY MS/NK											
						CHECKED BY LCC											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	GR	SA	SI	CL	
233.5	GROUND SURFACE																
233.5	TOPSOIL		1	SS	9		233										
232.4	Sand and gravel, trace to some silt, containing clayey silt lenses (FILL) Loose to dense Brown Moist		2	SS	32		232										
231.4	Silty SAND, trace gravel, trace clay Loose to dense Grey Moist		3	SS	9		231										
231.4	CLAYEY SILT with sand to some sand, containing sand layers Firm to very stiff Brown Moist		4	SS	5		230										
			5	SS	18		229										
			6	SS	7		228										
			7	SS	3		227										
			8	SS	15		226										
224.9	Silty SAND to SAND, trace clay and gravel, containing clayey silt layers Loose to compact Brown Wet		9	SS	14		225										
			10	SS	8		224										
			11	SS	7		223										
			12	SS	4		222										
220.2	SILTY CLAY, trace to some sand, containing some gravel below 16 m Firm Grey Moist						221										
220.2							220										
220.2							219										

MIS-MTO 001 09-1111-0022.GPJ GAL-MISS.GDT 22/11/10 DD/SAC







Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 09-1111-0022				RECORD OF BOREHOLE No 09-F-7				2 OF 2 METRIC							
G.W.P. 2039-06-00				LOCATION N 4920910.4 ; E 292856.7				ORIGINATED BY AB							
DIST Central HWY 400				BOREHOLE TYPE CME 55 Track-Mount, 108 mm Diameter Hollow Stem Auger				COMPILED BY MS/NK							
DATUM Geodetic				DATE August 4, 2010				CHECKED BY LCC <i>llc</i>							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _p W W _L	20 40 60 80 100	10 20 30				
--- CONTINUED FROM PREVIOUS PAGE ---															
	SILTY CLAY, trace to some sand, containing some gravel below 16 m Firm Grey Moist		13	SS	4		218								1 12 38 49
216.7			14	SS	6		217		2.8		10				
16.8	END OF BOREHOLE Dynamic Cone Penetration Test						216								
214.6							215								
18.9	END OF DCPT NOTES: 1. Vane shear testing at depths of 2.6 m and 2.9 m completed in shallow borehole adjacent to borehole 09-F-7. 2. Wet soils encountered at a depth of 6.1 m (Elevation 227.4 m)														

MIS-MTO 001 09-1111-0022.GPJ GAL-MISS.GDT 22/11/10 DD/SAC

PROJECT 09-1111-0022		RECORD OF BOREHOLE No 11-HML-01 SHEET 1 OF 2		METRIC
G.W.P. 2179-10-00	LOCATION N 4920520.4 ; E 292605.4	ORIGINATED BY DD		
DIST Central HWY 400	BOREHOLE TYPE D-50 Track-Mount, 108 mm Diameter Hollow Stem Auger	COMPILED BY NLP		
DATUM Geodetic	DATE December 22, 2011	CHECKED BY LCC <i>pl</i>		

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED							
229.5	GROUND SURFACE						20 40 60 80 100									
0.0	TOPSOIL		1	SS	13		229									
228.8							228									
0.7	SAND, trace to some silt Compact Brown to grey Moist		2	SS	12		227									
228.1							226									
1.4	Silty SAND to SAND and SILT, trace clay, trace gravel Very loose to loose Brown-grey Moist to wet		3	SS	5		225									
			4	SS	WH*		224									
			5	SS	4		223									
			6	SS	5		222									
225.1							221									
4.4	SAND, some silt, trace clay, containing silty clay seams at 4.6 m Very loose to loose Grey Wet		7	SS	4		220									
			8	SS	5		219									
			9	SS	3*	218										
220.9						217										
8.6	Silty SAND Loose Grey Wet		10	SS	3*	216										
			11	SS	5											
218.4	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)															
11.1																
215.8	END OF DCPT * SPT "N" values considered to be affected by sample disturbance due to groundwater inflow to borehole during sampling															
13.7																

GTA-MTO 001 09-1111-0022.GPJ GAL-MISS.GDT 3/30/12 DD/SAC

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



+ 3, X 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE



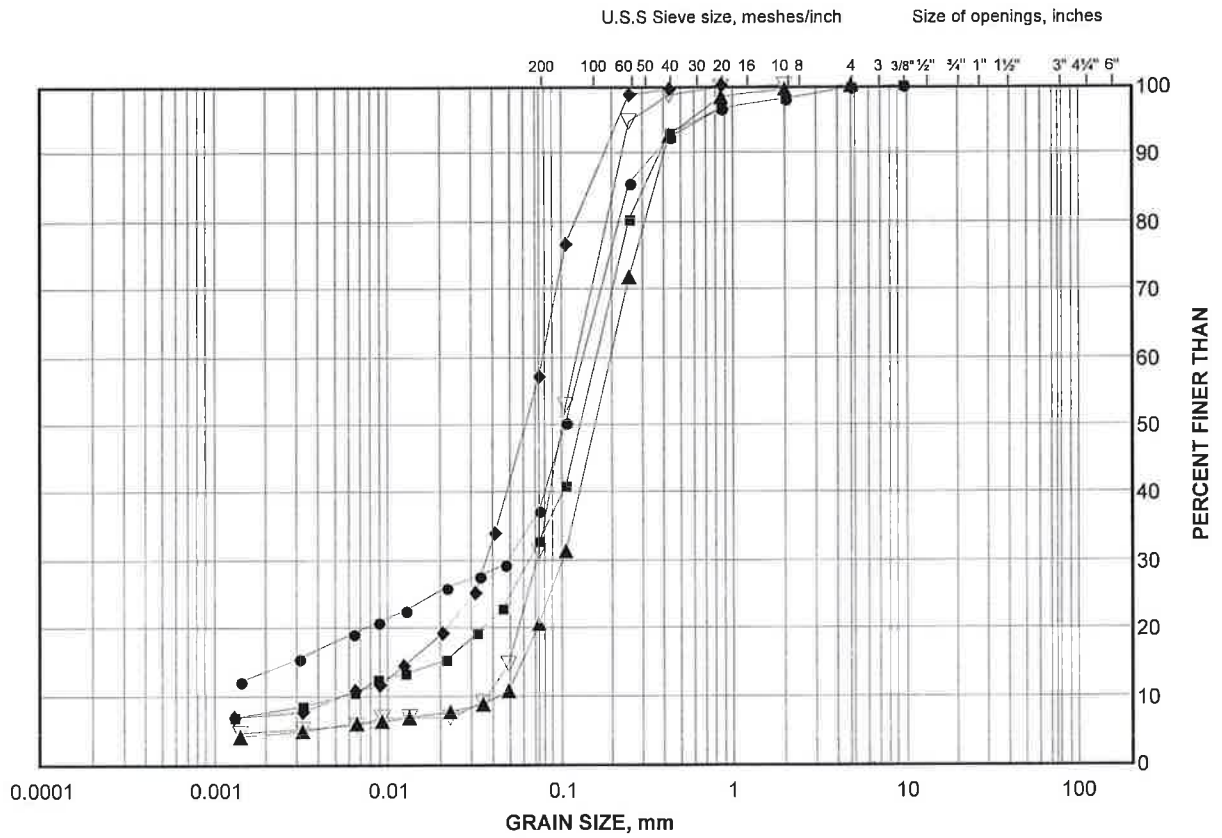
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Sand to Sandy Silt

FIGURE B1A



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	09-F-7	10	222.7
■	09-F-7	3	232.4
◆	09-F-5	4	229.0
▲	09-F-5	7	225.1
▽	09-F-5	9	222.1

Project Number: 09-1111-0022

Checked By: *Maye*

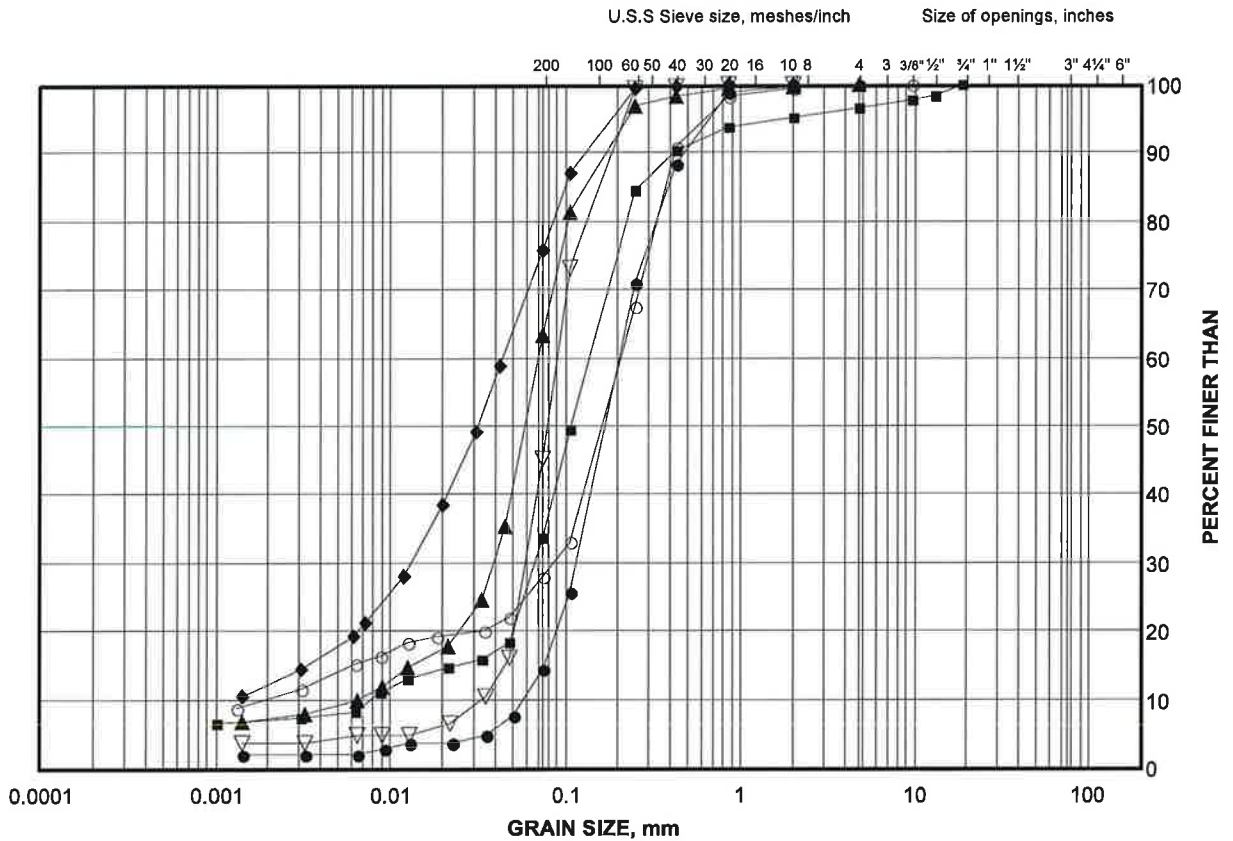
Golder Associates

Date: 16-Mar-12

GRAIN SIZE DISTRIBUTION

Sand to Sandy Silt

FIGURE B1B



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2007-45	10	222.1
■	11-HML-01	3	227.7
◆	2007-45	3	229.7
▲	11-HML-01	5	226.3
▽	2007-45	6	227.4
○	11-HML-01	7	229.5

Project Number: 09-1111-0022

Checked By: *[Signature]*

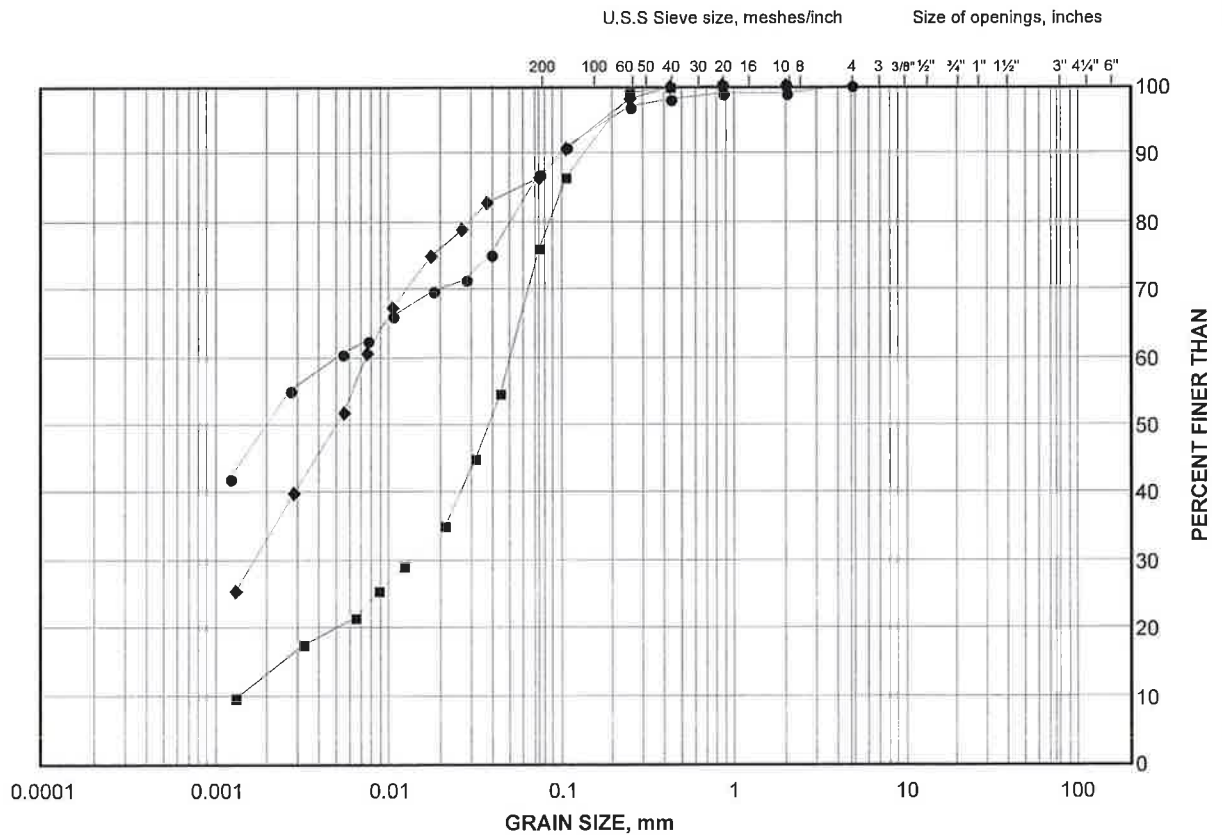
Golder Associates

Date: 05-Jun-12

GRAIN SIZE DISTRIBUTION

Clayey Silt to Silty Clay Interlayers

FIGURE B2



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

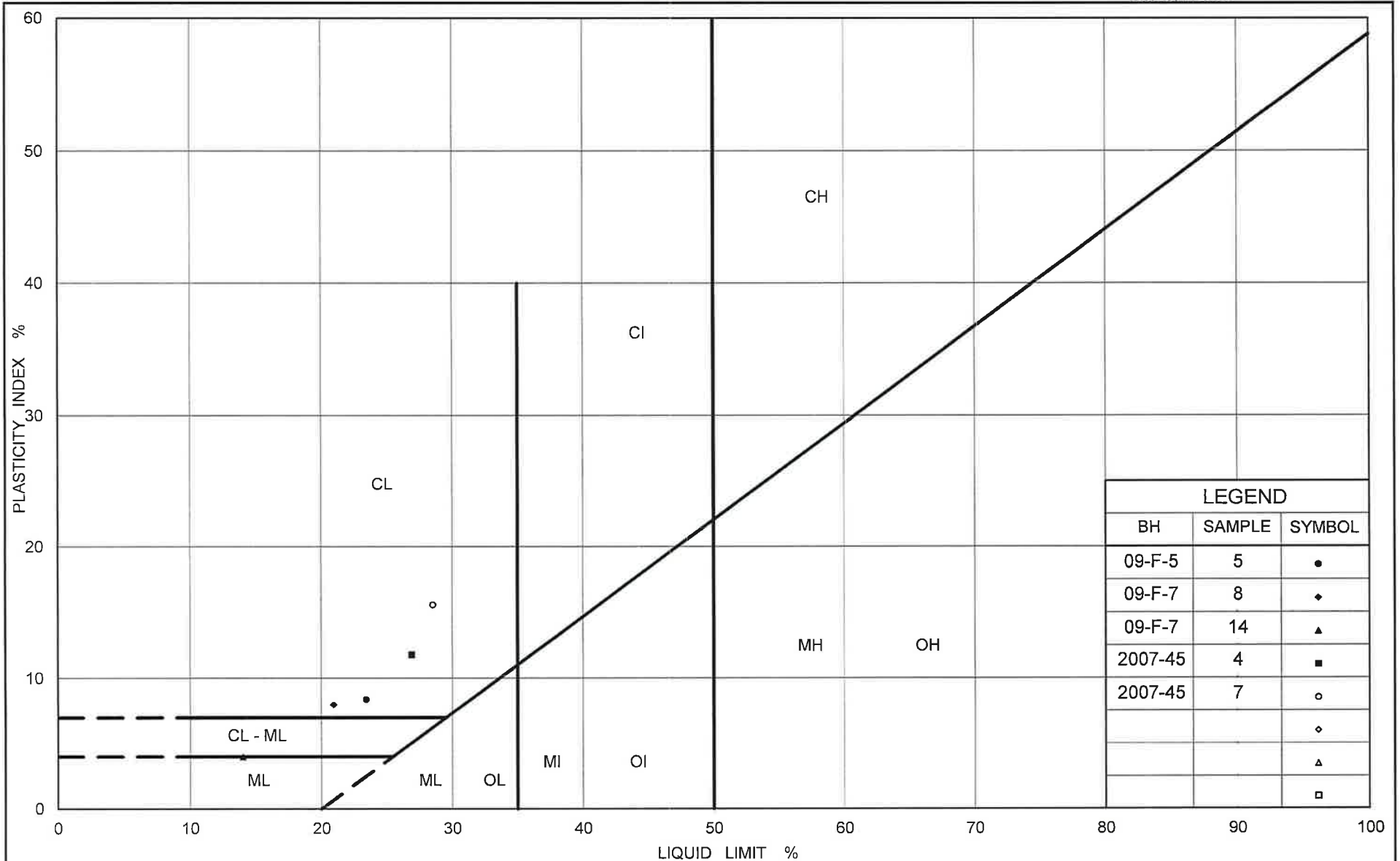
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	09-F-7	13	217.9
■	09-F-7	5	230.2
◆	2007-45	7	226.6

Project Number: 09-1111-0022

Checked By: *[Signature]*

Golder Associates

Date: 16-Mar-12



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Silty Clay Interlayers

Figure No. B3

Project No. 09-1111-0022

Checked By: ARM



APPENDIX C

Non-Standard Special Provisions



DRAFT FOUNDATION REPORT - HIGH MAST LIGHT POLES, HIGHWAY 400 NBL REHABILITATION

HML FOUNDATION INSTALLATION - Item No.

Special Provision

Excavations for the HML pole foundations will be advanced through topsoil and fill materials (where present) into cohesionless sand to silt soils, with lenses or layers of cohesive soils expected to be present within the deposit. The cohesionless soil deposits and lenses/interlayers should be expected to be unstable below the groundwater level. Where cohesionless soil deposits are encountered, appropriate construction procedures and equipment will be required to minimize ground loss during drilling and concrete placement.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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