June 12, 2017

FOUNDATION INVESTIGATION REPORT

Highway 401 Structural Culvert, Site No. 21-487/C
Structural Culvert Rehabilitation/Replacement
Highway 35/115 and Highway 401
Ministry of Transportation, Ontario
G.W.P. 2242-14-00

Submitted to:
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1 Copy - Golder Associates Ltd.

REPORT

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 401 STRUCTURAL CULVERT - SITE NO. 21-487/C
STRUCTURAL CULVERT REHABILITATION/REPLACEMENT
HIGHWAY 35/115 AND HIGHWAY 401
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 2242-14-00

Golder Associates

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Ltd. (D.M. Wills) on behalf of Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement / rehabilitation of various culverts on Highway 35/115 and Highway 401 in the Regional Municipality of Durham, Ontario.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Quotation, dated August 2015. Golder's proposal for the Foundation Engineering services associated with the culvert replacement is contained in Section 3.5 of D.M. Wills' Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated December 1, 2016.

This report addresses the investigation carried out for the Structural Culvert C9 at about STA 11+817 on Highway 401 (MTO Structure Site No. 21-487/C) which has been identified for rehabilitation or potential replacement. The foundation investigation associated with the other culverts, which forms part of the Foundation assignment are presented in separate reports.

2.0 SITE DESCRIPTION

The structural culvert Site No. 21-487/C (Culvert C9) requiring rehabilitation or replacement is located at approximately STA 11+817 on Highway 401, in the City of Oshawa, Regional Municipality of Durham, Ontario, as shown on the Key Plan on Drawing 1. The existing structural culvert is an open footing cast-in-place concrete structure and is 112.6 m long and 4.6 m wide by 3.6 m high. The structure is located across an embankment which provides approximately 7.9 m of soil cover. Details of the culvert are also summarized in Table 1 following the text of this report.

The overall surface topography in the vicinity of the site is generally flat-lying to gently sloping, with the natural ground surface at approximately Elevation 84 m. The Highway 401 grade in the vicinity of the culvert is at about Elevation 95 m. The existing Highway 401 embankment is comprised of earth fill, up to about 11 m high with side slopes inclined at approximately 2 horizontal to 1 vertical (2H:1V).

3.0 INVESTIGATION PROCEDURES

The fieldwork for the current investigation associated with structural culvert Site No. 21-487/C was carried out between July 24 and 26, 2016, between September 7 and 14, 2016 and December 7 and 8, 2016, during which time a total of six boreholes were advanced at, or in the immediate vicinity of the culvert alignment as shown in plan on Drawing 1.

The field investigation was carried out using portable and truck-mounted drilling equipment supplied and operated by specialist drilling contractors, Kodiak Drilling Inc. of Toronto, Ontario and Atcost Drilling Inc. of Gormley, Ontario, respectively. The boreholes that were advanced by portable equipment used 102 mm outer diameter (O.D.) hollow stem augers; the boreholes advanced by the truck-mounted drill used 208 mm outer diameter (O.D.) hollow stem augers. Soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m using a 50 mm O.D.

split-spoon sampler operated by an automatic hammer on the truck-mounted drill and by a manual hammer on the portable drill, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)[1].

A piezometer was installed in Borehole C9-6 to allow monitoring of the groundwater level at this site. The piezometer consists of a 50 mm diameter PVC pipe, with a slotted screen sealed positioned within the zone of silty clay fill / silty clay till / silty sand deposits. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to ground surface. The piezometer installation details and water level readings are noted on the Record of Borehole C9-6 in Appendix A. All of the remaining boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Regulation 903 (Wells) (as amended). The groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations and are described on the Record of Borehole sheets in Appendix A.

The fieldwork was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil samples. The soil samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and provided on Figures B1 to B10 in Appendix B.

A soil sample obtained during the field investigation at about the culvert invert elevation in Borehole C9-4, using appropriate sampling protocols, was submitted to a specialist analytical laboratory under chain of custody procedures for chemical analysis of conductivity / resistivity, pH, sulphate and chloride content and redox potential to assess the potential for the soil to cause deterioration of buried concrete and corrosion of steel. The results of the Analytical testing are presented in Appendix C and are discussed in Section 4.3.

The as-drilled borehole locations were measured relative to existing site features and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. The elevation of the boreholes was obtained by plotting the borehole locations on the topographic mapping provided by D.M. Wills on January 20, 2016. The borehole locations given on the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations (including geographic coordinates), ground surface elevations and drilled depths are as follows:

[1] ASTM D1586-11 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, ASTM International, West Conshohocken, PA, 2011

Borehole	Location (m)		Ground Surface Elevation (m)	Depth of Borehole (m)
	Northing (Latitude)	Easting (Longitude)		
C9-1	4859886.2 (43.876705)	362457.6 (-78.782548)	88.6	15.9
C9-2	4859865.2 (43.876516)	362456.0 (-78.782571)	95.1	26.0
C9-3	4859867.9 (43.876540)	362473.2 (-78.782356)	95.0	26.1
C9-4	4859836.3 (43.876245)	362486.6 (-78.782190)	95.0	26.1
C9-5	4859839.8 (43.876275)	362505.2 (-78.781959)	95.0	25.9
C9-6	4859818.6 (43.876091)	362533.8 (-78.781608)	85.8	12.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 401 is located within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)[2] and *Urban Geology of Canadian Cities* (Karrow and White, 1998)[3]. The Iroquois Plain extends around the western shores of Lake Ontario. The Plain is comprised of the flat to undulating lakebed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession. The surficial soils in this area of the Iroquois Plain are typically comprised of glaciolacustrine clays, silts and sands to gravelly sands.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are presented on the Record of Borehole sheets and the laboratory test sheets in Appendices A and B, respectively. The stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The stratigraphy at the borehole locations at the culvert location generally consists of a layer of asphalt at he boreholes drilled on the highway embankment, underlain by or an upper layer of non-cohesive embankment fill and a lower layer of cohesive embankment fill, underlain by a very stiff to hard clayey silt to silty clay till or silty clay to clay deposits in places. An interlayer of silty sand is present at one borehole location underlying the fill deposit. The embankment fill deposit, the silty sand interlayer and the clayey silt to silty clay till deposit are in turn underlain by a deposit of clayey silt to silty clay, in turn underlain by interlayers of silty sand, silty clay till and/or

[2] Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

[3] Karrow, P. F., and White, O. L., 1998. *Urban Geology of Canadian Cities.* Geological Association of Canada Special Paper No. 42. St. John's, Nfld.

silty clay. A detailed description of the subsurface conditions at the culvert crossing is provided in the following section of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

4.2.1 Asphalt

Boreholes C9-2, C9-3, C9-4 and C9-5, advanced through the existing Highway 401 roadway, penetrated an asphalt layer between approximately 100 mm and 200 mm thick.

4.2.2 Embankment Fill

Embankment fill, approximately 2.3 m to 10.6 m thick was encountered in all boreholes immediately below existing ground surface, or underlying the asphalt (where present). The embankment fill consists of: an upper non-cohesive layer of silty sand to gravelly silty sand to gravelly silt and sand to sand and gravel, approximately 0.6 m to 4.1 m thick in all six boreholes; and a lower layer of cohesive fill approximately 1.5 m to 9.4 m thick comprised of clayey silt to silty clay, trace sand to with sand, trace to some gravel. Trace organics were encountered within the fill deposit at some borehole locations. Cobbles and /or boulders were inferred to be present within the layer of non-cohesive fill based on grinding of the augers as noted on the Record of Borehole C9-2, C9-3 and C9-5. It is noted that in addition to the potential presence of cobbles and/or boulders within the fill deposit, our recent experience with trenchless crossings of major MTO highways suggests that there may also be debris present within the fill and at the interface with the underlying native materials consisting of abandoned temporary works associated with the original culvert construction. This debris buried in the fill may consist of logs, stumps, and brush from the clearing and grubbing operations.

The SPT ‘N’-values measured within the non-cohesive embankment fill layer range from 5 blows to 40 blows per 0.3 m of penetration, indicating a generally loose to dense relative density. The SPT ‘N’-values measured in the cohesive layers of the embankment fill deposit range from 4 blows to 28 blows per 0.3 m of penetration, suggesting a soft to very stiff consistency.

The natural water content measured on seven samples of the non-cohesive embankment fill ranges between about 4 per cent and 17 per cent. The natural water content measured on seven samples of the cohesive embankment fill ranges between about 6 per cent and 25 per cent.

The results of grain size distribution tests completed on three samples of the non-cohesive embankment fill are shown on Figure B1 in Appendix B. The results of grain size distribution tests completed on nine samples of the cohesive embankment fill are shown on Figures B2A and B2B in Appendix B.

Atterberg limits tests were carried out on eleven samples of the cohesive embankment fill deposit and measured liquid limits ranging between about 14 per cent and 41 per cent, plastic limits ranging between about 10 per cent and 17 per cent and plasticity indices ranging between about 4 and 25 per cent. These test results, which are plotted on a plasticity chart on Figure B3 in Appendix B, indicate that the cohesive fill material is a clayey silt of low plasticity to silty clay of intermediate plasticity.

Atterberg limits tests were carried out on the fines portion of two samples of the non-cohesive embankment fill deposit and measured liquid limits of about 14 per cent and 15 per cent, plastic limits of about 11 per cent and 12 per cent and plasticity indices of about 3 per cent. These test results, which are plotted on a plasticity chart on Figure B4 in Appendix B, indicate that the fines portion of the silt and sand to silty sand embankment fill is comprised of silt of slight plasticity.

4.2.3 Clayey Silt to Silty Clay Till

A 1.6 m and 9.3 m thick deposit of clayey silt to silty clay till, trace to some sand, trace gravel was encountered in Boreholes C9-1 and C9-6, underlying the embankment fill at Elevation 86.3 m and 80.2 m, respectively.

The SPT ‘N’-values measured within clayey silt till to silty clay deposit range between 19 blows and 101 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

The natural water content measured on four samples of the silty clay to clayey silt till deposit range between about 11 per cent and 21 per cent.

The results of grain size distribution tests completed on two samples of the clayey silt till to silty clay from Borehole C9-1 are shown on Figure B5 in Appendix B.

Atterberg limits testing was carried out on three samples of the cohesive till deposit and measured liquid limits between about 26 and 34 per cent, plastic limits between about 12 and 14 per cent and plasticity indices between about 13 and 20 per cent. These test results, which are plotted on a plasticity chart on Figure B6 in Appendix B, indicate that the material tested is a clayey silt of low to silty clay of intermediate plasticity.

4.2.4 Silty Clay to Clay

A cohesive deposit consisting of silty clay to clay, trace to some sand, trace gravel, containing silty sand seams/pockets, was encountered in all of the boreholes advanced at this site underlying the till, fill or interlayer of silty sand (described below), at depths ranging between about 10.2 m and 11.7 m below ground surface (Elevation 84.8 m and 74.1 m) and the thickness of the deposit ranges between 1.1 m and 14.4 m to the sampled depth, but is 13.2 m and 13.7 m thick in the boreholes where it was fully penetrated. Boreholes C9-1, C9-2 and C9-6 were terminated within this deposit at between Elevations 69.1 m and 73.0 m.

The SPT ‘N’-values measured within the clayey silt to silty clay deposit range from 18 blows to 62 blows per 0.3 m of penetration, with three ‘N’-values of 79 blows for 0.13 m of penetration to 50 blows for 0.08 m of penetration, suggesting a very stiff to hard consistency.

The natural water content measured on samples of the silty clay to clay deposit range between about 14 per cent and 31 per cent.

The results of grain size distribution tests completed on eight samples of the silty clay to clay deposit are shown on Figures B7A and B7B in Appendix B.

Atterberg limits testing was carried out on eight samples of the cohesive deposit and measured liquid limits between about 33 per cent and 58 per cent, plastic limits between about 15 per cent and 23 per cent and plasticity indices between about 18 per cent and 35 per cent. These test results, which are plotted on a plasticity chart on Figure B8 in Appendix B, indicate that the material tested is a silty clay of intermediate plasticity to clay of high plasticity.

4.2.5 Silty Sand

A deposit comprised of silty sand, trace to some clay, trace gravel was encountered as interlayers between the embankment fill and silty clay deposit at Elevation 85.0 m in Borehole C9-2, between the silty clay till and silty clay deposit at Elevation 78.6 m in Borehole C9-6 and underlying the silty clay to clay deposit at about Elevation 71.1 m in Boreholes C9-3, C9-4 and C9-5. Shale fragments were encountered within this deposit in Borehole C9-5. The thickness of the deposit ranges between about 0.8 m and 4.5 m in the boreholes where it was fully penetrated.

The SPT 'N'-values measured within the silty sand deposit range between 32 blows to 84 blows per 0.3 m of penetration, with two 'N'-values of 50 blows per 0.02 m of penetration and 50 blows per 0.1 m of penetration, indicating a dense to very dense relative density.

The natural water content measured on samples of the silty sand ranged between about 14 per cent and 24 per cent.

The results of the grain size distribution tests completed on three samples of the silty sand deposit are shown on Figure B9 in Appendix B.

An Atterberg limits test was carried out on the fines portion of one sample of the silty sand deposit from Borehole C5-9 and measured a liquid limit of about 17 per cent, a plastic limit of about 13 per cent and a plasticity index of about 4 per cent. This test result, which is plotted on a plasticity chart on Figure B10 in Appendix B, indicate that the fines portion of the silty sand sample tested is a silt of low plasticity.

4.2.6 Sandy Silty Clay Till

A till deposit consisting of sandy silty clay, some gravel, was encountered in Boreholes C9-3 and C9-4 at depths of about 25.5 m and 24.7 m below ground surface (Elevation 69.5 m and 70.3 m, respectively). The thickness of the deposit is 0.6 m and 1.4 m in the respective borehole but the deposit was not fully penetrated in either of the boreholes to a depth of 26.1 m below ground surface (Elevation 68.9 m).

The SPT 'N'-values measured in the sandy silty clay till deposit are 50 blows per 0.05 m of penetration and 50 blows per 0.02 m of penetration, suggesting a hard consistency.

4.2.7 Groundwater Conditions

The water levels were measured in Borehole C9-1, C9-3, C9-4 and C9-5 upon completion of drilling operations and noted on the Record of Borehole sheets in Appendix A and summarised below. The water level was not recorded in Borehole C9-2 prior to backfilling.

A standpipe piezometer was installed in Borehole C9-6 to allow for future monitoring of the groundwater level. The water level observed in the open boreholes upon completion of drilling and the groundwater level measured in the piezometer is shown on the Record of Borehole sheets and summarized below:

Borehole	Depth to Water Level (m)	Groundwater Elevation (m)	Date of Measurement
C9-1	Dry	--	July 26, 2016 – open borehole
C9-3	9.1	85.9	September 14, 2016 – open borehole
C9-4	9.5	85.5	September 9, 2016 – open borehole
C9-5	10.7	84.3	September 13, 2016 – open borehole
C9-6	7.6	78.2	July 24, 2016 – Piezometer
	7.4	78.4	March 28, 2017 – Piezometer

The water level observed in the boreholes during and/or upon completion of drilling may not represent the longer-term, stabilized groundwater level at the site. 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 and periods of precipitation.

4.3 Analytical Testing of Soil Sample

Analytical testing was carried out on a composite soil sample constituted from the SPT samples recovered from near the culvert invert elevation in Borehole C9-4. The analytical parameters include conductivity / resistivity, pH sulphate and chloride to allow for the assessment of the potential for the soil to cause deterioration of concrete and corrosion of steel. The laboratory test results are included in Appendix C and are summarized below.

Parameter	Test Result
Soil Resistivity	880 ohm-cm
Soil Conductivity	1130 umho/cm
Sulphate Concentration	<20 ug/g
Chloride Concentration	570 ug/g
Soil pH	7.42

5.0 CLOSURE

Messrs. Pat Speirs and Michael Bentley, supervised the borehole investigation program. This report was prepared by Mr. Matthew Kelly, P.Eng., a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Senior Consultant and Designated MTO Foundations Contact with Golder conducted an independent quality control review of this report.

Report Signature Page

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MWK/JMAC/mck/rb

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REFERENCES

Chapman, L. J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

Karrow, P. F., and White, O. L., 1998. Urban Geology of Canadian Cities. Geological Association of Canada Special Paper No. 42. St. John's, Nfld.

Ontario Water Resources Act:

Ontario Regulation 372/9 Amendment to Ontario Regulation 903

ASTM

ASTM D1586-11 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

TABLES

Table 1: Summary of Existing Culvert Details

Culvert Location (City)	Culvert ID	Approximate Height of Embankment [1]	Existing Culvert			Approximate Invert Elevation [2]		Boreholes
			Type	Approximate Dimension	Approximate Length	North End of Culvert	South End of Culvert	
STA 11+817 (Oshawa)	C9	Up to about 11 m	Open Footing	4.6 m x 3.6 m	112.6 m	84.4 m	82.4 m	6 Boreholes (C9-1 to C9-6)

Notes: 1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.

2. Culvert invert elevations are estimated based on the top of culvert surveys and culvert dimensions provided by MTO.

DRAWINGS

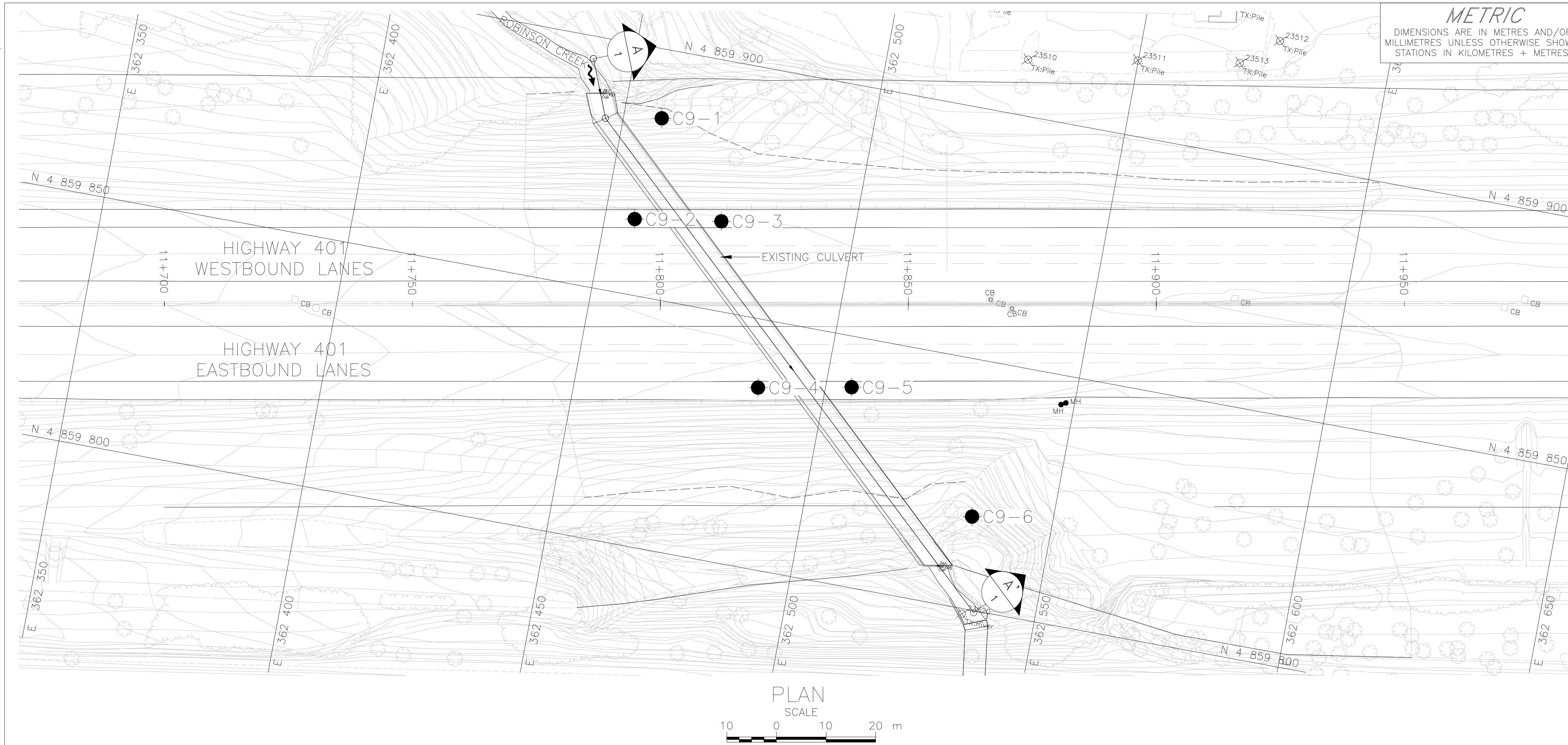
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

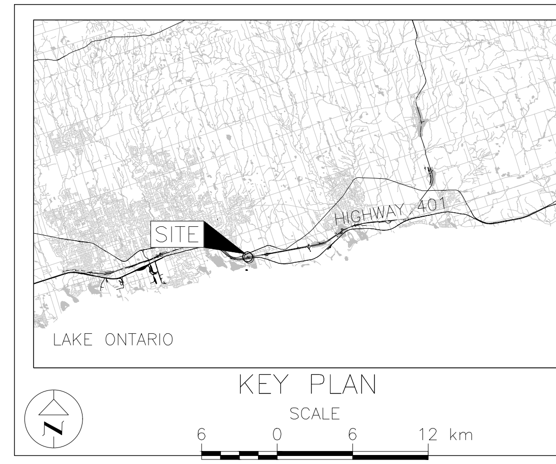
CONT No. 2017-2016
WP No. 2242-14-00

HIGHWAY 401
SITE 21-487/C
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 22

Golder Associates





KEY PLAN

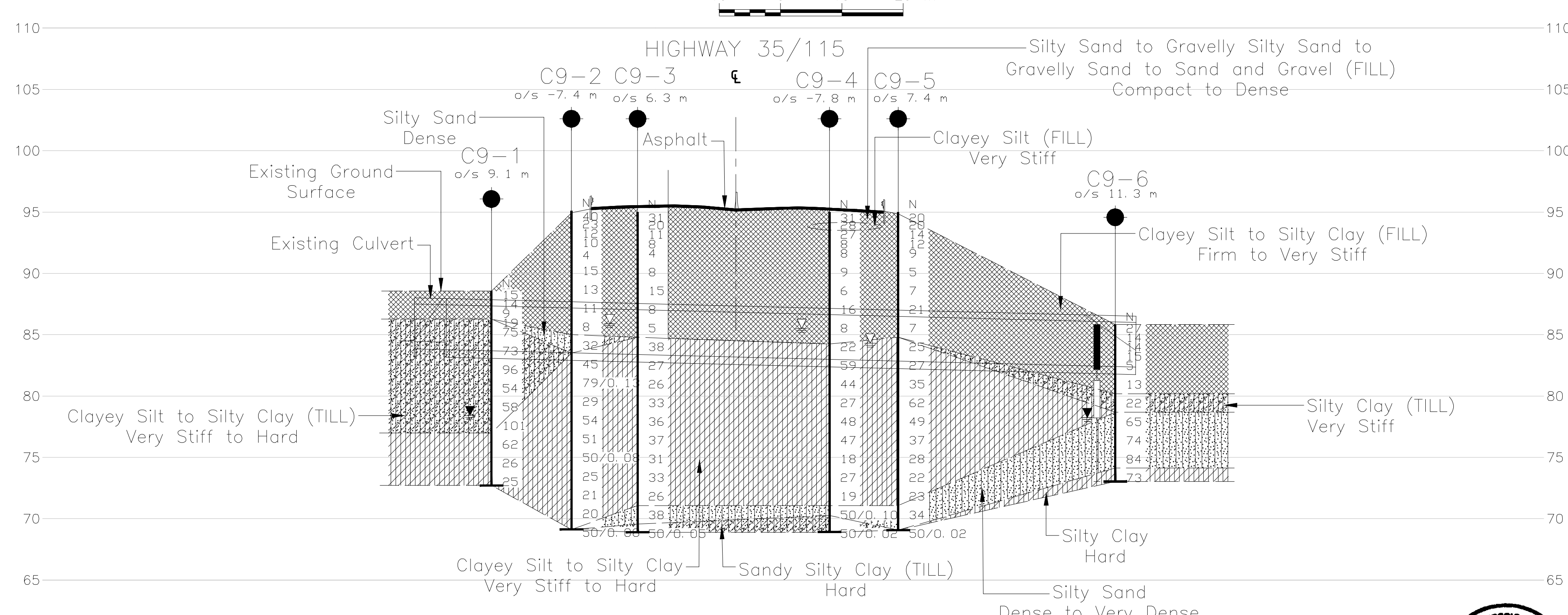
SCALE

6 0 6 12 km

LEGEND

- ● Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 J/blow)
- WL in piezometer, measured on Mar. 28, 2017
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C9-1	88.6	4859886.2	362457.6
C9-2	95.1	4859865.2	362456.0
C9-3	95.0	4859867.9	362473.2
C9-4	95.0	4859836.3	362486.6
C9-5	95.0	4859839.8	362505.2
C9-6	85.8	4859818.6	362533.8



A-A' 1
CULVERT C9
STA. 11+817

HORIZONTAL SCALE 10 0 10 20 m

VERTICAL SCALE 5 0 5 10 m

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 Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

Geographic Coordinates of Culvert: Latitude 43.875983; Longitude -78.781664.

REFERENCE

Base Plan and Contours provided in digital format by DM Wills, drawing file nos. 124208.dwg, received Jan. 20, 2016. Design Plan and Section provided in digital format by DM Wills, drawing file no. 4561-C9 GA.dwg, received Jan. 3, 2017.

NO.	DATE	BY	REVISION

Geocres No. 30M15-311

HWY. 401	PROJECT NO. 1540419	DIST.
SUBM'D. MCK	CHKD. MCK	DATE: 6/12/2017	SITE: 21-487/C
DRAWN: SMD	CHKD. MWK	APPD. JMAC	DWG. 1

APPENDIX A

Record of Boreholes

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
FoS	factor of safety

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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

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

(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 $= \sigma'_p / \sigma'_{vo}$

(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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2

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
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
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 cm^2 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) Non-Cohesive Soils

Density Index Relative Density	N 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	c_u, s_u 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

Per cent 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 (non-cohesive (cohesionless))	Sand and Gravel
	or With (cohesive)	Silty Clay with sand / Clayey Silt with sand

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RECORD OF BOREHOLE No C9-1

SHEET 1 OF 2 **METRIC**

PROJECT 1540419
G.W.P. 2242-14-00
DIST ___ HWY 401
DATUM Geodetic

LOCATION N 4859886.2; E 362457.6 MTM ZONE 10 (LAT. 43.876705; LONG. -78.782548)
BOREHOLE TYPE Mini-Mole 102 mm O.D. Solid Stem Augers (Manual Hammer)
DATE July 25 and 26, 2016

ORIGINATED BY PKS
COMPILED BY ZMR/MR
CHECKED BY MCK

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%) / LIMITS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
88.6	GROUND SURFACE						
0.0	Silty Sand, trace gravel (FILL) Compact Moist Brown	1	SS	15			
88.0 / 0.6	Clayey silt with sand, trace to some gravel, trace organics (FILL) Stiff Brown Moist	2	SS	14	88	w plotted with wP–wL range	10 39 34 17
		3	SS	9	87		
86.3 / 2.3	CLAYEY SILT to SILTY CLAY, trace to some sand, trace gravel (TILL) Very stiff to hard Brown Moist	4	SS	19	86	w plotted	
		5	SS	75	85		
	- Becoming grey below a depth of 4.6 m (Elev. 84.0 m)	6	SS	73	84	w plotted with wP–wL range	3 16 44 37
		7	SS	96	83, 82		
		8	SS	54	81	w plotted	
		9	SS	58	80, 79		
		10	SS	101	78	w plotted with wP–wL range	1 16 42 41
77.0 / 11.6	SILTY CLAY, trace sand, containing silty sand seams Very stiff to hard Grey Moist to wet	11	SS	62	77, 76		
		12	SS	26	75, 74	w plotted	

Continued Next Page

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT.

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

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RECORD OF BOREHOLE No C9-1

METRIC

PROJECT 1540419

G.W.P. 2242-14-00

LOCATION N 4859886.2; E 362457.6 MTM ZONE 10 (LAT. 43.876705; LONG. -78.782548)

ORIGINATED BY PKS

DIST ___ HWY 401

BOREHOLE TYPE Mini-Mole 102 mm O.D. Solid Stem Augers (Manual Hammer)

COMPILED BY ZMR/MR

DATUM Geodetic

DATE July 25 and 26, 2016

CHECKED BY MCK

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
72.7	SILTY CLAY, trace sand, containing silty sand seams Very stiff to hard Grey Moist to wet		13	SS	25		73				
15.9	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling.										

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$+^3, \times^3$: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No C9-2

SHEET 1 OF 2 **METRIC**

PROJECT 1540419

G.W.P. 2242-14-00 LOCATION N 4859865.2; E 362456.0 MTM ZONE 10 (LAT. 43.87652; LONG. -78.7826) ORIGINATED BY AJ

DIST HWY 401 BOREHOLE TYPE CME 75, 208 mm O.D., 108 mm I.D. Hollow Stem Augers COMPILED BY MR

DATUM Geodetic DATE December 7 and 8, 2016 CHECKED BY MWK

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
95.1	GROUND SURFACE					
0.0	ASPHALT					
0.2	Sand and gravel (FILL) Dense Brown Moist	1	SS	40		
94.3 / 0.8	Clayey silt to silty clay, trace sand to with sand, trace to some gravel, trace organics (FILL) Firm to very stiff Mottled brown to mottled grey/black Moist	2	SS	23		
		3	SS	12		
		4	SS	10		12 37 41 10
		5A	SS	4		
		5B				
		6	SS	15		2 22 44 32
	- Auger grinding at a depth of 5.5 m (Elev. 89.6 m)					
		7	SS	13		
		8	SS	11		
	- Auger grinding at a depth of 8.2 m (Elev. 86.9 m)					
		9	SS	8		0 22 55 23
85.0 / 10.1	Silty SAND Dense Mottled grey/dark grey Wet					
		10	SS	32		
83.5 / 11.6	SILTY CLAY, trace sand, trace gravel Very stiff to hard Grey Moist to wet					
		11	SS	45		
		12	SS	79/0.13		

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (95 to 81); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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

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RECORD OF BOREHOLE No C9-2

SHEET 2 OF 2 **METRIC**

PROJECT 1540419

G.W.P. 2242-14-00 LOCATION N 4859865.2; E 362456.0 MTM ZONE 10 (LAT. 43.87652; LONG. -78.7826) ORIGINATED BY AJ

DIST HWY 401 BOREHOLE TYPE CME 75, 208 mm O.D., 108 mm I.D. Hollow Stem Augers COMPILED BY MR

DATUM Geodetic DATE December 7 and 8, 2016 CHECKED BY MWK

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ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY, trace sand, trace gravel Very stiff to hard Grey Moist to wet				80		
		13	SS	29		w	0 2 40 58
					79		
		14	SS	54	78		
					77		
		15	SS	51		w	
					76		
		16	SS	50/0.08	75		
					74		
		17	SS	25		w_P – w – w_L (50)	0 4 29 67
					73		
		18	SS	21	72		
					71		
		19	SS	20		w	
	- 20 mm thick sand pocket encountered at a depth of 25.0 m below ground surface				70		
69.1 26.0	END OF BOREHOLE	20	SS	50/0.08			

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

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RECORD OF BOREHOLE No C9-3

SHEET 1 OF 2 **METRIC**

PROJECT 1540419

G.W.P. 2242-14-00

LOCATION N 4859867.9; E 362473.2 MTM ZONE 10 (LAT. 43.87654; LONG. -78.7824)

ORIGINATED BY MB

DIST HWY 401

BOREHOLE TYPE 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)

COMPILED BY SD

DATUM Geodetic

DATE September 13 and 14, 2016

CHECKED BY MCK

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 | PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
95.0	GROUND SURFACE									
0.0	ASPHALT									
0.2	Gravelly sand (FILL) Dense Brown Dry	1	SS	31						
94.2 / 0.8	Silty clay, with sand, trace gravel (FILL) Firm to very stiff Brown Moist to wet - Auger grinding at a depth of 1.8 m (Elev. 93.2 m)	2	SS	20	94					
		3	SS	11	93					
		4	SS	8						
		5	SS	4	92					
					91					
		6	SS	8	90	40	2	30	39	29
					89					
		7	SS	15	88					
87.8 / 7.2	Silty clay, some sand, trace gravel, organics and rootlets (FILL) Firm Brown Moist to wet	8	SS	8	87		1	16	52	31
					86					
		9	SS	5	85					
84.8 / 10.2	SILTY CLAY, trace to some sand, trace gravel Very stiff to hard Grey Moist to wet	10	SS	38	84					
					83					
		11	SS	27	82	44	0	1	35	64
		12	SS	26	81					

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$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No C9-3

SHEET 2 OF 2 **METRIC**

PROJECT 1540419
G.W.P. 2242-14-00
LOCATION N 4859867.9; E 362473.2 MTM ZONE 10 (LAT. 43.87654; LONG. -78.7824)
ORIGINATED BY MB
DIST HWY 401
BOREHOLE TYPE 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)
COMPILED BY SD
DATUM Geodetic
DATE September 13 and 14, 2016
CHECKED BY MCK

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY, trace to some sand, trace gravel; Very stiff to hard; Grey; Moist to wet	13	SS	33		wP–w–wL, 49	
					79		
		14	SS	36	78		
					77		
		15	SS	37		wP–w–wL	1 15 40 44
					76		
		16	SS	31	75		
					74		
		17	SS	33	73		
		18	SS	26	72		
71.1 / 23.9	Silty SAND, trace to some clay, trace gravel; Dense; Grey; Wet				71		
		19	SS	38	70	w	1 67 22 10
69.6 / 25.5	Sandy SILTY CLAY, some gravel (TILL); Hard; Grey; Moist						
68.9 / 26.1	- Auger grinding at a depth of 25.6 m (Elev. 69.4 m)	20	SS	50/0.05	69		

END OF BOREHOLE

NOTES:

1. Groundwater encountered during drilling at a depth of 9.1 m below ground surface. (Elev. 85.9 m)

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

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RECORD OF BOREHOLE No C9-4

SHEET 1 OF 2 **METRIC**

PROJECT 1540419
G.W.P. 2242-14-00
LOCATION N 4859836.3; E 362486.6 MTM ZONE 10 (LAT. 43.876245; LONG. -78.78219)
ORIGINATED BY MK
DIST HWY 401
BOREHOLE TYPE CME 75, 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)
COMPILED BY SZ/MR
DATUM Geodetic
DATE September 7 and 9, 2016
CHECKED BY MCK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
95.0	GROUND SURFACE					
0.0	ASPHALT (130 mm)					
0.1	Sand and gravel (FILL) Dense Brown Dry	1	SS	31		
94.1 0.9	Clayey silt, trace sand, some gravel (FILL) Very stiff Brown Moist	2	SS	28		
93.5 1.5	Sand and gravel, trace to some silt, trace clay (FILL) Compact Brown Dry	3	SS	27		45 47 6 2
92.6 2.4	Clayey silt, trace to some sand, trace to some gravel (FILL) Stiff Brown Moist to wet	4	SS	8		
		5	SS	8		
		6	SS	9		
89.4 5.6	Clayey silt, sandy to with sand, trace gravel, trace organics to a depth of 8.7 m (FILL) Firm to very stiff Brown Moist to wet	7	SS	6		1 38 41 20
		8	SS	16		
		9	SS	8	∇	3 25 46 26
84.3 10.7	SILTY CLAY, trace sand, trace gravel Very stiff to hard Grey Moist	10	SS	22		
		11	SS	59		
		12	SS	44		

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 10 20 30
UNIT WEIGHT γ kN/m³
ELEVATION SCALE: 94, 93, 92, 91, 90, 89, 88, 87, 86, 85, 84, 83, 82, 81

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

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RECORD OF BOREHOLE No C9-4

SHEET 2 OF 2 **METRIC**

PROJECT 1540419
G.W.P. 2242-14-00
LOCATION N 4859836.3; E 362486.6 MTM ZONE 10 (LAT. 43.876245; LONG. -78.78219)
ORIGINATED BY MK
DIST HWY 401
BOREHOLE TYPE CME 75, 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)
COMPILED BY SZ/MR
DATUM Geodetic
DATE September 7 and 9, 2016
CHECKED BY MCK

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILTY CLAY, trace sand, trace gravel Very stiff to hard Grey Moist	13	SS	27		○	0	1	33	66
					79					
		14	SS	48	78					
					77					
		15	SS	47		⊢○—⊣	1	13	37	49
					76					
		16	SS	18	75					
					74					
		17	SS	27	73					
		18	SS	19	72	○				
71.1 23.9	Silty SAND Very dense Grey Moist				71					
		19	SS	50/0.10		○				
70.3 24.7	Sandy SILTY CLAY, some gravel (TILL) Hard Grey Moist to wet - Auger grinding at a depth of 25.3 m (Elev. 69.7 m)				70					
68.9 26.1	END OF BOREHOLE	20	SS	50/0.02	69					

NOTE:

1. Water level in open borehole at a depth of 9.5 m below ground surface (Elev. 85.5 m) upon completion of drilling.

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

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RECORD OF BOREHOLE No C9-5

SHEET 1 OF 2 **METRIC**

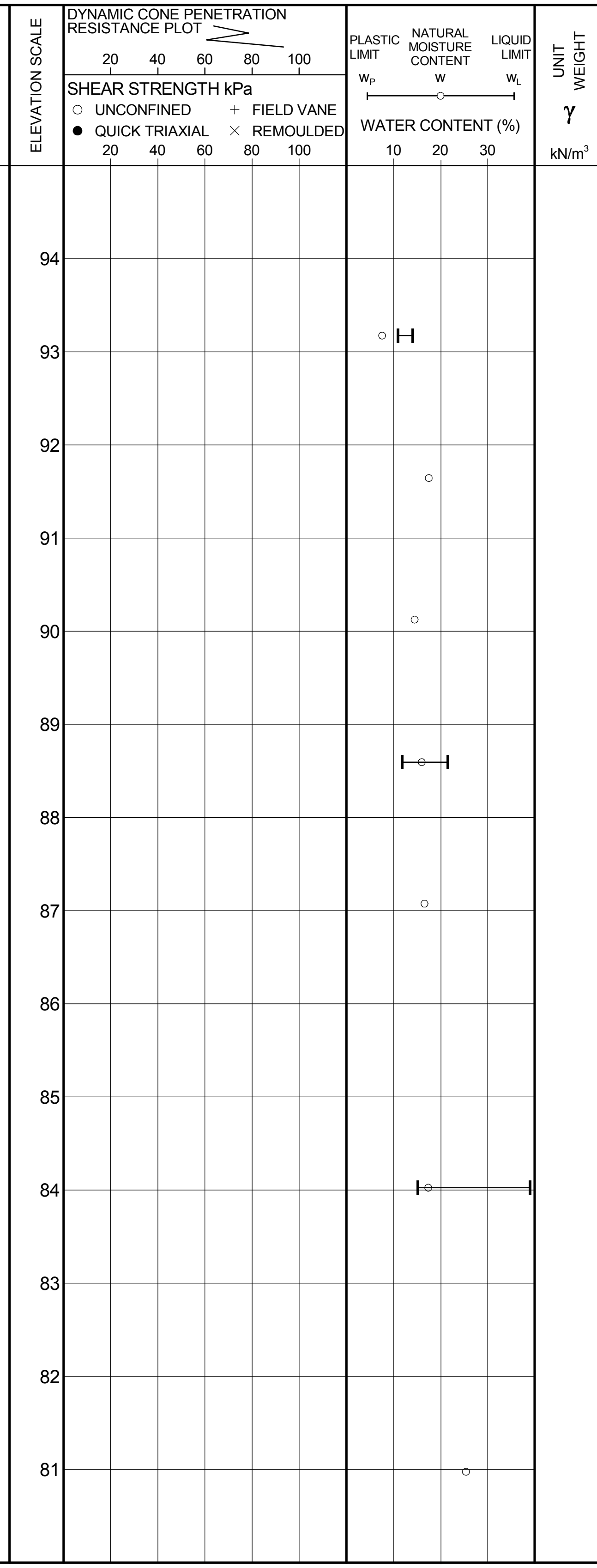
PROJECT: 1540419			
G.W.P.: 2242-14-00	LOCATION: N 4859839.8; E 362505.2 MTM ZONE 10 (LAT. 43.876275; LONG. -78.781959)	ORIGINATED BY: MB
DIST:	HWY: 401	BOREHOLE TYPE: CME 75, 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)	COMPILED BY: SD
DATUM: Geodetic	DATE: September 13 and 14, 2016	CHECKED BY: MCK

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
95.0	GROUND SURFACE
0.0	ASPHALT
0.2	Gravelly sand (FILL) Compact Brown Dry
94.2 / 0.8	Gravelly silty sand, trace to some clay (FILL) Compact Brown Moist - Auger grinding at a depth of 1.2 m (Elev. 93.8 m) - Auger grinding at a depth of 2.1 m (Elev. 92.9 m)
92.8 / 2.2	Clayey silt, trace sand to sandy (FILL) Firm to very stiff Brown Moist - Auger grinding at a depth of 6.9 m (Elev. 88.1 m)
84.8 / 10.2	Sandy SILTY CLAY, trace gravel Very stiff to hard Brown to grey Moist to wet
80.2 / 14.8	

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	20					
2	SS	20					
3	SS	14		27	39	26	8
4	SS	12					
5	SS	9					
6	SS	5					
7	SS	7		3	26	56	15
8	SS	21					
9	SS	7					
10	SS	25	∇	3	22	41	34
11	SS	27					
12	SS	35					



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

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RECORD OF BOREHOLE No C9-5

SHEET 2 OF 2

METRIC

PROJECT 1540419			
G.W.P. 2242-14-00	LOCATION	N 4859839.8; E 362505.2 MTM ZONE 10 (LAT. 43.876275; LONG. -78.781959)	ORIGINATED BY MB
DIST ___ HWY 401	BOREHOLE TYPE	CME 75, 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)	COMPILED BY SD
DATUM Geodetic	DATE	September 13 and 14, 2016	CHECKED BY MCK

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILTY CLAY to CLAY, trace to some sand Very stiff to hard Grey Moist to wet	13	SS	62						
					79					
		14	SS	49	78					
					77					
		15	SS	37	76					
		16	SS	28	75	58	0	1	30	69
					74					
		17	SS	22	73					
		18	SS	23	72					
71.1 23.9	Silty SAND, trace to some clay, trace gravel Dense Grey Wet				71					
		19	SS	34	70		1	65	23	11
69.1 25.9	- Containing shale fragments at a depth of 25.9 m below ground surface (Elev. 69.1 m) END OF BOREHOLE	20	SS	50/0.02						

NOTES:

1. Groundwater encountered during drilling at a depth of 10.7 m below ground surface (Elev. 84.3 m)

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

RECORD OF BOREHOLE No C9-6

SHEET 1 OF 1 METRIC

PROJECT 1540419
G.W.P. 2242-14-00
LOCATION N 4859818.6; E 362533.8 MTM ZONE 10 (LAT. 43.876091; LONG. -78.781608)
ORIGINATED BY PKS
DIST HWY 401
BOREHOLE TYPE Mini-Mole 102 mm O.D. Solid Stem Augers (Manual Hammer)
COMPILED BY ZMR/MR
DATUM Geodetic
DATE July 24, 2016
CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
85.8	GROUND SURFACE				
0.0	Silty sand, trace gravel, trace organics (FILL) Compact Brown Moist	1	SS	27	
		2	SS	14	
84.4 / 1.4	Gravelly silt and sand, trace organics, trace to some clay (FILL) Loose to compact Brown Moist	3	SS	14	
		4	SS	15	23 36 35 6
		5	SS	5	
81.7 / 4.1	Silty clay, some sand, trace gravel, trace organics (FILL) Stiff Brown Moist to wet	6	SS	13	
80.2 / 5.6	SILTY CLAY, trace sand, trace gravel (TILL) Very stiff Grey Moist	7	SS	22	
78.6 / 7.2	Silty SAND Very dense Grey Wet	8	SS	65	0 69 27 4
		9	SS	74	
		10	SS	84	
74.1 / 11.7	SILTY CLAY, trace sand Hard Grey Moist	11	SS	73	
73.0 / 12.8	END OF BOREHOLE				

Elevation scale: 85, 84, 83, 82, 81, 80, 79, 78, 77, 76, 75, 74

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

NOTES:
1. Borehole caved to a depth of 7.6 m upon completion of drilling.

2. Water level measured in piezometer:

Date	Depth (m)	Elev. (m)
24/07/16	7.6	78.2
28/03/17	7.4	78.4

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

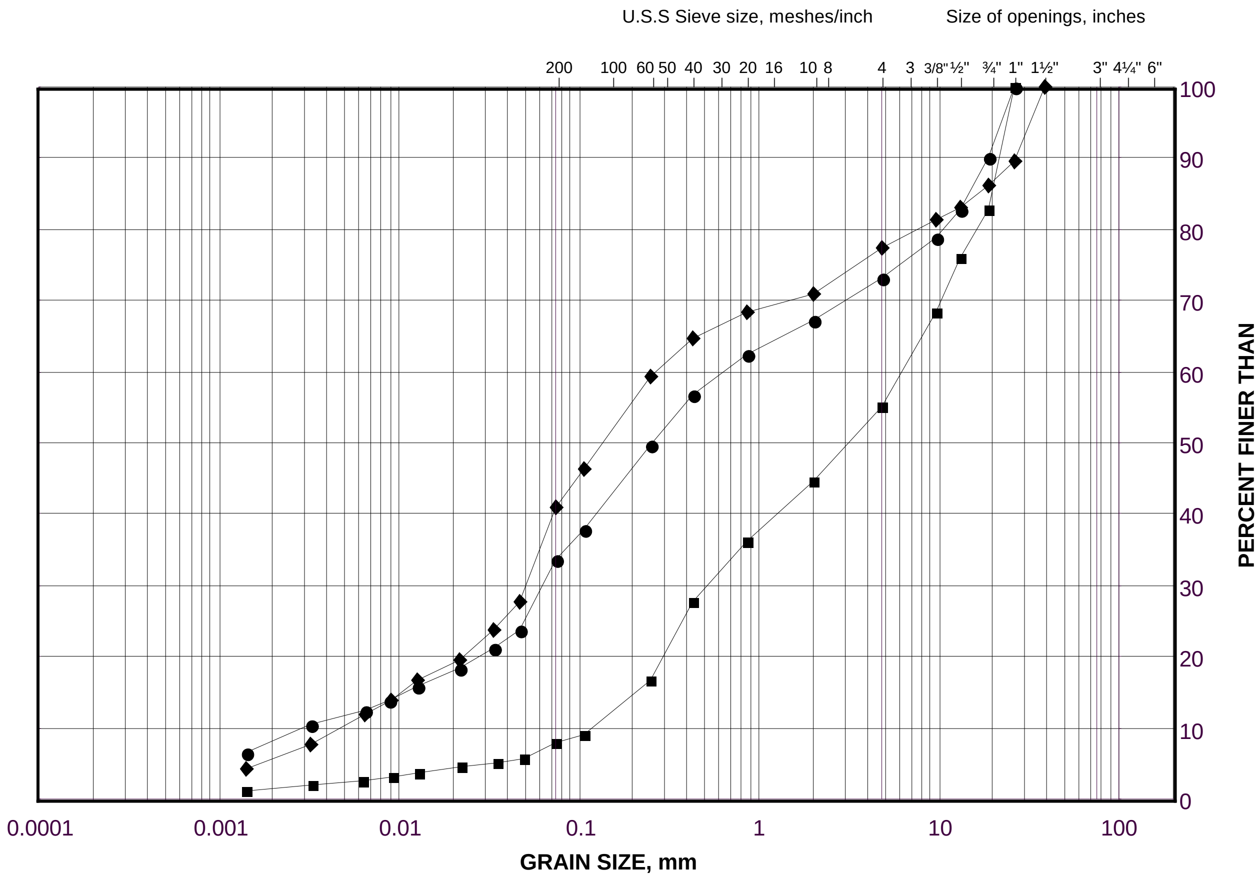
APPENDIX B

Laboratory Results

GRAIN SIZE DISTRIBUTION

Gravelly Silt and Sand to Sand and Gravel (Fill)

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-5	3	93.2
■	C9-4	3	93.2
◆	C9-6	4	83.2

Project Number: 1540419

Checked By: MWK

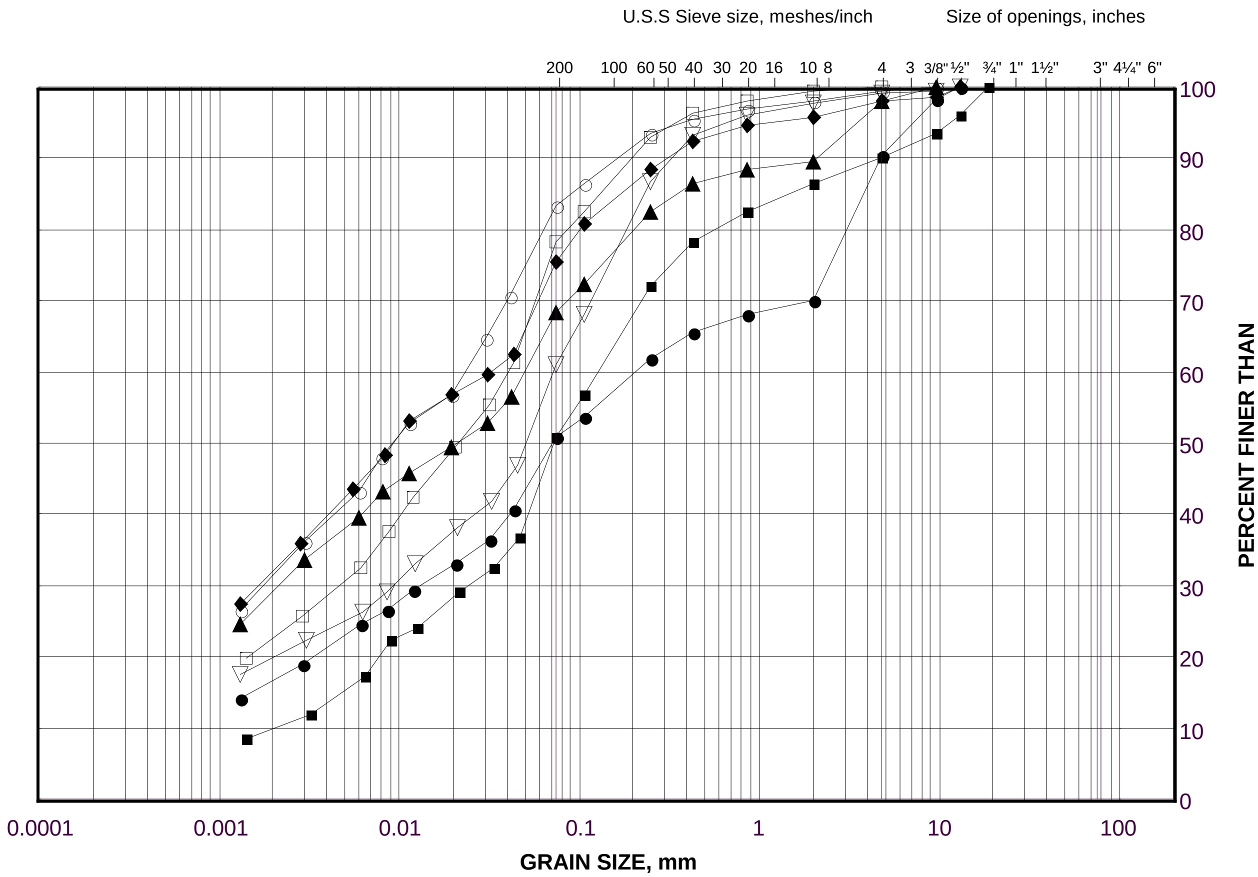
Golder Associates

Date: 31-Jan-17

GRAIN SIZE DISTRIBUTION

Clayey Silt to Silty Clay with Sand (Fill)

FIGURE B2A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-1	2	87.5
■	C9-2	4	92.5
◆	C9-2	6	90.2
▲	C9-3	6	90.1
▽	C9-4	7	88.6
❍	C9-3	8	87.1
□	C9-2	9	85.6

Project Number: 1540419

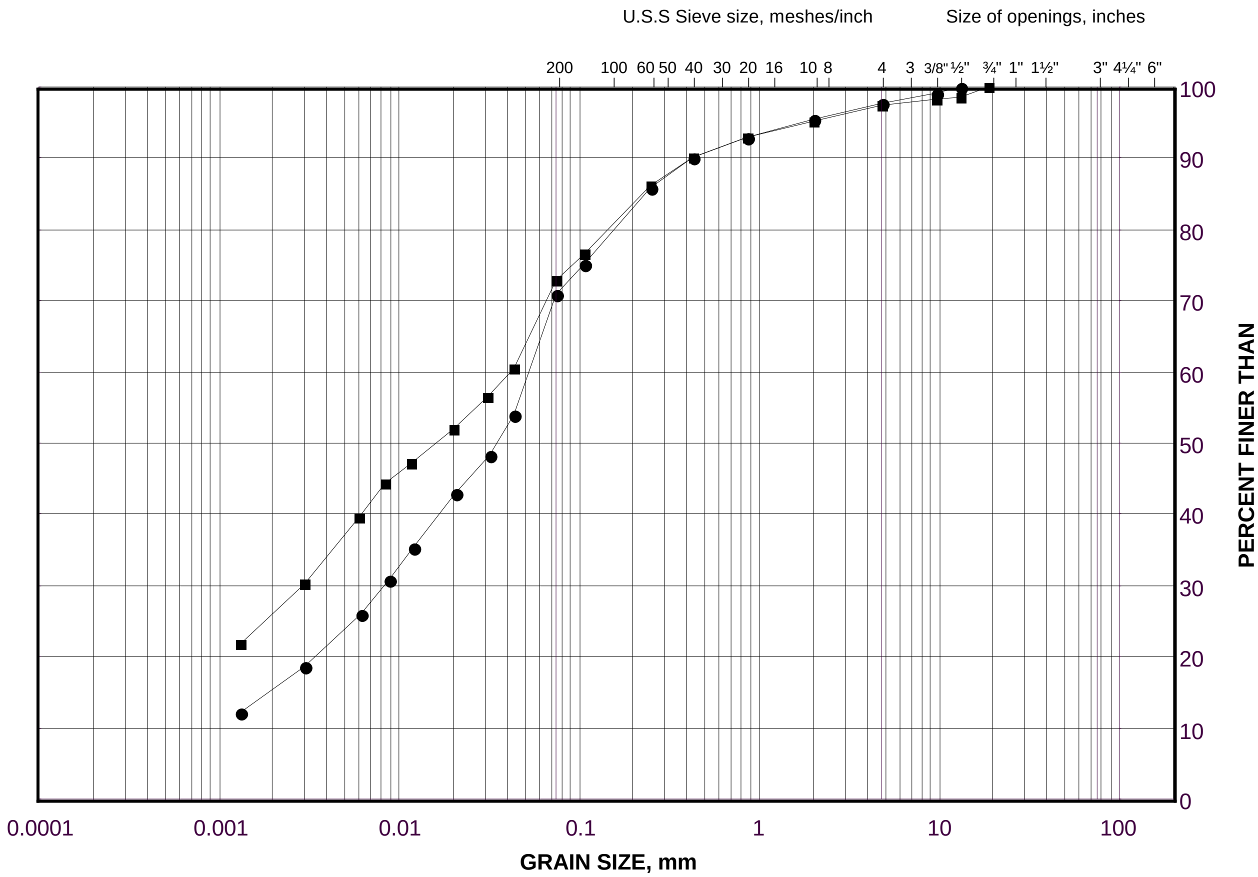
Checked By: MWK

Golder Associates

Date: 31-Jan-17

GRAIN SIZE DISTRIBUTION
Clayey Silt (Fill)

FIGURE B2B



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

LEGEND

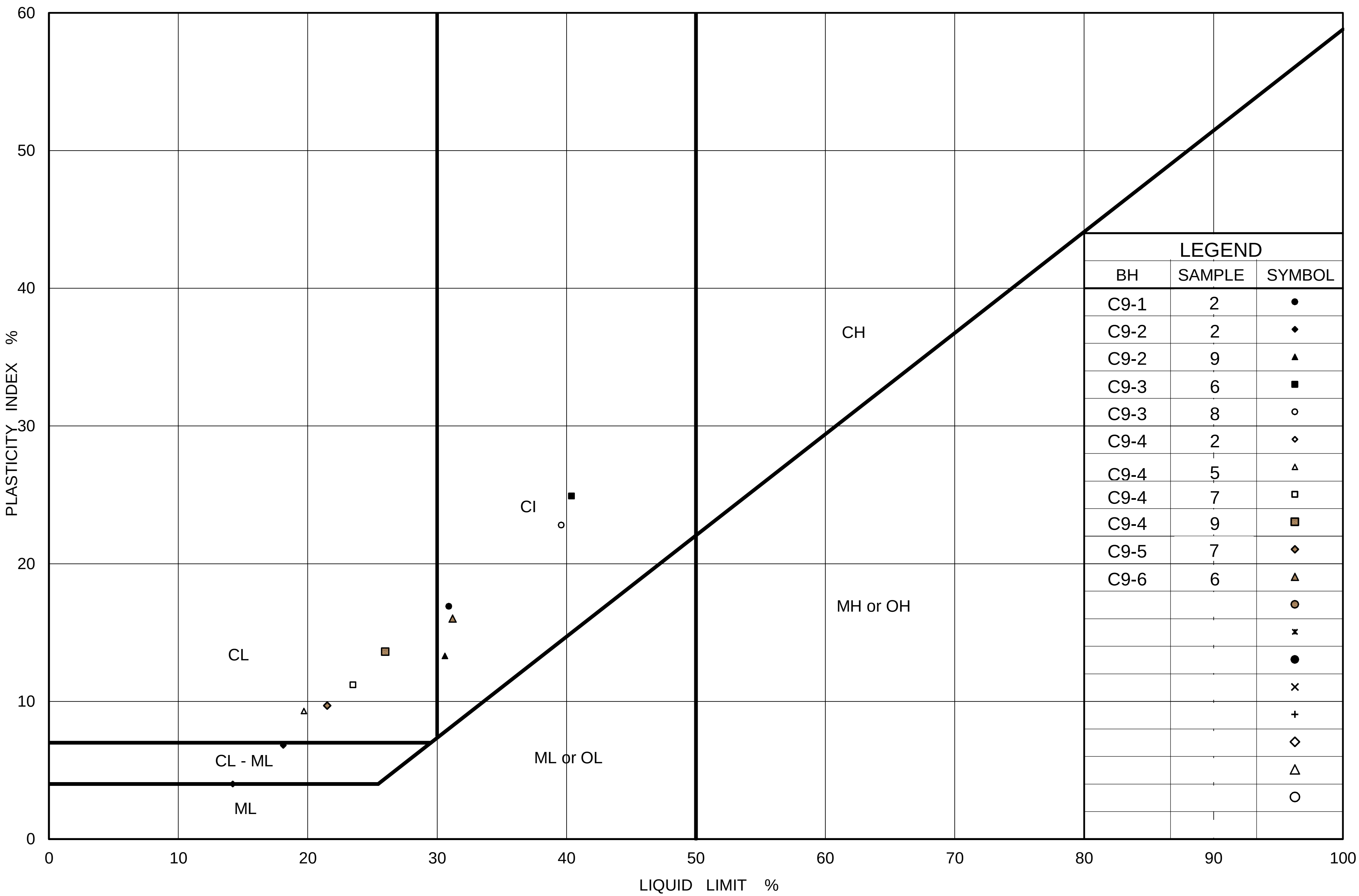
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-5	7	88.6
■	C9-4	9	85.5

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 31-Jan-17



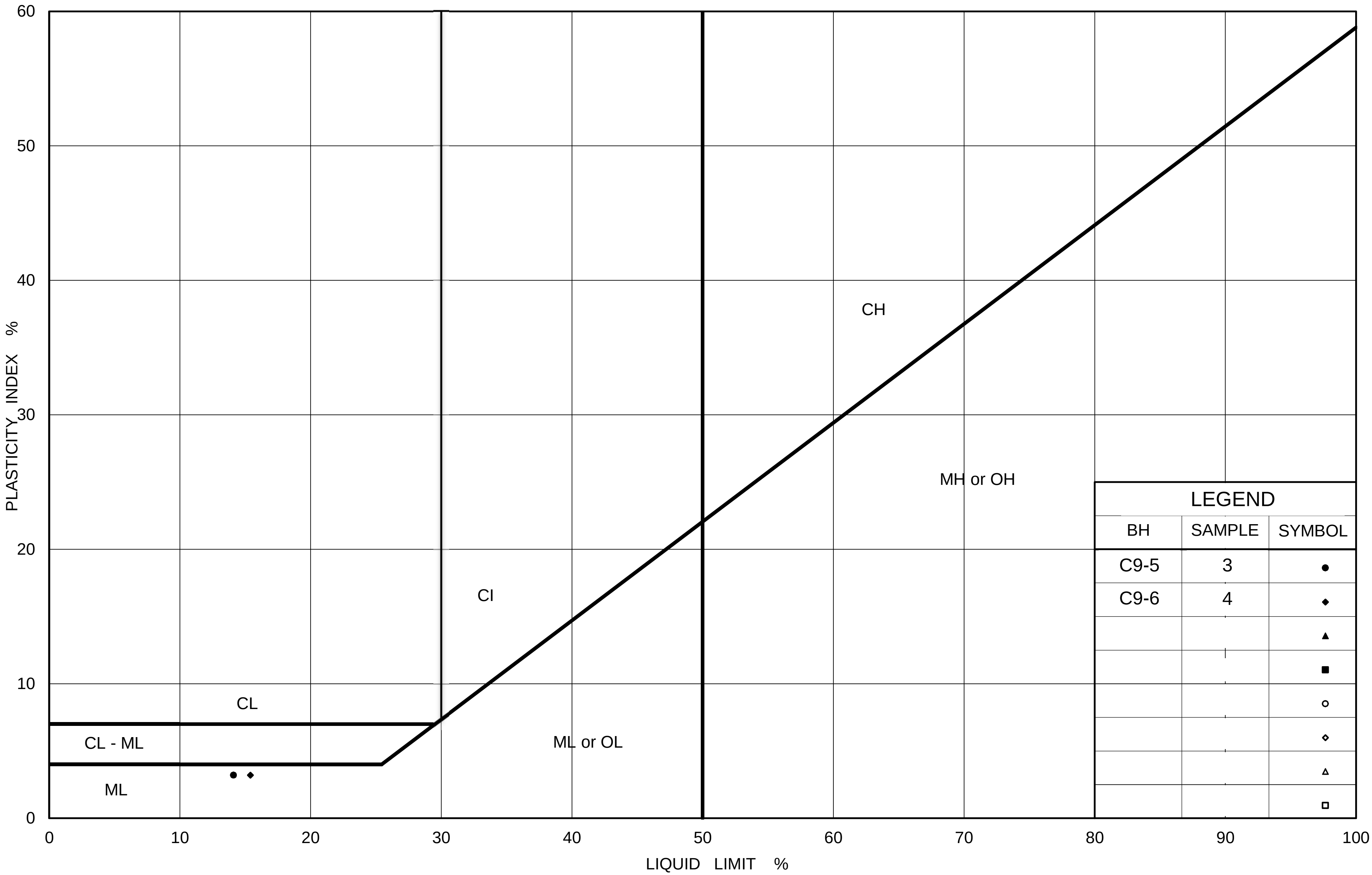
Golder Associates

PLASTICITY CHART
Clayey silt to silty clay (Fill)

Figure No. B3

Project No. 1540419

Checked By: MWK



PLASTICITY CHART
Silt and Sand to Silty Sand (Fill)

Figure No. B4

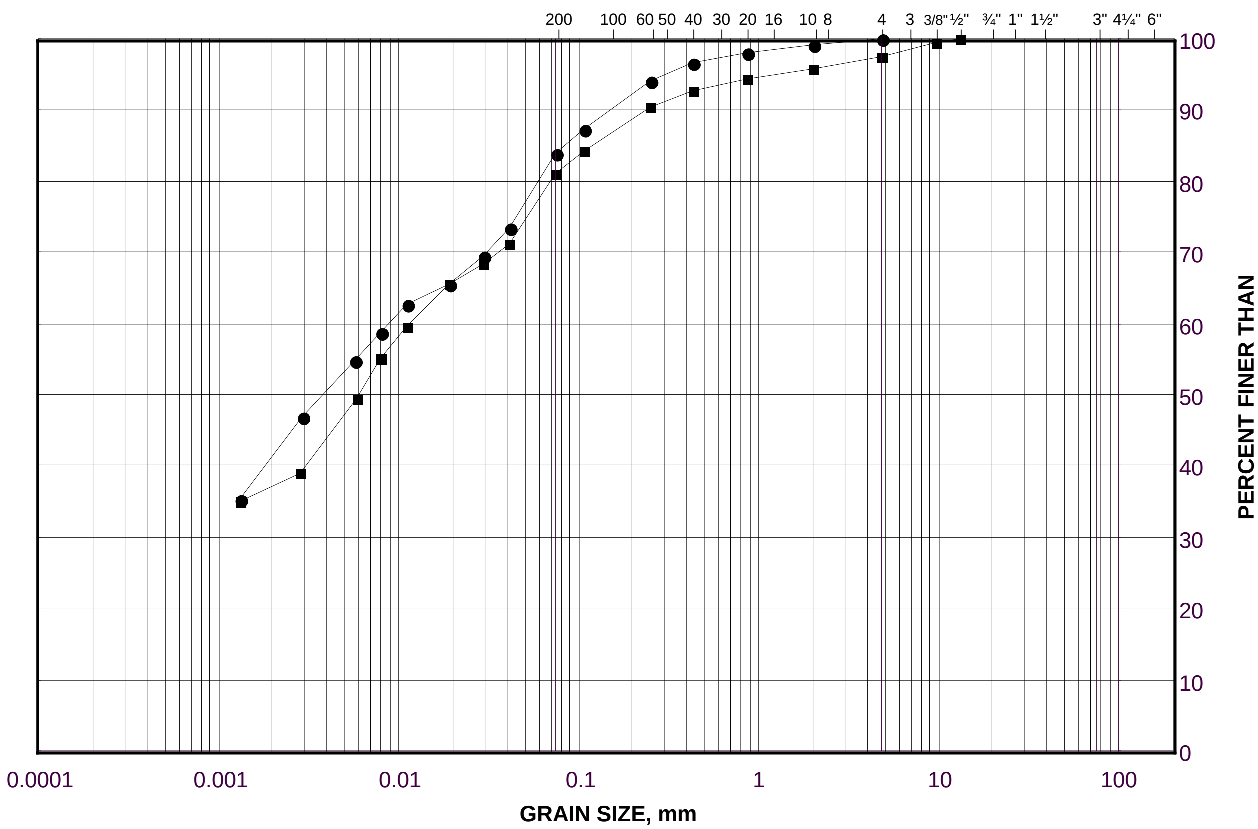
Project No. 1540419

Checked By: MWK

GRAIN SIZE DISTRIBUTION

Clayey Silt to Silty Clay (Till)

FIGURE B5



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

LEGEND

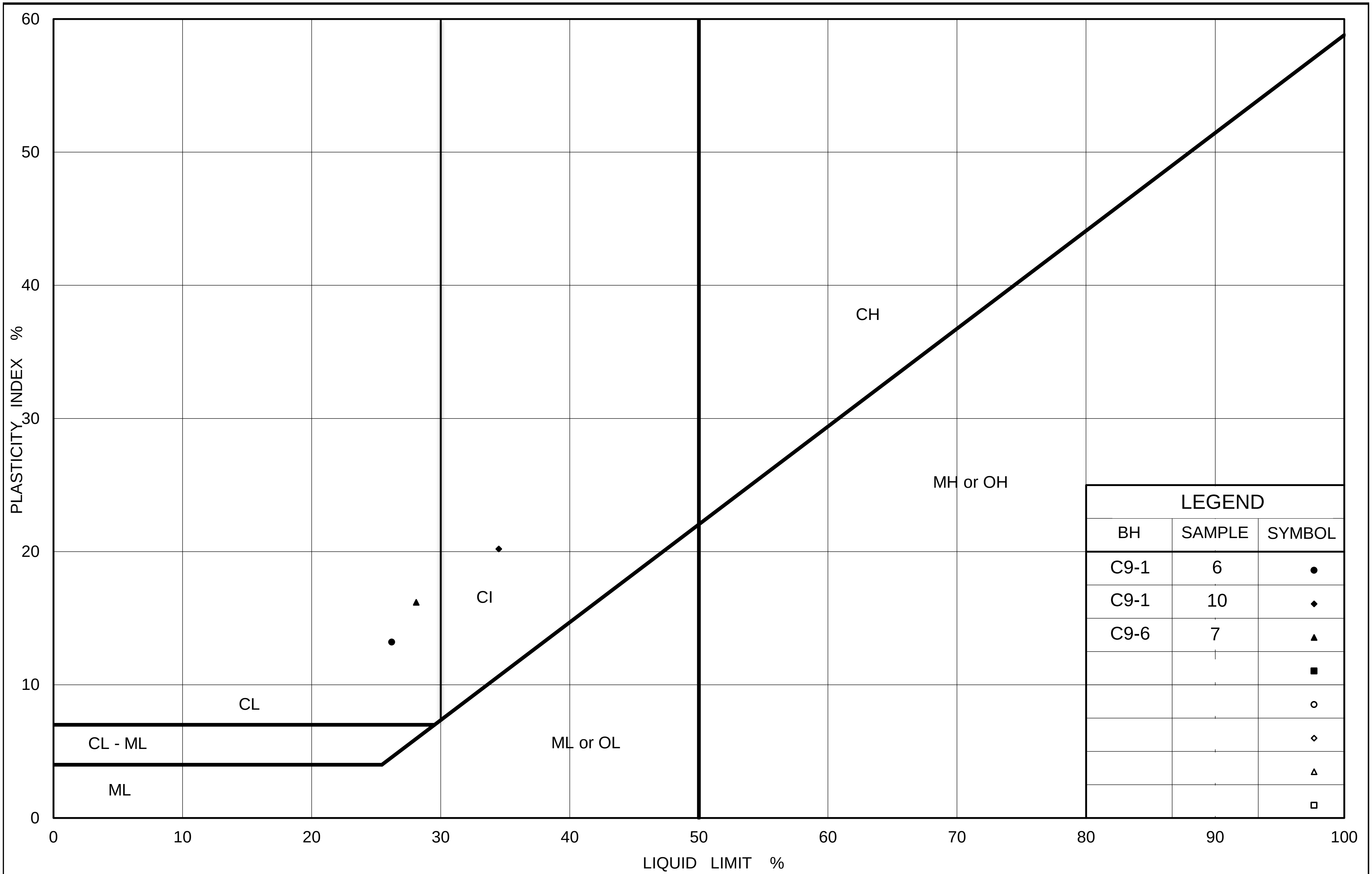
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-1	10	77.5
■	C9-1	6	83.7

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 31-Jan-17

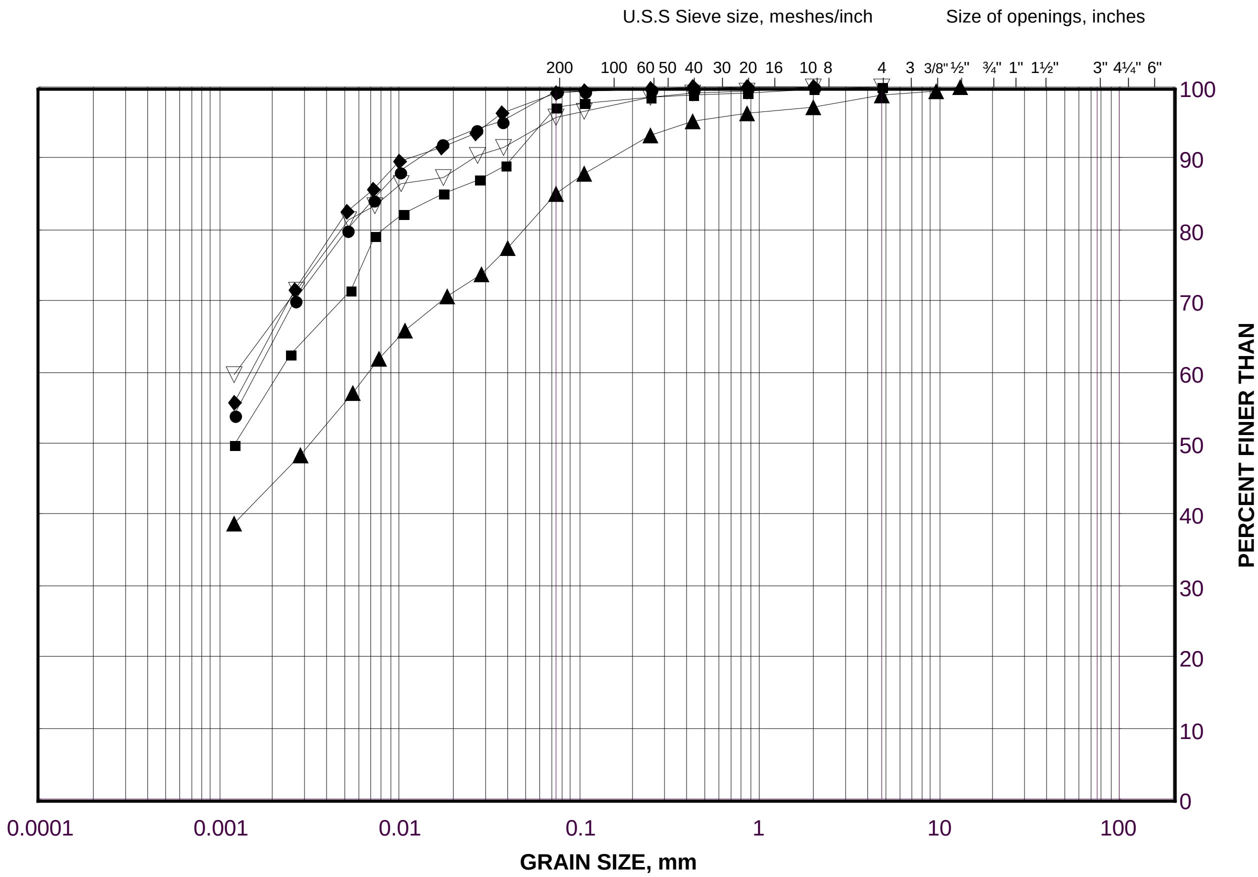


Golder Associates	PLASTICITY CHART Clayey Silt to Silty Clay (Till)	Figure No. B6 Project No. 1540419 Checked By: MWK

GRAIN SIZE DISTRIBUTION

Silty Clay

FIGURE B7A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-3	11	82.5
■	C9-2	13	79.5
◆	C9-4	13	79.5
▲	C9-3	15	76.4
▽	C9-2	17	73.5

Project Number: 1540419

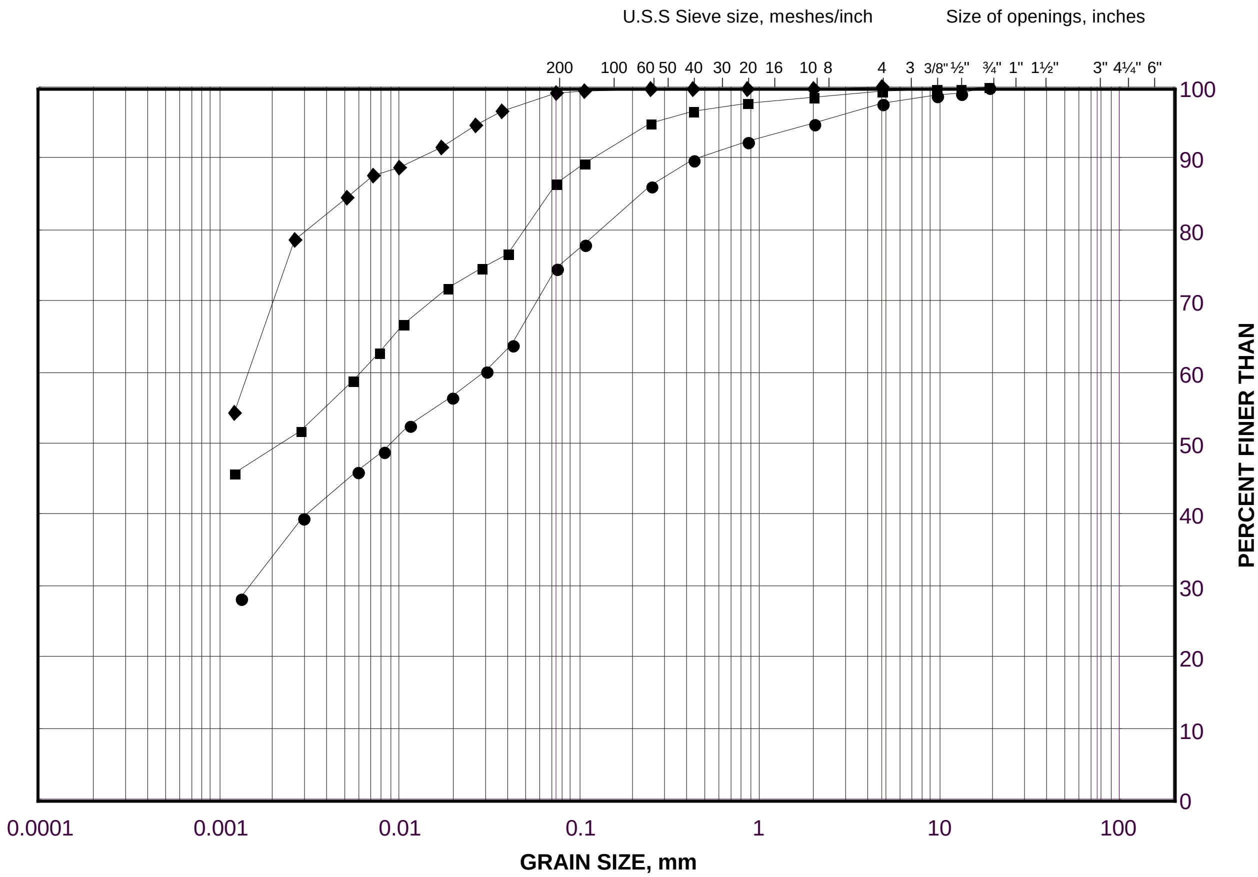
Checked By: MWK

Golder Associates

Date: 31-Jan-17

GRAIN SIZE DISTRIBUTION
Silty Clay to Clay

FIGURE B7B



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

LEGEND

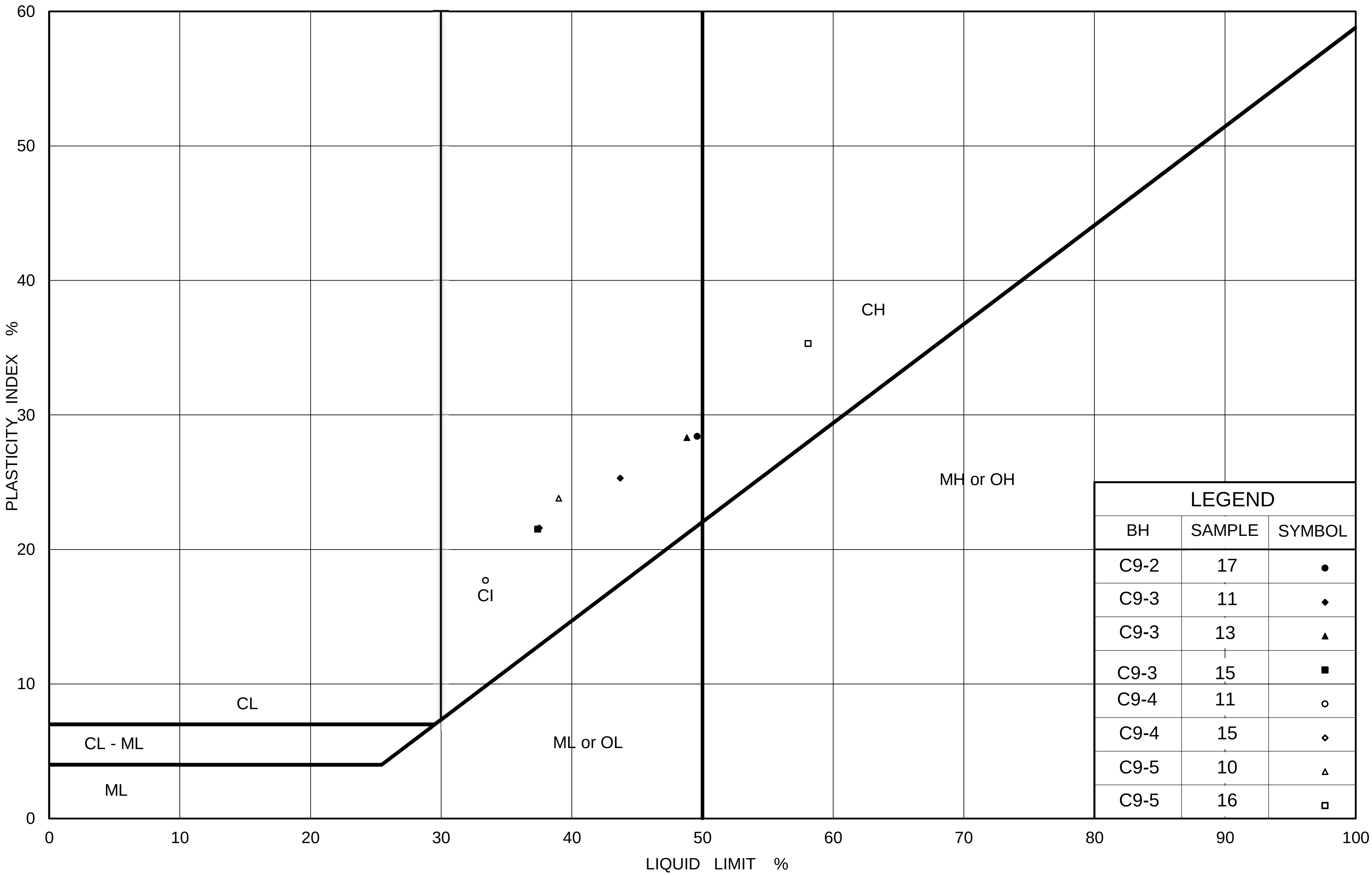
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-5	10	84.0
■	C9-4	15	76.4
◆	C9-5	16	74.9

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 31-Jan-17



Golder Associates

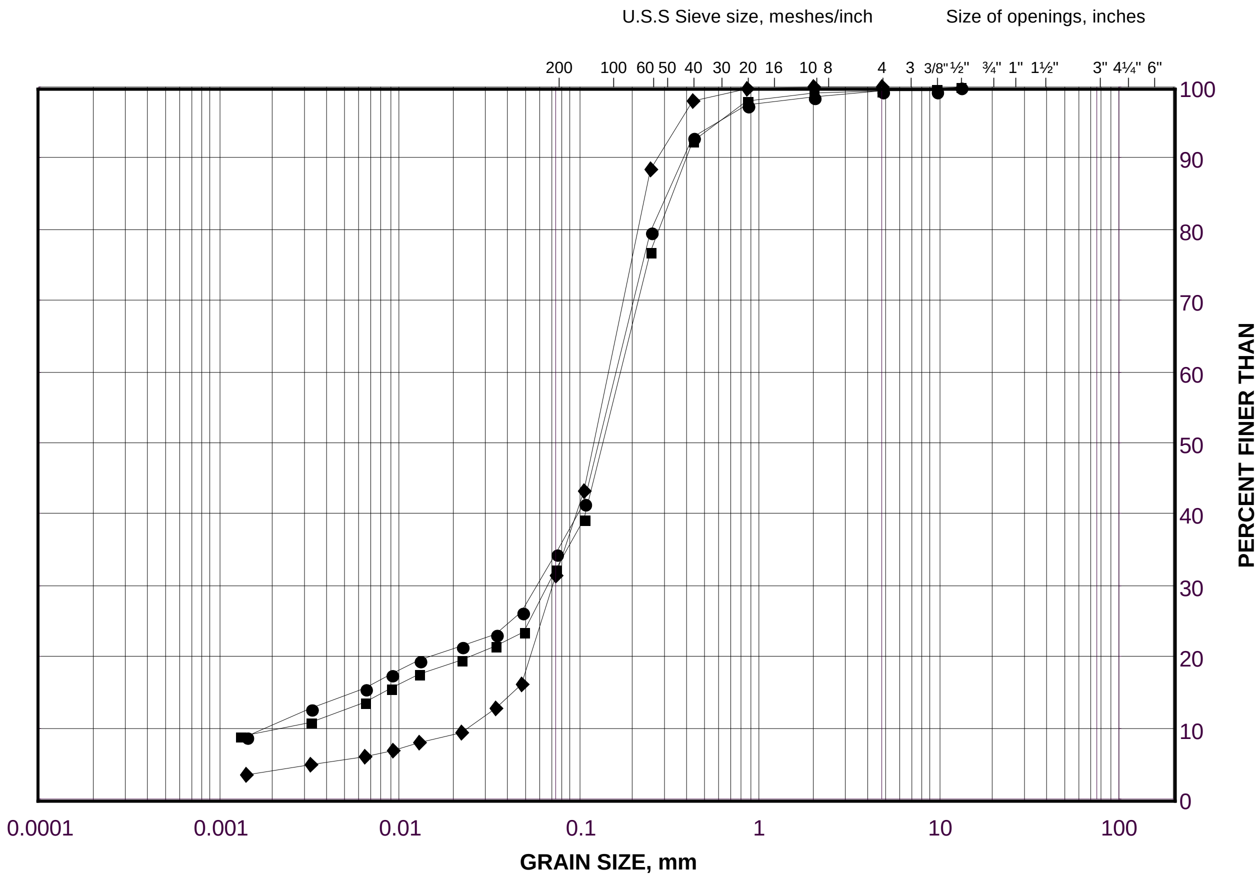
PLASTICITY CHART
Silty Clay to Clay

Figure No. B8
Project No. 1540419
Checked By: MWK

GRAIN SIZE DISTRIBUTION

Silty Sand

FIGURE B9



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

LEGEND

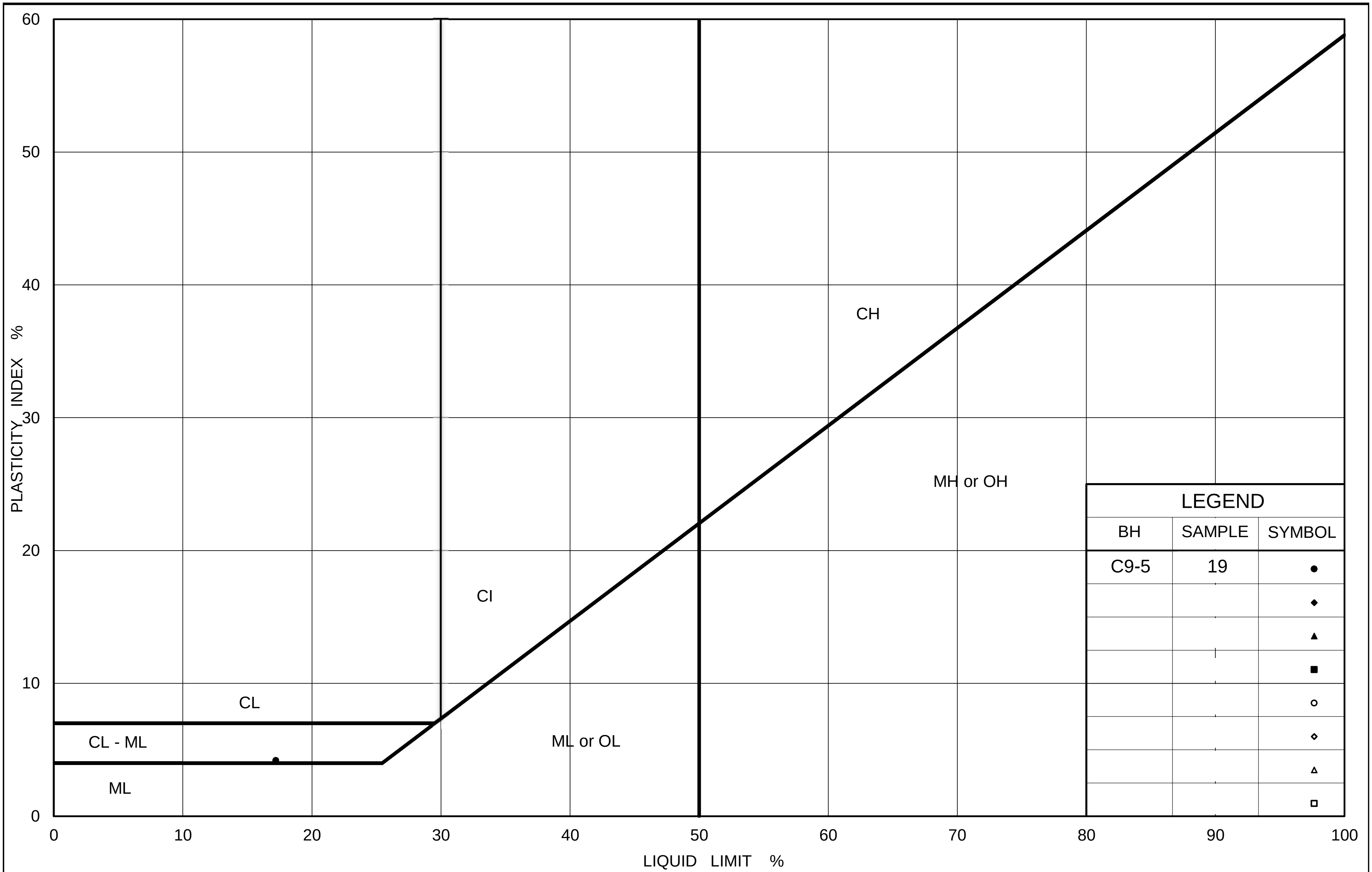
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C9-5	19	70.3
■	C9-3	19	70.3
◆	C9-6	8	77.9

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 31-Jan-17



Golder Associates	**PLASTICITY CHART** Silty Sand

Figure No. B10

Project No. 1540419

Checked By: MWK

APPENDIX C

Analytical Test Results

Maxxam
A Bureau Veritas Group Company

Your Project #: 1540419
Your C.O.C. #: 573330-01-01

Attention:Matt Kelly

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2016/09/29
Report #: R4184963
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6K5174
Received: 2016/09/23, 12:57

Sample Matrix: Soil
Samples Received: 5

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	5	N/A	2016/09/29	CAM SOP-00463	EPA 325.2 m
Conductivity	5	N/A	2016/09/29	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	5	2016/09/28	2016/09/28	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	5	2016/09/23	2016/09/29	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	5	N/A	2016/09/29	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics has performed all analytical testing herein in accordance with ISO 17025 and the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. All methodologies comply with this document and are validated for use in the laboratory. The methods and techniques employed in this analysis conform to the performance criteria (detection limits, accuracy and precision) as outlined in the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act.

Maxxam Analytics is accredited for all specific parameters as required by Ontario Regulation 153/04. Maxxam Analytics is limited in liability to the actual cost of analysis unless otherwise agreed in writing. There is no other warranty expressed or implied. Samples will be retained at Maxxam Analytics for three weeks from receipt of data or as per contract.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: EGitej@maxxam.ca
Phone# (905)817-5829
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam Job #: B6K5174
Report Date: 2016/09/29

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

RESULTS OF ANALYSES OF SOIL

Maxxam ID		DCX431	DCX432	DCX433	DCX434	DCX435		
Sampling Date		2016/08/23 10:00	2016/08/27 13:00	2016/08/28 13:00	2016/08/31 11:00	2016/09/08 02:00		
COC Number		573330-01-01	573330-01-01	573330-01-01	573330-01-01	573330-01-01		
	UNITS	**C1**	**C2**	**C3**	**C4**	**C9**	**RDL**	**QC Batch**
Calculated Parameters								
Resistivity	ohm-cm	1800	1900	1300	1500	880		4673817
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	190	280	410	360	570	20	4681464
Conductivity	umho/cm	557	540	798	687	1130	2	4681504
Available (CaCl2) pH	pH	7.57	7.77	7.63	7.61	7.42		4679490
Soluble (20:1) Sulphate (SO4)	ug/g	200	26	<20	<20	<20	20	4681465

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Maxxam Job #: B6K5174
Report Date: 2016/09/29

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

TEST SUMMARY

Maxxam ID: DCX431 **Collected:** 2016/08/23
Sample ID: C1 **Shipped:**
Matrix: Soil **Received:** 2016/09/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4681464	N/A	2016/09/29	Alina Dobreanu
Conductivity	AT	4681504	N/A	2016/09/29	Neil Dassanayake
pH CaCl2 EXTRACT	AT	4679490	2016/09/28	2016/09/28	Neil Dassanayake
Resistivity of Soil		4673817	2016/09/29	2016/09/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4681465	N/A	2016/09/29	Alina Dobreanu

Maxxam ID: DCX432 **Collected:** 2016/08/27
Sample ID: C2 **Shipped:**
Matrix: Soil **Received:** 2016/09/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4681464	N/A	2016/09/29	Alina Dobreanu
Conductivity	AT	4681504	N/A	2016/09/29	Neil Dassanayake
pH CaCl2 EXTRACT	AT	4679490	2016/09/28	2016/09/28	Neil Dassanayake
Resistivity of Soil		4673817	2016/09/29	2016/09/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4681465	N/A	2016/09/29	Alina Dobreanu

Maxxam ID: DCX433 **Collected:** 2016/08/28
Sample ID: C3 **Shipped:**
Matrix: Soil **Received:** 2016/09/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4681464	N/A	2016/09/29	Alina Dobreanu
Conductivity	AT	4681504	N/A	2016/09/29	Neil Dassanayake
pH CaCl2 EXTRACT	AT	4679490	2016/09/28	2016/09/28	Neil Dassanayake
Resistivity of Soil		4673817	2016/09/29	2016/09/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4681465	N/A	2016/09/29	Alina Dobreanu

Maxxam ID: DCX434 **Collected:** 2016/08/31
Sample ID: C4 **Shipped:**
Matrix: Soil **Received:** 2016/09/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4681464	N/A	2016/09/29	Alina Dobreanu
Conductivity	AT	4681504	N/A	2016/09/29	Neil Dassanayake
pH CaCl2 EXTRACT	AT	4679490	2016/09/28	2016/09/28	Neil Dassanayake
Resistivity of Soil		4673817	2016/09/29	2016/09/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4681465	N/A	2016/09/29	Alina Dobreanu

Maxxam ID: DCX435 **Collected:** 2016/09/08
Sample ID: C9 **Shipped:**
Matrix: Soil **Received:** 2016/09/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4681464	N/A	2016/09/29	Alina Dobreanu
Conductivity	AT	4681504	N/A	2016/09/29	Neil Dassanayake

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TEST SUMMARY

Maxxam ID: DCX435
Sample ID: C9
Matrix: Soil

Collected: 2016/09/08
Shipped:
Received: 2016/09/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	4679490	2016/09/28	2016/09/28	Neil Dassanayake
Resistivity of Soil		4673817	2016/09/29	2016/09/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4681465	N/A	2016/09/29	Alina Dobreanu

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.7°C

Results relate only to the items tested.

Maxxam Job #: B6K5174
Report Date: 2016/09/29

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4679490	Available (CaCl2) pH	2016/09/28			99	97 - 103			0.48	N/A
4681464	Soluble (20:1) Chloride (Cl)	2016/09/29	NC	70 - 130	109	70 - 130	<20	ug/g	NC	35
4681465	Soluble (20:1) Sulphate (SO4)	2016/09/29	NC	70 - 130	107	70 - 130	<20	ug/g	NC	35
4681504	Conductivity	2016/09/29			99	90 - 110	<2	umho/cm	2.9	10

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

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VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Cristina Carriere, Scientific Services

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

23-Sep-16 12:57
Ema Gitej
B6K5174
JFU ENV-107

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Page of

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:	
Company Name:	#1326 Golder Associates Ltd	Company Name:	Golder Associates Ltd	Quotation #:	B63104
Attention:	Central Acct:1112, 1113, 1118	Attention:	Matt Kelly / Madison Kennedy	P.O. #:	
Address:	6925 Century Ave Suite 100	Address:		Project:	1540419
	Mississauga ON L5N 7K2			Project Name:	
Tel:	(905) 567-4444 Fax: (905) 567-6561	Tel:	Fax:	Site #:	
Email:	Catherine_Guiao@golder.com, Rachel_Benjamin@gol	Email:	Matthew_Kelly@golder.com, MadKennedy@golder.com	Sampled By:	

Only:
Bottle Order #: 573330
COC #: C#573330-01-01
Project Manager: Ema Gitej

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011): ☐ Table 1 ☐ Res/Park ☐ Medium/Fine ☐ Table 2 ☐ Ind/Comm ☐ Coarse ☐ Table 3 ☐ Agri/Other ☐ For RSC ☐ Table ___

Other Regulations: ☐ CCME ☐ Sanitary Sewer Bylaw ☐ Reg 558 ☐ Storm Sewer Bylaw ☐ MISA Municipality ___ ☐ PWQO ☐ Other ___

Special Instructions

Include Criteria on Certificate of Analysis (Y/N)? ___

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects

Regular (Standard) TAT: ☒
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: ___ Time Required: ___
Rush Confirmation Number: ___ *(call lab for #)*

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered (please circle):	Metals / Hg / Cr VI	Corrosivity pkg (Cl, SO4, EC, Resistivity, pH)										# of Bottles	Comments
1		C1	2016/08/23	10:00am	Soil			X										1	
2		C2	2016/08/27	1:00pm	Soil			X										1	
3		C3	2016/08/28	1:00pm	Soil			X										1	
4		C4	2016/08/31	11:00am	Soil			X										1	
5		C9	2016/09/08	2:00am	Soil			X										1	
6																			
7																			
8																			
9																			
10																			

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
[signature] Madison Kennedy	16/09/23	12:57	Tanvir [signature] TANVIRSTAN	2016/09/23	12:57	

Laboratory Use Only

Time Sensitive	Temperature (°C) on Receipt	Custody Seal	Yes	No
	7/6/7	Present		✓
		Intact		✓

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

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