



Foundation Investigation and Design Report

Temporary Protection Systems, Humber River Culvert Rehabilitation, Site 24-554/C, Highway 9, County of Simcoe, Ontario, WP 2207-14-00

Submitted to:

AECOM Canada

300 Water Street
Whitby, Ontario
L1N 9J2

Submitted by:

Golder Associates Ltd.

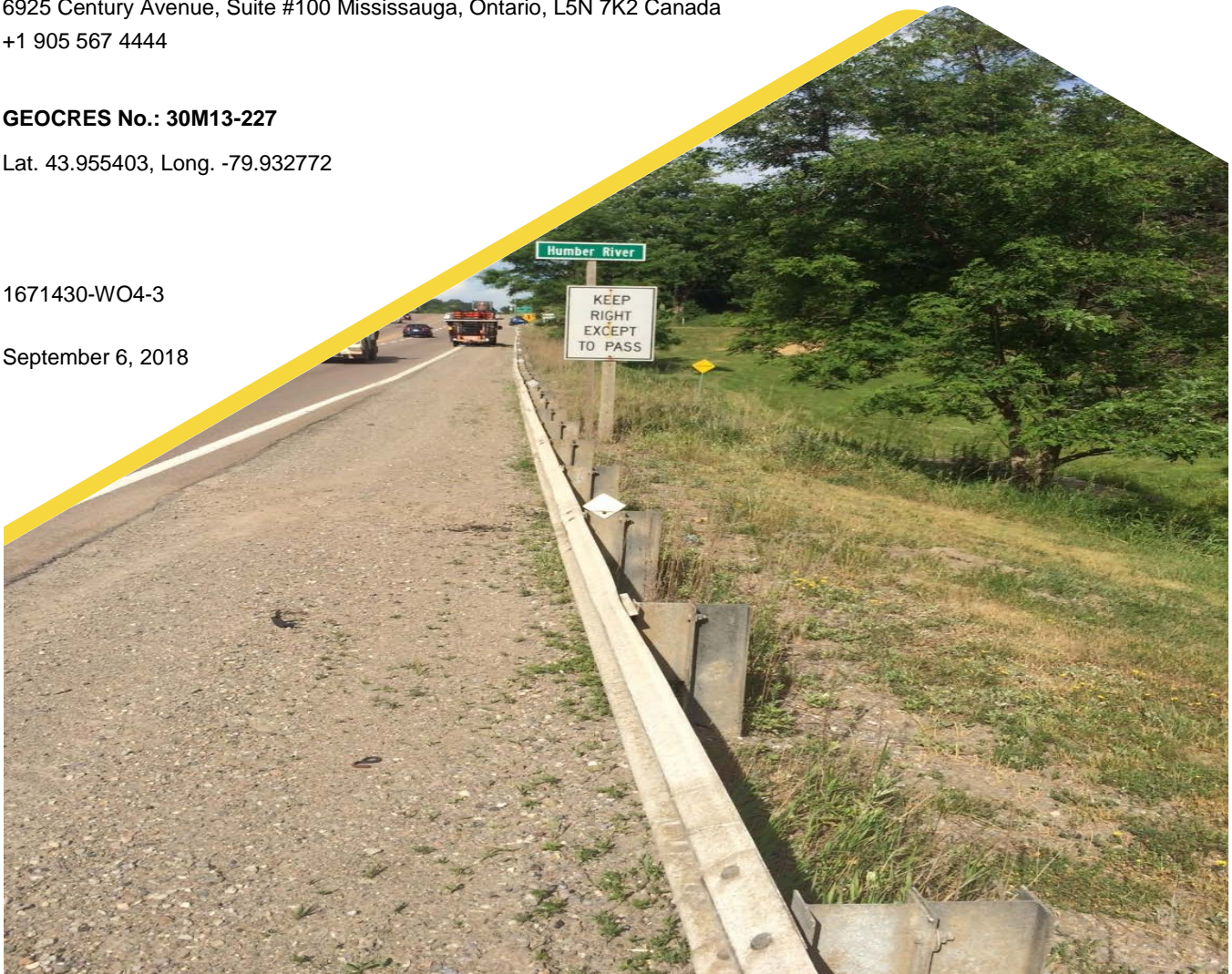
6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada
+1 905 567 4444

GEOCRES No.: 30M13-227

Lat. 43.955403, Long. -79.932772

1671430-WO4-3

September 6, 2018



Distribution List

3 Hard Copies, 1 Electronic Copy - MTO - Central Region

1 Hard Copy, 1 Electronic Copy - MTO - Foundations Section

1 Electronic Copy - AECOM Canada Ltd.

1 Electronic Copy - Golder Associates Ltd.

Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS.....	2
4.1 Regional Geology.....	2
4.2 General Overview of Subsurface Conditions	2
4.2.1 Asphalt	3
4.2.2 Fill.....	3
4.2.3 Organic Silt.....	3
4.2.4 Sand and Gravel	3
4.2.5 Silt and Sand to Sand	4
4.3 Groundwater Conditions	4
5.0 CLOSURE	5

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	6
6.1 General.....	6
6.2 Excavation and Groundwater Control	6
6.3 Temporary Protection Systems.....	7
7.0 CLOSURE	8

REFERENCES

DRAWINGS

Drawing 1 Borehole Locations

APPENDICES

APPENDIX A - Borehole Records

Lists of Symbols and Abbreviations
Records of Boreholes 18-1 and 18-2

APPENDIX B - Geotechnical Laboratory Test Results

- Figure B1 Grain Size Distribution – Silt and Sand (Fill)
- Figure B2 Grain Size Distribution – Sand and Gravel
- Figure B3 Grain Size Distribution – Silt and Sand to Sand

PART A

FOUNDATION INVESTIGATION REPORT
TEMPORARY PROTECTION SYSTEMS
HUMBER RIVER CULVERT REHABILITATION, SITE 24-554/C
HIGHWAY 9, COUNTY OF SIMCOE, ONTARIO
WP 2207-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation investigation and engineering services for the temporary protection systems associated with the proposed rehabilitation of the Humber River culvert (MTO Structure Site No. 24-544/C), located on Highway 9 in the County of Simcoe, Ontario, under W.P. 2207-14-00.

The scope of work for this assignment is outlined in Golder's change order request dated February 26, 2018. The original Terms of Reference for the foundation engineering services are outlined in MTO's Work Item Order No. 4, dated August 2017, under the Central Region Large Value Retainer, Agreement No. 2016-E-0029.

2.0 SITE DESCRIPTION

The Humber River culvert is located along Highway 9, about 3.2 km east of Airport Road and the Town of Mono Mills, and about 250 m east of Centreville Creek Road and 1.3 km west of The Gore Road, in the County of Simcoe, Ontario. The topography in the area comprises rolling hills, with the natural ground surface immediately adjacent to the river channel at approximately Elevation 323.5 m to 324.5 m, and the creek channel at about Elevation 323 m. Highway 9 has been constructed on an approximately 2.5 m high embankment, with its grade at about Elevation 326.5 m. At the time of the borehole investigation, no visual evidence of slope instability or settlement was observed on the Highway 9 embankment side slopes.

The existing culvert is approximately 30.6 m long, 6.1 m wide and 0.9 m high, with about 1.4 m of fill above the culvert. The creek flows from south to north under Highway 9.

3.0 INVESTIGATION PROCEDURES

The field work was carried out on May 8 and May 9, 2018, during which time two boreholes (Boreholes 18-1 and 18-2) were advanced. Borehole 18-1 is located on the south shoulder of Highway 9 and was drilled close to the guardrail of the eastbound lane, and Borehole 18-2 is located on the north shoulder of Highway 9 near the edge of pavement. Boreholes 18-1 and 18-2 were advanced to depths of 14.3 m and 12.8 m below ground surface, respectively. The borehole locations are shown on Drawing 1.

Both boreholes were drilled using 210 mm outer diameter hollow-stem augers with a D90 truck-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler. The sampler driven by an automatic hammer in both boreholes in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)¹.

The groundwater conditions in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in Boreholes 18-1 to permit monitoring of the water level. The installed piezometer consists of a 50 mm diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack with the bottom of the well about 13.4 m below ground surface within the borehole.

¹ ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, directed the sampling and in situ testing operations, logged the boreholes and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further visual review and geotechnical laboratory testing on selected samples, consisting of natural moisture content, Atterberg limits and grain size distribution analyses conducted in accordance with MTO and / or ASTM Standards as applicable. The results of this testing program are shown on the borehole records as well as on the laboratory test figures contained in Appendix B.

The borehole locations were marked in the field by Golder personnel relative to the existing culvert and other site features. The locations given on the borehole records and shown on Drawing 1 are positioned relative to MTM NAD 1983 (Zone 10) northing and easting coordinates, as well as geographic (latitude/longitude) coordinates; the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below.

Borehole No.	MTM NAD83 Zone 10		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
18-1	4,868,470.3 (43.955403)	270,066.8 (-79.932772)	326.7	14.3
18-2	4,868,482.7 (43.955515)	270,084.1 (-79.932557)	326.4	12.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 9 is located in the Oak Ridges Moraine physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)².

The Oak Ridges Moraine forms the height of land that extends from the Niagara Escarpment in the west to north of Trenton in the east. Its surface is hilly, with a "knob and basin" relief pattern. At the Humber River culvert site on Highway 9, the near-surface soil deposits are described as kame moraine. These types of moraine typically consist of stratified sand, silt and gravel that was laid down at a glacial ice margin and indeed, the majority of the hills in this area are composed of sandy or gravelly materials.

4.2 General Overview of Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory tests are provided on the borehole records in Appendix A. The results of the in situ field tests (i.e., SPT "N"-values) as presented on the borehole records and in Section 4 are uncorrected.

² Chapman, L.J. and Putnam, D.F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected; however, the factual data presented on the borehole records governs any interpretation of the site conditions.

In general, the native soils encountered at the Humber River culvert site consist of the Highway 9 embankment fill, underlain by an organic silt deposit, further underlain by sand and gravel and silt and sand to sand deposits.

4.2.1 Asphalt

Borehole 18-2 was advanced through the Highway 9 road surface and encountered approximately 200 mm of asphalt was immediately beneath the ground surface.

4.2.2 Fill

Approximately 2.2 m and 2.0 m of fill material was encountered immediately beneath the ground surface or asphalt layer in Boreholes 18-1 and 18-2, respectively.

The upper portion of the fill consists of sand and gravel containing trace to some silt, extending to a depth of 1.5 m and 0.8 m in Boreholes 18-1 and 18-2, respectively. The lower portion of the fill consists of sand containing some silt, some clay and trace gravel in Borehole 18-1 and silt and sand containing trace gravel in Borehole 18-2. The fill layer extends to a depth of 2.2 m, corresponding to Elevations 324.5 m and 324.2 m in Boreholes 18-1 and 18-2, respectively. A grain size distribution test was carried out on one sample of the silt and sand fill layer in Borehole 18-1 and the result is shown on Figure B1, contained in Appendix B. The natural water contents measured on two samples of the sand and silt and sand fill layer are 17 and 11 per cent, respectively.

Standard Penetration Test (SPT) “N”-values measured within the fill range from 7 to 47 blows per 0.3 m of penetration, indicating a loose to very dense level of compactness.

4.2.3 Organic Silt

A 1.5 m thick organic silt deposit was encountered in both Boreholes 18-1 and 18-2 underlying the fill layer. The organic silt deposit extends to a depth of 3.7 m, corresponding to Elevations 322.7 m and 323.0 m in Boreholes 18-1 and 18-2, respectively.

The deposit consists of organic silt containing some sand to sandy with sand seams, trace clay, as well as trace rootlets and trace wood fragments. The natural water contents measured on two samples of this deposit are 20 and 40 per cent. Organic contents measured on two samples of the deposit are about 2 and 8 per cent.

The SPT “N”-values measured within the organic silt deposit range from 3 to 24 blows per 0.3 m of penetration, indicating a very loose to compact level of compactness.

4.2.4 Sand and Gravel

A 0.8 m thick layer of sand and gravel was encountered underlying the organic silt deposit in Borehole 18-1 at a depth of 3.7 m below ground surface, corresponding to Elevation 323.0 m.

The sand and gravel contains some silt and trace clay. A grain size distribution test was carried out on one sample of this deposit, and the result is shown on Figure B2, contained in Appendix B. The natural water content measured on one sample is 12 per cent.

One SPT “N”-value of 16 blows per 0.3 m of penetration was measured within the sand and gravel deposit, indicating a compact level of compactness.

4.2.5 Silt and Sand to Sand

An interlayered deposit of sand to silt and sand was encountered underlying the sand and gravel layer in Borehole 18-1, and underlying the organic silt deposit in Borehole 18-2. The surface of the deposit was encountered at a depth of 4.5 m and 3.7 m, corresponding to Elevations 322.2 m and 322.7 m in Boreholes 18-1 and 18-2, respectively. Both boreholes terminated within the silt and sand to sand deposit, penetrating it for a thickness of 9.8 m and 9.1 m in Boreholes 18-1 and 18-2, respectively.

The deposit consists of sand containing trace silt to silty, some gravel, trace clay, to silt and sand containing trace to some clay. The results of grain size distribution tests completed on five samples of the silt and sand to sand deposit are shown on Figure B3 in Appendix B. The natural water content measured on seven samples of this deposit range between 13 and 19 per cent.

The SPT “N”-values measured within this deposit generally range from 8 to 31 blows per 0.3 m of penetration, indicating a loose to dense level of compactness. One lower SPT “N” value of 2 blows per 0.3 m of penetration was measured in Borehole 18-1, although this is attributed to sample disturbance due to water conditions in the borehole, and is not considered representative of the compactness condition.

4.3 Groundwater Conditions

The groundwater level in the open Borehole 18-1 was measured upon completion of drilling operations; the water level was not measured in Borehole 18-2 on completion of drilling operations, as water had been added to the borehole to minimize disturbance during soil sampling. A standpipe piezometer was installed in Borehole 18-1 to permit monitoring of the groundwater level at this site. Details of the piezometer installation and the measured groundwater levels are shown on the borehole records in Appendix A. The groundwater level recorded in the open borehole and piezometer are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
18-1	326.7	3.0	323.7	May 8, 2018	Open borehole
		2.8	323.9	May 9, 2018	Piezometer

A water level reading was attempted in Borehole 18-1 on June 22, 2018 and July 6, 2018; however on both occasions, the flush-mounted cap (buried in the shoulder) could not be found.

The groundwater level at this site will be subject to seasonal fluctuations and precipitation events; the water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Samira Ebrahimi and reviewed by Ms. Nikol Kochmanová, P.Eng. Ms. Lisa Coyne, P.Eng., a Principal and MTO Foundations Designated Contact of Golder, conducted an independent technical and quality control review of this report.

Golder Associates Ltd.



Nikol Kochmanová, Ph.D., P.Eng., PMP
Geotechnical Engineer



Lisa Coyne, P.Eng.
Principal, MTO Foundations Designated Contact

SE/NK/LCC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

c:\users\rbenjamin\golder associates\1671430, aecom mto mega retainer 2016e0029 - 3. final\1671430 wo4 fidr 2018sept06 humber river temp protection.docx

PART B

FOUNDATION DESIGN REPORT
TEMPORARY PROTECTION SYSTEMS
HUMBER RIVER CULVERT REHABILITATION, SITE 24-554/C
HIGHWAY 9, COUNTY OF SIMCOE, ONTARIO
WP 2207-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides discussion and general geotechnical/foundation design considerations for the proposed protection systems required for rehabilitation of Humber River culvert, Site 24-544/C located along Highway 9, in the County of Simcoe, Ontario.

These discussions are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and geotechnical parameters presented are intended to provide the designers with sufficient information to assess the feasible alternatives, and to develop approximate costs for the temporary protection systems. The Foundation Design Report discussion and recommendations are intended for the use of the MTO and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report to develop their temporary protection system designs. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

The proposed culvert rehabilitation includes the removal of the full depth of the top slab of the existing culvert at the construction joints under the embankment side slopes. Protection systems are required to facilitate the excavation through the existing side slopes above and beside the culvert to facilitate this top slab removal and replacement, while maintaining traffic on Highway 9. Although the geometry and design of the protection system is the responsibility of the contractor, based on the design drawings provided by AECOM, it is anticipated that the temporary protection systems will extend parallel to Highway 9 on top of the concrete box and into all four quadrants of the site.

6.2 Excavation and Groundwater Control

It is understood that the excavations for the culvert rehabilitation works will extend to approximately Elevation 324 m, an approximate depth of 2.5 m to 3.0 m below the Highway 9 grade. The proposed excavations will require removal of the asphalt, existing non-cohesive fill and a portion of the organic silt. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fills are classified as Type 3 soils above the groundwater level, and Type 4 soils if below the groundwater table. The organic silt, which is below the groundwater table, is classified as a Type 4 soil. Temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V) in Type 3 soil and 3H:1V in Type 4 soils. Depending upon the construction procedures adopted by the contractor and the weather conditions at the time of construction, some local flattening of the slopes could be required.

During construction, stockpiles/equipment/materials should be located a minimum distance of 1.5 m from the top of the excavation or a distance equal to the depth of the excavation, whichever is greater; stockpile heights should be controlled to prevent surcharging the sides of the excavation and/or overall slope.

The water level was measured in the piezometer in Borehole 18-1 at a depth of approximately 2.8 m below ground surface, corresponding to Elevation 323.9 m, at or just below the proposed base of excavation to facilitate the removal and replacement of the existing top slab of the culvert in the vicinity of the construction joints. The organic silt deposit that is anticipated at this level should be expected to be water-bearing. However, as this deposit will not

form the bearing surface for proposed permanent works, it is anticipated that the groundwater can be controlled by pumping from properly filtered sump pumps installed within the excavation.

6.3 Temporary Protection Systems

The protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539.

It is anticipated that a driven interlocking sheet pile system would be suitable and constructible at this site, as the Standard Penetration Test (SPT) "N"-values in the fills and in the native deposits are generally less than about 30 blows per 0.3 m of penetration. A soldier pile and lagging system is also feasible, although it would be necessary to include measures to control seepage from behind the lagging boards, where the excavation extends below the water table.

The sheet piles or soldier piles will need to extend/be socketed to a sufficient depth below the organic silt layer to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers or temporary anchors, if and as required.

While the selection and design of the protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in assessment of the approximate construction costs.

Soil Type	Unit Weight (γ , kN/m ³)	Internal Angle of Friction (Φ , degrees)	Coefficient of Lateral Earth Pressure ¹		
			Active K_a	At Rest K_o	Passive K_p ²
Existing Sand and Gravel to Silt and Sand Fill (Loose to dense)	20	28	0.36	0.53	2.8
Organic Silt (Very loose to compact)	17	26	0.39	0.56	2.56
Sand and Gravel (Compact)	20	32	0.31	0.47	3.25
Silt and Sand to Sand (Generally loose to compact)	20	30	0.33	0.5	3.0

1. The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present behind the temporary protection system, the coefficient of earth pressure should be adjusted accordingly.
2. The total passive resistance below the base of the excavation (i.e., adjacent to the protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It should be noted that the pressure distributions resulting from the above parameter values are the minimum for the ultimate stress condition. A stiffer design may be required to maintain displacements within an acceptable range.

Depending on the time of year, there may be perched water in the fill materials, above the organic silt layer. As noted above, if perched groundwater is present and/or where the excavation extends below the groundwater level at the site, it would be necessary to control seepage or include measures to mitigate loss of soil particles through lagging boards if a soldier pile and lagging system is employed.

Consideration could be given to either partial or full removal of the protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work at the culvert site, or to the road structure above. An NSSP is included in Appendix C which addressed the removal or cutoff of the protection system, and it is understood that this NSSP has been included in the Contract Documents.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Nikol Kochmanová, P.Eng. Ms. Lisa Coyne, P.Eng., a Principal and MTO Foundations Designated Contact of Golder, conducted an independent technical and quality control review of this report.

Golder Associates Ltd.



Nikol Kochmanová, Ph.D., P.Eng., PMP
Geotechnical Engineer



Lisa Coyne, P.Eng.
Principal, MTO Foundations Designated Contact

SE/NK/LCC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

c:\users\rbenjamin\golder associates\1671430, aecom mto mega retainer 2016e0029 - 3. final\1671430 wo4 fidr 2018sept06 humber river temp protection.docx

REFERENCES

Canadian Standards Association, 2014. Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-14. CSA Group.

Chapman, L.J. and Putnam, D. F. 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

ASTM International

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

Ontario Water Resources Act

Ontario Regulation 903/90 Wells: O. Reg. 468/10 Amendment to Ontario Regulation 903

Ontario Occupational Health and Safety Act

Ontario Regulation 213 (Construction Projects)



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

HUMBER RIVER CULVERT
HIGHWAY 9
BOREHOLE LOCATIONS PLAN



● Borehole – Current Investigation

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
18-1	326.7	4868470.3	270066.8
18-2	326.4	4868482.7	270084.1

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.

Base plans provided in digital format by Aecom, drawing file nos. SITE 24-554C.dwg and 1_60555407_HUMBER RIVER_SITE_24-554-GA & Repair Details.dwg, received June 06, 2018, AL-279-9.dwg and X-60555407-C-BASE-Hwy9-24-554C-CALLON.dwg, received June 20, 2018.

-	-	-			
NO.	DATE	BY	REVISION		
Geocres No. 30M13-227					
HWY. 9		PROJECT NO. 1671430		DIST. .	
SUBM'D. NK		CHKD. NK	DATE: 07/30/2018		SITE: 24-544
DRAWN: DD		CHKD. NK	APPD. LCC		DWG. 1



APPENDIX A

Borehole Records

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
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

$\tau = c' + \sigma' \tan \phi'$
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 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) Non-Cohesive (Cohesionless) Soils

Compactness	N
Condition	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	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)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT		1671430 (WO4)		RECORD OF BOREHOLE No 18-1		SHEET 1 OF 2		METRIC					
G.W.P.		2207-14-00		LOCATION		N 4868470.3; E 270066.8 MTM NAD 83 ZONE 10 (LAT. 43.955403; LONG. -79.932772)		ORIGINATED BY					
DIST		CENTRAL HWY 9		BOREHOLE TYPE		210 mm O.D. Hollow Stem Augers, Truck-mounted Drill Rig		COMPILED BY					
DATUM		Geodetic		DATE		May 8, 2018		CHECKED BY					
								NK/LCC					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p W W _L			
326.7	GROUND SURFACE												
0.0	Sand and gravel, trace to some silt (FILL) Brown Compact Moist		1	SS	20								
			2	SS	19								
325.3													
1.5	Silt and sand, trace gravel and clay (FILL) Brown Compact Moist to wet		3	SS	12								
324.5													
2.2	ORGANIC SILT, some sand, trace gravel, trace rootlets, trace wood fragments Dark brown Compact Moist		4	SS	16								
			5	SS	24								
323.0													
3.7	SAND and GRAVEL, some silt, trace clay Grey Compact Moist		6	SS	18								
322.2													
4.5	SAND, some silt to silty, trace clay Grey Loose to compact Wet		7	SS	15								
			8	SS	11								
			9	SS	14								
			10	SS	12								
			11	SS	2*								
			12	SS	8								
			13	SS	12								
312.4													
14.3													

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTOWHY_9\02_DATA\GTA-MTO_9.GPJ GAL-GTA.GDT 07/18/18

PROJECT		RECORD OF BOREHOLE No 18-1				SHEET 2 OF 2		METRIC									
1671430 (WO4)		G.W.P. 2207-14-00		LOCATION N 4868470.3; E 270066.8 MTM NAD 83 ZONE 10 (LAT. 43.955403; LONG. -79.932772)		ORIGINATED BY CC											
DIST CENTRAL HWY 9		BOREHOLE TYPE 210 mm O.D. Hollow Stem Augers, Truck-mounted Drill Rig		COMPILED BY SE													
DATUM Geodetic		DATE May 8, 2018		CHECKED BY NK/LCC													
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	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE --- END OF BOREHOLE NOTES: 1. Water level at a depth of 3.0 m (Elev. 323.7 m) upon completion of drilling. 2. Water level measured in standpipe piezometer. Date Depth (m) Elev. (m) 9/05/18 2.8 323.9 * SPT "N" - value may be disturbed due to addition of drilling water																

PROJECT		1671430 (WO4)		RECORD OF BOREHOLE No 18-2		SHEET 1 OF 1		METRIC								
G.W.P.		2207-14-00		LOCATION		N 4868482.7; E 270084.1 MTM NAD 83 ZONE 10 (LAT. 43.955515; LONG. -79.932557)		ORIGINATED BY								
DIST		CENTRAL HWY 9		BOREHOLE TYPE		210 mm O.D. Hollow Stem Augers, Truck-mounted Drill Rig		COMPILED BY								
DATUM		Geodetic		DATE		May 9, 2018		CHECKED BY								
								NK/LCC								
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			SHEAR STRENGTH kPa								
326.4	GROUND SURFACE															
0.0	ASPHALT															
0.2	Sand and gravel, trace silt (FILL)		1	SS	47											
325.6	Dense Brown Moist															
0.8	Sand, some silt, trace clay, trace gravel, oxidation staining (FILL)		2	SS	19											
	Loose to compact Brown Moist															
			3	SS	7											
324.2	ORGANIC SILT, some sand to sandy with sand seams, trace clay, trace gravel, trace rootlets, trace wood fragments		4	SS	3											
2.2	Very loose Dark brown Moist															
			5	SS	3											
322.7	SAND, some gravel, trace to some silt		6	SS	20											
3.7	Compact to dense Brown Wet															
			7	SS	31											
			8	SS	19											
319.2	SILT and SAND, trace to some clay		9	SS	20											
7.2	Loose to compact Grey to brown Wet															
			10	SS	10											
			11	SS	9											
			12	SS	11											
313.6	END OF BOREHOLE															
12.8	NOTE: 1. Water level not measured upon completion of drilling because water was added during drilling.															

GTA-MTO 001 S:\CLIENTS\MTOWHY_9\02_DATA\GINT\HWY_9.GPJ GAL-GTA.GDT 07/18/18

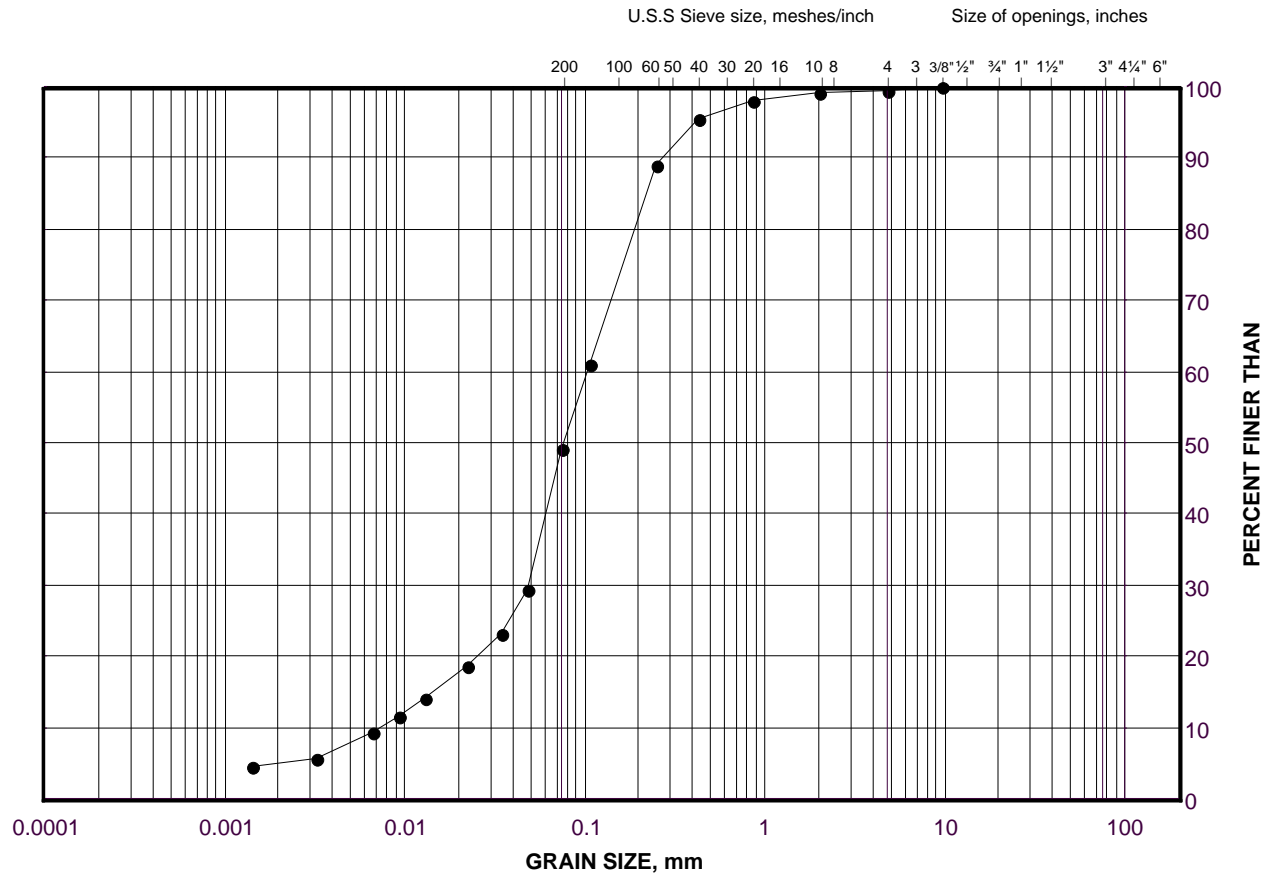
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silt and Sand (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)
•	18-1	3	324.9

Project Number: 1671430 - W04 - 3

Checked By: NK

Golder Associates

Date: 05-Jul-18

Sand and Gravel

U.S.S. Sieve size, meshes/inch

Size of openings, inches

PERCENT FINER THAN

GRAIN SIZE, mm

Grain Size (mm)	U.S.S. Sieve Size (meshes/inch)	Size of openings (inches)	Percent Finer (%)
0.075	No. 200	3/4"	100
0.085			95
0.15			85
0.25			75
0.425	No. 40	3/8"	65
0.6			55
0.85			45
1.18			35
1.75			25
2.5			20
3.55			15
4.75	No. 40	3/8"	10
6.0			8
7.5			7
10.0			6
15.0			5
20.0			4
30.0			3
40.0			2
60.0			1
100.0			0

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

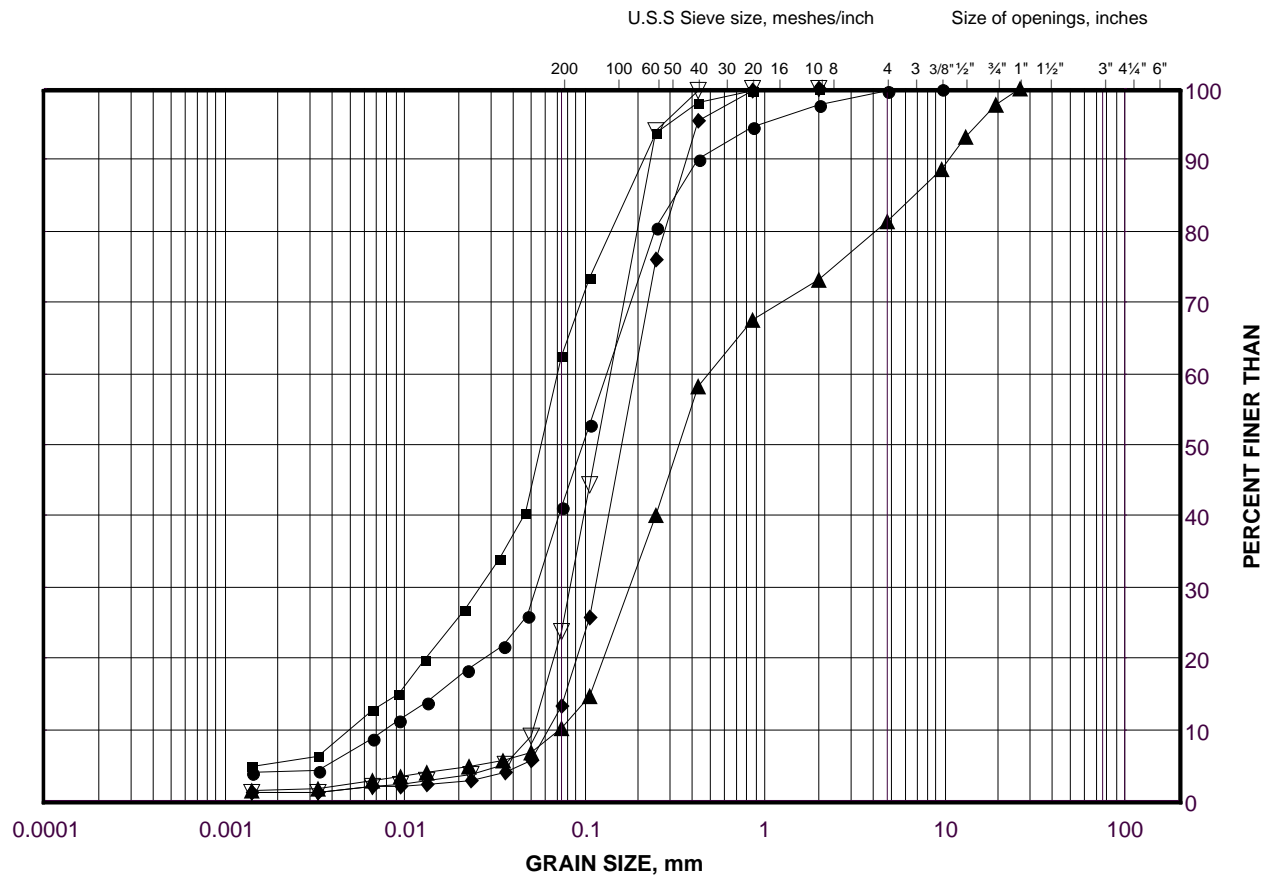
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-1	6	322.6

Date: 05-Jul-18

GRAIN SIZE DISTRIBUTION

Silt and Sand to Sand

FIGURE B3



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-2	10	316.9
■	18-2	12	313.9
◆	18-1	13	312.7
▲	18-2	7	321.5
▽	18-1	9	318.8

Project Number: 1671430 - W04 - 3

Checked By: NK

Golder Associates

Date: 18-Jul-18



golder.com