



March 28, 2017

FOUNDATION INVESTIGATION REPORT

Highway 401 Structural Culvert, Site No. 22-571/C
Structural Culverts Rehabilitation/Replacement -
Highway 35/115 and Highway 401
Ministry of Transportation, Ontario
W.P. 2286-15-00

Submitted to:

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GEOCRE NO.: 30M15-303

Report Number: 1540419-4

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REPORT





Table of Contents

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	1
3.1 Current Investigation.....	1
3.2 2015 Investigation.....	3
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	4
4.1 Regional Geology	4
4.2 General Overview of Local Subsurface Conditions	4
4.2.1 Asphalt and Road Base	4
4.2.2 Embankment Fill	4
4.2.3 Sandy Clayey Silt.....	5
4.2.4 Silt and Sand Till	6
4.2.5 Clayey Silt Till to Silty Clay Till	6
4.2.6 Gravelly Sand to Gravelly Silty Sand Till.....	6
4.2.7 Silty Sand.....	7
4.2.8 Bedrock.....	7
4.2.9 Groundwater Conditions	8
4.3 Analytical Testing of Soil Sample.....	8
5.0 CLOSURE.....	8

REFERENCES

TABLES

Table 1	Summary of Existing Culvert Details
---------	-------------------------------------

DRAWINGS

Drawing 1	Borehole Locations and Soil Strata
-----------	------------------------------------

APPENDICES

Appendix A Record of Boreholes

List of Symbols and Abbreviations	
Record of Boreholes and Drillholes	C4-1 to C4-3



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

Appendix B Laboratory Results

Table B1	Unconfined Compression (UC) Test of Intact Rock Core Specimens
Table B2	Point Load Tests on Rock Samples
Figure B1	Grain Size Distribution Test Results – Clayey Silt (Fill)
Figure B2	Plasticity Chart – Clayey Silt to Silty Clay (Fill)
Figure B3	Grain Size Distribution Test Results – Sandy Clayey Silt
Figure B4	Plasticity Chart – Clayey Silt
Figure B5	Grain Size Distribution Test Results – Clayey Silt to Silty Clay (Till)
Figure B6	Plasticity Chart – Clayey Silt to Silty Clay (Till)
Figure B7	Grain Size Distribution Test Results – Gravelly Sand to Gravelly Silty Sand (Till)

Appendix C Analytical Test Results

Appendix D Record of Borehole and Laboratory Test Results from 2015 Investigation

Record of Borehole B2

Figure D1	Grain Size Distribution Test Results – Sandy Clayey Silt
Figure D2	Plasticity Chart – Clayey Silt
Figure D3	Grain Size Distribution Test Results – Silt and Sand (Till)
Figure D4	Grain Size Distribution Test Results – Gravelly Sand to Gravelly Silty Sand (Till)



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 a structural culvert at STA 22+550 on Bloor Street East, south of Highway 401 in the City of Oshawa, Regional Municipality of Durham, Ontario (MTO Structure Site No. 21-571/C) at the location shown in the key plan on Drawing 1.

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 at about STA 22+550 on Bloor Street East (MTO Structure Site No. 21-571/C) which has been identified for potential replacement. The foundation investigation and design associated with the other culverts, which forms part of the Foundation assignment are presented in separate reports. The current investigation was supplemented with information from a previous investigation for the Bloor Street / Highway 401 underpass, as follows:

- **MTO G.W.P. No. 10-2011:** Report titled "Draft Preliminary Foundation Report, Bloor Street Underpass Structure Site No. 22-183, Highway 401 Improvements from Brock Road to Courtice Road, Regional Municipality of Durham" by Golder Associates Ltd (to be submitted).

2.0 SITE DESCRIPTION

The structural culvert at Site No. 21-571/C (Culvert C4) requiring replacement is located at approximately STA 22+250 on Bloor Street East, south of Highway 401, in the City of Oshawa, in the Regional Municipality of Durham. The existing culvert is a concrete open footing structure, 54 m in total length (including previously constructed cast-in-place extensions to the east and west ends) and is 3.7 m wide by 1.8 m high. The structure is located within a 6 m to 8 m high embankment and has approximately 5 m to 6 m of cover. Details of the existing culvert are 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 down to the culvert, with the natural ground surface at approximately Elevation 83.5 m and the creek bed in the vicinity of the culvert at about Elevations 80.6 m to 80.9 m. The Bloor Street grade over the culvert is at about Elevation 89 m. The existing Bloor Street embankment consist of earth fill, up to about 5.5 m high over the culvert at the street centreline, with side slopes inclined at approximately 2 horizontal to 1 vertical (2H:1V).

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation

The fieldwork for the current investigation associated with structural culvert 21-571/C was carried out between August 31 and September 1, 2016 and September 12 to 15, 2016 during which time a total of three boreholes were advanced at, or in the immediate vicinity of the culvert alignment as shown in plan on Drawing 1.



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

The field investigation was carried out using track-mounted and truck-mounted drilling equipment supplied and operated by Atcost Drilling Inc. of Gormley, Ontario. The boreholes were advanced through the overburden using 208 mm outer diameter (O.D.) hollow stem augers and the bedrock was cored using NQ coring equipment. 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 drill rig, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586¹). A borehole was advanced to a depth of 7.6 m adjacent to Borehole C4-3 to permit determining the in-situ undrained shear strength of the clayey silt till deposit using a Standard MTO 'N'-vane (ASTM D2573²).

A piezometer was installed in Borehole C4-3 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 within the sandy clayey silt till deposit and underlying silty sand deposit. 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 C4-3 sheet in Appendix A. The other two 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 and bedrock core samples. The soil and bedrock core 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 and strength testing (Unconfined Compression and point load index) was carried out on selected samples of the cored bedrock. The results of the laboratory testing are summarized on the Record of Borehole and Record of Drillhole sheets in Appendix A and the details of the geotechnical testing are provided in Appendix B.

A soil sample was obtained during the field investigation at about the culvert invert elevation, using appropriate sampling protocols, and was submitted to a specialist analytical laboratory under chain of custody procedures for chemical analysis of a suite of parameters (corrosivity package) to assess the potential for the soil to cause deterioration of buried concrete or corrosion to steel reinforcing elements. The results of the analytical testing are presented in Appendix C and are summarized 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 Geodetic elevation of the boreholes were 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 and Record of Drillhole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations

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

² ASTM D2573-94 Standard Test Method for Field Vane Shear Test in Cohesive Soil, ASTM International, West Conshohocken, PA, 2001



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

Borehole	Location (m)		Ground Surface Elevation (m)	Depth of Borehole (m)*
	Northing	Easting		
C4-1	4,860,954.8	358,602.8	83.6	14.0
C4-2	4,860,943.2	358,637.4	90.0	20.1
C4-3	4,860,941.7	358,659.0	83.3	13.4

*Includes 3.4 m bedrock coring in Borehole C4-1 and 3.3 m Bedrock coring in Boreholes C4-2 and C4-3.

3.2 2015 Investigation

The field work for the previous investigation was carried out in April 2015, during which time Borehole B2 was drilled at the approximate location shown on Drawing 1. The borehole was advanced by a CME-75 truck-mounted drill rig, supplied and operated by Strong Soil Search Inc. of Claremont, Ontario, using 150 mm diameter continuous flight solid stem augers. The borehole extends to a depth of 14.2 m below ground surface. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586¹).

A standpipe piezometer was installed in Borehole B2 to permit monitoring of the groundwater level at the site. The piezometer consists of 50 mm diameter PVC pipe, with a slotted screen sealed at a select depth interval within the borehole. Above the sand filter pack and piezometer screen, the annulus surrounding the piezometer pipe was sealed and backfilled to the ground surface with bentonite pellets. The Record of Borehole B2, including the piezometer installation details and water level readings is contained in Appendix D.

Index and classification tests consisting of water contents, Atterberg limits, and grain size distributions were carried out on selected soil samples, the results of which are presented on the Record of Borehole sheet and detailed on the laboratory test sheets in Appendix D.

The borehole location (referenced to the MTM NAD83 (Zone 10) co-ordinate system) and ground surface elevation (referenced to Geodetic datum) are presented on Drawing 1, and summarized below, together with the drilled depth.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
B2	4,860,928.9	358,606.5	88.1	14.2



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)³ and *Urban Geology of Canadian Cities* (Karrow and White, 1998)⁴. 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, which are underlain by an extensive till deposit that is mapped in this area as the Bowmanville Till.

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 and Drillhole sheets for the current and previous investigations and the laboratory test sheets in Appendices A to D. The stratigraphic boundaries shown on the Record of Boreholes and Record of Drillhole sheets and stratigraphic profiles 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 culvert Site No. 21-571/C consists of surficial layers of non-cohesive and cohesive embankment fill, underlain by a localized silt and sand till pocket and by a soft to stiff clayey silt to silty clay till deposit which is, at the northern portion of the site, underlain by a deposit of compact to very dense gravelly silty sand to gravelly sand till deposit. The clayey silt to silty clay till deposit on the eastern portion of the site, and the gravelly silty sand till deposit (where present) are underlain by shale bedrock. 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 and Road Base

Boreholes B2 and C4-2 were advanced through the existing Bloor Street East roadway and penetrated an asphalt layer between approximately 200 mm and 250 mm thick.

4.2.2 Embankment Fill

Embankment fill, approximately 1.5 m to 9.9 m thick was encountered in all boreholes immediately below existing ground surface, or underlying the asphalt (where present).

³ 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.

⁴ 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.



Non-Cohesive Fill

The embankment fill consists of an upper non-cohesive layer of silty sand to sand, approximately 0.4 m to 1.2 m thick in Borehole B2 and C4-2.

The SPT 'N'-values measured within the non-cohesive embankment fill layer are 15 blows and 37 blows per 0.3 m of penetration, indicating a generally compact to dense relative density.

Cohesive Fill

Beneath the non-cohesive layer of fill in Boreholes B2 and C4-2 and immediately below the existing ground surface in Boreholes C4-1 and C4-3 the fill consists of a 1.3 to 8.7 m thick deposit of clayey silt to silty clay, some sand to sandy. Trace organics were encountered in the sandy clayey silt to clayey silt fill deposit up to a depth of 2.1 m below ground surface in Borehole C4-1 (Elevation 83.6 m to 81.5 m) and at a depth of 9.1 m (Elevation 80.9) in Borehole C4-2. Although not encountered in the boreholes advanced at this site, our recent experience with trenchless crossings of major MTO highways suggests that there may be debris 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, and cobbles and/or boulders.

The SPT 'N'-values measured in the cohesive embankment fill deposit generally range from 4 blows to 23 blows per 0.3 m of penetration, suggesting a soft to very stiff consistency.

The natural water content measured on seven samples of the cohesive embankment fill ranges between about 11 per cent and 31 per cent.

The results of grain size distribution tests completed on two samples of the cohesive fill from Borehole C4-2 are shown on Figure B1 in Appendix B.

Atterberg limits tests were carried out on four samples of the sandy clayey silt to clayey silt embankment fill deposit and measured liquid limits ranging between about 23 per cent and 46 per cent, plastic limits ranging between about 12 per cent and 18 per cent and plasticity indices ranging between about 11 and 28 per cent. These test results, which are plotted on a plasticity chart on Figure B2 in Appendix B, indicate that the material is a clayey silt of low plasticity to silty clay of intermediate plasticity.

4.2.3 Sandy Clayey Silt

A 1.5 m and 2.1 m thick sandy clayey silt deposit was encountered in Boreholes C4-3 and B2, respectively, underlying the embankment fill at Elevation 80.3 m and 85.5 m. Trace organics were encountered throughout the sandy clayey silt deposit in Borehole C4-3.

The SPT 'N'-values measured within sandy clayey silt deposit range between 9 blows and 16 blows per 0.3 m of penetration, indicating a loose to compact relative density. An SPT 'N'-value of 18 blows per 0.3 m of penetration was measured at the boundary of the sandy clayey silt and the overlying clayey silt fill in Borehole B2 at about Elevation 85.5 m.

The natural water content measured on four samples of the sandy clayey silt deposit are between about 14 per cent and 21 per cent.

The results of grain size distribution tests completed on two samples of the sandy clayey silt deposit are shown on Figure B3 in Appendix B and D1 in Appendix D.



Atterberg limits testing was carried out on three samples of the sandy clayey silt deposits and measured liquid limits between about 23 and 28 per cent, plastic limits between about 12 and 15 per cent and plasticity indices between about 11 and 13 per cent. These test results, which are plotted on a plasticity chart on Figure B4 in Appendix B and Figure D2 in Appendix D, indicate that the material tested is a clayey silt of low plasticity.

4.2.4 Silt and Sand Till

A 2.3 m thick till deposit consisting of silt and sand, trace gravel, trace clay was encountered in Borehole B2 underlying the clayey silt deposit at a depth of about 4.7 m below ground surface (Elevation 83.4 m).

The SPT 'N'-values measured within the silt and sand till deposit are 5 blows and 31 blows per 0.3 m of penetration, indicating a loose to dense relative density, however the lower 'N'-Value is interpreted to have been affected by soil disturbance due to groundwater inflow during drilling.

The natural water content measured on one sample of the silt and sand till is about 16 per cent.

The result of a grain size distribution test completed on one sample of the silt and sand till is shown on Figure D3 in Appendix D.

4.2.5 Clayey Silt Till to Silty Clay Till

A till deposit consisting of clayey silt to silty clay, some sand to with sand, was encountered in all of the boreholes advanced at this site between depths of about 2.1 m and 10.2 m below ground surface (Elevation 81.5 m and 79.8 m, respectively) and the thickness of the deposit ranges between 3.2 m and 6.6 m.

The SPT 'N'-values measured within the clayey silt to silty clay till deposit range from 2 blows to 22 blows per 0.3 m of penetration, suggesting a soft to very stiff consistency. Three field vane tests were carried out in the sandy clayey silt till portion of the deposit in a companion borehole immediately adjacent to Borehole C4-3 at Elevations 78.9 m, 77.5 m and 75.8 m. The results of the field shear vane tests range from 65 kPa to greater than 96 kPa, indicating a stiff to very stiff consistency.

The natural water content measured on nine samples of this cohesive till deposit range between about 8 per cent and 30 per cent.

The results of grain size distribution tests completed on three samples of the silty clay to clayey silt till deposit are shown on Figure B5 in Appendix B.

Atterberg limits testing was carried out on four samples of the clayey silt to silty clay till deposit and measured liquid limits between about 16 per cent and 46 per cent, plastic limits between about 12 per cent and 16 per cent and plasticity indices between about 6 per cent and 32 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 plasticity to silty clay of intermediate plasticity.

4.2.6 Gravelly Sand to Gravelly Silty Sand Till

A till deposit consisting of gravelly sand to gravelly silty sand was encountered in Boreholes C4-1 and B2 at depths of 5.2 m and 10.2 m below ground surface (Elevation 78.4 m to 77.9 m, respectively) and the thickness of the deposit is 5.4 m and 4.0 m, respectively.



Grinding of the augers was observed at a depth of 6.6 m (Elevation 77 m) in the gravelly sand to gravelly silty sand deposit in Borehole C4-1, suggesting the presence of cobbles and/or boulders.

The SPT 'N'-values measured within the gravelly sand to gravelly silty sand till deposit range from 16 blows to 33 blows per 0.3 m of penetration, with one "N"-value of 80 blows per 0.13 m of penetration, indicating a compact to very dense relative density.

The natural water content measured on two samples of the gravelly sand to gravelly silty sand were about 8 per cent and 9 per cent.

The results of the grain size distribution tests completed on two samples of the gravelly sand to gravelly silty sand are shown on Figure B7 in Appendix B and Figure D4 in Appendix D.

4.2.7 Silty Sand

A 0.5 m thick deposit of silty sand was encountered below the till deposit at Elevation 73.7 m in Borehole C4-3.

An SPT 'N'-value measured at the transition between the silty sand and the overlying clayey silt till is 16 blows per 0.3 m of penetration, indicating a compact relative density.

4.2.8 Bedrock

Bedrock was encountered in Boreholes C4-1, C4-2 and C4-3 at depths between 10.1 m and 16.8 m below ground surface (between Elevations 73.3 m and 73.0 m). Based on a review of the recovered bedrock core samples, the bedrock consists of grey, moderately weathered to fresh, shale. Detailed descriptions of the bedrock are presented on the Record of Drillhole sheets in Appendix A.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered range between 44 per cent and 100 per cent and between 19 per cent and 78 per cent, respectively. The Rock Quality Designation (RQD) of the bedrock core samples from the boreholes ranges from 0 per cent to 20 per cent, indicating a rock mass of very poor quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

An Unconfined Compressive Strength (UCS) test carried out on one sample of the Shale bedrock from Borehole C4-1 measured a uniaxial compressive strength of about 30 MPa. The test result which is shown on the Record of Drillhole sheet in Appendix A and summarised in Table B1 in Appendix B, indicates that the bedrock is medium strong (R3) as per Table 3.5 of CFEM (2006).

Axial point load index tests were performed on nine selected samples of the rock core recovered from the boreholes at this site and the strength index values are presented on the Record of Drillhole Sheets in Appendix A and detailed in Table B2 in Appendix B. The point load index (Is_{50}) results of core samples of the Shale bedrock range from approximately 0.3 MPa to 2.6 MPa. These index values correspond to UCS values ranging between about 5 MPa and 44 MPa, based on a relationship between Is_{50} and UCS which is given by a correlation factor (k), estimated to be equal to 16.7 for this site, and calculated as the ratio of the laboratory UCS and average corresponding point load test index value from all of the drillholes at this site. These values have been given for comparison only and should be interpreted together with the results of the UCS tests.

Based on the laboratory UCS tests and point load testing results, the estimated intact strength of the Limestone bedrock generally ranges from weak (R2, 5 MPa < UCS < 25 MPa) to medium strong (R3, 25 MPa < UCS < 50 MPa); (CFEM, 2006).



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

4.2.9 Groundwater Conditions

The water level was measured in Borehole C4-1 upon completion of drilling operations at depth of 5.8 m below ground surface (Elevation 77.8 m). The water level was not recorded in Borehole C4-2 prior to bedrock coring.

A standpipe piezometer had been installed in Borehole B2 in the Westbound Lane of Bloor Street and a piezometer was installed in Borehole C4-3 on the south side of Bloor Street. The observed groundwater level is shown on the Record of Borehole sheets and summarized below:

Borehole	Depth to Water Level (m)	Groundwater Elevation	Date of Measurement
B2	6.1	82.0	April 12, 2015
	5.8	82.3	June 7, 2016
C4-3	2.0	81.3	September 13, 2016
	1.7	81.6	March 28, 2017

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 at Borehole C4-1. 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 D and are summarized below.

Parameter	Test Result
Soil Resistivity	1500 ohm-cm
Soil Conductivity	687 umho/cm
Sulphate Concentration	<20 ug/g
Chloride Concentration	360 ug/g
PH	7.6

5.0 CLOSURE

The borehole investigation program was supervised by Mr. Michael Bentley and Ms. Marzieh Kamranzadeh, two members of Golder's technical staff. This report was prepared by Mr. Matthew Kelly, P.Eng. Mr. Jorge Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

Report Signature Page

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Designated MTO Foundations Contact, Senior Consultant

MCK/MWK/JMAC/sm

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FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

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, ASTM International, West Conshohocken, PA, 2011

ASTM D2573-94 Standard Test Method for Field Vane Shear Test in Cohesive Soil, ASTM International, West Conshohocken, PA, 2001



TABLES



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 22-571/C

Table 1: - Summary of Existing Culvert Details

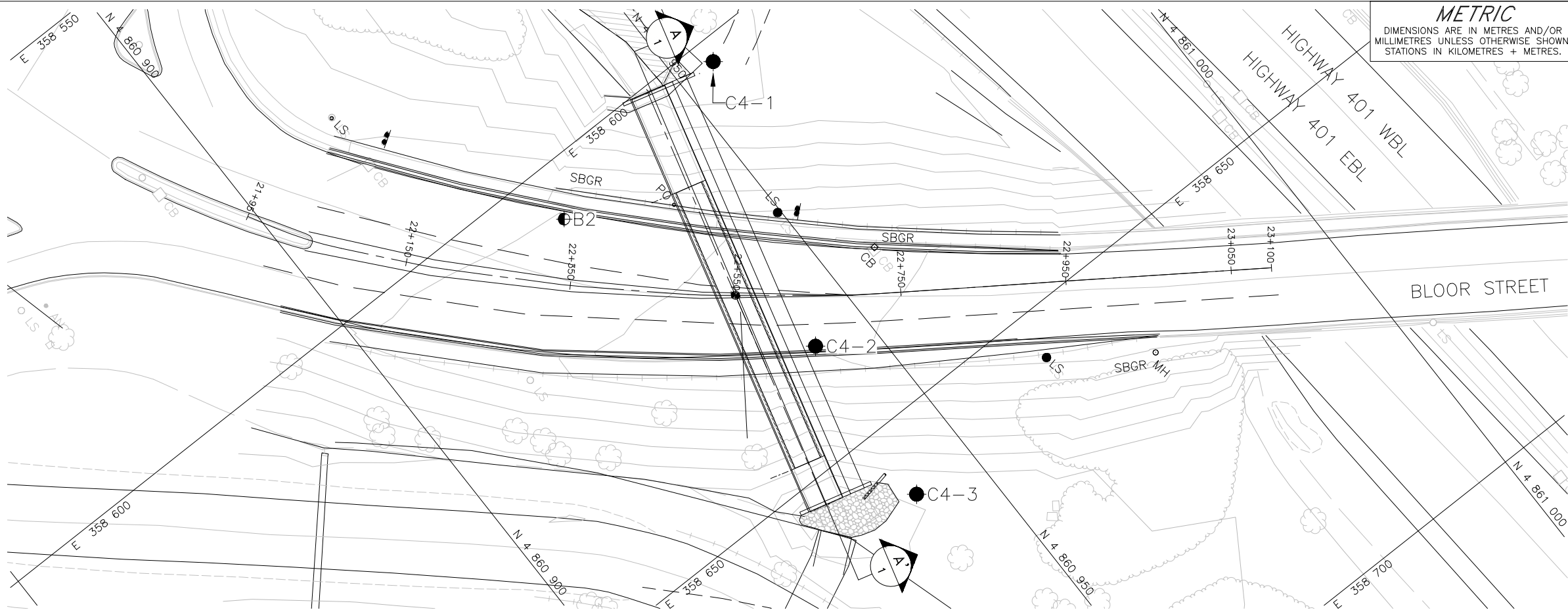
Culvert Location (Township)	Culvert ID	Approximate Height of Embankment/ Cover ¹	Existing Culvert			Approximate Invert Elevation ²		Boreholes from Current Investigation	Boreholes from Previous Investigation
			Type	Approximate Dimension	Approximate Length	West End of Culvert	East End of Culvert		
STA 22+550 Bloor Street East, Regional Municipality of Durham	C4 22-571/C	6 m to 8 m / 5 m to 6 m	Open Footing Concrete Box	3.7 m x 1.8 m	54 m	80.9 m	80.6 m	3 Boreholes (C4-1 to C4-3)	1 Borehole (B2)

Notes: 1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert and the thickness of cover is based on drawings provided by D.M. Wills dated November 24, 2016

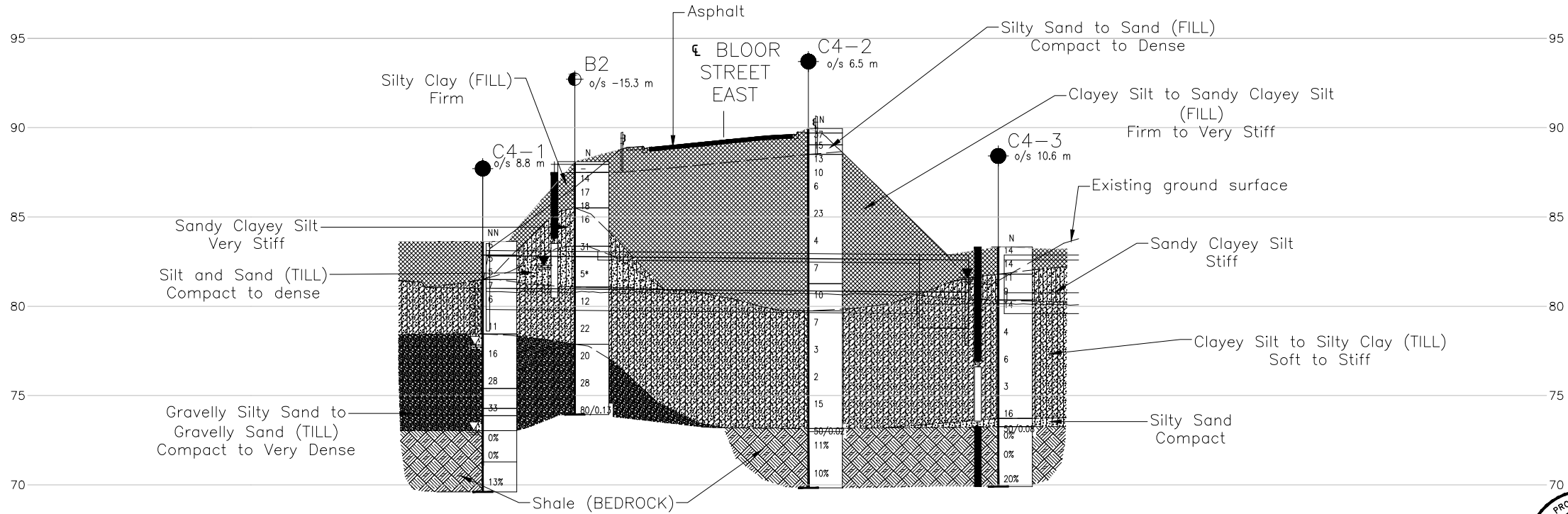
2. Culvert invert elevations are based on drawings provided by D.M. Wills dated November 24, 2016.



DRAWINGS



PLAN
SCALE
0 6 12 m



HORIZONTAL SCALE
0 6 12 m

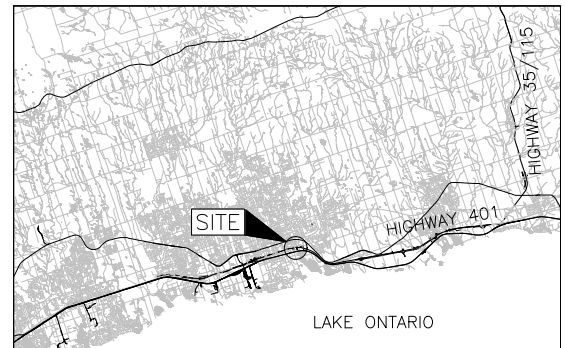
CULVERT C4
STA. 22+550

SCALE
0 3 6 m

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

CONT No.
WP No.2186-15-00

HIGHWAY 401
CULVERT C4 STA 22+550
BOREHOLE LOCATIONS AND
SOIL STRATA



KEY PLAN

SCALE
0 6 12 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation 1
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on SEP 13, 2016
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
B2	88.1	4860928.9	358606.5
C4-1	83.6	4860954.8	358602.8
C4-2	90.0	4860943.2	358637.4
C4-3	83.3	4860941.7	358659.0

NOTES

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

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

REFERENCE

Base Plan and Contours provided in digital format by DM Wills, drawing file nos. 132306.dwg and 132307.dwg, received Jan. 20, 2016. Design Plan and Section provided in digital format by DM Wills, drawing file no. 4561-C4 GA.dwg, received Nov. 24, 2016.



NO.	DATE	BY	REVISION
Geocres No. 30M15-303			
HWY. 401	PROJECT NO. 1540419		DIST. .
SUBM'D. MCK	CHKD. MCK	DATE: 6/14/2013	SITE: 22-571/C
DRAWN: MR	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
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

* 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 = 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

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 Soils

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

(b) Cohesive Soils Consistency

	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.



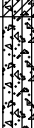
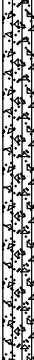
V. MINOR SOIL CONSTITUENTS

Per cent by Weight

Modifier	
0 to 5	Trace
5 to 12	Trace to Some (or Little)
12 to 20	Some
20 to 30	(ey) or (y)
over 30	And (non-cohesive (cohesionless)) or With (cohesive)

Example

Trace sand
Trace to some sand
Some sand
Sandy
Sand and Gravel
Silty Clay with sand / Clayey Silt with sand

PROJECT		1540419		RECORD OF BOREHOLE No C4-1		SHEET 1 OF 2		METRIC													
W.P.		2186-15-00		LOCATION		N 4860954.8; E 358602.8 MTM ZONE (LAT. 43.886614; LONG. -78.830405)		ORIGINATED BY MK													
DIST		HWY 401		BOREHOLE TYPE		CME 55, 208 mm O.D., 108 mm I.D. Hollow Stem Augers		COMPILED BY SZ/MR													
DATUM		Geodetic		DATE		August 31, 2016		CHECKED BY MCK													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
83.6	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p — W — W _L 10 20 30			kN/m ³					
0.0	Silty clay, some sand, trace gravel, trace organics (rootlets) (FILL)		1	SS	6		83														
82.8	Firm Brown Moist		2	SS	5		82														
0.8	Sandy silty clay, trace gravel, trace organics (rootlets) (FILL)		3	SS	5																
81.5	Firm Brown Moist						81														
2.1	SILTY CLAY, trace to some sand, trace gravel (TILL)		4	SS	7		80														
	Firm to stiff Brown to grey Moist		5	SS	6		79														
			6	SS	11		78														
78.4	Gravelly Silty SAND, trace to some clay to Gravelly SAND, some silt (TILL)						77														
5.2	Compact to dense Grey Moist to wet		7	SS	16		76														
	- Cobble/boulder inferred at a depth of 6.6 m (Elev. 77.0 m) based on grinding of augers		8	SS	28		75														
							74														
							73														
							72														
							71														
							70														
73.0	SHALE (BEDROCK)		1	RC	REC 44%		73														
10.6	Bedrock cored from depths of 10.6 m to 14.0 m.		2	RC	REC 93%		72														
	For bedrock coring details refer to Record of Drillhole C4-1.		3	RC	REC 100%		71														
							70														
69.6	END OF BOREHOLE																				
14.0																					

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

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PROJECT <u>1540419</u>		RECORD OF BOREHOLE No C4-1				SHEET 2 OF 2		METRIC												
W.P. <u>2186-15-00</u>		LOCATION <u>N 4860954.8; E 358602.8 MTM ZONE (LAT. 43.886614; LONG. -78.830405)</u>				ORIGINATED BY <u>MK</u>														
DIST <u> </u> HWY <u>401</u>		BOREHOLE TYPE <u>CME 55, 208 mm O.D., 108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>SZ/MR</u>														
DATUM <u>Geodetic</u>		DATE <u>August 31, 2016</u>				CHECKED BY <u>MCK</u>														
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa												
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between; font-size: small;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between; font-size: x-small;"> ○ UNCONFINED ○ FIELD VANE </div> <div style="display: flex; justify-content: space-between; font-size: x-small;"> ● QUICK TRIAXIAL × REMOULDED </div>													
	NOTES: 1. Water level in open borehole at a depth of 5.8 m below ground surface (Elev. 77.8 m) upon completion of drilling. 2. A borehole was advanced 0.5 m north of borehole C4-1 to carry out bedrock coring.																			

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PROJECT 1540419		RECORD OF BOREHOLE No C4-2		SHEET 1 OF 2		METRIC	
W.P. 2242-14-00		LOCATION N 4860943.2; E 358637.4 MTM ZONE (LAT. 43.886507; LONG. -78.829975)		ORIGINATED BY MB			
DIST _____ HWY 401		BOREHOLE TYPE CME 75, 208 mm O.D., 108 mm I.D. Hollow Stem Augers		COMPILED BY SZ/MR			
DATUM Geodetic		DATE September 14 to 15, 2016		CHECKED BY MCK/ACK			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80
90.0	GROUND SURFACE															
0.0	ASPHALT (250 mm)															
0.3	Silty sand to sand, trace to some gravel (FILL) Compact to dense Brown Dry to moist		1	SS	37											
			2	SS	15											
88.5	Clayey silt, trace to some sand to sandy clayey silt (FILL) Firm to very stiff Brown Moist		3	SS	13											
			4	SS	10											
			5	SS	6											
			6	SS	23											
			7	SS	4											
			8	SS	7											
			9	SS	10											
79.8	- Trace organics at a depth of 9.1 m (Elev. 80.8 m)															
10.2	CLAYEY SILT with SAND, trace to some gravel (TILL) Very soft to stiff Grey Wet		10	SS	7											
			11	SS	3											
			12	SS	2											

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

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PROJECT 1540419		RECORD OF BOREHOLE No C4-2				SHEET 2 OF 2		METRIC										
W.P. 2242-14-00		LOCATION N 4860943.2; E 358637.4 MTM ZONE (LAT. 43.886507; LONG. -78.829975)				ORIGINATED BY MB												
DIST _____ HWY 401		BOREHOLE TYPE CME 75, 208 mm O.D., 108 mm I.D. Hollow Stem Augers				COMPILED BY SZ/MR												
DATUM Geodetic		DATE September 14 to 15, 2016				CHECKED BY MCK/ACK												
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 ---							20	40	60	80	100						
73.2	CLAYEY SILT with SAND, trace to some gravel (TILL) Very soft to stiff Grey Wet		13	SS	15		74											
16.8	SHALE (BEDROCK)		14	SS	50/0.02		73											
	Bedrock cored from depths of 17.0 m to 20.1 m. For bedrock coring details refer to Record of Drillhole C4-2.		1	RC	REC 88%		72											RQD = 11%
			2	RC	REC 77%		71											RQD = 10%
69.9	END OF BOREHOLE						70											
20.1	NOTE: 1. Water level in borehole not recorded prior to rock coring.																	

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SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: At Cost Drilling Inc.

[illegible]

CHECKED:

PROJECT 1540419		RECORD OF BOREHOLE No C4-3		SHEET 1 OF 2		METRIC											
W.P. 2186-15-00		LOCATION N 4860941.7; E 358659.0 MTM ZONE (LAT. 43.886492; LONG. -78.829707)		ORIGINATED BY MCK													
DIST _____ HWY 401		BOREHOLE TYPE CME 55, 208 mm O.D., 108 mm I.D. Hollow Stem Augers		COMPILED BY SZ/MR													
DATUM Geodetic		DATE September 12 and 13, 2016		CHECKED BY MCK													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	γ	GR	SA	SI	CL
83.3	GROUND SURFACE																
0.0	Sandy clayey silt (FILL) Stiff Brown Moist		1	SS	14		83										
			2	SS	14		82										
81.8																	
1.5	Sandy CLAYEY SILT, trace organics Stiff Black to brown Moist		3	SS	11		81										0 20 58 22
			4	SS	9		80										
80.3																	
3.0	Sandy CLAYEY SILT, trace gravel (TILL) Soft to very stiff Grey Moist		5	SS	14		79										
			6	SS	4		78										
			7	SS	6		77										4 28 41 27
			8	SS	3		76										
			9A	SS	16		75										
73.7			9B				74										
9.6	Silty SAND, some gravel, some clay		10	SS	50/0.08		73										RQD = 0%
73.3	Compact Grey Wet		1	RC	REC 56%		72										RQD = 0%
10.1	SHALE (BEDROCK)		2	RC	REC 72%		71										RQD = 20%
			3	RC	REC 87%		70										
69.9																	
13.4	END OF BOREHOLE																

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

PROJECT <u>1540419</u>	RECORD OF BOREHOLE No C4-3	SHEET 2 OF 2	METRIC
W.P. <u>2186-15-00</u>	LOCATION <u>N 4860941.7; E 358659.0 MTM ZONE (LAT. 43.886492; LONG. -78.829707)</u>	ORIGINATED BY <u>MCK</u>	
DIST <u> </u> HWY <u>401</u>	BOREHOLE TYPE <u>CME 55, 208 mm O.D., 108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>SZ/MR</u>	
DATUM <u>Geodetic</u>	DATE <u>September 12 and 13, 2016</u>	CHECKED BY <u>MCK</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		GR	SA	SI	CL	
	<div>— CONTINUED FROM PREVIOUS PAGE —</div> <div>NOTES: 1. Water level measurement in piezometer: Date Depth Elev. 09/13/2016 2.0 m 81.3 m 03/28/2017 1.7 m 81.6 m 2. An additional borehole was advanced approximately 1.5 m northwest to carry out vanes between</div>																				

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[illegible]



APPENDIX B

Laboratory Test Results

**UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS
ASTM D7012**

Table B1

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1540419	SAMPLE NUMBER	Run #3
PROJECT NAME	DM Wills/Culverts Hwy35/ON	SAMPLE DEPTH, m	13.01-13.19
BOREHOLE NUMBER	C4-1	DATE:	2016-09-12
TEST CONDITIONS			
MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.20
SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	10.37	WATER CONTENT, (specimen) %	1.49
SAMPLE DIAMETER, cm	4.71	UNIT WEIGHT, kN/m ³	25.30
SAMPLE AREA, cm ²	17.39	DRY UNIT WT., kN/m ³	24.93
SAMPLE VOLUME, cm ³	180.37	SPECIFIC GRAVITY	-
WET WEIGHT, g	465.55	VOID RATIO	-
DRY WEIGHT, g	458.72		
VISUAL INSPECTION		FAILURE SKETCH	
TEST RESULTS			
STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	30.2
REMARKS: L/D Ratio not in accordance with ASTM Standard			

Checked By: MWK

Golder Associates

POINT LOAD TESTS ON ROCK SAMPLES

TABLE B2

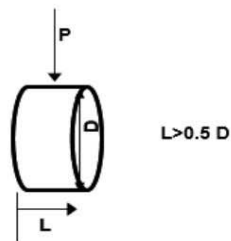
PROJECT NO. 1540419
 TITLE DM Wills/Culverts Hwy35/115/ON
 DATE September, 2016

Borehole Number	Sample Number	Sample Depth (m)	Test Type	Core Length (mm)	Core Diameter (mm)	Equivalent Diameter (mm)	Is Axial (MPa)	Is Diametral (MPa)	Is (50mm) (MPa)	Approx. ⁽¹⁾ UCS (MPa)
C4-1	Run 2	11.59-11.61	Axial	20.67	47.23	35.26	2.837	-	2.424	40
C4-1	Run3	12.65-12.69	Axial	24.92	47.17	38.69	2.926	-	2.607	44
C4-1	Run 3	14.02-14.05	Axial	20.59	47.22	35.18	2.451	-	2.092	35
C4-2	Run 1	17.30-17.33	Axial	24.71	46.66	38.31	0.827	-	0.733	12
C4-2	Run 2	18.18-18.21	Axial	26.45	47.31	39.92	0.321	-	0.290	5
C4-2	Run 2	19.46-19.49	Axial	23.18	46.87	37.19	2.508	-	2.196	37
C4-3	Run 1	10.12-10.15	Axial	21.23	46.82	35.58	1.753	-	1.504	25
C4-3	Run 2	10.72-10.75	Axial	23.46	47.08	37.50	2.157	-	1.895	32
C4-3	Run 3	12.53-12.55	Axial	18.98	46.71	33.60	3.158	-	2.641	44

⁽¹⁾ $I_{s50} \times C$, from ISRM "Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60. $C=16.7$, calculated from I_{s50} average (9 tests) equal to 1.8 MPa on axial orientation and UCS equal to 30 MPa (1 test)

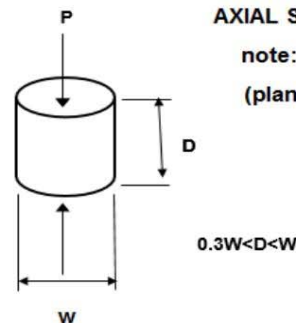
DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis
 (planes of weakness)



AXIAL SPECIMEN SHAPE REQUIREMENTS

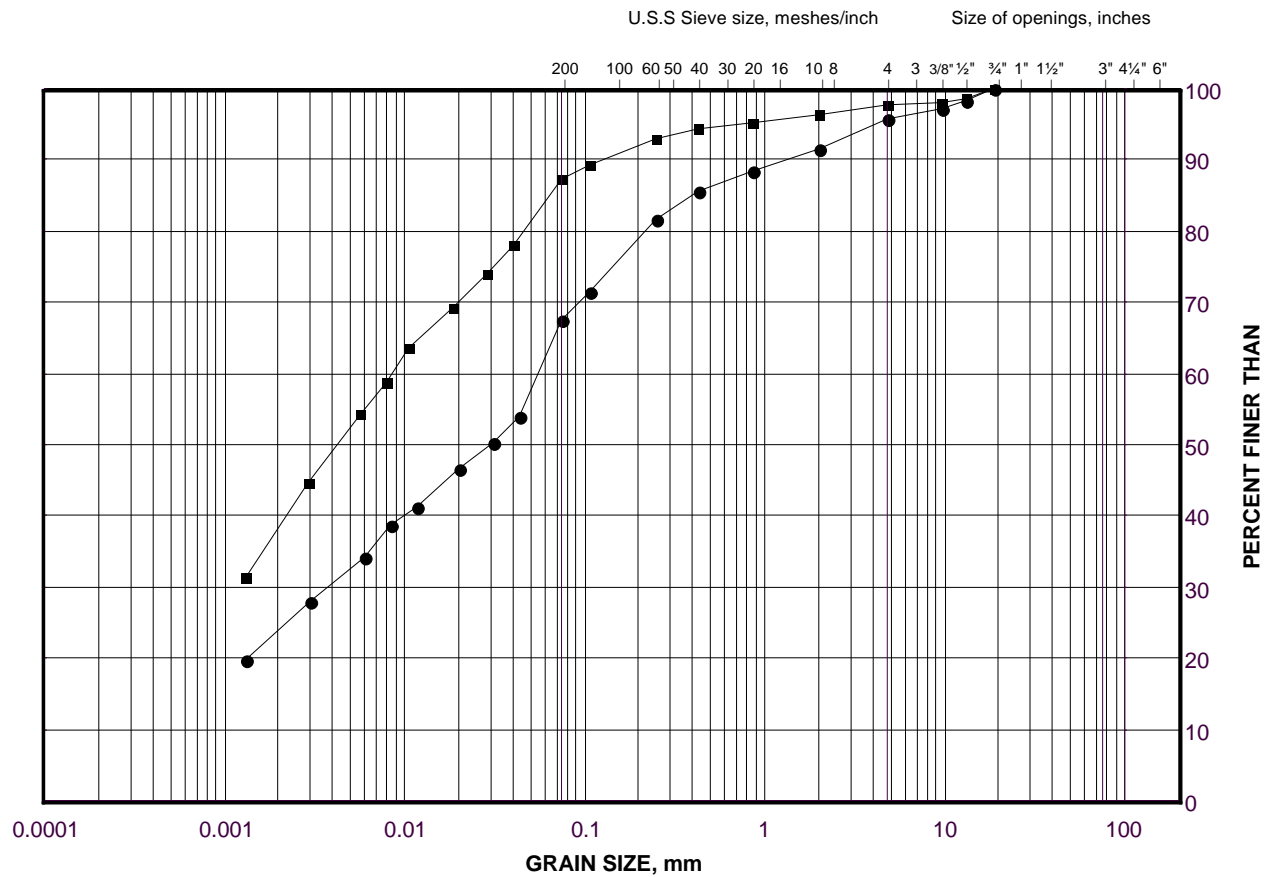
note: Axial tests are parallel to core axis
 (planes of weakness)



GRAIN SIZE DISTRIBUTION

Clayey Silt (Fill)

FIGURE B1



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

LEGEND

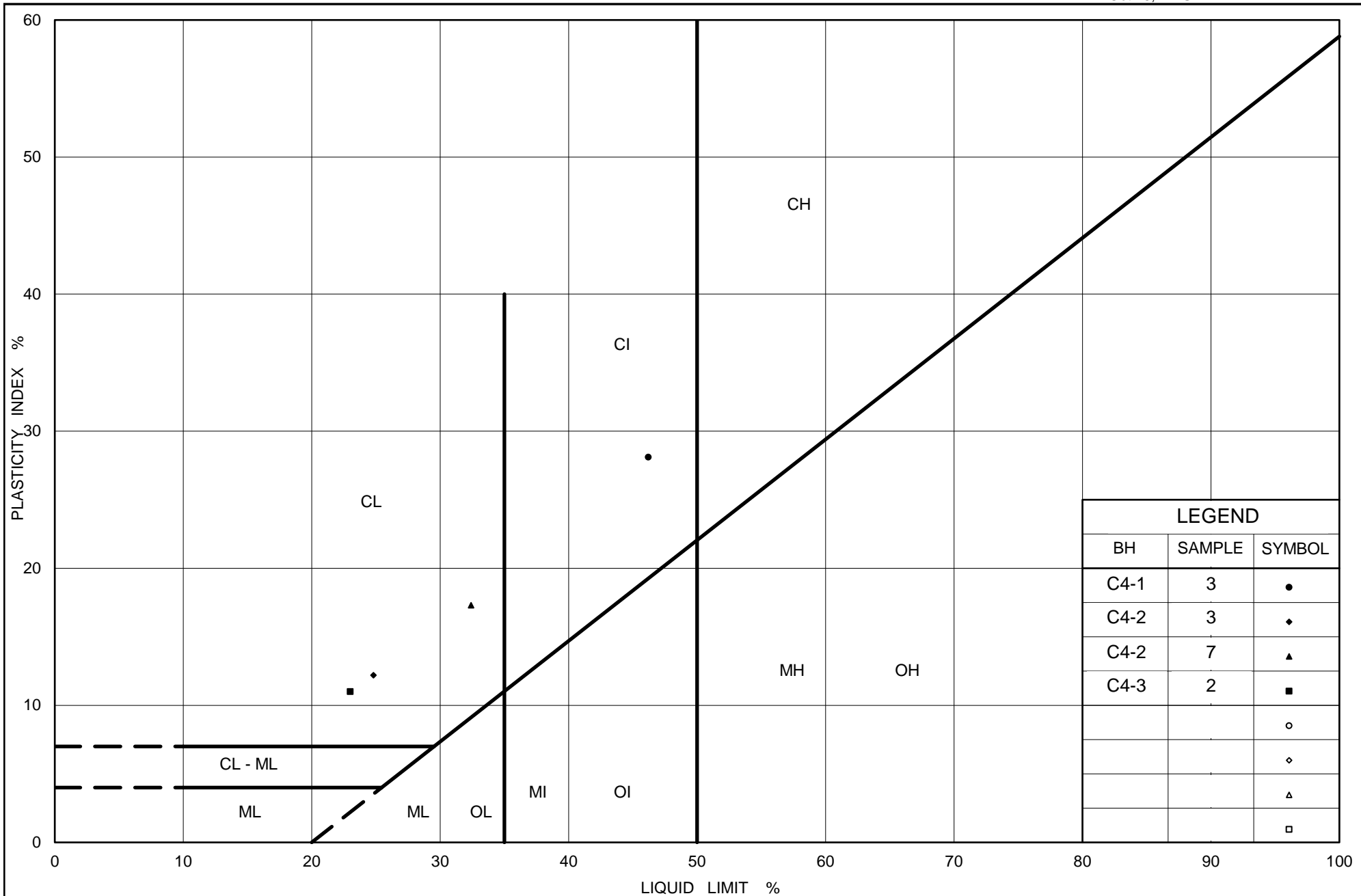
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C4-2	4	87.3
■	C4-2	7	83.5

Project Number: 1540419

Checked By: _____

Golder Associates

Date: 09-Dec-16



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt to Silty Clay (Fill)

Figure No. B2

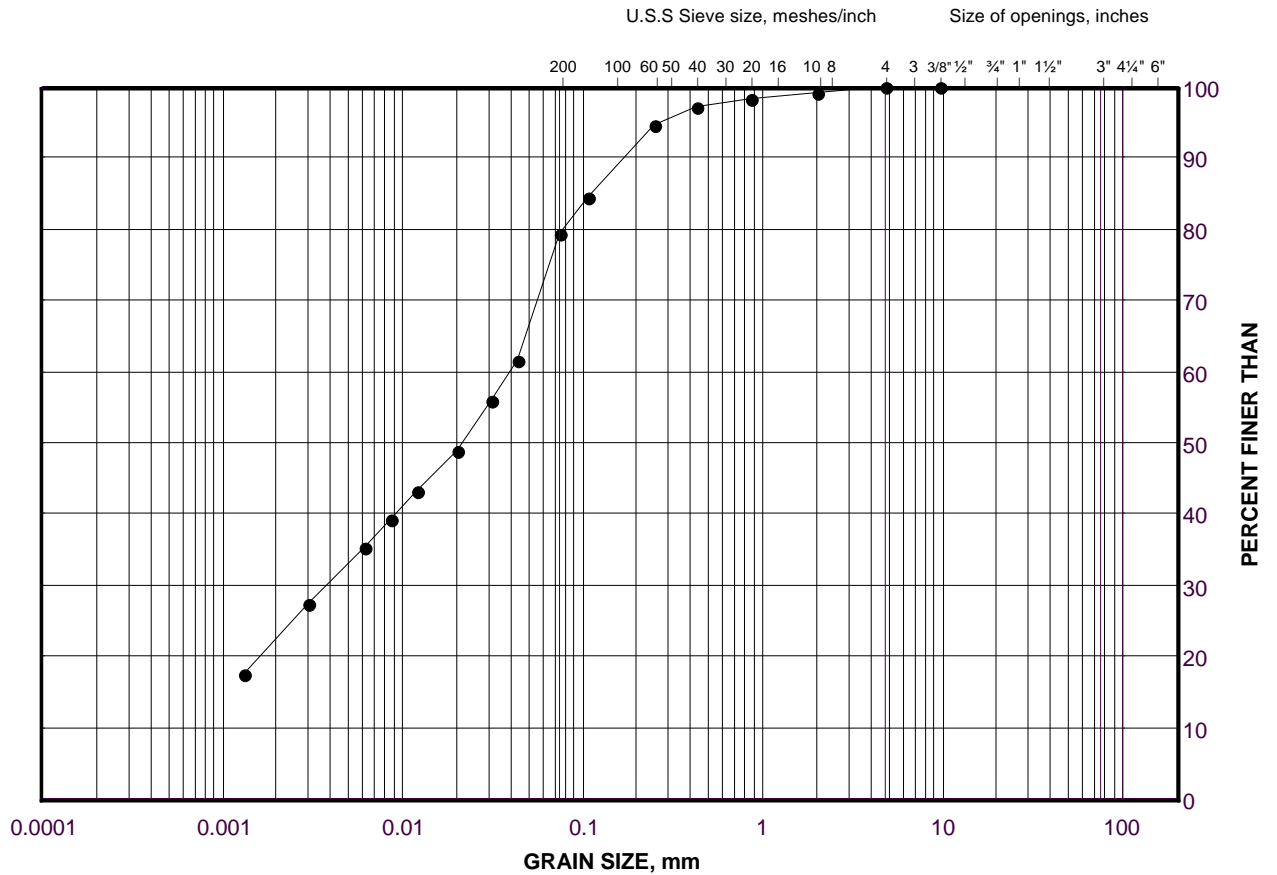
Project No. 1540419

Checked By: MWK

GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt

FIGURE B3



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

LEGEND

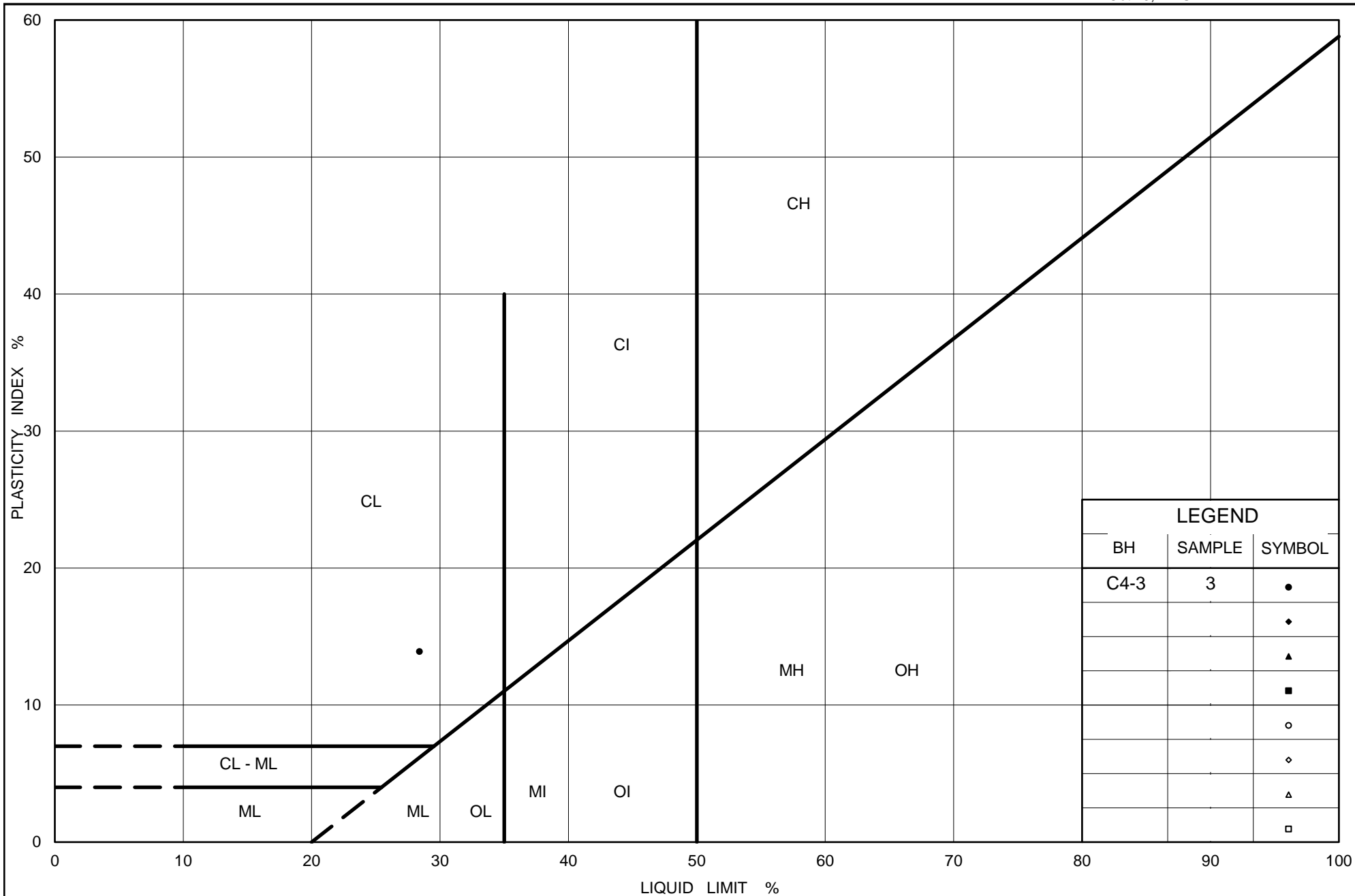
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C4-3	3	81.5

Project Number: 1540419

Checked By: _____

Golder Associates

Date: 21-Dec-16



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt

Figure No. B4

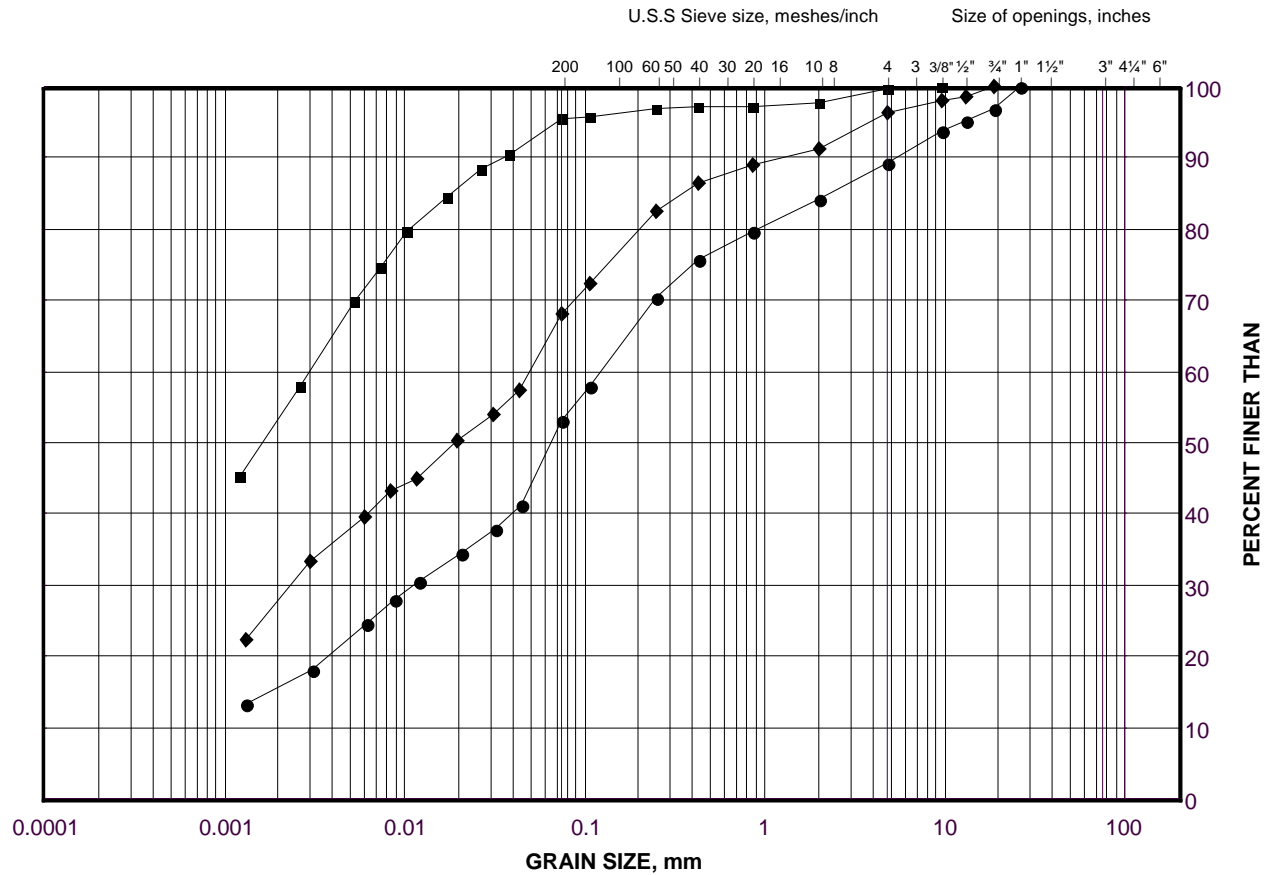
Project No. 1540419

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

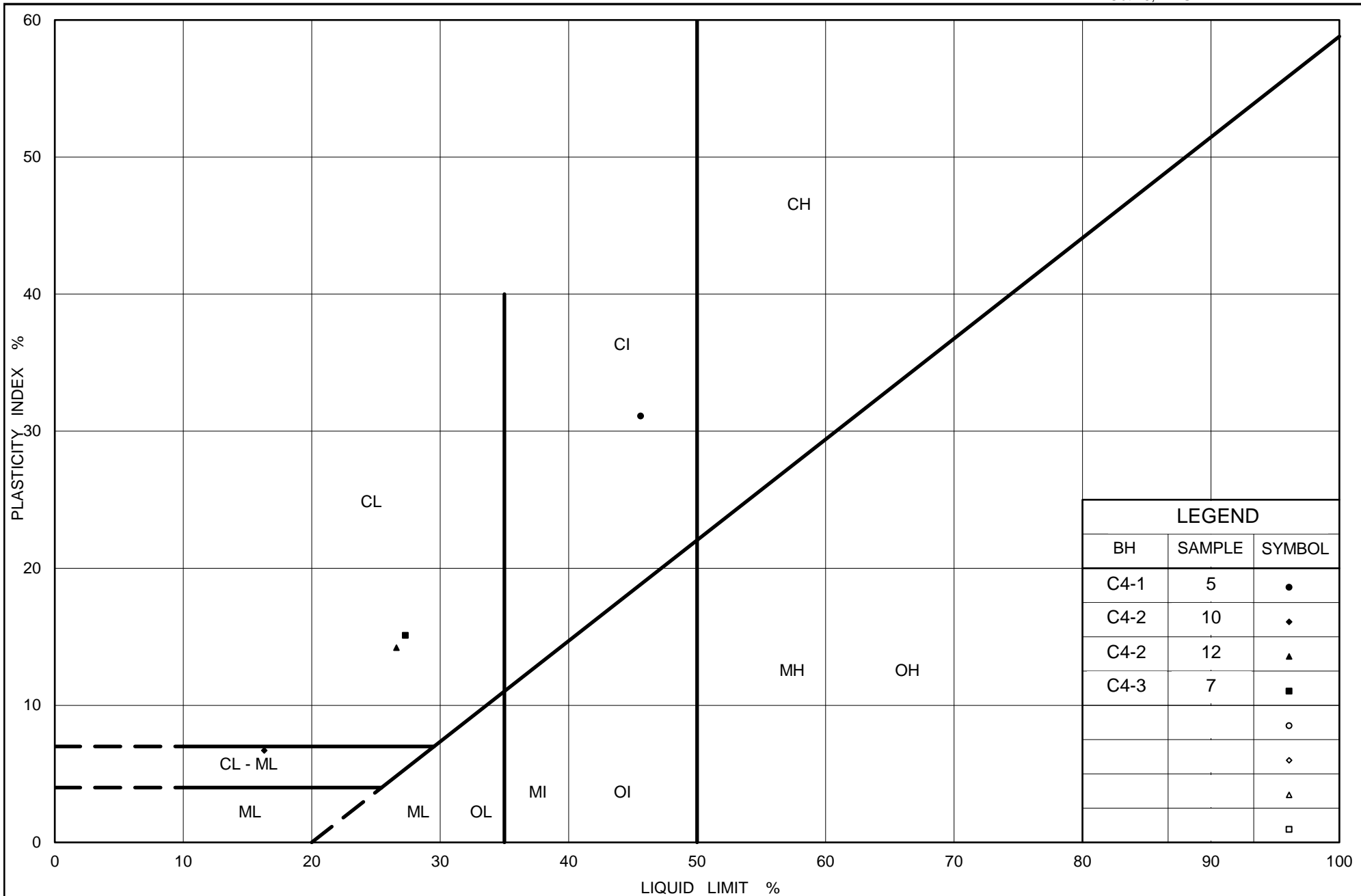
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C4-2	10	79.0
■	C4-1	5	80.2
◆	C4-3	7	76.9

Project Number: 1540419

Checked By: _____

Golder Associates

Date: 09-Dec-16



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Silty Clay (Till)

Figure No. B6

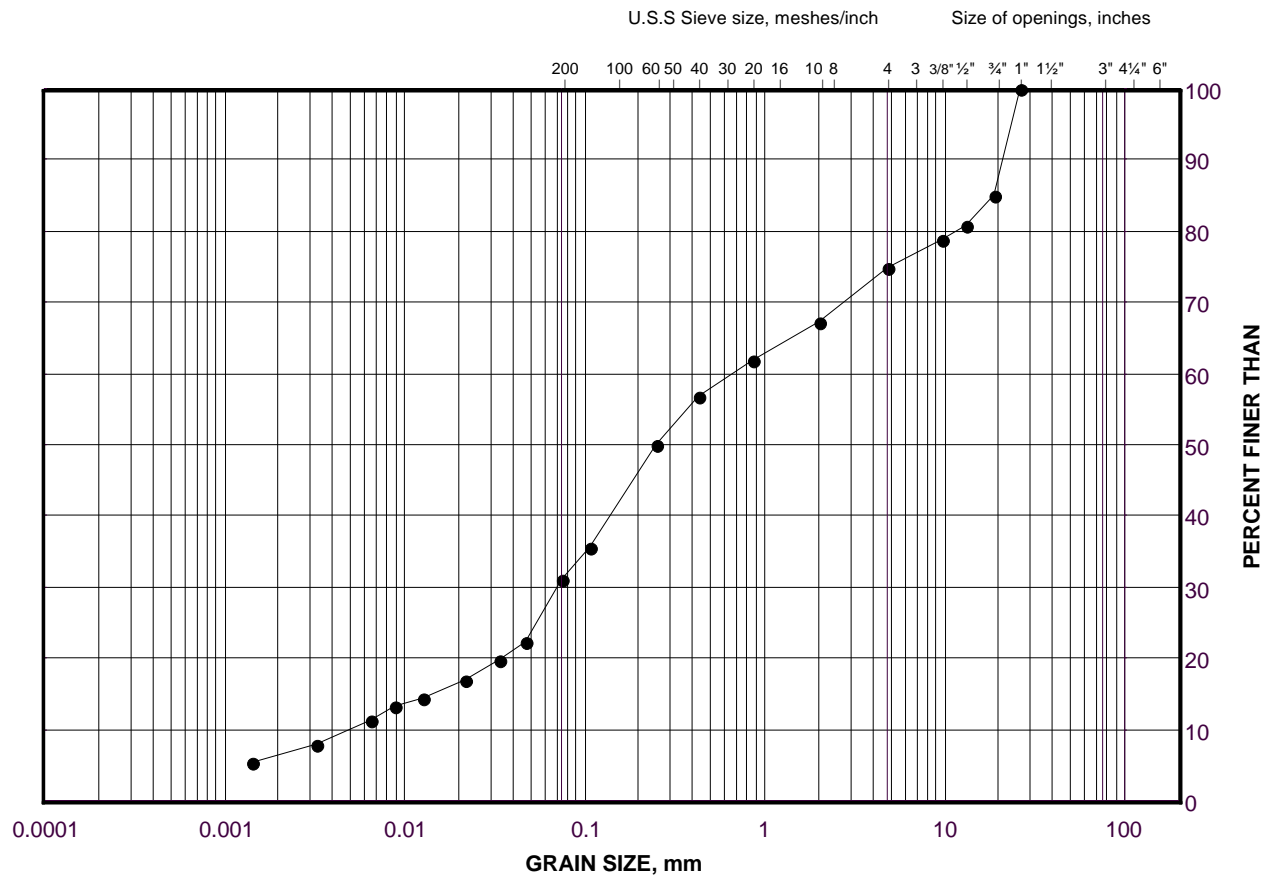
Project No. 1540419

Checked By: MWK

GRAIN SIZE DISTRIBUTION

Gravelly Sand to Gravelly Silty Sand (Till)

FIGURE B7



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C4-1	7	77.2

Project Number: 1540419

Checked By: _____

Golder Associates

Date: 21-Dec-16



APPENDIX C

Analytical Test Results

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	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
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.

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								

TEST SUMMARY

Maxxam ID: DCX431
Sample ID: C1
Matrix: Soil

Collected: 2016/08/23
Shipped:
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
Sample ID: C2
Matrix: Soil

Collected: 2016/08/27
Shipped:
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
Sample ID: C3
Matrix: Soil

Collected: 2016/08/28
Shipped:
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
Sample ID: C4
Matrix: Soil

Collected: 2016/08/31
Shipped:
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
Sample ID: C9
Matrix: Soil

Collected: 2016/09/08
Shipped:
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

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

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

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.

QUALITY ASSURANCE REPORT

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4679490	Available (CaCl ₂) 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 (SO ₄)	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).

VALIDATION SIGNATURE PAGE

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

Cristina Carriere

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.



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

23-Sep-16 12:57

Ema Gitej
B6K5174

Page of

Only:

Bottle Order #:

579330

Project Manager:

Ema Gitej

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	Tel:		Site #:	
Fax:	(905) 567-6561	Fax:		Sampled By:	
Email:	Catherine_Guiao@golder.com, Rachel_Benjamin@gol	Email:	Matthew_Kelly@golder.com, MadKennedy@golder.com		

JFU

ENV-107

COC #:



CM573330-01-01

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

Regulation 153 (2011)		Other Regulations		Special Instructions
<input type="checkbox"/> Table 1	<input type="checkbox"/> Res/Park	<input type="checkbox"/> CCME	<input type="checkbox"/> Sanitary Sewer Bylaw	
<input type="checkbox"/> Table 2	<input type="checkbox"/> Ind/Comm	<input type="checkbox"/> Reg 558	<input type="checkbox"/> Storm Sewer Bylaw	
<input type="checkbox"/> Table 3	<input type="checkbox"/> Agri/Other	<input type="checkbox"/> MISA	Municipality	
<input type="checkbox"/> Table	<input type="checkbox"/> For RSC	<input type="checkbox"/> PWQO		
		<input type="checkbox"/> Other		

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

Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix
1	C1	2016/08/23	10:00am	Soil
2	C2	2016/08/27	1:00pm	Soil
3	C3	2016/08/28	1:00pm	Soil
4	C4	2016/08/31	11:00am	Soil
5	C9	2016/09/06	2:00am	Soil
6				
7				
8				
9				
10				

Field Filtered (please circle):

Metals / Hg / Cr VI

Corrosivity pkg (CI, SO4, EC, Resistivity, pH)

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 Dioxin/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 it)

of Bottles

Comments

RELINQUISHED BY: (Signature/Print)		Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)		Date: (YY/MM/DD)	Time	# Jars used and not submitted	Laboratory Use Only				
Madison Kennedy		26/09/23	12:57	Tanvir By Tanvir RST		2016/09/23	12:57		Time Sensitive	Temperature (°C) on Receipt	Custody Seal	Yes	No
										7/6/7	Present		c
											Intact		✓

* IT IS THE RESPONSIBILITY OF THE RELINQUISHING PARTY 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



APPENDIX D

Record of Borehole and Laboratory test Results from 2015 Investigation



GTA-MTO 001 T:\PROJECTS\2011\11-1184-0143 (HWY 401 FROM BROCK RD TO COURTYARD)\LOG\11-1184-0143.GPJ GAL-GTA.GDT 08/12/16 KD

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

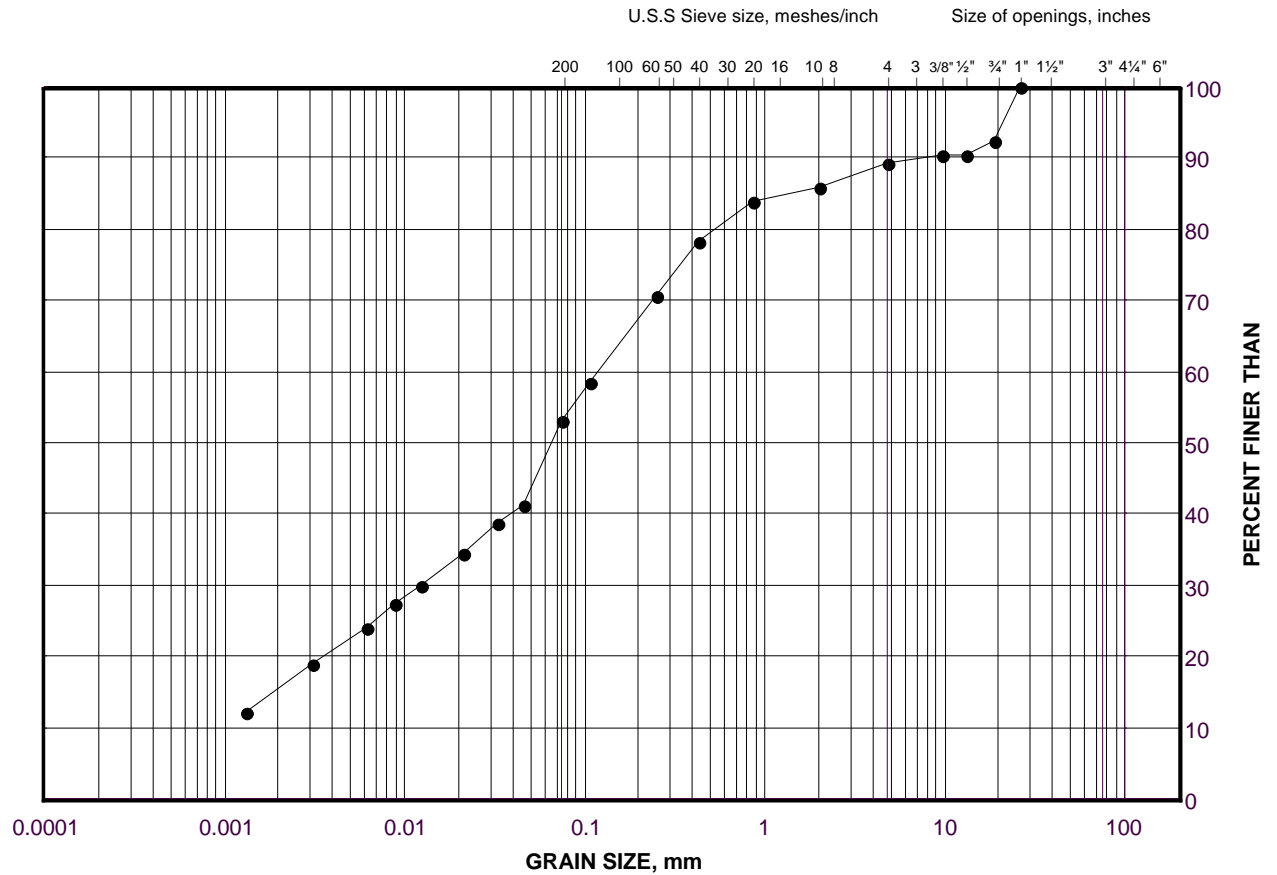
PROJECT 11-1184-0143		RECORD OF BOREHOLE No B2				SHEET 2 OF 2		METRIC								
W.O. 10-20011		LOCATION N 4860928.9 ; E 358606.5				ORIGINATED BY TD										
DIST Central HWY 401		BOREHOLE TYPE 150 mm O.D. Continuous Flight Solid Stem Augers				COMPILED BY BM/MGP										
DATUM Geodetic		DATE April 12, 2015				CHECKED BY 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								
	--- CONTINUED FROM PREVIOUS PAGE --- NOTES: * SPT 'N' value interpreted to be affected by disturbance due to groundwater inflow during sampling. 1. Borehole caved to a depth of 6.1 m below ground surface (Elev. 82.0 m) upon completion of drilling, April 12, 2015. 2. Water level in borehole measured at a depth of 6.1 m below ground surface (Elev. 82.0 m) upon completion of drilling, April 12, 2015. 3. Water level in piezometer measured at a depth of 5.8 m below ground surface (Elev. 82.3 m) on June 7, 2016.															

GTA-MTO 001 T:\PROJECTS\2011\11-1184-0143 (HWY 401 FROM BROCK RD TO COURTYARD RD)\LOG\11-1184-0143.GPJ GAL-GTA.GDT 08/12/16 KD

GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt

FIGURE D1



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

LEGEND

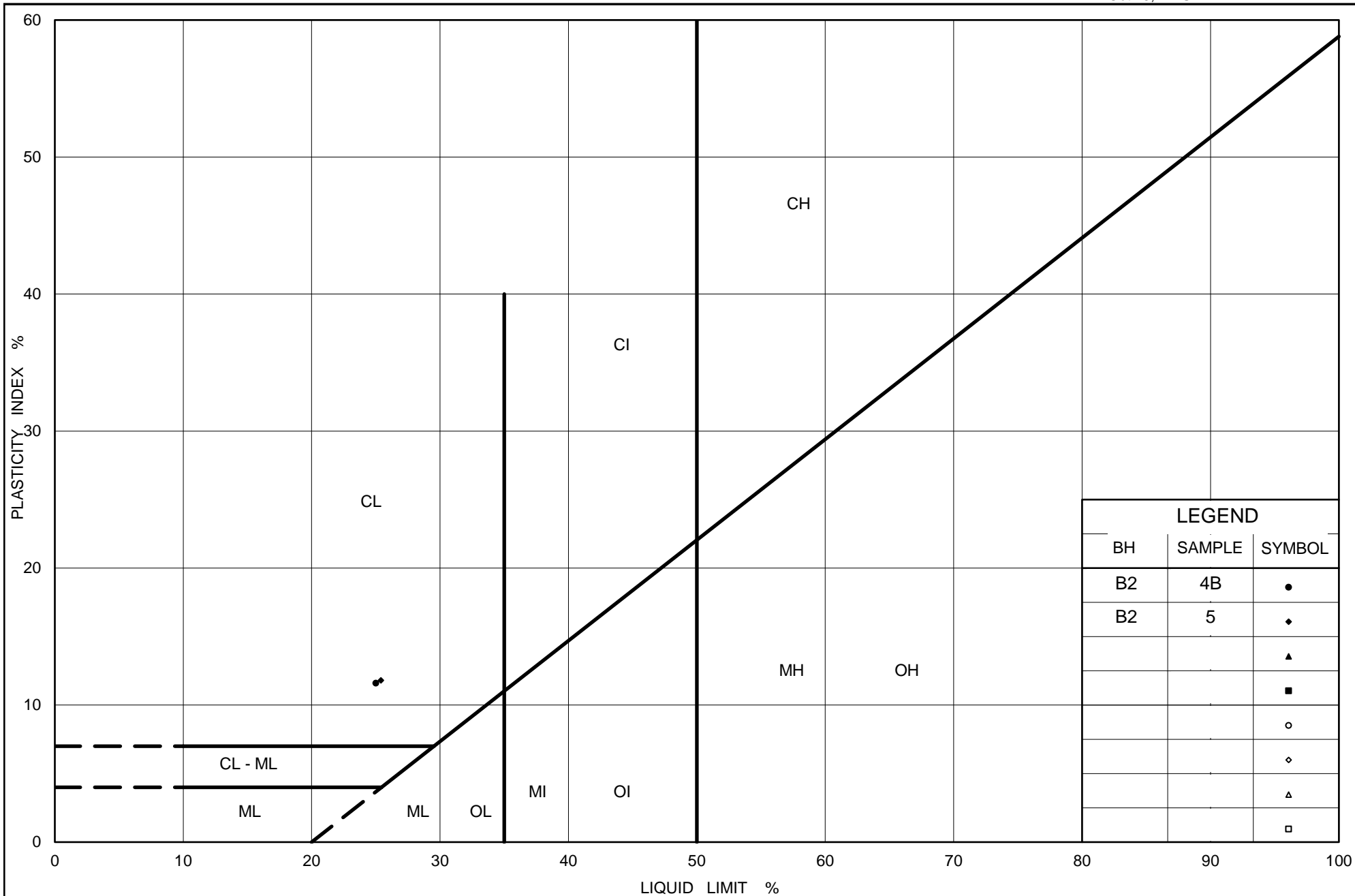
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	B2	5	84.8

Project Number: 1540419

Checked By: _____

Golder Associates

Date: 21-Dec-16



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Ontario

PLASTICITY CHART

Clayey Silt

Figure No. D2

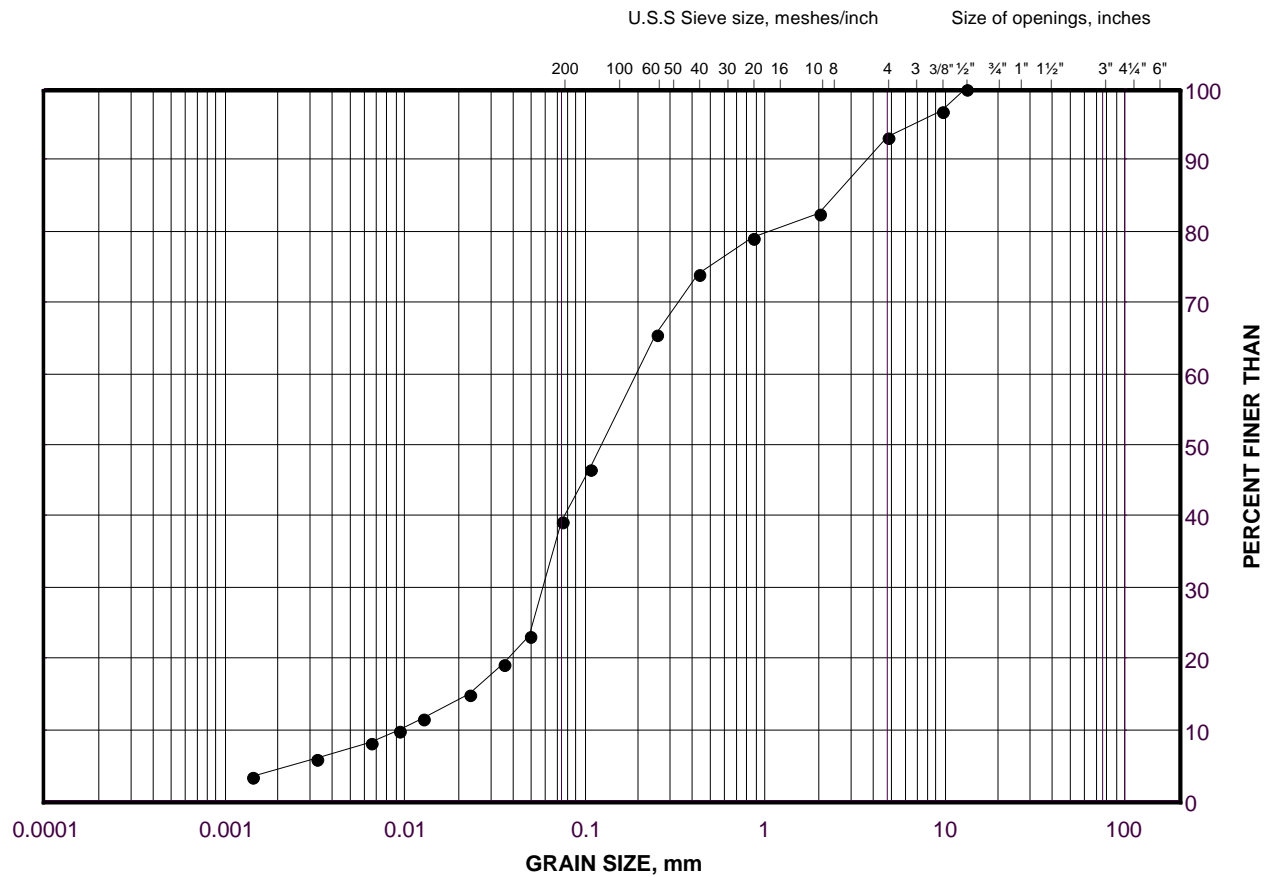
Project No. 11-1184-0143

Checked By:MWK

GRAIN SIZE DISTRIBUTION

Silt and Sand (Till)

FIGURE D3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	B2	7	81.8

Project Number: 11-1184-0143

Checked By: MWK

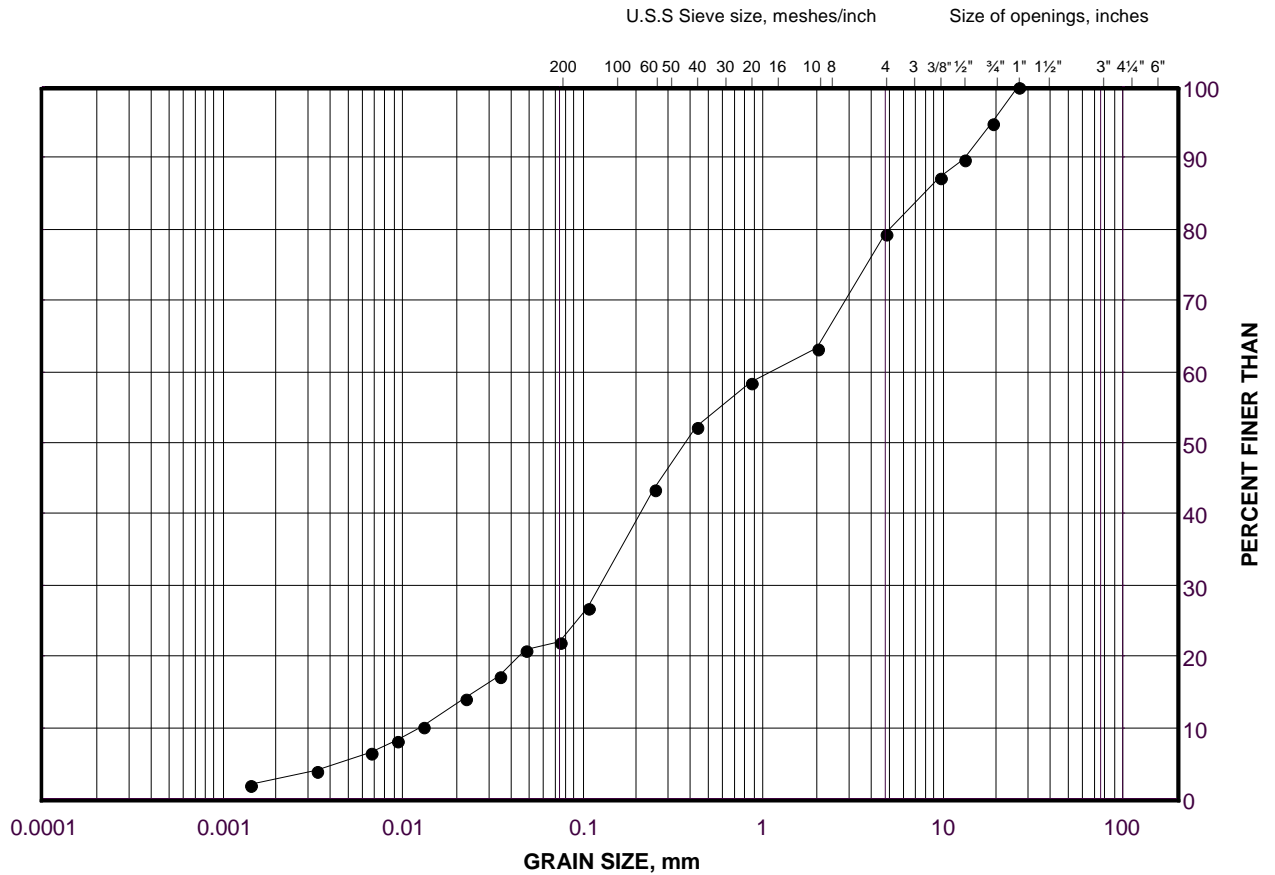
Golder Associates

Date: 09-Dec-16

GRAIN SIZE DISTRIBUTION

Gravelly Sand to Gravelly Silty Sand (Till)

FIGURE D4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	B2	10	77.2

Project Number: 1540419

Checked By: _____

Golder Associates

Date: 21-Dec-16

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

Africa	+ 27 11 254 4800
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