



June 12, 2017

FOUNDATION INVESTIGATION AND DESIGN REPORT

**Highway 401 Structural Culvert
Rehabilitation/Replacement - Site No. 21-491/C
Highway 35/115 and Highway 401
Ministry of Transportation, Ontario
W.P. 2242-14-00**

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REPORT

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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 401 STRUCTURAL CULVERT REPLACEMENT
SITE NO. 21-491/C
MINISTRY OF TRANSPORTATION, ONTARIO
AGREEMENT NO. 5015-E-0013; W.P. 2242-14-00**



1.0 INTRODUCTION

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

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

This report addresses the investigation carried out for the structural culvert at about Station 19+159 on Highway 401 (MTO Structure Site No. 21-491/C) which has been identified for rehabilitation or potential replacement. The foundation investigation and design associated with the other culverts under this assignment are presented in separate reports.

2.0 SITE DESCRIPTION

The structural culvert at Site No. 21-491/C (Culvert C7) is located at approximately Station 19+159 on Highway 401 at West Side Creek in the Town of Bowmanville, Regional Municipality of Durham, Ontario. The existing structure is a concrete box culvert and is approximately 57.5 m long, 3.2 m wide and 1.2 m high, including a 5.8 m long open footing extension previously constructed on the north end of the culvert. The structure is located within an earth fill embankment and has approximately 0.9 m of cover. Details of the culvert are also summarized in Table 1 following the text of this report.

The overall surface topography in the vicinity of the site is generally a relatively flat lacustrine plain used for agricultural purposes with clusters of trees and brush present along the ditch line adjacent to the highway. The natural ground surface in the vicinity of the culvert is at about Elevation 82 m, and the culvert invert is at approximately Elevation 81.8 m to 81.6 m. The Highway 401 grade in the vicinity of the culvert is at about Elevation 84 m. The existing Highway 401 embankment consists of earth fill, up to about 2 m to 2.5 m high with side slopes inclined at approximately 2 horizontal to 1 vertical (2H:1V).

3.0 INVESTIGATION PROCEDURES

The field work for the foundations investigation associated with structural culvert 21-491/C was carried out between December 6 and December 14, 2016 during which time a total of four boreholes were advanced at or in the vicinity of the culvert alignment as shown in plan on Drawing 1.

The field investigation was carried out using truck-mounted drilling equipment supplied and operated by a specialist drilling contractor, Atcost Drilling Inc., of Gormley, Ontario. The boreholes were advanced through the overburden using 208 mm outer diameter hollow stem augers or 127 mm outer diameter solid stem augers, and the bedrock was cored using NQ-size coring equipment. Soil samples were obtained at intervals of depth of about



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0.75 m and 1.5 m using a 50 mm outer diameter split-spoon sampler operated by an automatic hammer, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586¹).

A piezometer was installed in Borehole C7-1 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 across the silty sand/sand and gravel/gravelly silty sand deposits. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to ground surface. The piezometer installation details and water level readings are noted on the Record of Borehole C7-1 in Appendix A. All other 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 borehole records in Appendix A.

The field work 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 samples. The soil and bedrock samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's 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 (UC) and point load index) was carried out on selected samples of the cored bedrock. The results of the laboratory testing are summarized on the borehole/drillhole records in Appendix A and the results of the geotechnical testing are provided in Appendix B.

A soil sample obtained from near the culvert invert elevation was submitted to a specialist analytical laboratory under chain of custody procedures for chemical analysis of conductivity / resistivity, pH and sulphate, chloride content and redox potential to assess the potential for the soil to cause corrosion to buried concrete and steel. The results of the analytical testing are provided in Appendix C.

The as-drilled borehole locations were measured relative to existing site features and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. The elevation of the boreholes 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 borehole records and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations (including both NAD 83 coordinates and latitude/longitude coordinates), ground surface elevations and drilled depths are as follows:

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



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Borehole	Location (m)		Ground Surface Elevation (m)	Depth of Borehole (m)*
	Northing	Easting		
C7-1	4861689.2(43.892347)	369496.5 (-78.694508)	84.0	10.5
C7-2	4861671.0 (43.892192)	369506.6 (-78.695000)	84.0	13.6
C7-3	4861679.4 (43.892259)	369516.1 (-78.694508)	84.0	10.2
C7-4	4861665.0 (43.892127)	369541.6 (-78.694193)	83.4	12.1

*Includes 3.1 m bedrock coring in Borehole C7-2, and 2.8 m bedrock coring in Borehole C7-4.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

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

The surficial soils in this area of the Iroquois Plain are typically comprised of glaciolacustrine clays, silts and sands to gravelly sands, which are underlain by an extensive till deposit that is mapped in this area as the Bowmanville Till.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during the foundation investigation, together with the results of the geotechnical laboratory tests carried out on selected soil and bedrock samples, are presented on the borehole records in Appendix A. The stratigraphic boundaries shown on the borehole records and stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil and rock 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 structural culvert Site No. 21-491/C consists of an upper layer of non-cohesive fill underlain by a lower layer of cohesive fill which comprises the roadway embankment, underlain by a cohesive deposit of silty clay to clayey silt which is underlain by granular deposits of silty sand to sand and gravel to gravelly silty sand and silt and sand till. The overburden deposits are underlain by limestone bedrock. A more

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

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



detailed description of the subsurface conditions at the culvert crossing is provided in the following sections of this report.

4.2.1 Asphalt and Road Base

All four boreholes were advanced through the existing Highway 401 roadway and penetrated an asphalt layer between approximately 200 mm and 300 mm thick.

4.2.2 Embankment Fill

Embankment fill approximately 2.0 m to 3.8 m thick was encountered in all boreholes advanced at this site under a layer of asphalt. The embankment fill consists of an upper non-cohesive layer of sand and gravel to gravelly sand, approximately 1.2 m to 1.3 m thick, with the base of the granular fill encountered between Elevations 82.0 m and 82.6 m. Beneath the upper granular layer the embankment fill is comprised of a 0.7 m to 2.6 m thick cohesive stratum comprised of clayey silt with sand to sandy silty clay, trace gravel to gravelly; the base of the cohesive fill was encountered between Elevations 78.4 m and 80.3 m. Trace organics were encountered in the sandy clayey silt fill in Borehole C7-1. The presence of cobbles and/or boulders within the fill layers was inferred from auger grinding in Boreholes C7-2, C7-3 and C7-4, as noted on the borehole records in Appendix A.

The Standard Penetration Test (SPT) 'N'-values measured within the non-cohesive fill zones of the embankment range from 13 blows to 57 blows per 0.3 m of penetration, indicating a variable, compact to very dense relative density. The SPT 'N'-values measured in the cohesive fill zone of the embankment range from 3 blows to 14 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

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

Atterberg limits testing was carried out on four samples of the cohesive embankment fill and measured liquid limits between about 16 per cent and 38 per cent, plastic limits between about 11 per cent and 18 per cent and plasticity indices between about 5 per cent and 20 per cent. The 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. The natural water content measured on samples of the cohesive embankment fill ranges between about 7 per cent and 29 per cent. The natural water content measured on samples of the non-cohesive embankment fill ranges between about 4 per cent and 10 per cent.

4.2.3 Clayey Silt to Silty Clay

A 1.9 m to 6.3 m thick cohesive deposit was encountered below the embankment fill in all of the boreholes at this site, with its surface between Elevation 79.9 m and 81.8 m, and its base between about Elevation 74.1 m and 79.9 m. This deposit is comprised of clayey silt with sand and gravel, to silty clay trace to some sand to sandy. The presence of cobbles and/or boulders within this deposit in Borehole C7-4 was inferred from auger grinding, as noted on the borehole record in Appendix A.

The SPT 'N'-values measured within the clayey silt to silty clay deposit range between 3 blows and 42 blows per 0.3 m of penetration, and 50 blows for 0.05 m of penetration, suggesting a variable, soft to hard consistency.

The results of grain size distribution tests completed on four samples of the clayey silt to silty clay deposit are shown on Figure B3 in Appendix B.



Atterberg limits testing was carried out on three samples of the clayey silt to silty clay deposit and measured liquid limits between about 26 and 37 per cent, plastic limits between about 15 and 17 per cent and plasticity indices between about 11 and 20 per cent. The test results, which are plotted on a plasticity chart on Figure B4 in Appendix B, indicate that the material tested is comprised of clayey silt of low plasticity to silty clay of intermediate plasticity. The natural water content measured on three samples of the clayey silt to silty clay deposit ranges between about 8 per cent and 27 per cent.

4.2.4 Silty Sand to Sand and Gravel

A silty sand to gravelly silty sand to sand and gravel deposit was encountered below the cohesive deposit in Boreholes C7-1 and C7-2, with its surface between Elevation 78.4 m and 79.9 m. It ranged in thickness from 3.1 m in Borehole C7-2, to 6.4 m in Borehole C7-1 where the borehole was terminated on sampler and auger refusal.

The SPT 'N'-values measured within the silty sand to sand and gravel deposit range between 8 blows and 56 blows per 0.3 m of penetration, indicating a variable, loose to very dense relative density.

The results of grain size distribution tests completed on two samples of the silty sand to sand and gravel deposit are shown on Figure B5 in Appendix B. The natural water content measured on three samples of the silty sand to sand and gravel deposit ranges from about 4 per cent to 8 per cent.

Atterberg limits testing was carried out on the fines portion of two samples of the silty sand to sand and gravel deposit and measured liquid limits of about 12 per cent, plastic limits of about 8 and 9 per cent and plasticity indices of about 3 and 4 per cent. The test results, which are plotted on a plasticity chart on Figure B6 in Appendix B, indicate that the fines portion of this deposit consists of silt of slight plasticity.

4.2.5 Silt and Sand Till

A till deposit comprised of silt and sand, trace to some gravel, trace to some clay, was encountered in Boreholes C7-2 and C7-3 at about Elevation 75.3 m. The deposit ranged in thickness from 1.8 m in Borehole C7-2 to 1.5 m in Borehole C7-3 where the borehole was terminated on sampler and auger refusal.

The SPT 'N'-values measured within the silt and sand till deposit range from 35 blows per 0.3 m of penetration to 50 blows for 0.13 m of penetration, indicating a dense to very dense relative density.

The results of grain size distribution tests completed on two samples of the silt and sand till deposit are shown on Figure B7 in Appendix B. The natural water content measured on samples of this non-cohesive till deposit range between about 6 per cent and 9 per cent.

4.2.6 Limestone Bedrock

Refusal to further auger and sampler penetration on probable bedrock was encountered in Boreholes C7-1 and C7-3 at Elevations 73.5 m and 73.8 m, respectively. Bedrock was encountered and core samples were recovered in Boreholes C7-2 and C7-4 at depths between 9.3 m and 10.5 m below ground surface (between Elevations 73.5 m and 74.1 m). Based on a review of the recovered bedrock core samples, the bedrock consists of grey, slightly weathered limestone. Detailed descriptions of the bedrock are presented on the Record of Drillhole sheets in Appendix A.



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The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered range between 98 per cent and 100 per cent. The Rock Quality Designation (RQD) of the bedrock core samples ranges from 57 per cent to 92 per cent, indicating a rock mass of fair to excellent 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 limestone bedrock from Borehole C7-2 measured a uniaxial compressive strength of about 47 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 six 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 limestone bedrock range from approximately 2.7 MPa to 5.2 MPa. These index values correspond to UCS values ranging between about 35 MPa and 57 MPa, based on a relationship between Is_{50} and UCS which is given by a correlation factor (C), estimated to be equal to 13.1 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 test.

Based on the laboratory UCS tests and point load testing results, the estimated intact strength of the Limestone bedrock generally ranges from medium strong (R3, 25 MPa < UCS < 50 MPa) to strong (R3, 50 MPa < UCS < 100 MPa) (CFEM, 2006).

4.2.7 Groundwater Conditions

The water level was measured in Boreholes C7-2 and C7-3 upon completion of drilling operations at depths of 10.2 m and 2.8 m below ground surface (Elevation 73.8 m and 81.2 m, respectively). The water level was not recorded in Borehole C7-4 prior to bedrock coring. A piezometer was installed in Borehole C7-1 on the north side of Highway 401. The measured groundwater level is shown on the borehole record and summarized below:

Borehole No.	Depth to Water Level (m)	Groundwater Elevation (m)	Date of Measurement
C7-1 (Piezometer)	2.2	81.8 m	December 6, 2016
C7-2 (Open Borehole)	10.2	73.8 m	December 14, 2016
C7-3 (Open Borehole)	2.8	81.2 m	December 12, 2016

The water level measured in the piezometer was near the culvert invert in December 2016. The water level observed in the open 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 from Borehole C7-1 to assess the corrosivity and concrete degradation potential of the soils for the new culvert structure. The composite sample was constituted



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from 'SPT' samples obtained near the invert of the existing culvert. The results from the specialist analytical laboratory are presented in Appendix C and are summarised below:

Parameter	Test Result
Soil Resistivity	2100 ohm-cm
Soil Conductivity	467 $\mu\text{mho/cm}$
Sulphate Concentration	49 $\mu\text{g/g}$
Chloride Concentration	180 $\mu\text{g/g}$
Soil pH	7.86

5.0 CLOSURE

Ms. Amelia Jewison, supervised the borehole investigation program. This report was prepared by Mr. Matthew Kelly, P.Eng., a geotechnical engineer with Golder. Lisa Coyne, P.Eng., a Principal and Designated MTO Foundations Contact for Golder, conducted an independent technical and quality control review of this report.



Report Signature Page

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PART B

**FOUNDATION DESIGN REPORT
HIGHWAY 401 STRUCTURAL CULVERT REPLACEMENT
SITE NO. 21-491/C
MINISTRY OF TRANSPORTATION, ONTARIO
AGREEMENT NO. 5015-E-0013; W.P. 2242-14-00**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the replacement of the structural culvert at Site No. 21-491/C (C7)), located at about Station 19+159 on Highway 401 at West Side Creek, in the Town of Bowmanville, Regional Municipality of Durham, Ontario. The existing culvert is about 57.5 m long and consists of a 3.2 m wide by 1.2 m high concrete box culvert. The current design based on direction provided at the 60% executive review meeting requires rehabilitation of the existing culvert and replacement of two section of culvert that are outside of the travelled lanes of the Highway by open cut methods. Although foundation design recommendations are not required for the proposed rehabilitation, MTO's Foundation Section requested preliminary recommendations for feasible trenchless installation methods for this site for a new or replacement culvert in the future.

These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the investigation. This Foundation Design Report, including the interpretations and recommendations presented herein, are intended for the use of MTO to provide the designer with sufficient information to assess the feasible design alternatives only. This Foundation Design Report shall not be used or relied upon for any other purpose or by any other parties, including contractors. Additional detailed recommendations will be required to carry out the design of a future replacement culvert(s), if required, once invert elevations, alignments and culvert sizes are known.

Where comments are made on construction, they are provided in order to highlight those aspects that could affect the design of the project, and for which special provisions or operational constraints may be required in the contract documents in the future. Contractors must make their own interpretation of the factual information provided in the Foundation Investigation Report (Part A), as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC 2014) and its Commentary, a classification of 'typical' consequence has been assumed for a replacement culvert section and foundation system. This consequence classification should be confirmed by the MTO.

The degree of understanding based on the scope of the foundation investigation and proximity of the boreholes to the culvert is considered 'typical' as described in Clause 6.5.3.2 of the 2014 CHBDC. The appropriate Ultimate Limit States (ULS) and Serviceability Limits (SLS) consequence factor Ψ , geotechnical resistance factors at ULS (ϕ_{gu}) and SLS (ϕ_{gs}), respectively from Tables 6.1 and 6.2 of the CHBDC should be used for design.

6.3 Design Assumptions – Future Trenchless Replacement

It is anticipated that a future new replacement or relief culvert at Site No. 21-491/C would likely be installed adjacent to and at a vertical profile near the existing invert elevation of approximately 81.6 m, or lower. Assuming that the existing open footing culvert is representative of the minimum size required to convey flows from West Side Creek and satisfy hydraulic requirements, a replacement culvert is expected to have an equivalent diameter of 3.2 m (similar to the existing width) or greater; however, larger diameters may be required for larger precipitation events, higher water levels and greater conveyances required under MTO's climate change considerations. At this stage, the maximum diameter of a replacement culvert is assumed to be 3.2 m. It is likely that one or more culverts up to 3.2 m in diameter could be required to satisfy hydraulic design in the future. Based on these diameters, the depth



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of cover to the existing Highway 401 pavement surface is expected to be less than 1 m above the culvert obvert. Multiple smaller diameter culverts could be installed to provide a greater cover thickness; however, hydraulic analysis would be required to ensure that adequate flow conveyance is provided.

It has been assumed that the alignment of any replacement or relief culvert would be close to the existing culvert. If space and hydraulic requirements permit, it is recommended that any new or relief culvert be installed no closer than 1 m from the closest edge of the existing culvert; however a minimum separation distance of two tunnel diameters is preferred and recommended.

6.4 Anticipated Ground Conditions for Trenchless Construction

Progressing from south to north, the subsurface conditions encountered along the assumed alignment for a future replacement or relief culvert generally consist of compact to very dense gravelly sand to sand and gravel fill comprising the upper portion of the highway embankment, and soft to stiff cohesive fill comprising the lower portion of the highway embankment. The fill is underlain by a deposit of firm to hard clayey silt to silty clay, a deposit of loose to very dense silty sand to sand and gravel and a silt and sand till stratum. The overburden deposits are underlain by limestone bedrock at a depth of about 8 m below the assumed culvert invert.

Although the cohesive embankment fill and potentially native cohesive deposit would occupy a portion of the tunnel face for a majority of the alignment, granular embankment fill is anticipated near the tunnel crown, and native deposits would also be anticipated to be encountered near the inlet and outlet ends of the culvert installation. The presence of cobbles and boulders within the embankment fill and native silty clay and silt and sand till deposits has been inferred from auger resistance/grinding encountered in Boreholes C7-2, C7-3 and C7-4. Our recent experience with trenchless crossings of major MTO highways suggests that there may be obstructions or debris consisting of abandoned temporary works associated with the original culvert construction. This debris may be buried in the fill, and/or present at the interface between the embankment fill and native soil. It may consist of logs, stumps, and brush from the clearing and grubbing operations, together with potentially temporary protection system elements parallel to the culvert itself. Generally, the groundwater level along the tunnel profile is anticipated to be near or slightly above the existing culvert (and presumed new culvert) invert, at about Elevation 81.6 m to 81.8 m. During construction, groundwater may be encountered perched in the granular fill layers overlying the lower permeability cohesive fill or native deposits.

The anticipated behavior of the subsurface materials can be classified using Terzaghi's Tunnelman's Ground Classification system as modified by Heuer (1974). The behaviour of the materials within the tunnel alignment is summarized as follows.

Material	Tunnelman's Ground Classification	
	Above Groundwater Level	Below Groundwater Level
Non-Cohesive Fill	Cohesive running to slow raveling	Flowing
Cohesive Fill	Firm	Firm
Clayey Silt to Silty Clay	Firm to slow raveling	Firm to fast raveling
Silty Sand	Cohesive running	Flowing
Silt and Sand Till	Firm to slow raveling	Firm to fast raveling



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In the absence of dewatering, the fills and native granular soils will collapse and flow in an unsupported excavation. The native cohesive soils would have a stand-up time ranging from a few minutes to several hours depending on the degree of seepage, disturbance and localized gradation of the deposits. The stand-up time of this material will likely be unpredictable.

Trenchless installations will be primarily affected by four factors associated with the subsurface and groundwater conditions, namely:

- The nature of the embankment fill within the face and above the crown of the tunnel: Fill near the inlet and outlet is granular in composition and can be excavated using several trenchless methods provided that the appropriate precautions are taken to preserve face stability, control water pressures and seepage, and prevent potential loss of ground.
- Buried obstructions: Golder's experience with trenchless culvert replacements below MTO highway embankments suggests that there may be debris consisting of abandoned temporary works associated with the original construction: logs, stumps and brush from previous clearing and grubbing operations, and cobbles and boulders buried in the fill. Such obstructions have the potential to damage/clog/obstruct machinery and halt trenchless operations, particularly if there is no person-access to the excavation face to clear the obstruction.
- Presence of cobbles and boulders: Cobbles and boulders should be anticipated in the fill deposits as inferred by auger grinding in some boreholes. The advance of microtunneling tunnel boring machines (TBM) and jack and bore equipment can be hindered by cobble nests or boulders. The diameter of the proposed replacement culvert may be large enough such that person entry for removal of obstructions is possible depending on the selected means and methods and culvert diameter.
- Groundwater at the invert level: This groundwater condition is favourable since it permits a wider range of trenchless methodologies to be used. However, those that do not provide effective face support for raveling or flowing granular fill should be prohibited. In addition, further monitoring of the groundwater level would be recommended to confirm that the groundwater level is below the invert even with seasonal variations.

6.5 Review of Trenchless Construction Methods

Trenchless installation of a future replacement/relief culvert(s) at this location is considered to be very high risk for any methodology due to the minimal embankment cover over the culvert. Decreasing the culvert diameter to a sufficient size to allow for the recommended minimum cover of two culvert diameters, and installing a series of culverts, was assessed by the design team prior to the 30 per cent executive review meeting, but it was determined that this alternative was not feasible for hydraulic reasons. At the 30 per cent executive review meeting it was decided that any type of trenchless installation at this site had too high of a risk of impacting the existing highway and other alternatives of culvert installation should be considered for replacement of this culvert. Therefore, all trenchless installation methodologies are considered to be not feasible for this site and recommendations for a trenchless installation have not been provided.

6.6 Replacement of Culvert Sections by Open-Cut Methods

It is understood that two sections of the existing open footing culvert are proposed to be replaced using open-cut methods, below the centre median and to the north of the Highway 401 travelled lanes partially below the Highway 401/Waverly Road N-W Ramp. It is understood that the replacement culvert sections will match the size of the



existing culvert and will be supported on the existing footings; therefore, no recommendations for the design of the culvert foundations are required.

6.6.1 Culvert Backfill, Cover and Erosion Protection

Frost treatment (i.e. backfill and cover) for the concrete culvert should be in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 (*Backfill and Cover for Concrete Culverts*). Cover to the rigid culvert walls and top should consist of granular fill meeting the specifications of OPSS.PROV 1010 Granular A or Granular B. Backfill above the cover soil could consist of the excavated soils (i.e. re-use the excavated soils) provided they are free of organics and/or other deleterious materials. Alternatively, imported soil meeting OPSS.PROV 1010 Select Subgrade Material (SSM) could be used for backfill. The backfill and cover should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*). The culvert should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 22 kN/m³ for Granular A, and 21 kN/m³ for Granular B Type II or SSM above and/or surrounding the culvert.

6.6.2 Groundwater and Surface Water Control for Culvert Replacement Excavations

Control of surface water and groundwater will be necessary for the construction of the culvert replacement sections to allow subexcavation, culvert section removal, placement/construction of the new culvert sections, and backfilling to be carried out in dry conditions.

Depending on the volume of water flow through the culvert at the time of construction, the surface water flow could be passed through the culvert by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam/cut-off wall. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the soils immediately surrounding the existing footings.

The groundwater table in the vicinity of the culvert is anticipated to be at or slightly below the culvert invert, but will fluctuate seasonally in response to changes in precipitation and snow melt. Perched groundwater may be encountered within the granular embankment fill overlying the lower permeability native clayey silt deposit. Excavations for the culvert replacement could extend to approximately the measured groundwater level at this site. Groundwater control may be required to control seepage from the existing embankment fill. It is anticipated that the groundwater inflow can be controlled by pumping from properly installed sumps within the excavations. The groundwater level should be maintained at least 0.3 m below the maximum excavation depth (anticipated to be the top of the existing culvert footings) until such time as engineered fill is placed to above the static groundwater level.

6.6.3 Excavation and Temporary Roadway Protection

Temporary excavations for the culvert replacement sections will be made through the existing compact to very dense granular fill, and possibly into the firm to hard clayey silt to silty clay stratum. Excavation works must be carried out in accordance with the guidelines outlined in the latest version of the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fill and firm to hard clayey silt to silty clay are classified as Type 3 soil, according to the OHSA. Where space permits, temporary open-cut excavations through these materials should be made with side slopes formed no steeper than 1H:1V, assuming proper groundwater and surface water control is in place.

If adequate space for open cut excavations is not available any temporary excavation support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Construction Specification for Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any adjacent utilities can tolerate this magnitude of deformation.



6.7 Corrosion Assessment and Protection

Soil corrosivity may affect concrete pipes and headwalls, steel pipes and reinforced steel and other concrete elements buried in the soil. The long-term performance and durability of the structures are directly related to their respective corrosion resistance. Generally, the corrosivity of a structure depends on the soil resistivity, hydrogen ion concentration, salts (chloride and sulphate) concentrations and redox potential. The analytical results for a single composite sample are presented in Section 4.3 and are included in Appendix C.

The analytical test results were compared to CSA Standard, CAN/CSA-A23.1-14 Table 3 (*"Additional requirements for concrete subjected to sulphate attack"*) for potential sulphate attack on concrete. The sulphate concentration measured in the soil sample tested is less than 0.1 per cent, which is below the exposure class of S-3 (Moderate). Therefore, based on the test results of the single composite sample of existing fill and native soils, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the existing fill and native deposits around the culvert may not need to be considered.

The soil has a pH of 7.9 and a resistivity of 2,100 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. However, the resistivity is less than 4,500 ohm-cm, which indicates that the soil corrosiveness is Moderate (2,000 ohm-cm < R < 4,500 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). Based on these results some level of pipe protection will be required depending on pipe material may be required.

Based on the results of the sample tested, and given that the culvert is located under the roadway shoulder and will be exposed to de-icing salt, consideration should be given by the designer to designing for a "C" type exposure class as defined by CSA A23.1 Table 1.

It is ultimately up to the designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 "Durability Requirements" are followed.

6.8 Further Investigation for Detailed Design of Future Replacement/Relief Culverts

The foundation investigation carried out for this report is considered adequate for detailed design of a replacement culvert using conventional cut-and-cover excavation techniques in conjunction with temporary protection systems and construction staging. However it may be necessary to advance test pits or shallow boreholes at the outlet locations for design of any temporary shoring and wingwalls / headwalls, particularly if multiple culverts are proposed or the new alignments will be offset some distance from the existing boreholes.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Matthew Kelly, P.Eng., a member of Golder's geotechnical engineering staff. Ms. Lisa Coyne, P.Eng. a Principal and Designated MTO Foundations Contact for Golder, conducted an independent technical and quality control review of this report.



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 21-491/C

Report Signature Page

GOLDER ASSOCIATES LTD.



Matthew Kelly, P.Eng.
Geotechnical Engineer



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

MWK/KJB/LCC/sm

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REFERENCES

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

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Canadian Standards Association (CSA), 2014. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14*. CSA Special Publication, S6.1-14.

Canadian Standards Association (CSA), 2014. CAN/CSA-A23.1-14: *Concrete Materials and Methods of Concrete Construction/Test Methods and Standard Practices for Concrete*.

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 Ministry of Transportation, 2014. *MTO Gravity Pipe Design Guidelines: Circular Culverts and Storm Sewers*. St. Catharines, Ontario

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects as amended by O. Reg. 443/09

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

Ontario Provincial Standard Specifications (OPSS) and Drawings (OPSD)

OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSD 803.010	Backfill and Cover for Concrete Culverts



TABLES



FOUNDATION REPORT - STRUCTURAL CULVERT REPLACEMENT - HIGHWAY 401, SITE NO. 21-491/C

Table 1: Summary of Existing Culvert Details

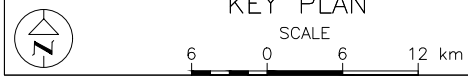
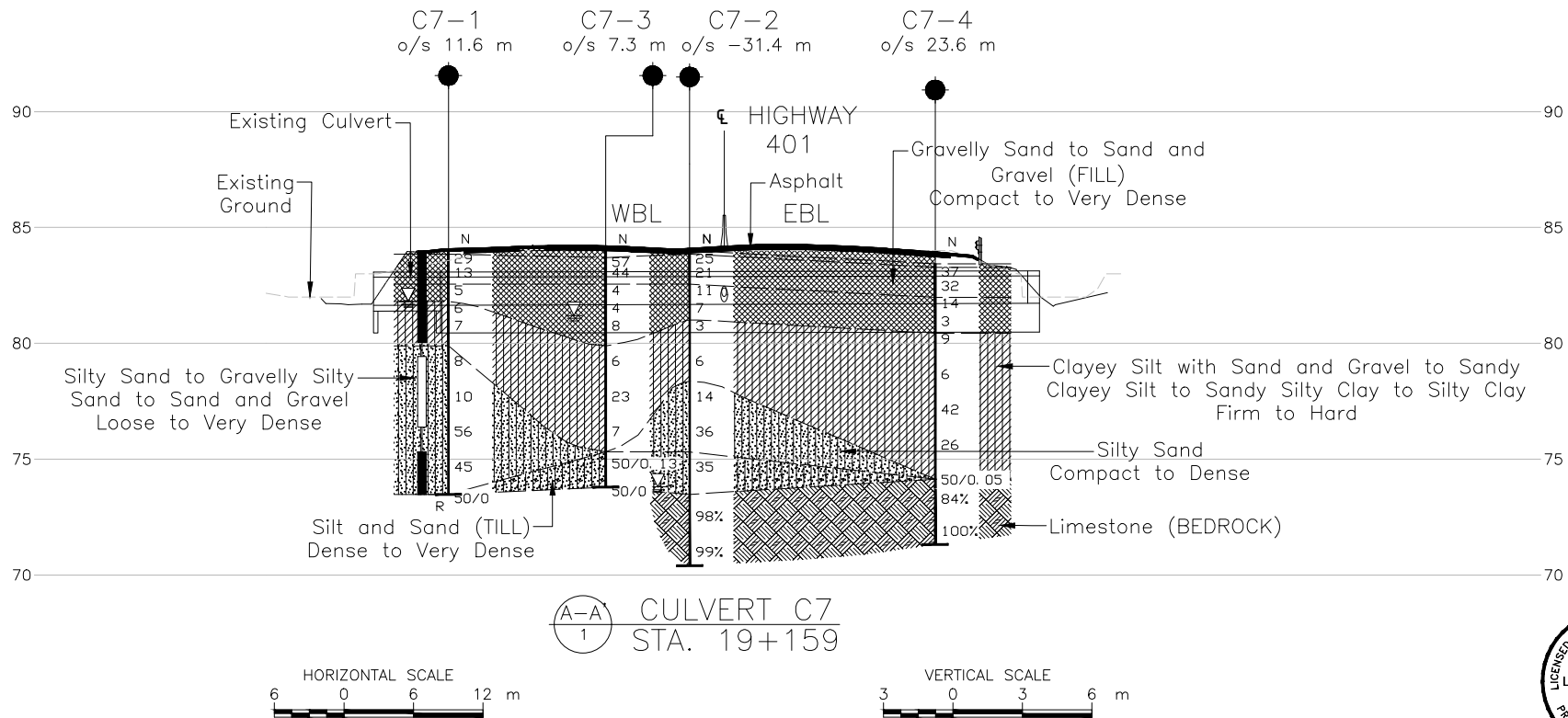
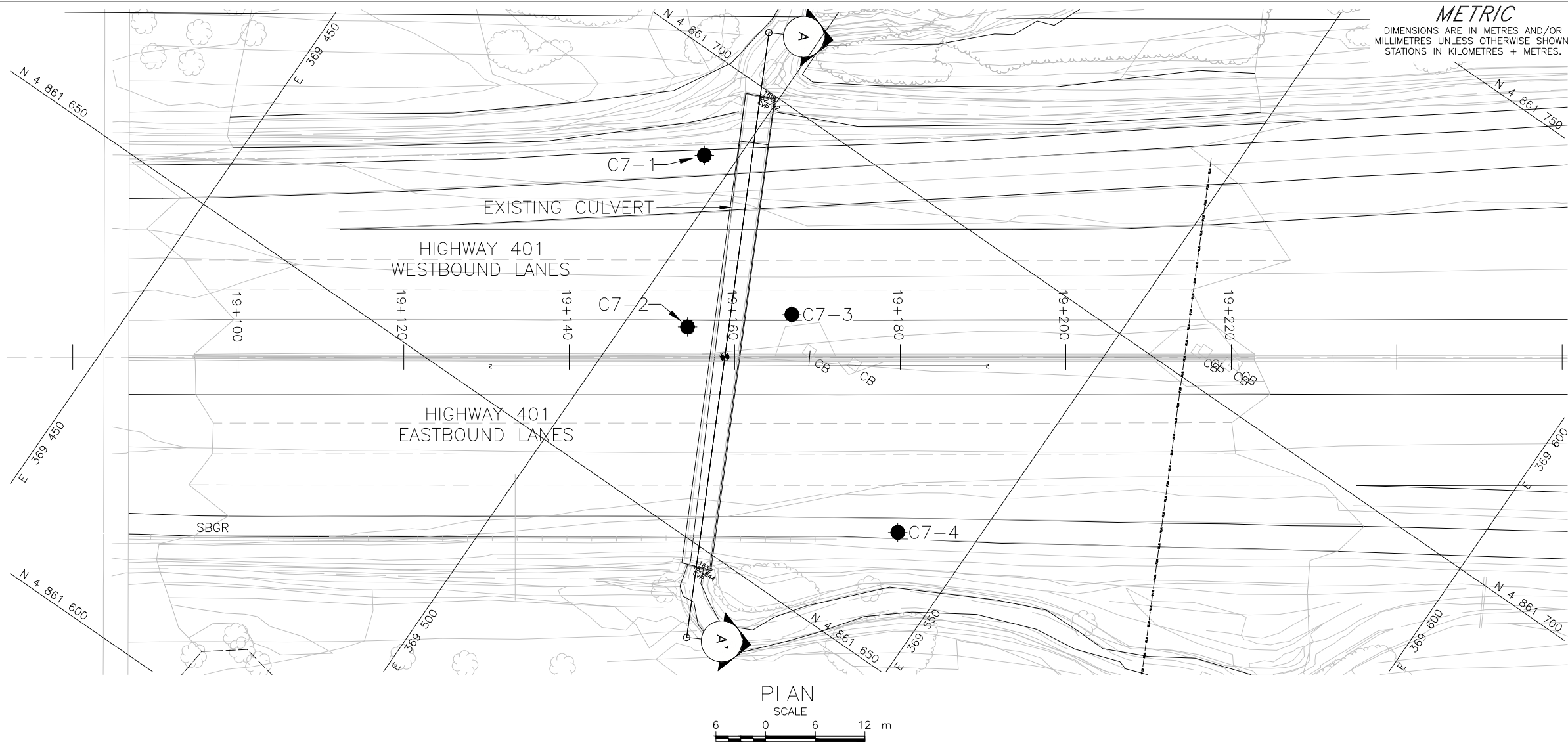
Culvert Location (Municipality)	Culvert Site No. / ID	Approximate Height of Embankment ¹	Existing Culvert			Approximate Invert Elevation ²		Boreholes
			Type	Approximate Dimension	Approximate Length	North End of Culvert	South End of Culvert	
Station 19+159 (Bowmanville)	21-491/C (C7)	Up to about 2 m to 2.5 m	Concrete box with open footing extension	3.2 m x 1.2 m	57.5 m	81.6 m	81.8 m	4 Boreholes (C7-1 to C7-4)

- Notes:
1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.
 2. Culvert invert elevations are estimated based on GA Drawings for culvert rehabilitation provided by D.M. Wills.
 3. Including a previously constructed 5.8 m open footing extension at north end.

Prepared By: MWK
Reviewed By: LCC



DRAWINGS



LEGEND

- Borehole - Current Investigation
- 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 DEC 6, 2016
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C7-1	84.0	4861689.2	369496.5
C7-2	84.0	4861671.0	369506.6
C7-3	84.0	4861679.4	369516.1
C7-4	83.4	4861665.0	369541.6

NOTES

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

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

Geographic Coordinates of Culvert: Latitude 43.891961; Longitude -78.694400

REFERENCE

Base Plan and Contours provided in digital format by DM Wills, drawing file nos. 124215.dwg, received Jan. 20, 2016. Design Plan and Section provided in digital format by DM Wills, drawing file no. 4561-C7 GA.dwg, received Jan. 03, 2017.



NO.	DATE	BY	REVISION
Geocres No. 30M16-61			
HWY. 401	PROJECT NO. 1540419	DIST. .	
SUBM'D. MCK	CHKD. MCK	DATE: 6/12/2017	SITE: 21-491/C
DRAWN: SMD	CHKD. MWK	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

* 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	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		1540419		RECORD OF BOREHOLE No C7-1		SHEET 1 OF 1		METRIC								
G.W.P.		2242-14-00		LOCATION		N 4861689.2; E 369496.5 MTM ZONE 10 (LAT. 43.89235; LONG. -78.6945)		ORIGINATED BY								
DIST		HWY 401		BOREHOLE TYPE		CME 75, 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)		COMPILED BY								
DATUM		Geodetic		DATE		December 6, 2016		CHECKED BY								
								MCK								
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 (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80
84.0	GROUND SURFACE															
0.0	ASPHALT															
0.2	Gravelly sand, trace silt, trace clay (FILL) Compact Brown Moist		1	SS	29											
			2	SS	13											
82.6																
1.5	Sandy clayey silt, trace gravel to gravelly, trace organics (FILL) Firm Grey Moist		3	SS	5											
81.8																
2.2	SILTY CLAY, trace to some sand, trace gravel Firm Brown Moist		4	SS	6											
			5	SS	7											
79.9																
4.1	Silty SAND, trace to some clay, some gravel Loose to compact Grey Wet		6	SS	8											
			7	SS	10											
76.8																
7.2	SAND and GRAVEL, trace to some silt, trace clay Very dense Grey Wet		8	SS	56											
75.4																
8.6	Gravelly silty SAND, trace clay Dense to very dense Grey Wet		9	SS	45											
73.5																
10.5	END OF BOREHOLE SAMPLER REFUSAL AUGER REFUSAL NOTE: 1. Water level measured in piezometer: Date Depth (m) Elev. (m) 12/06/16 2.2m 81.8		10	SS	50/0											

PROJECT		1540419		RECORD OF BOREHOLE No C7-2		SHEET 1 OF 1		METRIC						
G.W.P.		2242-14-00		LOCATION		N 4861671.0; E 369506.6 MTM ZONE 10 (LAT. 43.89219; LONG. -78.695)		ORIGINATED BY						
DIST		HWY 401		BOREHOLE TYPE		CME 75, 208 mm O.D., 102 mm I.D. Hollow Stem Augers (Automatic Hammer)		COMPILED BY						
DATUM		Geodetic		DATE		December 14, 2016		CHECKED BY						
								MCK						
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						
84.0	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	ASPHALT													
0.2	Sand and gravel (FILL) Compact Brown Moist - Auger grinding at a depth of 0.6 m (Elev. 83.4 m)		1	SS	25									
82.6			2	SS	21									
1.5	Sandy clayey silt, trace to some gravel (FILL) Firm to stiff Grey Wet		3	SS	11									
81.0			4	SS	7									
3.0	Sandy CLAYEY SILT, trace to some gravel Soft to firm Grey Wet		5	SS	3									
78.4			6	SS	6									
5.6	SILTY SAND, trace to some clay, some gravel Compact to dense Grey Wet		7	SS	14									
75.3			8	SS	36									
8.7	SILT and SAND, trace to some gravel, trace to some clay (TILL) Dense Grey Wet		9	SS	35									
73.5	- Auger grinding between 10.1 m and 10.5 m (Elev. 73.9 m to 73.5 m)													
10.5	LIMESTONE (BEDROCK) Bedrock cored from depths of 10.5 m to 13.6 m. For bedrock coring details, refer to Record of Drillhole C7-2.		1	RC	REC 98%									
70.4			2	RC	REC 99%									
13.6	END OF BOREHOLE													
NOTE: 1. Water level in open borehole at a depth of 10.2 m below ground surface (Elev. 73.8 m) upon completion of drilling.														

PROJECT: 1540419

RECORD OF DRILLHOLE: C7-2

SHEET 1 OF 1

LOCATION: N 4861671.00 ;E 369506.60

DRILLING DATE: December 12, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75, Truck-Mount

DRILLING CONTRACTOR: At Cost Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA						WEATH- ERING INDEX		Axial Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION						Jr	Ja				Jn	W1	W2	W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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11		Continued from Record of Borehole C7-2 Limestone bedded, fine grained, moderately porous, slightly weathered, weak		73.48 10.52	1																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		</

DEPTH SCALE

1 : 50



LOGGED: AJ

CHECKED:

GTA-RCK 049 S:\CLIENTS\MT\HWY 401 & HWY35-115\02_DATA\GINT\HWY 401 AJAX TO NEWTONVILLE.GPJ GAL-MISS.GDT 12/06/17

PROJECT		1540419		RECORD OF BOREHOLE No C7-3		SHEET 1 OF 1		METRIC																								
G.W.P.		2242-14-00		LOCATION		N 4861679.4; E 369516.1 MTM ZONE 10 (LAT. 43.89226; LONG. -78.6945)		ORIGINATED BY																								
DIST		HWY 401		BOREHOLE TYPE		CME 75, 127 mm O.D. Solid Stem Augers (Automatic Hammer)		COMPILED BY																								
DATUM		Geodetic		DATE		December 12, 2016		CHECKED BY																								
								MCK																								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			SHEAR STRENGTH kPa			WATER CONTENT (%)			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																										
84.0	0.0	GROUND SURFACE																														
83.7	0.3	ASPHALT																														
82.6	1.5	Sand and gravel, trace to some silt, trace to some some clay (FILL) Dense to very dense Brown Moist - Auger grinding at a depth of 1.2 m (Elev. 82.8 m)		1	SS	57																										
				2	SS	44																										
				3	SS	4																										
				4	SS	4																										
				5	SS	8																										
79.9	4.1	CLAYEY SILT with SAND and GRAVEL Firm to very stiff Brown Wet		6	SS	6																										
				7	SS	23																										
				8	SS	7																										
75.3	8.7	SILT and SAND, trace to some clay, some gravel (TILL) Very dense Grey Wet		9	SS	50/0.13																										
73.8	10.2	END OF BOREHOLE SAMPLER REFUSAL AUGER REFUSAL NOTE: 1. Water level in open borehole at a depth of 2.8 m below ground surface (Elev. 81.2 m) upon completion of drilling.		10	SS	50/0																										

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

PROJECT: 1540419

RECORD OF DRILLHOLE: C7-4

SHEET 1 OF 1

LOCATION: N 4861665.00 ;E 369541.60

DRILLING DATE: December 13, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG:

DRILLING CONTRACTOR: At Cost Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY															FEATURES	PIEZOMETER					
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA				WEATH- ERING INDEX								Axial Point Load Index (MPa)				
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	W1	W2	W3	W4	W5	W6							
		Continued from Record of Borehole C7-4		74.13																								
		Limestone bedded, fine grained, moderately porous, slightly weathered, weak		9.30																								
10					1																							
11																												
					2																							
12		END OF DRILLHOLE		71.33																								
13				12.10																								
14																												
15																												
16																												
17																												
18																												
19																												

DEPTH SCALE

1 : 50



LOGGED: AJ

CHECKED:

GTA-RCK 049 S:\CLIENTS\MT\HWY 401 & HWY35-115\02 DATA\GINT\HWY 401 AJAX TO NEWTONVILLE.GPJ GAL-MISS.GDT 12/06/17



APPENDIX B

Geotechnical Laboratory Test Results

UNCONFINED COMPRESSION TEST (UC)**Table B1****ASTM D 7012-04****SAMPLE IDENTIFICATION**

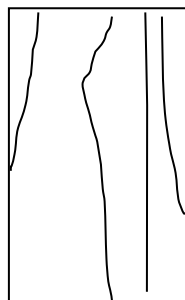
PROJECT NUMBER	1540419	SAMPLE NUMBER	Run1
BOREHOLE NUMBER	C7-2	SAMPLE DEPTH, m	11.12-11.28

TEST CONDITIONS

MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.38

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	11.22	WATER CONTENT, (specimen) %	0.34
SAMPLE DIAMETER, cm	4.72	UNIT WEIGHT, kN/m ³	25.81
SAMPLE AREA, cm ²	17.48	DRY UNIT WT., kN/m ³	25.73
SAMPLE VOLUME, cm ³	196.12	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	516.41	VOID RATIO	0.03
DRY WEIGHT, g	514.66		

VISUAL INSPECTION**FAILURE SKETCH****TEST RESULTS**

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	47.1
----------------------	---	-------------------------	------

REMARKS:

DATE:

1/16/2017

Checked By: MWK

Golder Associates

POINT LOAD TESTS ON ROCK SAMPLES

TABLE B2

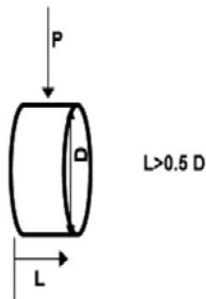
PROJECT NO. 1540419
 TITLE DM Wills/Culverts Hwy35/ON
 DATE September, 2016

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)
C7-2	Run 1	11.28-11.31	Axial	22.18	47.20	36.51	5.050	-	4.383	57
C7-2	Run 2	12.46-12.49	Axial	22.74	47.19	36.96	3.525	-	3.077	40
C7-2	Run 2	12.29-12.31	Axial	22.01	47.20	36.37	3.068	-	2.658	35
C7-4	Run 1	0.63-0.67	Axial	21.79	47.35	36.24	6.033	-	5.220	68
C7-4	Run 2	0.77-0.84	Axial	20.88	47.18	35.42	3.174	-	2.718	36
C7-4	Run 2	1.71-1.75	Axial	20.56	47.26	35.17	4.092	-	3.493	46

⁽¹⁾ $Is_{50} \times C$, 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.
 $C=13.1$, calculated from Is_{50} average (6 tests) equal to 3.59 MPa on axial orientation and UCS equal to 47.1 MPa (1 test)

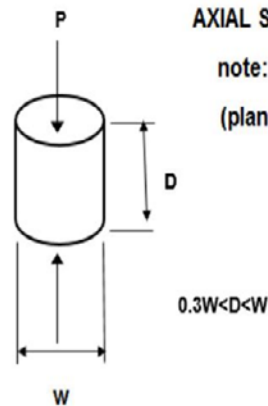
DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

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



AXIAL SPECIMEN SHAPE REQUIREMENTS

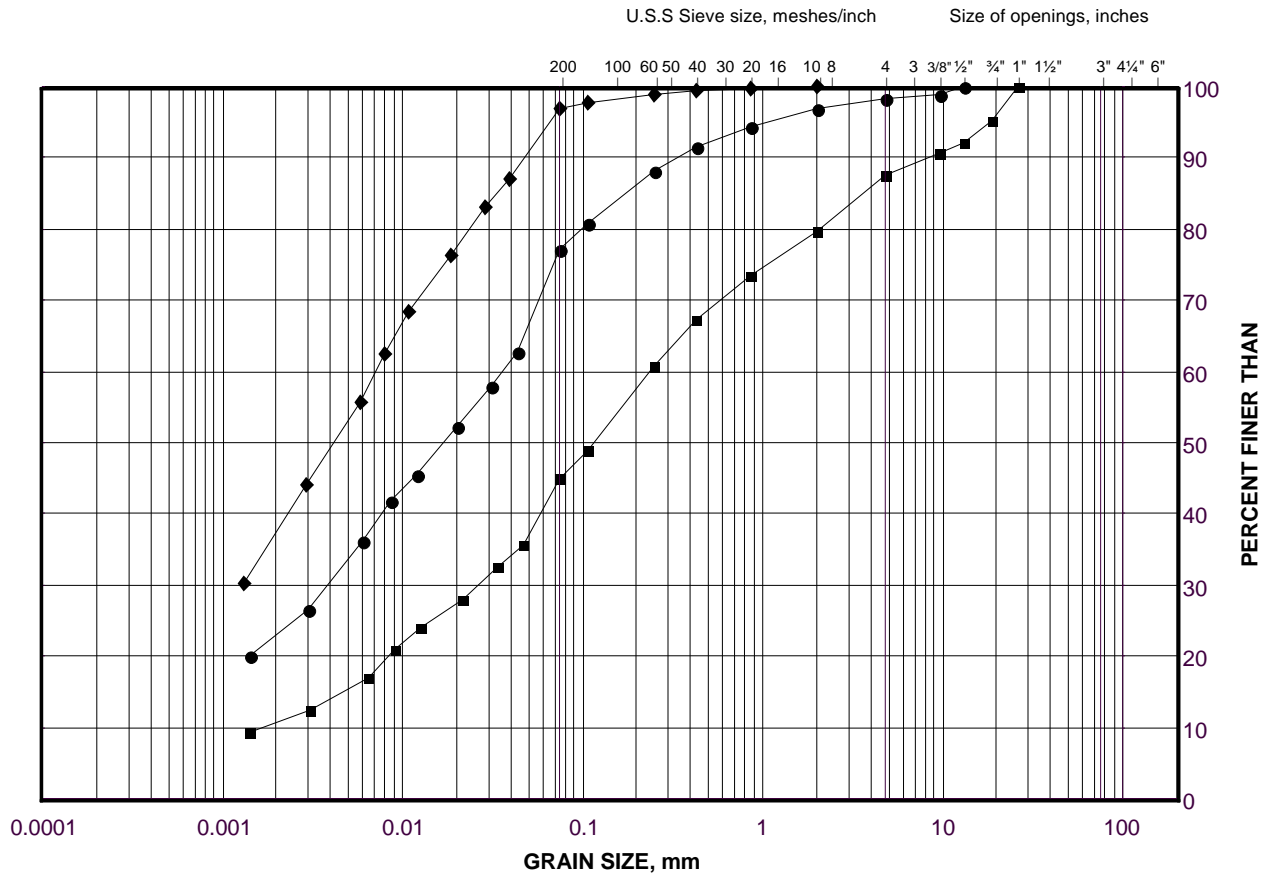
note: Axial tests are parallel to core axis
 (planes of weakness)



GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand to Sandy Silty Clay to Silty Clay (Fill)

FIGURE B1



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

LEGEND

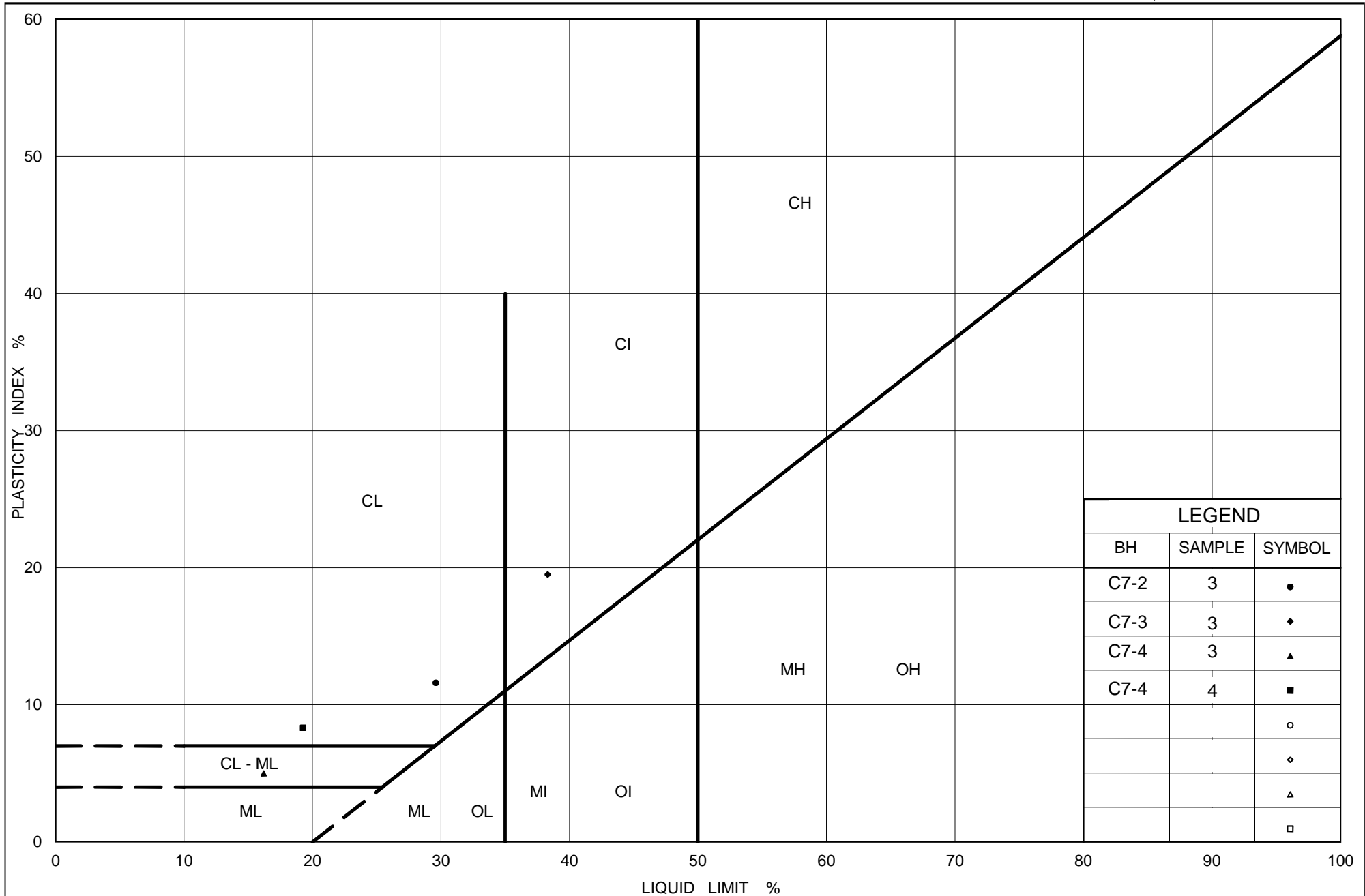
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C7-3	3	82.2
■	C7-4	3	81.6
◆	C7-3	5	80.6

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 24-Mar-17



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Silty Clay (Fill)

Figure No. B2

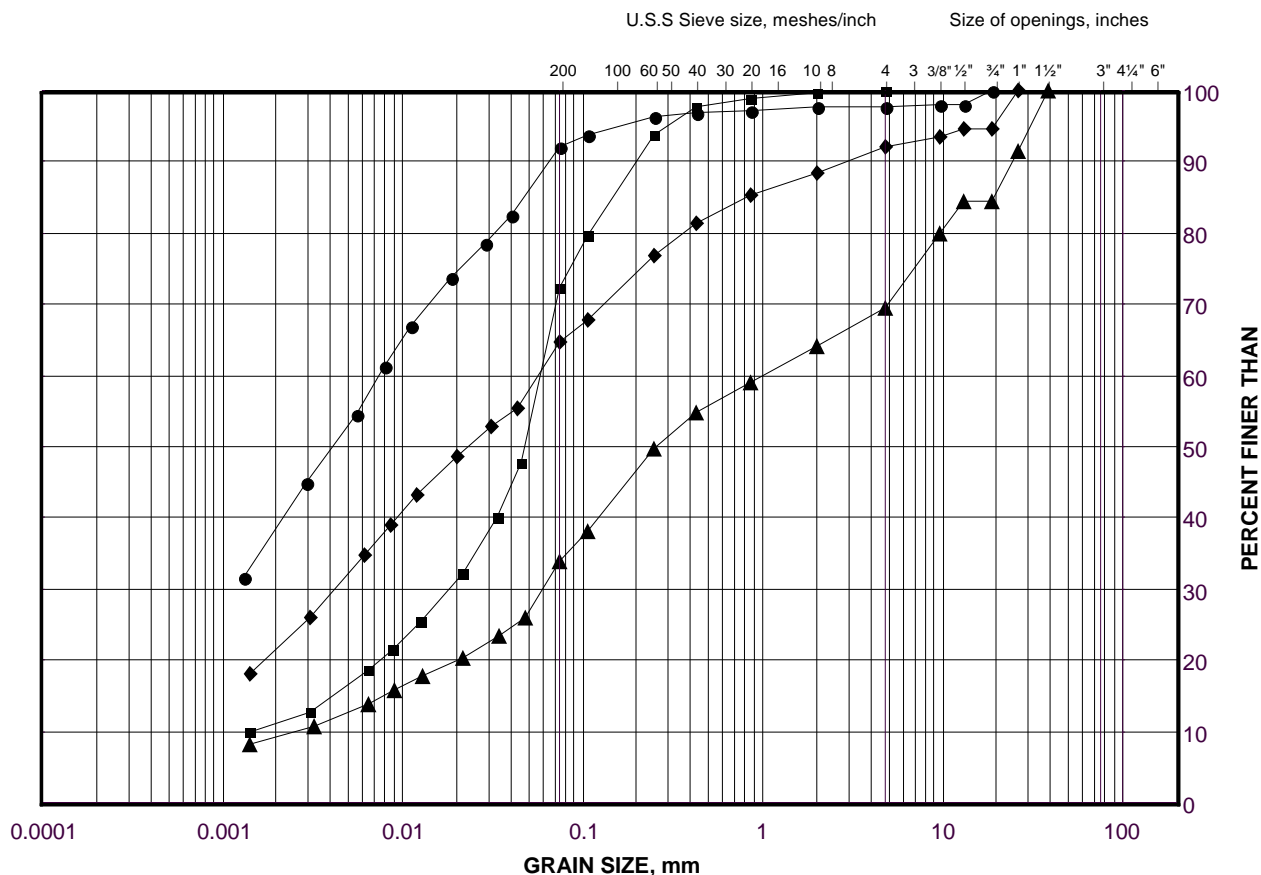
Project No. 1540419

Checked By:

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand and Gravel to Sandy Clayey Silt to Sandy Silty Clay to Silty Clay

FIGURE B3



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

LEGEND

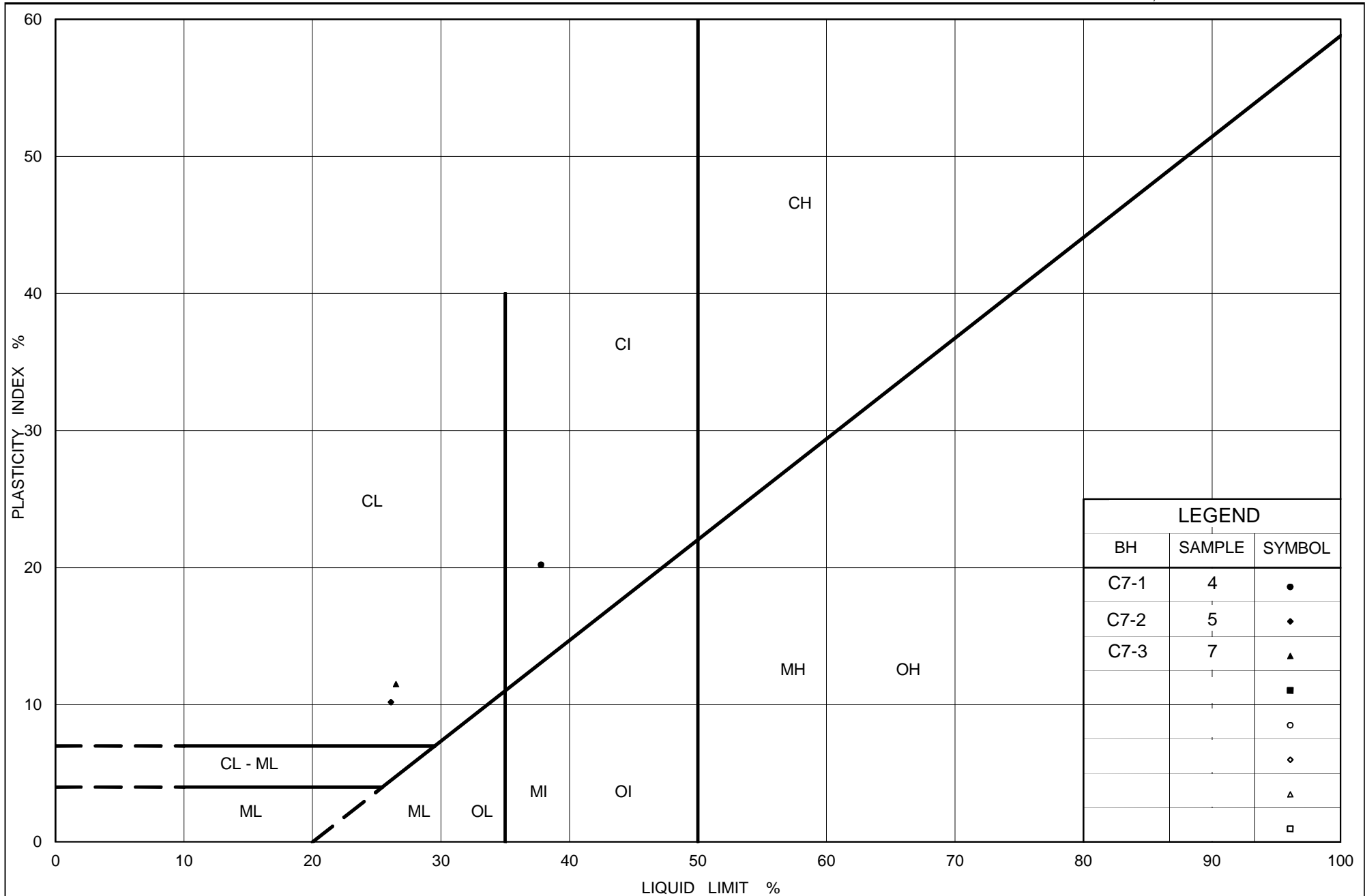
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C7-1	4	81.4
■	C7-2	5	80.7
◆	C7-4	6	78.6
▲	C7-3	7	77.6

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 24-Mar-17



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Silty Clay

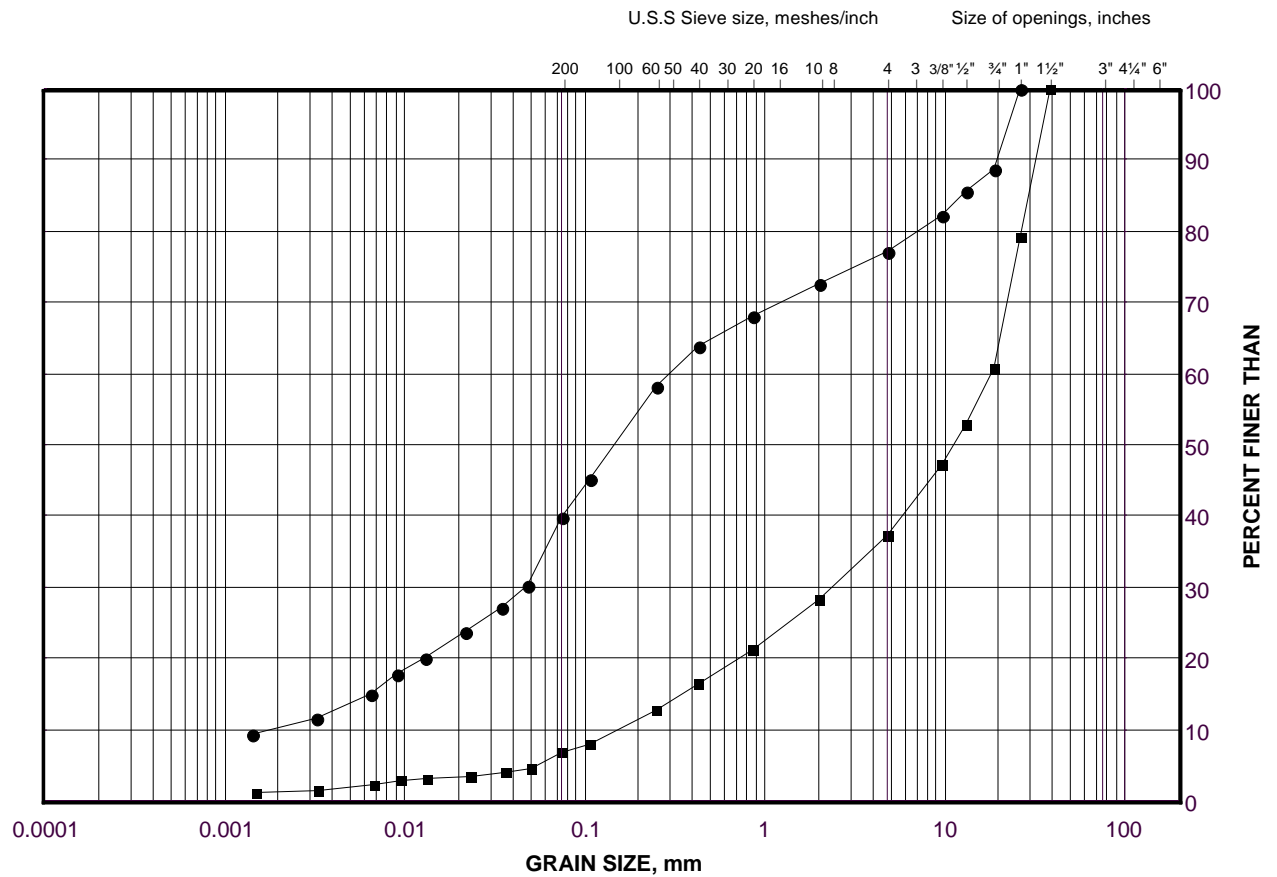
Figure No. B4

Project No. 1540419

Checked By: MWK

Silty Sand to Sand and Gravel

FIGURE B5



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

LEGEND

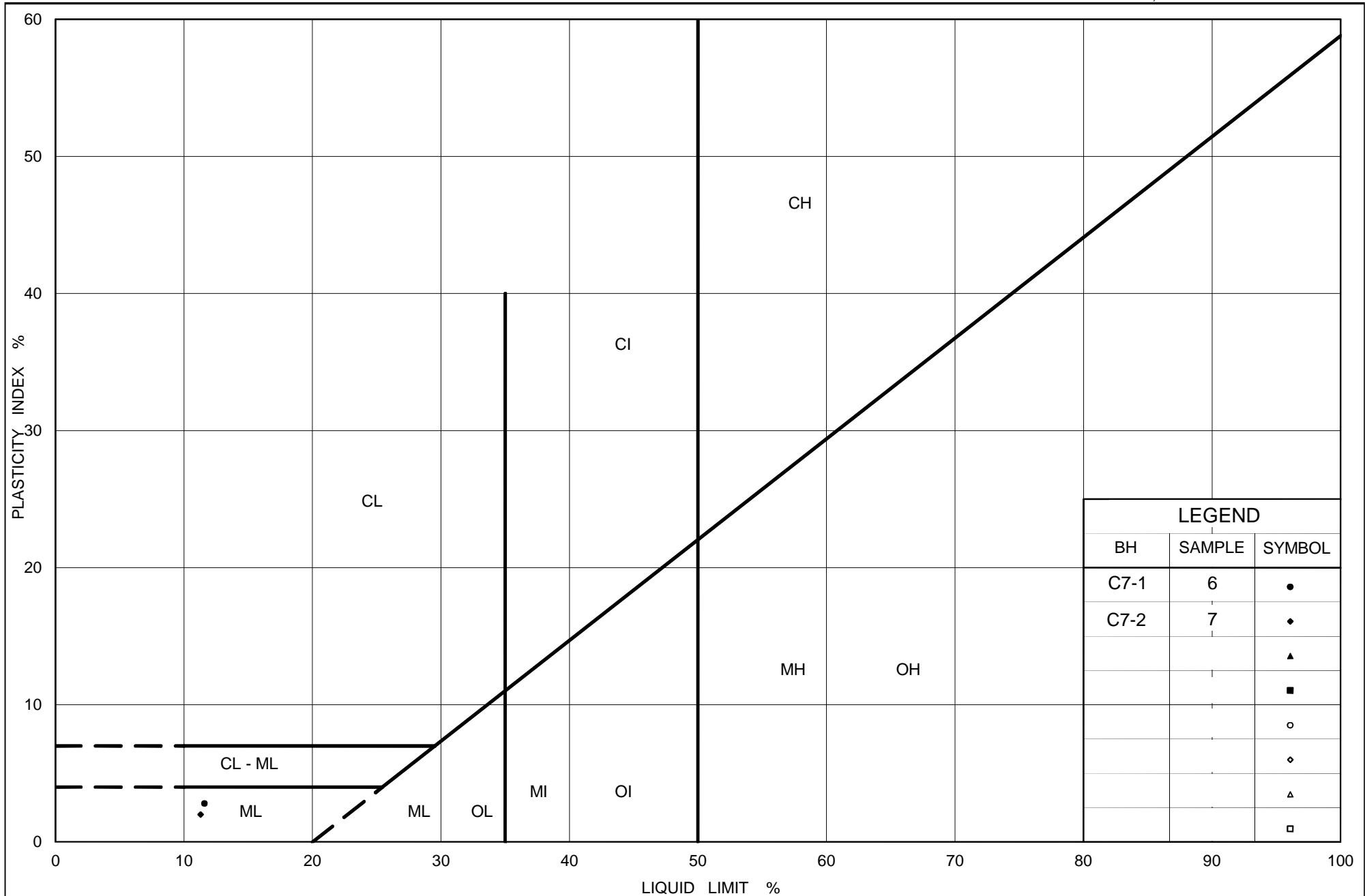
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C7-1	6	79.2
■	C7-1	8	76.1

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 24-Mar-17



Ministry of Transportation

Ontario

PLASTICITY CHART

Silty Sand

Figure No. B6

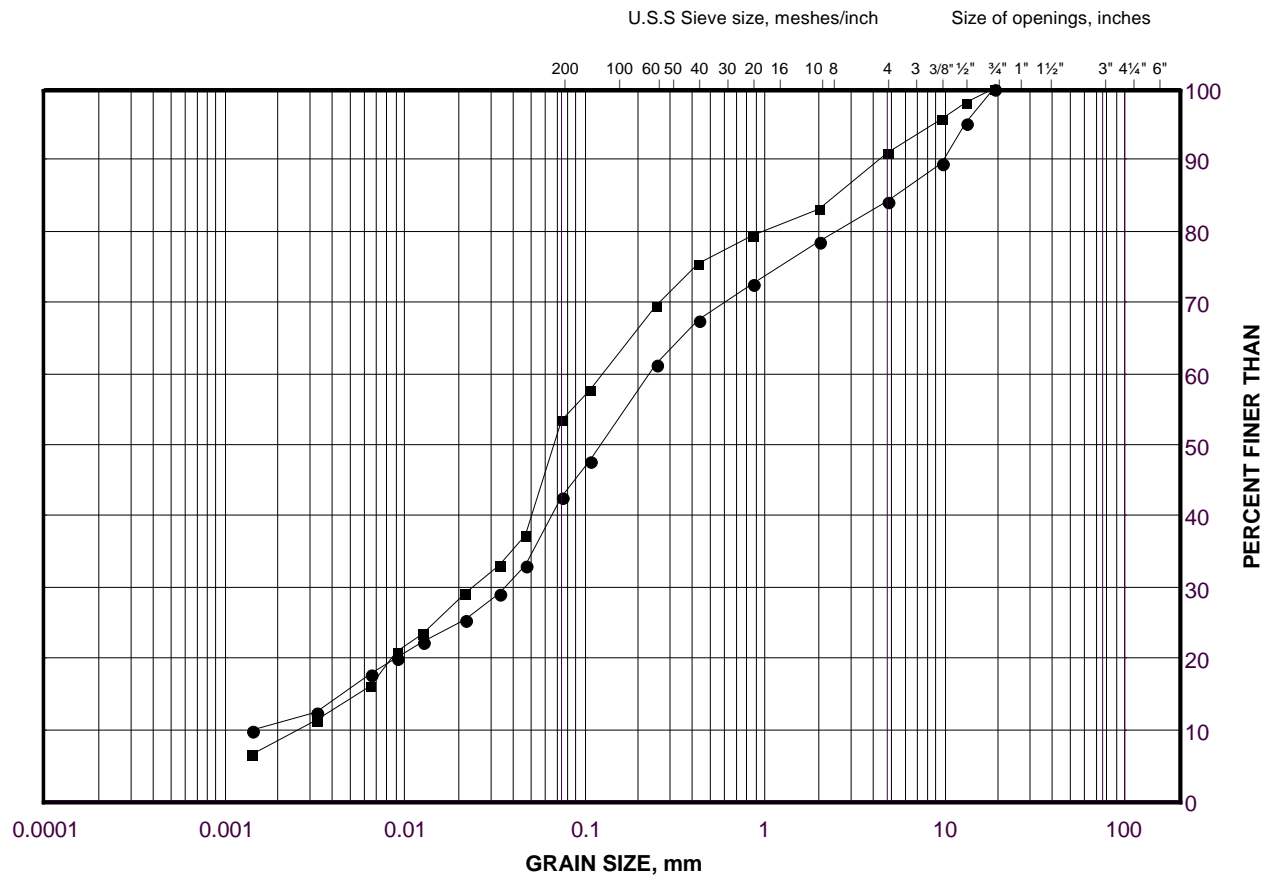
Project No. 1540419

Checked By: MWK

GRAIN SIZE DISTRIBUTION

Silt and Sand (Till)

FIGURE B7



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C7-3	9	74.8
■	C7-2	9	74.6

Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 24-Mar-17



APPENDIX C

Analytical Test Results

Your Project #: 1540419
Your C.O.C. #: 573330-02-01

Attention: Matt Kelly

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

Report Date: 2016/12/22
Report #: R4298821
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6R4426

Received: 2016/12/16, 15:25

Sample Matrix: Soil
Samples Received: 3

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride (20:1 extract)	3	N/A	2016/12/21	CAM SOP-00463	EPA 325.2 m
Conductivity	3	N/A	2016/12/21	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	3	2016/12/20	2016/12/20	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	3	2016/12/16	2016/12/22	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	3	N/A	2016/12/21	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

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.

Your Project #: 1540419
Your C.O.C. #: 573330-02-01

Attention:Matt Kelly

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

Report Date: 2016/12/22
Report #: R4298821
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6R4426
Received: 2016/12/16, 15:25

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		DQK405	DQK406	DQK407		
Sampling Date		2016/11/27 04:00	2016/12/01 22:00	2016/12/06 03:00		
COC Number		573330-02-01	573330-02-01	573330-02-01		
	UNITS	C5	C6	C7	RDL	QC Batch
Calculated Parameters						
Resistivity	ohm-cm	1100	1200	2100		4796272
Inorganics						
Soluble (20:1) Chloride (Cl)	ug/g	340	450	180	20	4799839
Conductivity	umho/cm	889	824	467	2	4800256
Available (CaCl2) pH	pH	7.69	7.95	7.86		4798509
Soluble (20:1) Sulphate (SO4)	ug/g	240	23	49	20	4799840
RDL = Reportable Detection Limit						
QC Batch = Quality Control Batch						

TEST SUMMARY

Maxxam ID: DQK405
Sample ID: C5
Matrix: Soil

Collected: 2016/11/27
Shipped:
Received: 2016/12/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4799839	N/A	2016/12/21	Deonarine Ramnarine
Conductivity	AT	4800256	N/A	2016/12/21	Tahir Anwar
pH CaCl2 EXTRACT	AT	4798509	2016/12/20	2016/12/20	Surinder Rai
Resistivity of Soil		4796272	2016/12/22	2016/12/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	4799840	N/A	2016/12/21	Deonarine Ramnarine

Maxxam ID: DQK406
Sample ID: C6
Matrix: Soil

Collected: 2016/12/01
Shipped:
Received: 2016/12/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4799839	N/A	2016/12/21	Deonarine Ramnarine
Conductivity	AT	4800256	N/A	2016/12/21	Tahir Anwar
pH CaCl2 EXTRACT	AT	4798509	2016/12/20	2016/12/20	Surinder Rai
Resistivity of Soil		4796272	2016/12/22	2016/12/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	4799840	N/A	2016/12/21	Deonarine Ramnarine

Maxxam ID: DQK407
Sample ID: C7
Matrix: Soil

Collected: 2016/12/06
Shipped:
Received: 2016/12/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4799839	N/A	2016/12/21	Deonarine Ramnarine
Conductivity	AT	4800256	N/A	2016/12/21	Tahir Anwar
pH CaCl2 EXTRACT	AT	4798509	2016/12/20	2016/12/20	Surinder Rai
Resistivity of Soil		4796272	2016/12/22	2016/12/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	4799840	N/A	2016/12/21	Deonarine Ramnarine

GENERAL COMMENTS

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

Package 1	5.7°C
-----------	-------

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

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

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4798509	Available (CaCl ₂) pH	2016/12/20			98	97 - 103			1.4	N/A
4799839	Soluble (20:1) Chloride (Cl)	2016/12/21	115	70 - 130	106	70 - 130	<20	ug/g	NC	35
4799840	Soluble (20:1) Sulphate (SO ₄)	2016/12/21	NC	70 - 130	106	70 - 130	<20	ug/g	NC	35
4800256	Conductivity	2016/12/21			100	90 - 110	<2	umho/cm	1.6	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.

CHAIN OF CUSTODY RECORD

INVOICE TO:				REPORT TO:				PROJECT INFORMATION:				Laboratory Use Only:																			
Company Name: #1326 Golder Associates Ltd Attention: Central Acct:1112, 1113, 1118 Address: 6925 Century Ave Suite 100 Mississauga ON L5N 7K2 Tel: (905) 567-4444 Fax: (905) 567-6561 Email: Catherine_Guiao@golder.com, Rachel_Benjamin@golder.com				Company Name: Attention: Matt Kelly ; Madison Kennedy Address: Tel: Email: Matthew_Kelly@golder.com ; Mad.Kennedy@golder.com				Quotation #: B63104 P.O. #: Project: 1540419 Project Name: Site #: Sampled By:				Maxxam Job #: Bottle Order #:  573330 Project Manager: CQC #:  C#573330-02-01 Ema Gitej																			
MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY												Turnaround Time (TAT) Required: Please provide advance notice for rush projects																			
Regulation 153 (2011) <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC <input type="checkbox"/> Table				Other Regulations <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Municipality <input type="checkbox"/> PWO <input type="checkbox"/> <input type="checkbox"/> Other				Special Instructions				ANALYSIS REQUESTED (PLEASE BE SPECIFIC)																			
Include Criteria on Certificate of Analysis (Y/N)?				Field Filled (please circle): Metals / Hg / Cr VI				Corrosivity pig (C, S04, EC, Resiliency, pH)				Regular (Standard) TAT: (will be applied if Rush TAT is not specified; Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details. Job Specific Rush TAT (if applies to entire submission) Date Required: Time Required: Rush Confirmation Number: (call lab for #)																			
Sample Barcode Label				Sample (Location) Identification				Date Sampled				Time Sampled				Matrix				# of Bottles				Comments							
1				C5				2016/11/27				4:00 am				Soil				X				1							
2				C6				2016/12/01				10:00 pm				Soil				X				1							
3				C7				2016/12/06				3:00 am				Soil				X				1							
4																															
5																															
6																															
7																															
8																															
9																															
10																															
16-Dec-16 15:25 Ema Gitej  B6R4426 SEL ENV-1146																															
* RELINQUISHED BY: (Signature/Print) Amelia Jennifer Benjamin				Date: (YY/MM/DD) Time 16/12/16 3:25				RECEIVED BY: (Signature/Print) Tawfik Tawfik				Date: (YY/MM/DD) Time 2016/12/16 15:25				# Jars used and not submitted				Laboratory Use Only Time Sensitive Temperature (°C) on Receipt 6/8/6				Custody Seal Present In tact Yes No							
* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.												SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM.												White: Maxxam Yellow: Client							

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.

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