REPORT

July 17, 2015

FOUNDATION INVESTIGATION REPORT

GRINDSTONE CREEK NEW / REPLACEMENT CULVERTS
FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE
CITY OF HAMILTON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2112-05-00

Submitted to:
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Table of Contents

Appendix D **Culvert C2A at Station 30+132 (Commercial Access Road), Record of Boreholes, Drillholes and Laboratory Test Results**

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by IBI Group (IBI) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the new/replacement Grindstone Creek culverts. The proposed work is part of the future Highway 5 and Highway 6 Interchange and associated Municipal Roads in the City of Hamilton, Ontario, which includes high fill embankments for the Highway 5 and Highway 6 re-alignments and interchange ramps, rock cut slope assessment, culvert extensions and retaining walls at Borer's Creek, high mast lighting and overhead signs.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated January 2010, which forms part of the Consultant's Assignment Number (Number 2008-E-0038) for this project. Golder's proposal for foundation engineering services associated with the Highway 5/Highway 6 Interchange structure is contained in Section 6.8 of IBI's Technical Proposal for this assignment and subsequent scope change dated December 9, 2013. The work has been carried out in accordance with Golder's Supplementary Specialty Quality Control Plan for foundation engineering services for this project, dated September 10, 2012.

This report addresses the investigation carried out for the new/replacement Grindstone Creek culverts. The purpose of this investigation is to establish the subsurface conditions at the proposed culverts, by borehole drilling, rock coring, in situ testing and laboratory testing on selected soil and rock core samples. The investigation area and the borehole location plan and soil strata for Culverts 1A, 1, 2 and 2A shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents.

2.0 SITE DESCRIPTION

The proposed new/replacement culverts are located in the vicinity of the existing Highway 5 and Highway 6 intersection, which is located west of Waterdown and approximately 3 km north of the Highway 403/Highway 6 Interchange, at Clappison's Corners in the City of Hamilton, Ontario. The existing Highway 5 alignment in this area is oriented generally in a west-east direction. The existing Highway 6 alignment is oriented generally in a north-south direction connecting with Highway 403 to the south and Highway 401 to the north of Highway 5, and it was last widened in 2005. At the location of the at-grade crossing of Highway 5 and Highway 6, Highway 5 consists of two lanes in both the eastbound and westbound directions with an additional two turning lanes; and Highway 6 consists of three lanes in both the northbound and southbound directions with an additional two turning lanes. The at-grade crossing is to be modified to an interchange with the Highway 5 structure crossing over Highway 6 to accommodate future traffic forecasts, which involves re-alignment of Highway 5 slightly to the north and Highway 6 slightly to the east, in the vicinity of the present crossing.

Grindstone Creek flows through an existing culvert that crosses Highway 6 then through an existing culvert that crosses Highway 5 about 75 m west of Highway 6; it is understood that these culverts will be replaced. With the construction of the new interchange, two additional culverts are required under the Ramp E-N (located north of Highway 5 and east of Highway 6) and beneath the proposed Commercial Access Road (located south of Highway 5 and west of Highway 6).

The topography at the site consists of relatively flat terrain which slopes downward south of the intersection along Highway 6 down the Niagara Escarpment. The existing Highway 5 and Highway 6 grades in the general area of the intersection vary between about Elevations 222.3 m and 221.9 m; and the existing grades outside of the highways in the general area of the intersection vary between about Elevations 221.7 m and 221.6 m.

3.0 INVESTIGATION PROCEDURES

A foundation investigation at the Grindstone Creek culverts was carried out between October 6 and November 2, 2014 during which time a total of eight sampled boreholes were advanced at the locations shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents. One additional borehole, Borehole C1-1B, was advanced approximately 1 m away from Borehole C1-1 for the purpose of bedrock coring and a piezometer installation. In addition Boreholes EN-3 and H5-3, drilled in November 2012 for proposed high fill areas, are also pertinent to the foundation investigation for these culverts.

The field borehole investigation was carried out using a track-mounted CME 55 drill rig and a truck-mounted CME 75 drill rig, supplied and operated by DBW Drilling Ltd. of Ajax, Ontario, as well as a truck-mounted CME 75 drill rig, supplied and operated by Davis Drilling Ltd. of Milton, Ontario. The boreholes were advanced through the overburden using 102 mm outside diameter solid stem augers. Soil samples were taken using 50 mm outer diameter split-spoon samplers driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soil). In general, split-spoon samples were obtained at ground surface and at depth intervals of about 0.75 m. The boreholes were advanced to auger and/or sampler refusal (i.e. inferred bedrock) and bedrock was confirmed by coring for approximately 3.2 m to 4.0 m in three selected boreholes, using NW casing and an NQ size rock core barrel and coring techniques.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations. Piezometers were installed in Borehole C1-1B, C1-2 and C2-2 to permit monitoring of the ground water level at the borehole locations. The installed piezometers consist of 37 mm (1 ¼ inch) diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack at a select depth within the borehole. The borehole and annulus surrounding the piezometer pipe above the screen and filter sand pack were backfilled to the ground surface with bentonite pellets. Piezometer installation details and water level readings are described on the Record of Borehole sheets presented in Appendices A to D. All open boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903, Wells (as amended).

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 and sampling operations, logged the boreholes, and examined and cared for the soil and rock core samples. The soil and bedrock core samples were identified in the field, placed in appropriate containers or core boxes, labelled and transported to Golder's Mississauga geotechnical laboratory. In the laboratory, the soil samples underwent further detailed visual examination and geotechnical classification testing (water contents, Atterberg limits and grain size distributions). The rock core samples also underwent further detailed visual examination and unconfined compression (uniaxial) strength testing was carried out on selected specimens of the rock core. The results of the laboratory testing are noted on the Record of Borehole and Drillhole sheets and are presented on the laboratory test sheets in Appendices A to D. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

The as-drilled borehole location and ground surface elevation were surveyed by Callon Dietz, a licensed surveying company retained by Golder. The locations given in the Record of Borehole/Drillhole sheets and shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.

The borehole locations, ground surface elevations and drilled depths are summarized below.

Culvert	Borehole No.	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing	Easting		
C1A	C1A-1	4797145.9	270893.8	222.6	5.5
	EN-3	4797126.1	270902.9	222.1	5.3
	C1A-2	4797102.3	270891.4	221.9	5.2
C1	C1-1	4797082.2	270878.4	222.0	5.5
	C1-1B	4797083.8	270878.6	222.0	9.5**
	C1-2	4797052.6	270852.7	221.9	5.9
	C1A-2	4797102.3	270891.4	221.9	5.2
C2	C2-1	4797013.4	270832.5	222.2	9.6**
	H5-3	4796972.2	270845.4	222.1	6.6
	C2-2	4796939.5	270861.0	222.3	6.6
C2A	C2A-1	4796872.1	270897.7	219.7	3.9
	C2A-2	4796845.2	270930.8	219.1	6.9**

** Including between 3.2 m and 4.0 m of rock coring

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The study area is located on the Niagara Escarpment[1], a topographic break that separates the two levels of the Niagara Peninsula, which is manifested in typically harder, resistant dolostone and limestone bedrock units forming vertical cliffs along the brow of the Escarpment, over the softer shale bedrock below. The Niagara Escarpment extends from the Niagara River to the northern tip of the Bruce Peninsula and is generally flanked by landscapes of glacial origin. Capping the Niagara Escarpment is the Lockport Formation consisting of white, grey and brown dolostone (Karrow, 1987)[2] at the crest underlain by the Rochester, Irondequoit, Reynales, Thorold, Grimsby and Cabot Head Formations consisting of grey to reddish brown shaley dolostone, limestone, siltstone and sandstone (Blair and McFarland, 1992)[3].

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

[2] Karrow, P.F. 1987. *Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario*, Ontario Geological Survey, Report 255. Ministry of Northern Development and Mines, Ontario.

[3] Blair, R. and McFarland, S. 1993. *Regional Correlation of the Middle and Lower Silurian Stratigraphy of the Niagara Escarpment Area*, Proceedings of the 1992 Conference of the Canadian National Chapter, International Association of Hydrogeologists, Hamilton, Ontario, 659-696.

Overburden within the study area is comprised primarily of glacial till mapped as the Halton Till which extends as a sheet in the Hamilton area, terminating in the Waterdown Moraines east of the Niagara Escarpment between the Lake Iroquois and the Trafalgar Moraine. The Halton Till is generally considered a fine-grained diamicton with minor fine-grained lacustrine sediments incorporated within the body of the unit, likely from glacial reworking of underlying lacustrine sediments. The Halton Till also contains cobbles and boulders and in some areas, "boulder pavements" (Watt, 1955) [4] can be encountered where boulders are nested or concentrated within the till unit.

During the retreat of the last ice sheet, lakes were formed in depressions on the land surface in which were deposited sand, gravel, silt and clay materials. The last major meltwater system along the Escarpment occurred when the Waterdown Moraines were formed. Several channels among the Waterdown Moraines functioned at various times, feeding melt waters southwest toward glacial lakes to create lacustrine and outwash sand deposits.

4.2 Subsurface Conditions

The detailed subsurface soil, bedrock, and groundwater conditions as encountered in the boreholes advanced during this investigation and the results of the laboratory tests carried out on selected soil and bedrock core samples are presented on the Record of Borehole and Drillhole sheets and laboratory test figures provided in Appendices A, B, C and D corresponding to Culverts C1, C1A, C2 and C2A, respectively. The Standard Penetration Test (SPT) 'N'-values as presented on the Record of Borehole sheets and in Section 4.0 are uncorrected.

The stratigraphic boundaries shown on the Record of Boreholes and on the interpreted stratigraphic profiles on the Borehole Location and Soil Strata drawings contained in the Contract Documents are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations. It should be noted that the interpreted stratigraphy shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents is a simplification of the subsurface conditions at each culvert site.

For the purposes of this report, the Highway 6 alignment is presented in a north-south orientation. Therefore, the directions indicated in the text may differ from those shown on the drawings. The stratigraphy generally consists of surficial layers of topsoil or fill overlying clayey silt till, which is underlain by dolostone bedrock. Between the fill and till deposit, a layer of silty sand to sand and gravel was encountered at some borehole locations. Detailed descriptions of the subsurface conditions at each investigated culvert crossing are provided in the following sections of this report.

4.2.1 Culvert C1A at Station 10+800 (Ramp E-N)

The borehole location plan and interpreted stratigraphic profile along Culvert C1A are shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents. Two sampled boreholes were completed to investigate the subsurface conditions at the culvert location: C1A-1 was advanced at the north end of the culvert and C1A-2 at the south end. Borehole EN-3 was previously advanced at approximately the

[4] Watt, A.K. 1955. *Pleistocene Geology and Groundwater Resources of the Township of North York*, York County, Ontario Department of Mines, Sixty Fourth Annual report, Volume LXIV, Part 7.

midpoint of Culvert C1A. In general, the topography in the area of the culvert is relatively flat and the terrain consists of grass and small bushes.

4.2.1.1 Topsoil

In Boreholes C1A-1, C1A-2 and EN-3, topsoil was encountered immediately below the ground surface. The thickness of the topsoil extends to depths between 0.1 m and 0.2 m below ground surface.

4.2.1.2 Fill

Fill materials were encountered underlying the topsoil in Boreholes C1A-1, C1A-2 and EN-3. The fill material is variable, containing layers of cohesive silty clay to clayey silt fill and layers of cohesionless silty sand and gravel to sandy silt fill, as follows:

- In Borehole C1A-1 a silty clay fill layer was encountered at a depth of 0.1 m (Elevation 222.5 m). The fill extends to a depth of 2.2 m (Elevation 220.4 m) and is about 2.1 m thick.
- In Borehole C1A-2 a silty clay to clayey silt fill layer was encountered at a depth of 0.2 m (Elevation 221.7 m). The cohesive fill layer extended to a depth of 1.4 m (Elevation 220.5 m). Within the cohesive fill material, a 0.7 m thick layer of silty sand and gravel fill was encountered at a depth of 0.5 m (Elevation 221.4 m) and extends to a depth of 1.2 m (Elevation 220.7 m).
- In Borehole EN-3 the topsoil is underlain by sandy silt fill which extends to a depth of 0.7 m (Elevation 221.4 m). The sandy silt fill is underlain by cohesive clayey silt fill that extends to a depth of 2.1 m (Elevation 220.0 m) and is about 1.4 m thick.

The SPT “N”-values measured within the cohesive fill range between 5 blows and 17 blows per 0.3 m of penetration, suggesting a firm to very stiff consistency. The SPT “N”-values measured within the non-cohesive fill range between 5 blows and 9 blows per 0.3 m of penetration, indicating a loose relative density.

A grain size distribution test was carried out on one selected sample of the silty clay fill and the results are shown on Figure A1 in Appendix A. An Atterberg limits test was carried out on one selected sample of the cohesive fill and measured a liquid limit of 36 per cent, plastic limit of 17 per cent and plasticity index of 19 per cent. These results, which are plotted on a plasticity chart on Figure A2 in Appendix A, indicate that the tested cohesive fill consists of silty clay of intermediate plasticity. The water content measured on two samples within the cohesive fill is 16 per cent, near the plastic limit of the material. The water content measured on one sample of cohesionless silty sand and gravel to sandy silt fill is 3 per cent.

4.2.1.3 Clayey Silt Till

A clayey silt till deposit was encountered underlying the fill in Boreholes C1A-1, C1A-2 and EN-3. The top of the till was encountered at depths between 1.4 m and 2.2 m (between Elevations 220.5 m and 220.0 m). The till deposit extends to depths between 5.2 m and 5.5 m (between Elevations 217.1 m and 216.7 m) and is between 3.2 m and 3.8 m thick.

The SPT “N”-values measured within the till deposit range from 9 blows to 37 blows per 0.3 m of penetration, suggesting that the till has a stiff to hard consistency.

The till deposit is generally comprised of clayey silt, some sand to sandy and trace to some gravel. Grain size distribution tests were carried out on five selected samples of the clayey silt till deposit and the results are shown on Figure A3 in Appendix A. Although cobbles and/or boulders were not encountered within the till deposit and

grinding of the augers during drilling was not observed, the till deposits in southern Ontario typically contain such materials and they should be expected within such glacial deposits.

Atterberg limits tests were carried out on four selected samples of this cohesive till deposit and measured liquid limits ranging from 18 per cent to 29 per cent, plastic limits ranging from 10 per cent to 17 per cent and plasticity indices ranging from 5 per cent to 18 per cent. These results, which are plotted on a plasticity chart on Figure A4 in Appendix A, indicate that the till deposit consists of clayey silt of low plasticity. The natural water content measured on eight selected samples of the clayey silt till ranges from 11 per cent to 17 per cent, near the plastic limit for the till material.

4.2.1.4 Refusal

In Boreholes C1A-1, C1A-2 and EN-3, the bedrock surface was inferred by refusal to further split-spoon penetration and/or auger refusal at depths ranging from about 5.2 m to 5.5 m, corresponding to about Elevations 217.1 m to 216.7 m.

4.2.1.5 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets, in Appendix A. The overburden samples taken in the boreholes were generally moist to wet. Borehole C1A-1 was dry upon completion of drilling, while the water level measured in Borehole EN-3 was at a depth of 4.1 m (Elevation 218.0 m) upon completion of drilling. However, these measurements do not represent stabilized groundwater levels at the site. Based on measurements in the piezometer installed at adjacent Culvert C1, it is anticipated that the groundwater level at this site is at approximately Elevation 220.5 m. The groundwater level in the area will be subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet periods of the year.

4.2.2 Culvert C1 at Station 20+045 (Highway 6)

The borehole location plan and interpreted stratigraphic profile along Culvert C1 are shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents. Two sampled boreholes were completed to investigate the subsurface conditions at the culvert location: C1-2 was advanced at the west end of the culvert and C1-1 at the mid-point. Approximately 1 m from Borehole C1-1, Borehole C1-1B was advanced for the purpose of coring of the bedrock and installation of a piezometer. Borehole C1A-2, which was advanced at the west end of the alignment for the proposed Culvert C1A, is near Culvert C1 and therefore is also described in this section of the report. In general, the topography in the area of the culvert consists mostly of a relatively flat section of Highway 6 and the terrain consists of grass and small bushes.

4.2.2.1 Topsoil

In Boreholes C1-1 and C1A-2, topsoil was encountered immediately below the ground surface to a depth of about 0.1 m and 0.2 m.

4.2.2.2 Asphalt

Borehole C1-2, advanced through the pavement structure of the southbound lanes of Highway 6, encountered approximately 200 mm of asphalt.

4.2.2.3 Fill

Fill materials were encountered in Boreholes C1-1, C1-2 and C1A-1. Underlying the asphalt surface of Highway 6 in Borehole C1-2, approximately 0.4 m of sand and gravel fill was encountered at a depth of 0.2 m (Elevation 221.7 m), extending to a depth of 0.6 m (Elevation 221.3 m).

Underlying the topsoil in Boreholes C1-1 and C1A-2, and the sand and gravel fill in Borehole C1-2, variable cohesive and cohesionless fill materials were encountered. The fill extends to a depth of 1.4 to 1.9 m (between Elevations 220.5 m and 220.0 m). The cohesive fill varies from clayey silt to sandy silty clay and the cohesionless fill material varies from gravel to silty sand. Auger grinding was observed in Borehole C1-1 at a depth of 0.9 m (Elevation 221.1 m) and in Borehole C1-1B from 0.6 m to 1.2 m (Elevation 221.4 m to 220.8 m) and is an indication of the possible presence of cobbles and boulders within this material.

One SPT "N"-value was measured within the sand and gravel base/subbase fill at 40 blows per 0.3 m of penetration, indicating a dense relative density. The SPT "N"-values recorded within the variable cohesive fill ranges from 5 blows to 24 blows per 0.3 m of penetration, suggesting a firm to very stiff consistency. The SPT "N"-values measured within the variable non-cohesive fill are between 5 blows and 22 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The water content measured on one sample within the sand and gravel fill below the asphalt is 4 per cent. The water content measured on two samples of the variable cohesive fill is 14 per cent and 16 per cent. The water content measured on two samples of variable non-cohesive fill is 3 and 8 per cent.

4.2.2.4 Silty Sand

Underlying the fill material in Boreholes C1-1 and C1-2, a silty sand layer was encountered at depths of 1.8 m and 1.9 m (Elevations 220.2 m and 220.0m). The deposit extends to depths of 2.7 m and 2.2 m (Elevations 219.3 m and 219.7 m) in Boreholes C1-1 and C1-2, respectively, and is 1.1 m and 0.3 m thick at these locations.

The measured SPT "N" values within the silty sand to sand deposit are between 5 blows and 19 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The silty sand contains trace gravel and trace to some clay. A grain size distribution test was carried out on one selected sample of the silty sand deposit and the result is shown on Figure B1 in Appendix B. The natural water content measured on one sample of the silty sand deposit is 20 per cent.

4.2.2.5 Clayey Silt Till

A clayey silt till deposit was encountered underlying the fill material in Borehole C1A-2, and the silty sand layer in Boreholes C1-1 and C1-2. The surface of the till was encountered at depths between 1.4 m and 2.7 m (between Elevations 220.5 m and 219.3 m). The till deposit extended to depths between 5.2 m and 5.9 m (between Elevations 216.7 m and 216.0 m) and is between 2.8 m and 3.8 m thick.

The SPT "N"-values measured within the till deposit range from 9 blows to 34 blows per 0.3 m of penetration, suggesting that the till has a stiff to hard consistency.

The till deposit is generally comprised of clayey silt, trace sand to sandy and trace to some gravel. Grain size distribution tests were carried out on five selected samples of the clayey silt till deposit and the results are shown on Figure B2 in Appendix B. Although cobbles and/or boulders were not encountered within the till deposit and grinding of the augers during drilling was not observed, the till deposits in southern Ontario typically contain such materials and they should be expected within such glacial deposits.

Atterberg limits tests were carried out on five selected samples of this cohesive till deposit and measured liquid limits ranging from 18 per cent to 28 per cent, plastic limits ranging from 10 per cent to 15 per cent and plasticity indices ranging from 5 per cent to 18 per cent. These results, which are plotted on a plasticity chart on Figure B3 in Appendix B, confirm that the till deposit consists of clayey silt of low plasticity. The natural water content measured on seven selected samples of the clayey silt till ranges from 12 per cent to 20 per cent.

4.2.2.6 Dolostone Bedrock

Bedrock was encountered and core samples were recovered in Borehole C1-1B. The bedrock surface is inferred from split-spoon and auger refusal in Boreholes C1-1, C1-2 and C1A-2. The depth to bedrock or refusal and the corresponding bedrock surface or refusal elevation are summarized below.

Location	Borehole	Depth to Bedrock Surface / Refusal (m)	Bedrock Surface / Refusal Elevation (m)	Comments
West End of Culvert	C1-2	5.9	216.0	Auger and Split-Spoon Refusal
Mid-Point of Culvert	C1-1/ C1-1B	5.5	216.5	Auger and Split-Spoon Refusal/ Bedrock Cored
East End of Culvert	C1A-2	5.2	216.7	Auger and Split-Spoon Refusal

In general, the bedrock surface as encountered or inferred in the area of the Grindstone Creek Culvert C1 is fairly level to gently sloping upwards from west to east.

Based on a review of the bedrock core samples, the bedrock consists of dolostone of the Lockport formation. In general, the bedrock core samples are described as slightly weathered to fresh, thinly to thickly bedded, fine to coarse grained, faintly to highly porous, medium strong to strong and grey, as presented in the Record of Drillhole sheet in Appendix B, and shown on the photographs of the recovered core samples on Figure B4 in Appendix B. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2), and the strength classification of the intact rock mass based on field identification (i.e. medium strong to strong – R3 to R4) are described in accordance with the International Society for Rock Mechanics (ISRM[5]) standard classification system.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 81 per cent and 100 per cent and between 77 per cent and 98 per cent, respectively. The Rock Quality Designation (RQD) measured on the core samples ranges from 81 per cent to 100 per cent, indicating a rock mass of good to excellent quality as per Table 3.10 of CFEM (2006)[6].

Point load strength index tests (ASTM D5731)[7] were carried out on selected samples of the bedrock core. The point load strength index values are shown on the Record of Drillhole sheets and are presented in Table B1 in Appendix B. The axial test carried out on one sample of the dolostone bedrock measured Is_{50} values of

[5] International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

[6] Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

[7] ASTM D5731 – Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classification

8.6 MPa. The diametral test carried out on one sample of the dolostone bedrock measured Is_{50} values of 10.4 MPa.

Also presented in Table B1 are the estimated UCS values for each sample tested for point load strength index based on a relationship between Is_{50} and UCS, which is given by a correlation factor (K)[7] which varies depending on the size of the core sample and the site specific strength of the rock as confirmed from the UC test completed on the selected core samples for the overall site of the overhead signs. For this culvert location, the estimated UCS values are based on a correlation factor (K) of about 9, based on the results from the boreholes at Culvert C2 and C2A. Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)[8], the dolostone bedrock is classified as strong (R4, 50 MPa < UCS < 100 MPa).

4.2.2.7 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets, in Appendix A. The overburden samples taken in the boreholes were generally moist to wet. The water level measured in Boreholes C1-1, C1-2 and C1-1B was between 2.0 m and 5.9 m below ground surface (Elevation 220.0 m and 216.0 m) upon completion of drilling; however, this measurement does not represent the stabilized groundwater level at the site.

A standpipe piezometer was installed in Boreholes C1-1B and C1-2 to allow monitoring of the groundwater level at the site. Details of the piezometer installation are shown on the Record of Borehole sheets in Appendix B. The groundwater level measured in the piezometer at Borehole C1-1B on January 8, 2015 was at a depth of 1.6 m (Elevation 220.4 m) and the groundwater level measured in the piezometer at Borehole C1-2 on January 27, 2015 was at a depth of 1.8 m (Elevation 219.8 m). The groundwater level in the area will be subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet periods of the year.

4.2.3 Culvert C2 at Station 29+903 (Highway 5)

The borehole location plan and interpreted stratigraphic profile along Culvert C2 are shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents. Two sampled boreholes were completed to investigate the subsurface conditions at the culvert location; C2-1 was advanced at the north end of the culvert and C2-2 at the south end. In addition, Borehole H5-3, drilled in November 2012 for the high fill embankments, is located at about the midpoint of Culvert C2. In general, the topography in the area of the culvert consists mostly of a relatively flat section of Highway 5 and a relatively flat section of abandoned asphalt surface at the northwest corner of Highway 5 and Highway 6.

4.2.3.1 Asphalt

Borehole C2-1 was advanced through the pavement structure of the eastbound lanes of Highway 5, and encountered 200 mm of asphalt immediately below the ground surface. Borehole C2-2 was advanced through the abandoned asphalt surface at the northwest corner of Highway 5 and Highway 6, and 150 mm of asphalt was encountered at ground surface.

[8] Canadian Geotechnical Society, 1992. Canadian Foundation Engineering Manual (CFEM), 3rd Edition. The Canadian Geotechnical Society, BiTech Published Ltd., British Columbia.

4.2.3.2 Fill

Sand and gravel to gravelly silt and sand fill materials were encountered below the asphalt in Boreholes C2-1 and C2-2, and immediately below ground surface in Borehole H5-3. This fill layer extends to a depth of 0.3 m to 2.0 m (between Elevations 221.4 and 220.2 m) and is between 0.3 m and 1.8 m thick.

Underlying the sand and gravel fill in Boreholes C2-2 and H5-3 is a layer of cohesive fill material consisting of clayey silt with sand to silty clay. This fill material was encountered at depths between 0.3 and 1.5 m (between Elevations 221.8 m and 220.9 m). The cohesive fill extends to depths of 0.7 and 2.3 m (Elevations 221.4 m and 220.0 m) and is 0.4 m and 0.8 m thick in Boreholes C2-2 and H5-3, respectively.

The SPT "N"-value measured within the non-cohesive fill range between 8 blows and 17 blows per 0.3 m of penetration indicating a loose to very dense relative density. The exception to this is the sample beneath the asphalt in Borehole C2-2 where the SPT "N"-value measured was 50 blows per 0.15 m of penetration, indicating a very dense relative density. The SPT "N"-values recorded within the cohesive fill were 11 and 12 blows per 0.3 m of penetration, indicating a stiff consistency.

The cohesionless fill is generally comprised of sand and gravel some silt, trace clay to gravelly silt and sand with some clay. Grain size distribution tests were carried out on two selected samples of the sand and gravel to gravelly silt and sand fill and the results are shown on Figure C1 in Appendix C. The cohesive fill varied from clayey silt with sand to silty clay trace sand, trace gravel. The water content measured on three samples within the non-cohesive fill was 2 to 14 per cent.

4.2.3.3 Sand

Underlying the cohesive fill in Borehole C2-1, sand was encountered at a depth of 2.0 m (Elevation 220.2 m). The deposit extended to a depth of 2.3 m (Elevation 219.9 m) and was 0.3 m thick.

The measured SPT "N" value within the sand deposit was 9 blows per 0.3 m of penetration, indicating that the sand has a loose relative density.

4.2.3.4 Clayey Silt Till

A till deposit was encountered underlying the cohesive fill layer in Boreholes C2-2 and H5-3, and underlying the sand layer in Borehole C2-1. The top of the till was encountered at depths between 0.7 m and 2.3 m (between Elevations 221.4 m and 219.9 m). The till deposit extends to depths between 6.1 m and 6.6 m (between Elevations 215.7 m and 216.1 m) and is between 4.3 m and 5.9 m thick.

The SPT "N"-values measured within the till deposit range from 12 blows per 0.3 m of penetration to 107 blows per 0.2 m of penetration, suggesting that the clayey silt till has a stiff to hard (but typically very stiff to hard) consistency.

The till deposit is generally comprised of clayey silt, some sand to sandy and trace to some gravel. Silt seams were present within the till in Borehole H5-3. Grain size distribution tests were carried out on five selected samples of the clayey silt till deposit and the results are shown on Figure C2 in Appendix C. Although cobbles and/or boulders were not encountered within the till deposit and grinding of the augers during drilling was not observed, the till deposits in southern Ontario typically contain such materials and they should be expected within such glacial deposits.

Atterberg limits tests were carried out on four selected samples of this cohesive till deposit and measured liquid limits ranging from 25 per cent to 32 per cent, plastic limits ranging from 14 per cent to 15 per cent and plasticity indices ranging from 11 per cent to 16 per cent. These results, which are plotted on a plasticity chart on Figure C3 in Appendix C, indicate that the till deposit consists of clayey silt of low plasticity. The natural water content measured on seven selected samples of the clayey silt till ranges from 13 per cent to 15 per cent, near the plastic limit for the till deposit.

4.2.3.5 Dolostone Bedrock

Bedrock was encountered and core samples were recovered in Borehole C2-1. The bedrock surface was inferred from split-spoon and auger refusal in Boreholes C2-2 and H5-3. The depths to bedrock or refusal and the corresponding bedrock surface or refusal elevation are summarized below.

Foundation Element	Borehole	Depth to Bedrock Surface / Refusal (m)	Bedrock Surface / Refusal Elevation (m)	Comments
North End of Culvert	C2-1	6.1	216.1	Bedrock Cored
Mid-Point of Culvert	H5-3	6.6	215.5	Split-Spoon Refusal
South End of Culvert	C2-2	6.6	215.7	Split-Spoon Refusal

In general, the bedrock surface as encountered or inferred in the area of the Grindstone Creek Culvert C2 is fairly level to gently sloping upwards from south to north.

Based on a review of the bedrock core samples, the bedrock consists of dolostone of the Lockport formation. In general, the bedrock core samples are described as slightly weathered to fresh, thinly to medium bedded, fine grained, faintly porous, strong and grey, as presented in the Record of Drillhole sheets in Appendix C, and shown on the photographs of the recovered core samples on Figure C4 in Appendix C. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2), and the strength classification of the intact rock mass based on field identification (i.e. strong –R4) are described in accordance with the International Society for Rock Mechanics (ISRM[9]) standard classification system.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 73 per cent and 100 per cent and between 55 per cent and 97 per cent, respectively. The Rock Quality Designation (RQD) measured on the core samples ranges from 73 per cent to 95 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of CFEM (2006)[6].

One Unconfined Compression (UC) test (ASTM D7012)[10] was carried out on a core sample of the dolostone bedrock obtained in Borehole C2-1 and measured a compressive strength of 68 MPa as shown in Figure C5 and as summarized in Table C1 in Appendix C. Point load strength index tests (ASTM D5731)[7] were carried out on selected samples of the bedrock core. The point load strength index values are shown on the Record of Drillhole sheets and are presented in Table C2 in Appendix C. The axial test carried out on one sample of the

[9] International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

[10] ASTM D7012 – Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

dolostone bedrock measured an Is_{50} value of 10.8 MPa. The diametral test carried out on one sample of the dolostone bedrock measured an Is_{50} value of 12.0 MPa.

Also presented in Table C2 are the estimated UCS values for each sample tested for point load strength index based on a relationship between Is_{50} and UCS, which is given by a correlation factor (K)[7] which varies depending on the size of the core sample and the site specific strength of the rock as confirmed from the UC test completed on the selected core samples for the overall site of the overhead signs. For this culvert location, the estimated UCS values are based on a correlation factor (K) of 6. Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)[11], the dolostone bedrock is classified as strong (R4, 50 MPa < UCS < 100 MPa).

4.2.3.6 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets in Appendix C. The overburden samples taken in the boreholes were generally moist to wet. The water level in Boreholes C2-1 and C2-2 were measured at depths of 3.0 m and 4.6 m (Elevation 220.0 m and 216.0 m) upon completion of drilling, and Borehole H5-3 was noted as dry upon completion of drilling. However, these measurements likely do not represent the stabilized groundwater level at the site.

The groundwater level measured in the piezometer at Borehole C2-2 on January 27, 2015 was at a depth of 2.7 m (Elevation 219.6 m). The groundwater level in the area will be subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet periods of the year.

4.2.4 Culvert C2A at Station 30+132 (Commercial Access Road)

The borehole location plan and interpreted stratigraphic profile along Culvert C2A are shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents. Two sampled boreholes were completed to investigate the subsurface conditions at the culvert location: C2A-1 was advanced at the north end of the culvert and C2A-2 at the south end. In general, the topography in the area of the culvert consists of a wet area with cattail vegetation.

4.2.4.1 Silty Clay

In Boreholes C2A-1 and C2A-2, a surficial silty clay layer was encountered. In both boreholes the deposit extended to a depth of 0.7 m (Elevation 219.0 in Borehole C2A-1 and 218.4 m in Borehole C2A-2).

The measured SPT “N” values within the silty clay deposit were 2 blows and 5 blows per 0.3 m of penetration, suggesting that the silty clay soft to firm consistency.

The natural water content measured on one sample of the silty clay deposit was 23 per cent.

4.2.4.2 Clayey Silt Till

A till deposit was encountered underlying the silty clay layer in Boreholes C2A-1 and C2A-2. The top of the till was encountered at a depth of 0.7 m (Elevation 219.0 in Borehole C2A-1 and 218.4 m in Borehole C2A-2). The till deposit extends to a depth of 3.9 m in Borehole C2A-1 and 3.7 m in Borehole C2A-2 (Elevation 215.8 m and 215.4 m, respectively) and is between 3.0 m and 3.2 m thick.

[11] Canadian Geotechnical Society, 1992. Canadian Foundation Engineering Manual (CFEM), 3rd Edition. The Canadian Geotechnical Society, BiTech Published Ltd., British Columbia.

The SPT "N"-values measured within the till deposit range from 17 blows to 41 blows per 0.3 m of penetration, suggesting that the clayey silt till has a very stiff to hard consistency.

The till deposit is generally comprised of clayey silt, trace sand to sandy and trace to some gravel. Dolostone fragments were also present within the samples of the till deposit. Grain size distribution tests were carried out on two selected samples of the clayey silt till deposit and the results are shown on Figure D1 in Appendix D. Although cobbles and/or boulders were not encountered within the till deposit and grinding of the augers during drilling was not observed, the till deposits in southern Ontario typically contain such materials and they should be expected within such glacial deposits.

Atterberg limits tests were carried out on three selected samples of this cohesive till deposit and measured liquid limits ranging from 23 per cent to 31 per cent, plastic limits ranging from 13 per cent to 17 per cent and plasticity indices ranging from 9 per cent to 16 per cent. These results, which are plotted on a plasticity chart on Figure D2 in Appendix D, indicate that the till deposit consists of clayey silt of low plasticity. The natural water content measured on four selected samples of the clayey silt till ranges from 12 per cent to 14 per cent, near or below the plastic limit for the material.

4.2.4.3 Dolostone Bedrock

Bedrock was encountered and core samples were recovered in Borehole C2A-2. The bedrock surface was inferred from split-spoon and auger refusal in Boreholes C2A-1. The depths to bedrock or refusal and the corresponding bedrock surface or refusal elevation are summarized below.

Foundation Element	Borehole	Depth to Bedrock Surface / Refusal (m)	Bedrock Surface / Refusal Elevation (m)	Comments
North End of Culvert	C2A-1	3.9	215.8	Auger and Split-Spoon Refusal
South End of Culvert	C2A-2	3.7	215.4	Bedrock Cored

In general, the bedrock surface as encountered or inferred in the area of the Grindstone Creek Culvert C2A is fairly level to gently sloping upwards from south to north.

Based on a review of the bedrock core samples, the bedrock consists of dolostone of the Lockport formation. In general, the bedrock samples are described as slightly weathered to fresh, thinly to medium bedded, fine grained, faintly porous, strong and grey, as presented in the Record of Drillhole sheets in Appendix D, and shown on the photographs of the recovered core samples on Figure D3 Appendix D. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2), and the strength classification of the intact rock mass based on field identification (i.e. strong – R4) are described in accordance with the International Society for Rock Mechanics (ISRM[12]) standard classification system.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 98 per cent and 100 per cent and between 89 per cent and 96 per cent. The Rock Quality Designation (RQD) measured on

[12] International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

the core samples ranges from 95 per cent to 100 per, indicating a rock mass of excellent quality as per Table 3.10 of CFEM (2006).

One Unconfined Compression (UC) test (ASTM D7012)[13] was carried out on a core sample of the dolostone bedrock obtained in Borehole C2A-2 and measured a compressive strength of 101 MPa as shown in Figure D4 and on Table D1 in Appendix D.

Point load strength index tests (ASTM D5731) were carried out on two selected samples of the bedrock core. The point load strength index values are shown on the Record of Drillhole sheets and are presented in Table D2 in Appendix D. The diametral test carried out on one sample of the dolostone bedrock measured an Is_{50} value of 7.4 MPa. The axial test carried out on one sample of the bedrock measured an Is_{50} value of 9.2 MPa.

Also presented in Table D2 are the estimated UCS values for each sample tested for point load strength index based on a relationship between Is_{50} and UCS, which is given by a correlation factor (K)[7] which varies depending on the size of the core sample and the site specific strength of the rock as confirmed from the UC test completed on the selected core samples for the overall site of the overhead signs. For this culvert location, the estimated UCS values are based on a correlation factor (K) of 12. Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)[14], the dolostone bedrock is classified as strong (R4, 50 MPa<UCS<100 MPa) to very strong (R5, 100 MPa < UCS < 250 MPa).

4.2.4.4 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets in Appendix D. The overburden samples taken in the boreholes were generally moist to wet. Boreholes C2A-1 and C2A-2 were noted as dry upon completion of drilling, although this may not represent the stabilized groundwater level at the site.

Based on the piezometers installed at the site of adjacent Culverts C1 and C2, it is anticipated that the groundwater level is at approximately Elevation 219.5 m to 220.5 m. The groundwater level in the area is subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet periods of the year.

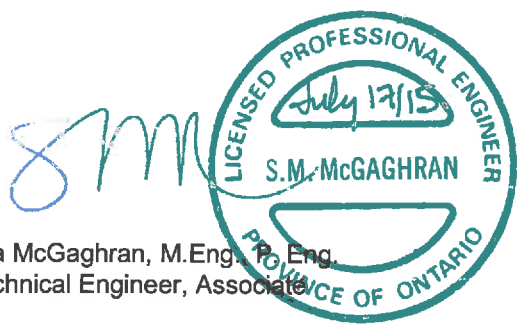
[13] ASTM D7012 – Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

[14] Canadian Geotechnical Society, 1992. Canadian Foundation Engineering Manual (CFEM), 3rd Edition. The Canadian Geotechnical Society, BiTech Published Ltd., British Columbia.

5.0 CLOSURE

Mr. Alex Szot, E.I.T., a geotechnical engineer-in-training with Golder directed the field drilling program. This report was prepared by Ms. Sandra McGaghran, M.Eng., P.Eng., a geotechnical engineer and Associate with Golder. Ms. Lisa Coyne, P.Eng., a Designated MTO Foundations Contact and Principal with Golder, conducted a technical and quality control review of the report.

GOLDER ASSOCIATES LTD.



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American Standard Test Methods (ASTM)

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

ASTM D7012 Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures

Ontario Water Resources Act

Ontario Regulation 903 Wells (as amended)

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	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 $\tau = c' + \sigma' \tan\phi'$

2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d:

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

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

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90^{o} angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint
FLT Fault
SH Shear
VN Vein
FR Fracture
SY Stylolite
BD Bedding
FO Foliation
CO Contact
AXJ Axial Joint
KV Karstic Void
MB Mechanical Break

PL Planar
CU Curved
UN Undulating
IR Irregular
K Slickensided
PO Polished
SM Smooth
SR Slightly Rough
RO Rough
VR Very Rough

APPENDIX A

Culvert 1A at Station 10+800 (Ramp E-N)
Record of Boreholes and Laboratory Test Results

Golder Associates

RECORD OF BOREHOLE No C1A-1

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4797145.9 ;E 270893.8 ORIGINATED BY AJS

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS

DATUM Geodetic DATE October 6, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.6	GROUND SURFACE										
0.0	TOPSOIL										
0.1	Silty clay, some sand, trace to some gravel, containing dolostone fragments (FILL) Brown Stiff to very stiff Moist		1	SS	17		222				
			2A 2B	SS	11						
			3A 3B	SS	11		221				2 17 49 32
220.4											
2.2	CLAYEY SILT, some sand, trace to some gravel, containing dolostone fragments (TILL) Brown Very Stiff to hard Moist		4	SS	15		220				
			5	SS	30						
			6	SS	21		219				
	Becoming grey below 4.8 m		7	SS	23		218				
217.1			8	SS	100/0.0						
5.5	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK										
	NOTE: 1. Open borehole dry upon completion of drilling.										

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

Golder Associates

RECORD OF BOREHOLE No C1A-2

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4797102.3 ;E 270891.4 ORIGINATED BY AJS

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS

DATUM Geodetic DATE October 6, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
221.9	GROUND SURFACE										
0.0	TOPSOIL		1A	SS	9				○		
221.4	Clayey silt, containing organics and rootlets (FILL) Stiff Brown Moist		1B								
0.5			2A	SS	5		221				
220.7	Silty sand and gravel (FILL) Loose Grey to brown Dry		2B								
1.4	Silty clay, containing organics (FILL) Firm Brown to black Moist		3	SS	9		220				
	CLAYEY SILT, some sand to sandy, trace to some gravel (TILL) Stiff to hard Grey and brown Moist to wet		4	SS	21				○		4 20 48 28
			5	SS	34		219				
			6A	SS	34		218		○—○		10 26 41 23
			6B								
	Becoming grey below 4.6 m		7A								
216.7			7B 7C	SS	18 100/0		217		○—○		1 16 67 16
5.2	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK		8								

NOTE:

1. Samples below a depth of 2.3 m (Elev. 219.6 m) were wet.

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

Golder Associates

RECORD OF BOREHOLE No EN-3

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4797126.1 ;E 270902.9 ORIGINATED BY JBH

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY BM

DATUM Geodetic DATE November 19, 2012 CHECKED BY TVA

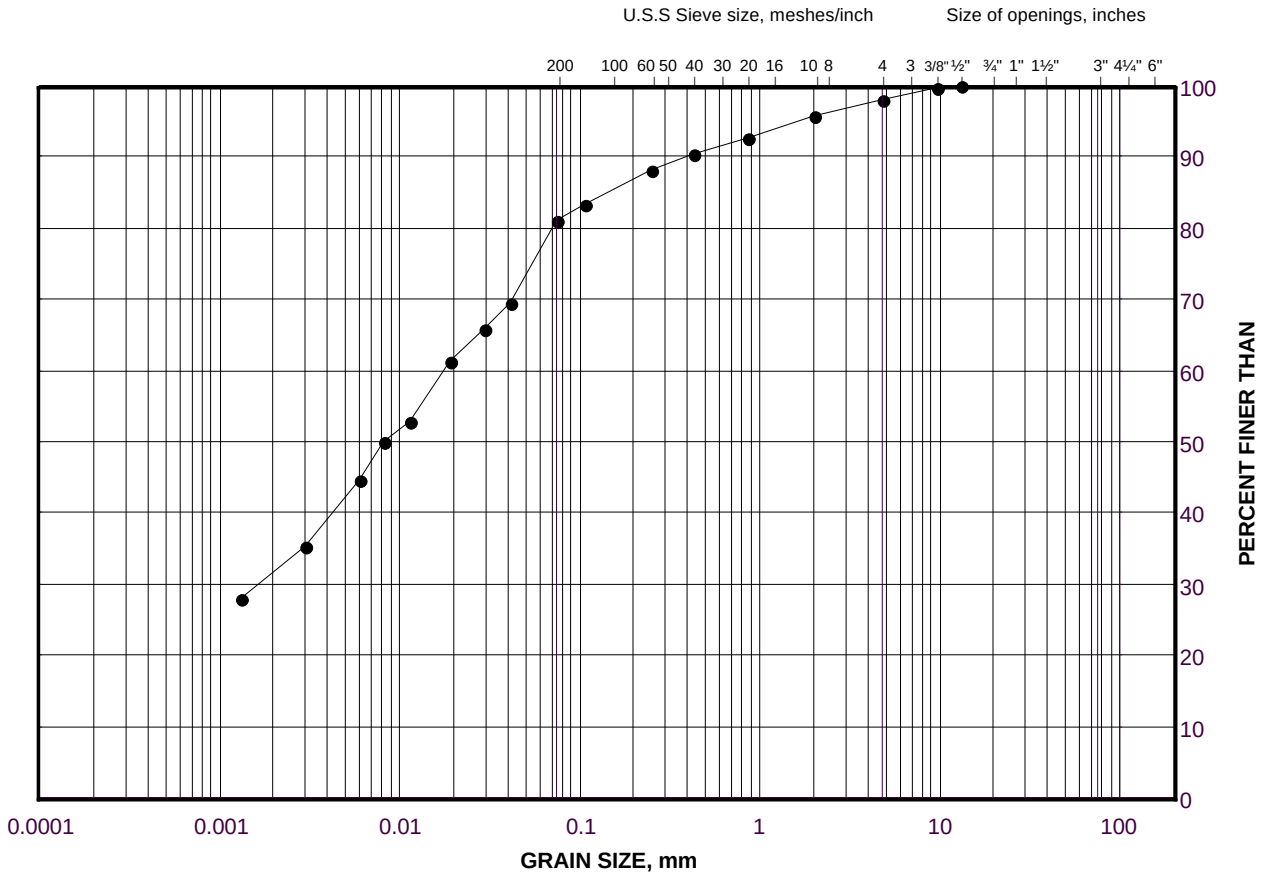
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.1	GROUND SURFACE						222				
0.0	TOPSOIL										
0.2	Sandy silt, trace clay, trace organics and pieces of brick (FILL) Loose		1	SS	9						
221.4							221				
0.7	Dark brown to brown Moist		2	SS	5						
	Clayey silt, trace to with sand, trace gravel, trace organics, sand pockets and topsoil between depths of 1.0 m and 1.1 m (FILL) Firm to stiff		3	SS	12						
220.0	Brown						220				
2.1	Moist										
	CLAYEY SILT, sandy to some sand, trace to some gravel (TILL) Very stiff to hard Brown Moist		4	SS	26						3 20 51 26
			5	SS	31		219				
			6	SS	37	▽	218				6 24 51 19
	----------Wet		7A 7B	SS	19						
216.8							217				
5.3	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK										
	NOTE: 1. Water level in open borehole measured at a depth of 4.1 m (Elev. 218.0 m) upon completion of drilling.										

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

GRAIN SIZE DISTRIBUTION

Silty Clay (Fill)

FIGURE A1



LEGEND

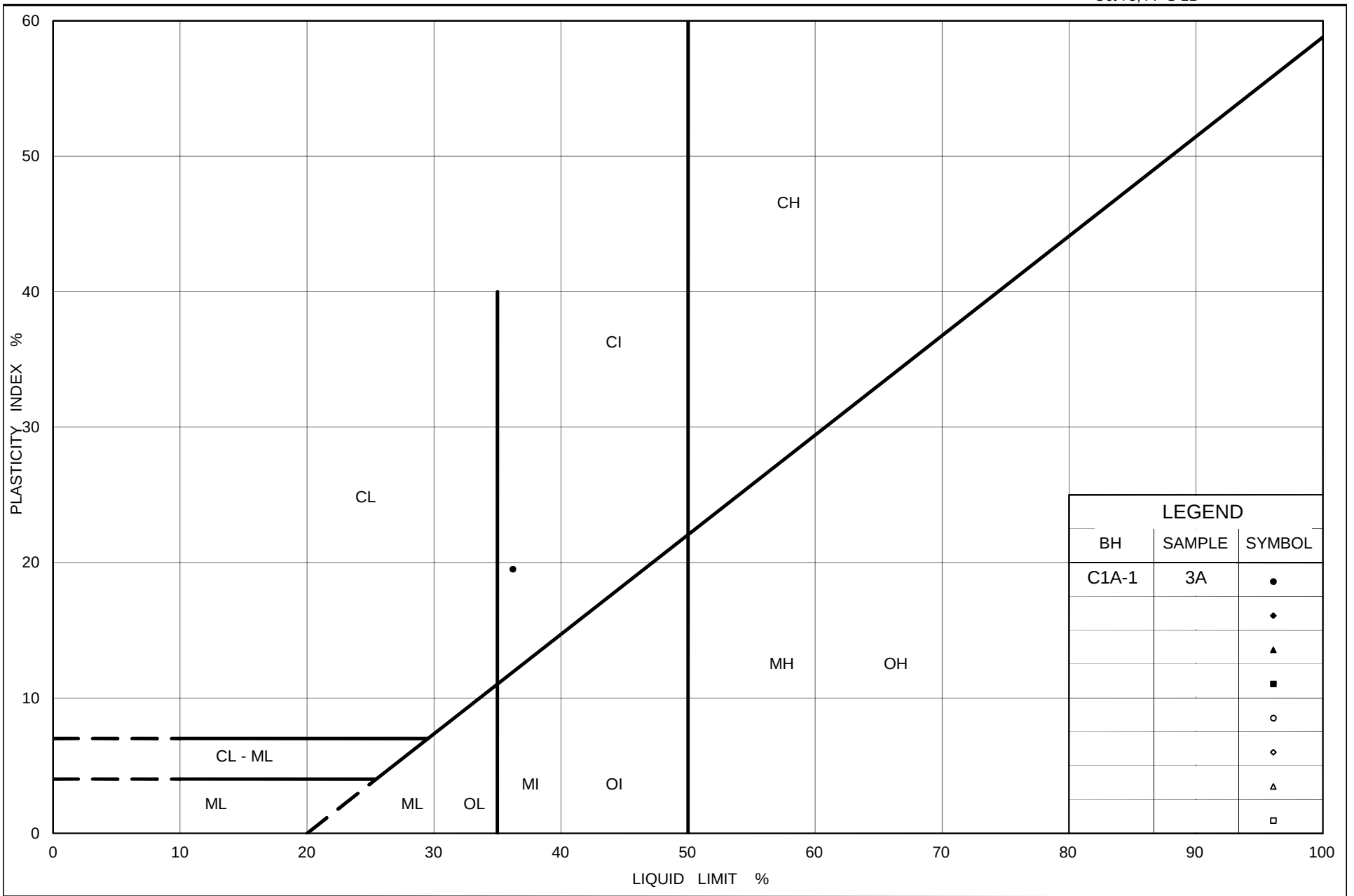
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C1A-1	3A	220.9

Project Number: 10-1184-0016

Checked By: SMM

Golder Associates

Date: 02-Feb-15



Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay (Fill)

Figure No. A2

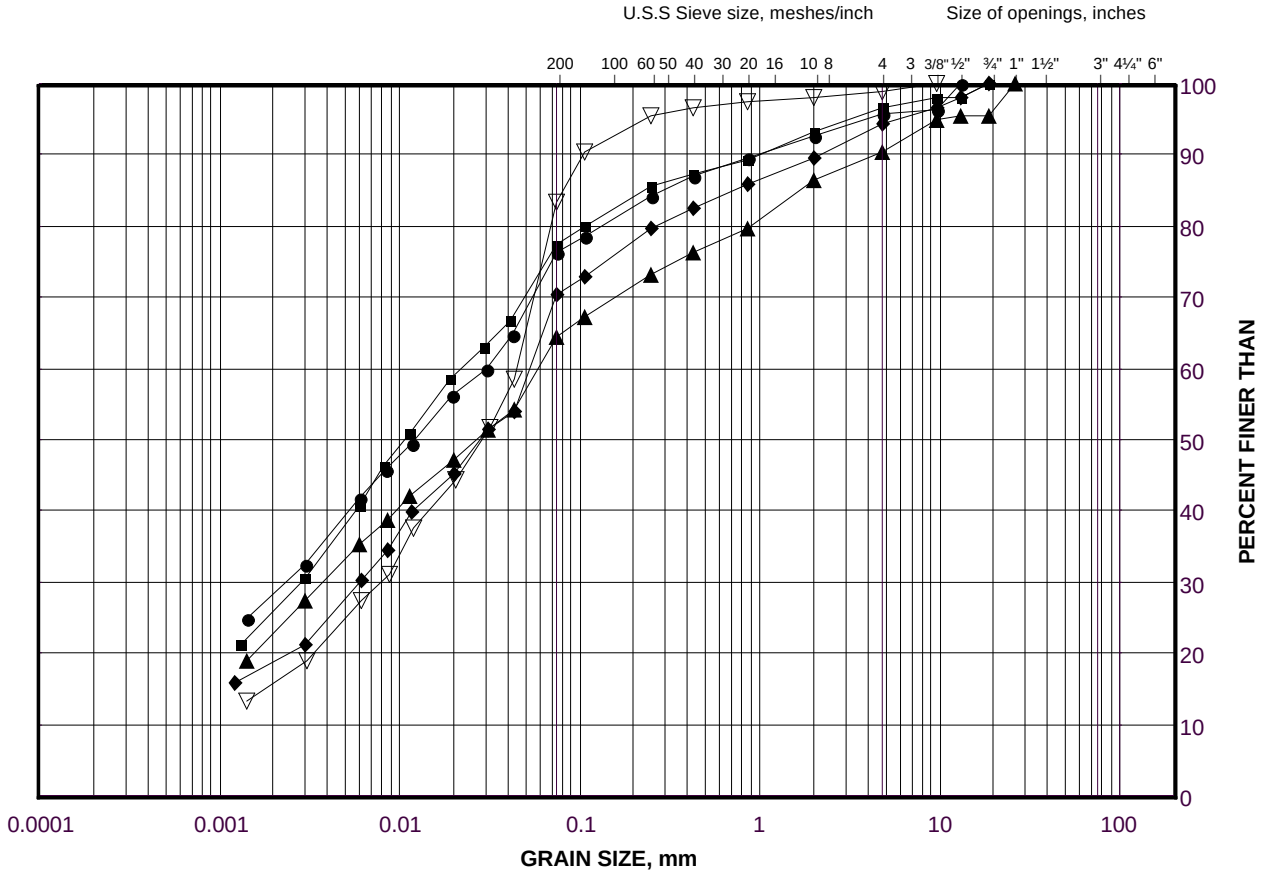
Project No. 10-1184-0016

Checked By: SMM

GRAIN SIZE DISTRIBUTION

Clayey Silt (Till)

FIGURE A3



LEGEND

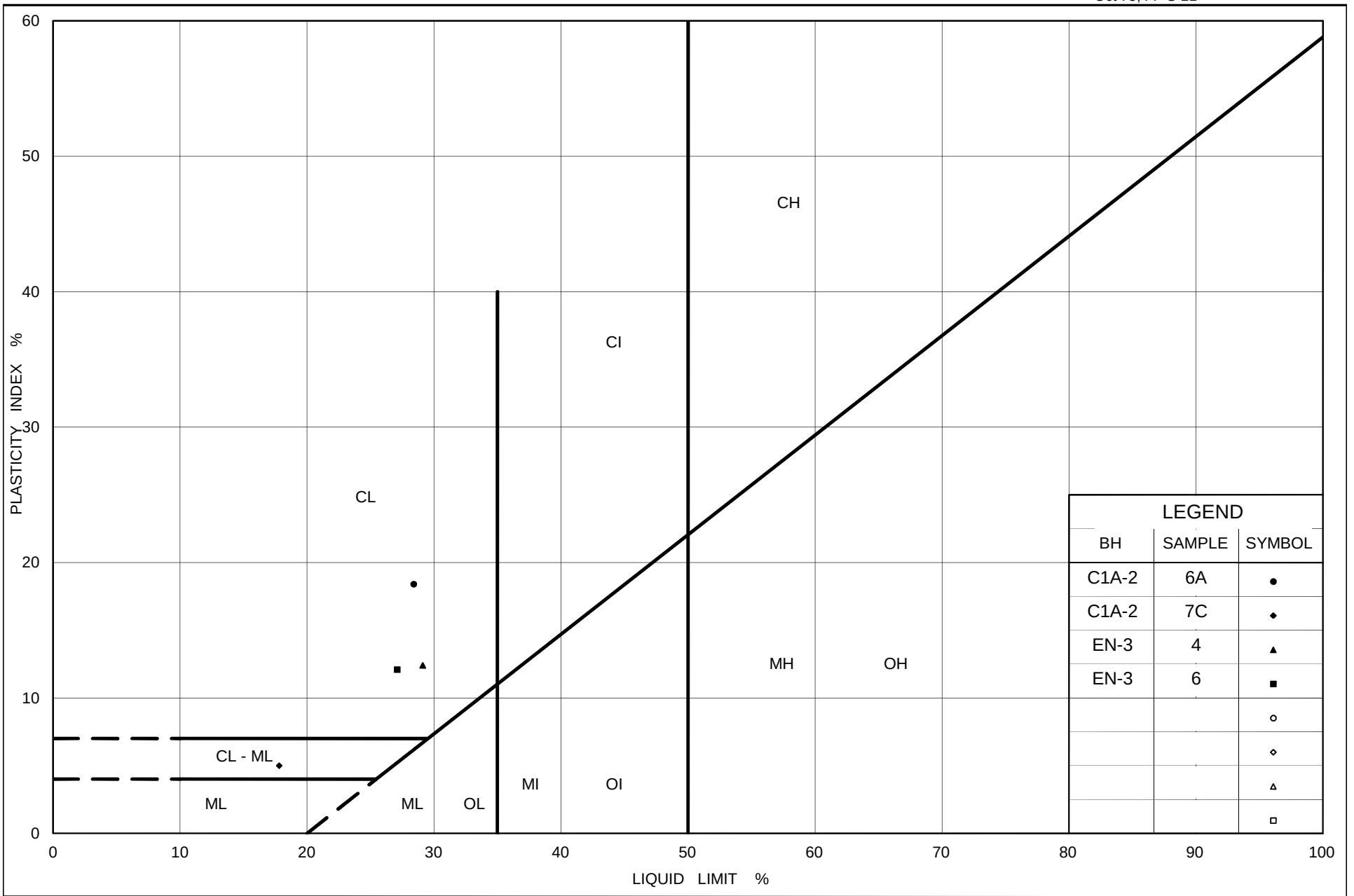
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C1A-2	4	219.4
■	EN-3	4	219.6
◆	EN-3	6	218.1
▲	C1A-2	6A	217.9
▽	C1A-2	7C	216.8

Project Number: 10-1184-0016

Checked By: SMM

Golder Associates

Date: 04-Feb-15



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Ontario

PLASTICITY CHART
Clayey Silt (Till)

Figure No. A4

Project No. 10-1184-0016

Checked By: SMM

APPENDIX B

Culvert 1 at Station 20+045 (Highway 6)
Record of Boreholes, Drillholes and Laboratory Test Results

Golder Associates

RECORD OF BOREHOLE No C1-1

SHEET 1 OF 1 **METRIC**

PROJECT 10-1184-0016
G.W.P. 2112-05-00 LOCATION N 4797082.2 ;E 270878.4 ORIGINATED BY AJS
DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS
DATUM Geodetic DATE October 6, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.0	GROUND SURFACE										
0.0	TOPSOIL		1A								
0.2	Gravel (FILL) Compact Grey Dry		1B	SS	22						
221.3							221				
220.9	Sandy silty clay, containing rootlets, containing cobbles and boulders (FILL) Compact Brown black Moist		2A 2B	SS	24				○		
220.6											
220.2			3A 3B	SS	5	▽	220				
1.8	Auger grinding at a depth of 0.9 m										
219.3	Sand and gravel, containing silty clay pockets (FILL) Loose Grey to black Moist		4A 4B	SS	19				○		5 64 25 6
2.7							219				
	Silty clay, some sand (FILL) Firm Grey-brown Moist		5	SS	24				⊖		9 21 49 21
	Silty SAND, trace gravel, trace to some clay Loose to compact Brown Moist to wet		6	SS	25		218				
	CLAYEY SILT, some sand to sandy, trace to some gravel (TILL) Very Stiff Brown Moist		7	SS	17		217		⊖		
216.5			8 9	AS SS	- 100/0.0						
5.5	Becoming grey below 4.6 m										
	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK										

NOTE:

1. Water level in open borehole measured at a depth of 2.0 m (Elev. 220.0 m) upon completion of drilling.

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

Golder Associates

RECORD OF BOREHOLE No C1-1B

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016
G.W.P. 2112-05-00
LOCATION N 4797083.8 ;E 270878.6
ORIGINATED BY AJS
DIST Central HWY 5 & 6
BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers
COMPILED BY PKS
DATUM Geodetic
DATE October 7, 2014
CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.0	GROUND SURFACE										
0.0	Refer to Description on Record of Borehole C1-1 for Stratographic Details						221				
	Auger grinding from 0.6 m to 1.2 m						220				
							219				
							218				
							217				
216.5	Auger grinding at 5.4 m										
5.5	DOLOSTONE (BEDROCK)						216				
	Bedrock cored from depths of 5.8 m to 9.5 m		1	RC	REC 81%						RQD = 81%
	For bedrock coring details, refer to Record of Drillhole C1-1B.		2	RC	REC 100%		215				RQD = 100%
							214				
			3	RC	REC 100%		213				RQD = 100%
212.5											
9.5	END OF BOREHOLE										

NOTES:

1. Spoon bouncing and auger refusal at 5.5 m depth below ground surface (Elev. 216.5 m) upon completion of drilling.

2. Water level in open borehole measured at a depth of 2.5 m below ground surface (Elev. 219.5m) upon completion of drilling and prior to coring.

3. Water level readings in piezometer:

Date	Depth (m)	Elev. (m)
10/10/14	1.5	220.5
10/16/14	1.5	220.5
10/26/14	1.8	220.2
11/02/14	1.7	220.3
01/08/15	1.6	220.4

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

$\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 10-1184-0016

RECORD OF DRILLHOLE: C1-1B

SHEET 1 OF 1

LOCATION: N 4797083.80 ;E 270878.57

DRILLING DATE: October 7, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-55 Track

DRILLING CONTRACTOR: DBW Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER .25	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	WEATH-ERING INDEX	Diametral Point Load Index (MPa)	FEATURES	PIEZOMETER
		Continued from Record of Borehole C1-1B		216.22															
6	NQRC NW Casing / Rock Coring	Slightly weathered, thinly to medium bedded, grey, fine grained, faintly porous, strong, DOLOSTONE (Lockport Formation, Goat Island Member)		5.80	1						90	JN,UN,RO							
											90	JN,PL,RO							
7																	8.61		8.6 MPa
					2						90	JN,UN,RO,SO							
8											90	JN,PL,RO							
											90	JN,PL,RO							
					3						90	JN,PL,RO							
9				213.02															
		Fresh, thinly to thickly bedded, grey, medium to coarse grained, moderately to highly porous, medium strong, DOLOSTONE (Lockport Formation, Gasport Member)		9.00													10.45		10.4 MPa
				212.52															
		END OF DRILLHOLE		9.50															
10																			
11																			
12																			
13																			
14																			
15																			

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: SP
CHECKED: SMM

GTA-RCK 046 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-MISS.GDT 7/2/15 DD

Golder Associates

RECORD OF BOREHOLE No C1-2

SHEET 1 OF 1 **METRIC**

PROJECT 10-1184-0016
G.W.P. 2112-05-00 LOCATION N 4797052.6 ;E 270852.7 ORIGINATED BY AJS
DIST Central HWY 5 & 6 BOREHOLE TYPE 150 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS
DATUM Geodetic DATE November 2, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
221.9	GROUND SURFACE										
0.0	ASPHALT										
	Sand and gravel (FILL) Dense Brown Moist		1A 1B	SS	40		221		○		
221.3 / 221.0											
0.9	Clayey silt, trace sand, trace gravel (FILL) Stiff Brown black Moist		2A 2B	SS	11				○		
220.4											
220.0	Silty sand, trace clay, some gravel (FILL) Compact Brown Moist		3A 3B	SS	7	▼	220		○		
219.7											
2.2	Clayey silt, trace sand, trace gravel (FILL) Firm Grey brown Moist		4	SS	10		219		⊢○⊣		4 15 54 27
	Silty SAND Loose Brown Moist		5	SS	18						
	CLAYEY SILT, trace gravel, trace to some sand (TILL) Brown Stiff to very stiff Wet		6	SS	20		218				
	Becoming grey below 3.9 m		7	SS	10		217				
216.0			8	SS	100/0		216				
5.9	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK										

NOTES:

1. Wet split-spoon encountered below 2.3 m (Elev. 219.6 m).
2. Water level in open borehole measured at a depth of 5.9 m (Elev. 216.0 m) upon completion of drilling.
3. Water level in piezometer measured at a depth of 1.8 m (Elev. 220.1 m) on January 27, 2015.

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

Golder Associates

RECORD OF BOREHOLE No C1A-2

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4797102.3 ;E 270891.4 ORIGINATED BY AJS

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS

DATUM Geodetic DATE October 6, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
221.9	GROUND SURFACE										
0.0	TOPSOIL		1A	SS	9				○		
221.4	Clayey silt, containing organics and rootlets (FILL) Stiff Brown Moist		1B								
0.5			2A	SS	5		221				
220.7	Silty sand and gravel (FILL) Loose Grey to brown Dry		2B								
1.4	Silty clay, containing organics (FILL) Firm Brown to black Moist		3	SS	9		220				
	CLAYEY SILT, some sand to sandy, trace to some gravel (TILL) Stiff to hard Grey and brown Moist to wet		4	SS	21				○		4 20 48 28
			5	SS	34		219				
			6A	SS	34		218		○—○		10 26 41 23
			6B								
	Becoming grey below 4.6 m		7A								
216.7			7B 7C	SS	18 100/0		217		○—○		1 16 67 16
5.2	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK		8								

NOTE:

1. Samples below a depth of 2.3 m (Elev. 219.6 m) were wet.

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

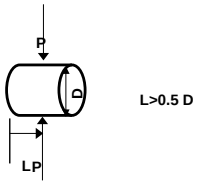
TABLE B1

POINT LOAD TEST RESULTS ON ROCK SAMPLES

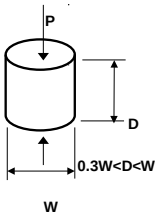
Borehole Number	Run	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Core Length (mm)	Core [(2)] Diameter (mm)	Is (50mm) (MPa)	Approx. UCS Value [(1)] (MPa)
C1-1B	2	6.9	215.1	Dolostone	Axial	38.74	47.33	8.613	78
C1-1B	3	9.1	212.9	Dolostone	Diametral	85.83	39.82	10.448	94

[(1)] Is_{50} x K, from ASTM Designation: D 5731 "Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications". A value of K = 9 has been used based on the average of two (2) Is_{50} axial tests and the average of two (2) UCS tests conducted at the culvert location.

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)

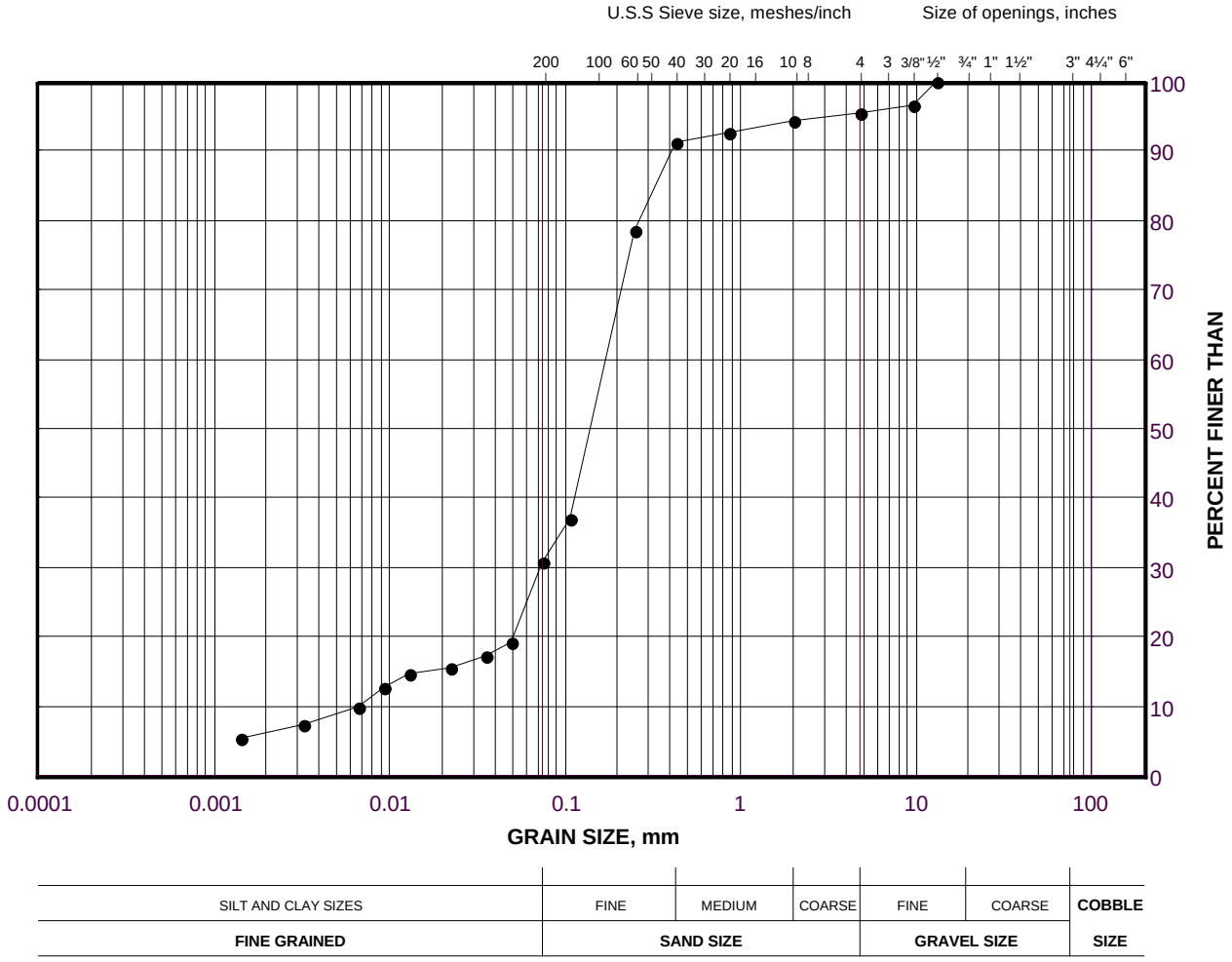


Compiled By: AJS
Checked By: SP
Reviewed By: SMM

GRAIN SIZE DISTRIBUTION

Silty Sand

FIGURE B1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C1-1	4A	219.6

Project Number: 10-1184-0016

Checked By: SMM

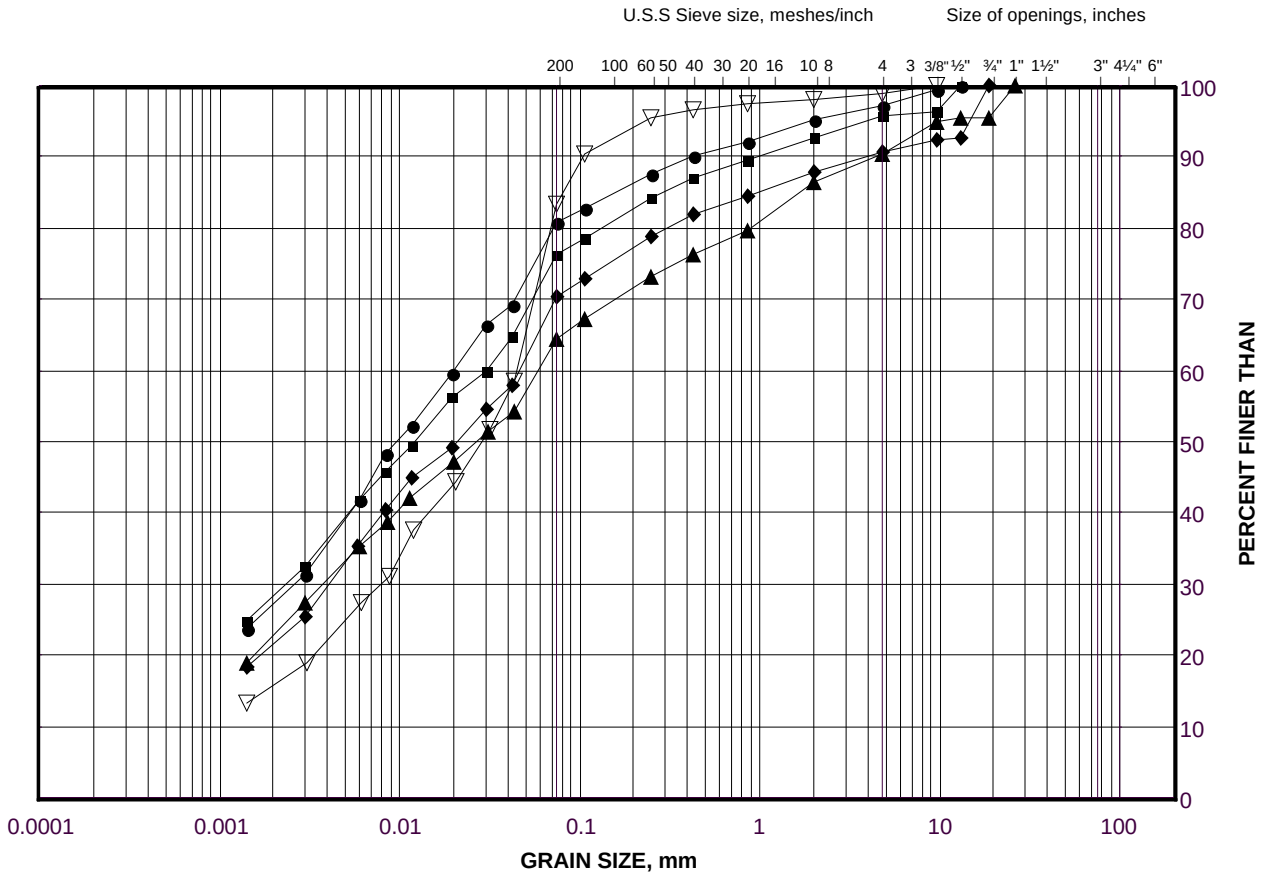
Golder Associates

Date: 10-Feb-15

GRAIN SIZE DISTRIBUTION

Clayey Silt (Till)

FIGURE B2



LEGEND

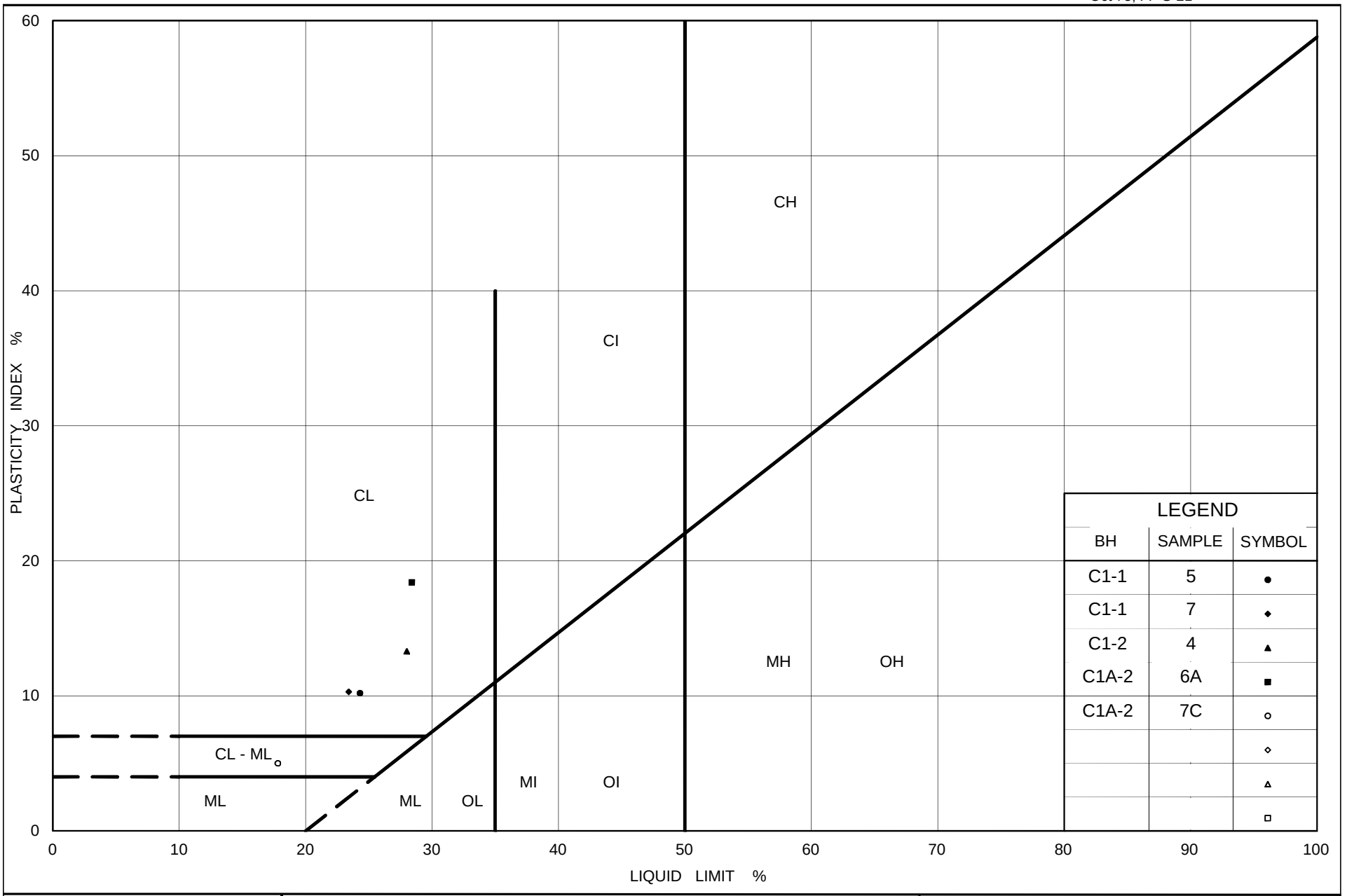
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C1-2	4	219.3
■	C1A-2	4	219.4
◆	C1-1	5	218.7
▲	C1A-2	6A	217.9
▽	C1A-2	7C	216.8

Project Number: 10-1184-0016

Checked By: SMM

Golder Associates

Date: 02-Feb-15



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PLASTICITY CHART
Clayey Silt (Till)

Figure No. B3

Project No. 10-1184-0016

Checked By: SMM

C1-1B : Box 1 of 1: Dry : 5.8 m to 9.5 m

C1-1B : Box 1 of 1: Wet : 5.8 m to 9.5 m

Note:
1. Intervals given above represent depth below ground surface.

PROJECT

Highways 5 and 6, Hamilton
Grindstone Creek Culverts

TITLE

Bedrock Core Photographs – Borehole C1-1B

Golder Associates

PROJECT No.:	10-1111-0211		FILE No.	----
DESIGN	--		SCALE	AS SHOWN
CADD	--		REV.	
CHECK	SP	JANUARY 2015	**FIGURE B4**	
REVIEW	SMM	JANUARY 2015		

APPENDIX C

Culvert 2 at Station 29+903 (Highway 5)
Record of Boreholes, Drillholes and Laboratory Test Results

Golder Associates

RECORD OF BOREHOLE No C2-1

SHEET 1 OF 1 **METRIC**

PROJECT 10-1184-0016
G.W.P. 2112-05-00 LOCATION N 4797013.4 ;E 270832.5 ORIGINATED BY AJS
DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS
DATUM Geodetic DATE October 7, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.2	GROUND SURFACE						222				
0.0	ASPHALT										
0.2	Sand and gravel (FILL) Compact Brown Dry		1	SS	17						
221.4							221				
0.8	Gravelly silt and sand, some clay (FILL) Loose Brown Moist		2	SS	8						
220.2			3A 3B	SS	9				○		21 33 33 13
219.9	Sand, some silt, some gravel Loose						220				
2.3	Brown Moist		4	SS	27						
	CLAYEY SILT, some gravel, some sand (TILL) Very stiff to stiff Grey-brown Moist to wet					▽					
	Becoming grey below 3.8 m		5	SS	28		219		ϕ——		3 20 48 29
			6	SS	20		218				
			7	SS	12						
216.1			8	SS	100/0.03		217				
6.1	DOLOSTONE (BEDROCK) Bedrock cored from depths of 6.5 m to 9.6 m For bedrock coring details, refer to Record of Drillhole C2-1.		1	RC	REC 73%		216				RQD = 73%
			2	RC	REC 100%		215				RQD = 95%
			3	RC	REC 97%		214				RQD = 90%
212.6							213				
9.6	END OF BOREHOLE										

NOTES:

1. Wet split-spoon encountered below 2.3 m (Elev. 219.9 m).
2. Spoon bouncing and auger refusal at a depth of 6.2 m (Elev. 216.0 m).
3. Water level in open borehole measured at a depth of 3.0 m (Elev. 219.2 m) upon completion of drilling and prior to rock coring.

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

PROJECT: 10-1184-0016

RECORD OF DRILLHOLE: C2-1

SHEET 1 OF 1

LOCATION: N 4797013.42 ;E 270832.51

DRILLING DATE: October 7, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-55 Track

DRILLING CONTRACTOR: DBW Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER .25	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	WEATH-ERING INDEX	Diametral Point Load Index (MPa)	FEATURES	PIEZOMETER
		Continued from Record of Borehole C2-1		215.68															
	NQRC NW Casing / Rock Coring	Slightly weathered to fresh, thinly to medium bedded, grey, fine grained, faintly porous, strong, nodular DOLOSTONE (Lockport Formation, Goat Island Member)		6.50	1						90	JN,PL,SM						12.04	12.0 MPa
7											90	BD,PL,RO,SO							UC=68.2 MPa
											90	BD,PL,RO,SO						10.77	10.8 MPa
					2						90	JN,PL,RO							
8											90	JN,PL,RO							
											90	JN,PL,RO							
											90	JN,UN,RO							
9					3						90	JN,PL,VRO							
				212.58															
		END OF DRILLHOLE		9.60															
10																			
11																			
12																			
13																			
14																			
15																			
16																			

DEPTH SCALE
1 : 50

LOGGED: SP
CHECKED: SMM

Golder Associates

RECORD OF BOREHOLE No C2-2

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4796939.5 ;E 270861.0 ORIGINATED BY AJS

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS

DATUM Geodetic DATE October 26, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.3	GROUND SURFACE										
0.0	ASPHALT										
0.2	Sand and gravel (FILL) Compact to very dense Brown Dry		1	SS	50/0.15		222				
			2	SS	15				○		
220.8							221				
1.5	Silty clay, trace to some sand, trace gravel (FILL) Stiff Grey Moist		3	SS	12						
220.0							220				
2.3	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Very stiff to hard Brown Moist to wet		4	SS	17	▼			○ —		4 15 53 28
			5	SS	35		219				
	Becoming grey below 4.6 m		6	SS	16		218		○		6 24 47 23
							217				
			7	SS	107/0.28		216				
215.7											
6.6	END OF BOREHOLE SPOON REFUSAL INFERRED BEDROCK										

NOTES:

1. Wet split-spoon encountered below 4.6 m (Elev. 217.7 m).
2. Water level in open borehole measured at a depth of 4.6 m (Elev. 217.7 m) upon completion of drilling.
3. Water level in piezometer measured at a depth of 2.7 m (Elev. 219.6 m) on January 27, 2015.

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

Golder Associates

RECORD OF BOREHOLE No H5-3

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016
G.W.P. 2112-05-00
LOCATION N 4796972.2 ;E 270845.4
ORIGINATED BY JBH
DIST Central HWY 5 & 6
BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers
COMPILED BY BM
DATUM Geodetic
DATE November 12, 2012
CHECKED BY TVA

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.1	GROUND SURFACE						222				
0.0 / 221.8	Sand and gravel, some silt, trace clay (FILL) Compact Brown Moist		1A 1B	SS	11				○		38 43 18 1
221.4 / 0.7	Clayey silt with sand, trace gravel, trace organics (FILL) Stiff Brown Moist		2	SS	12		221				
	CLAYEY SILT, sandy, trace gravel (TILL) Stiff to hard Brown to grey Moist		3	SS	30						
			4	SS	27		220		○ —		3 24 50 23
			5	SS	32		219		○ —		3 27 47 23
			6	SS	18		218		○		
	- - - - - - - - - - - - silt seams - - - - - - - - - - - -		7	SS	20						
			8	SS	17		217		○		
215.5			9	SS	25/0.08		216				
6.6	END OF BOREHOLE SPOON BOUNCING REFUSAL INFERRED BEDROCK										

NOTE:

1. Borehole dry upon completion of drilling.

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

$\circ^{3\%}$ STRAIN AT FAILURE

TABLE C1
SUMMARY OF UNIAXIAL COMPRESSIVE STRENGTH TEST RESULTS
GRINDSTONE CREEK NEW / REPLACEMENT CULVERTS
HIGHWAY 5 AND HIGHWAY 6, HAMILTON, ONTARIO

Borehole Number (Core Run)	Sample Depth (m)	Sample Elevation (m)	Rock Type	Core Diameter (mm)	Uniaxial Compressive Strength (MPa)
C2-1 (2)	7.1	215.1	Dolostone	47.3	68

Compiled By: AJS
Reviewed By: SMM

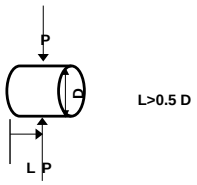
TABLE C2

POINT LOAD TEST RESULTS ON ROCK SAMPLES

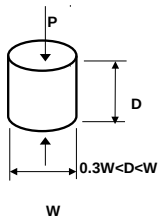
Borehole Number	Run	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Core Length (mm)	Core Diameter (mm)	Is (50mm) (MPa)	Approx. UCS Value [(1)] (MPa)
C2-1	1	6.5	215.7	Dolostone	Diametral	76.76	41.29	12.040	72
C2-1	2	7.4	214.8	Dolostone	Axial	23.46	47.98	10.774	64

[(1)] Is_{50} x K, from ASTM Designation: D 5731 "Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications". A value of K = 6 has been used based on the average of two (2) Is_{50} axial tests and one (1) UCS tests conducted at the culvert location.

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)

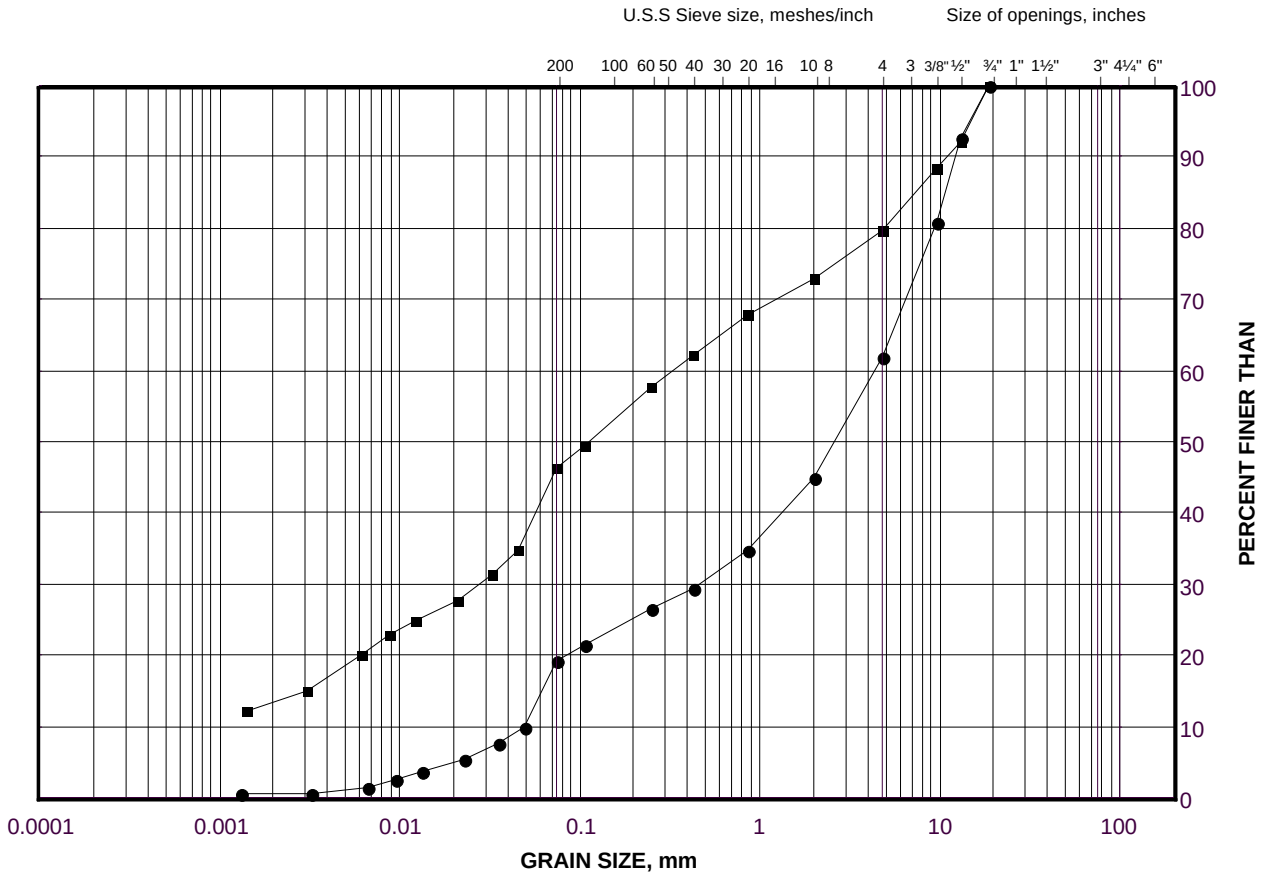


Compiled By: AJS
Checked By: SP
Reviewed By: SMM

GRAIN SIZE DISTRIBUTION

Gravelly Silt and Sand to Sand and Gravel (Fill)

FIGURE C1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	H5-3	1A	221.9
■	C2-1	3A	220.5

Project Number: 10-1184-0016

Checked By: SMM

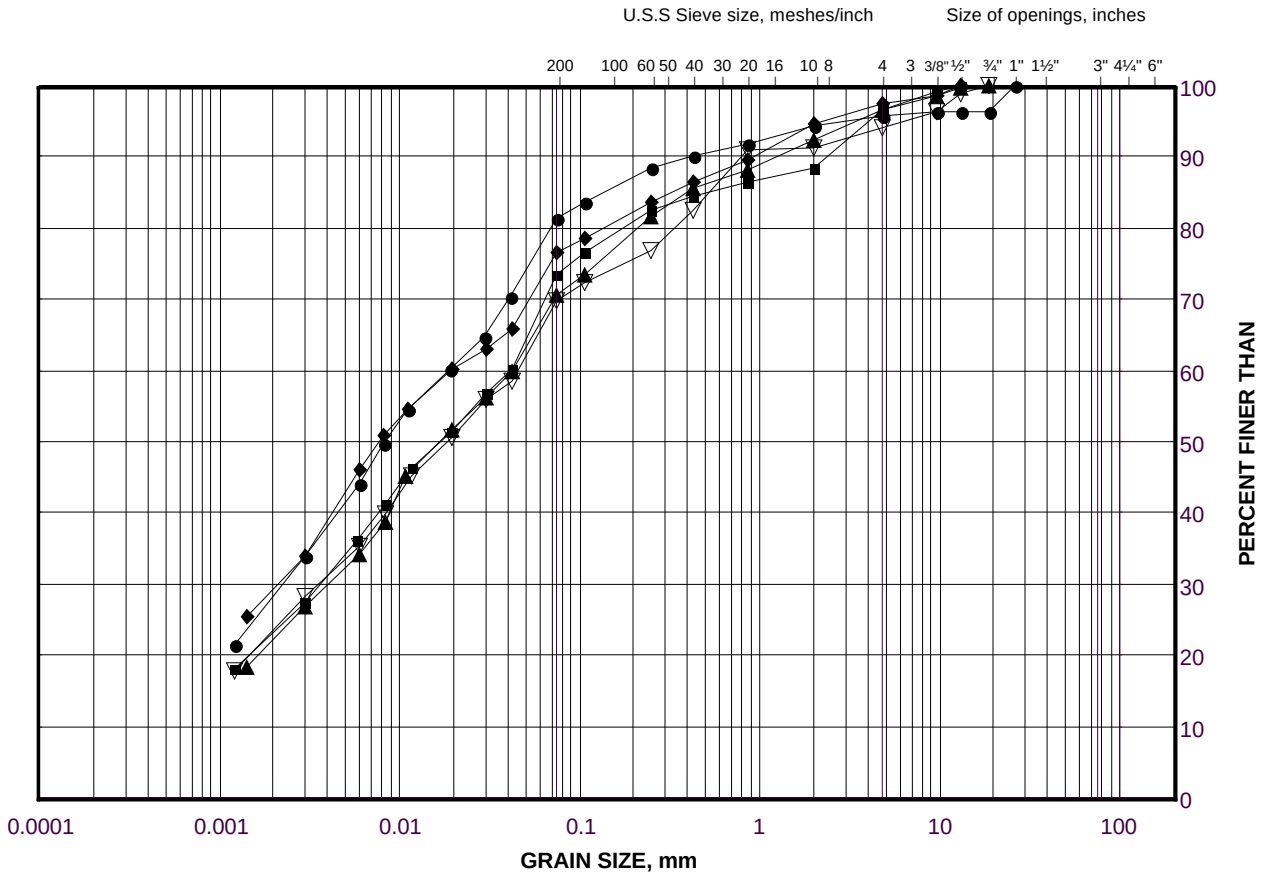
Golder Associates

Date: 10-Feb-15

GRAIN SIZE DISTRIBUTION

Clayey Silt (Till)

FIGURE C2



LEGEND

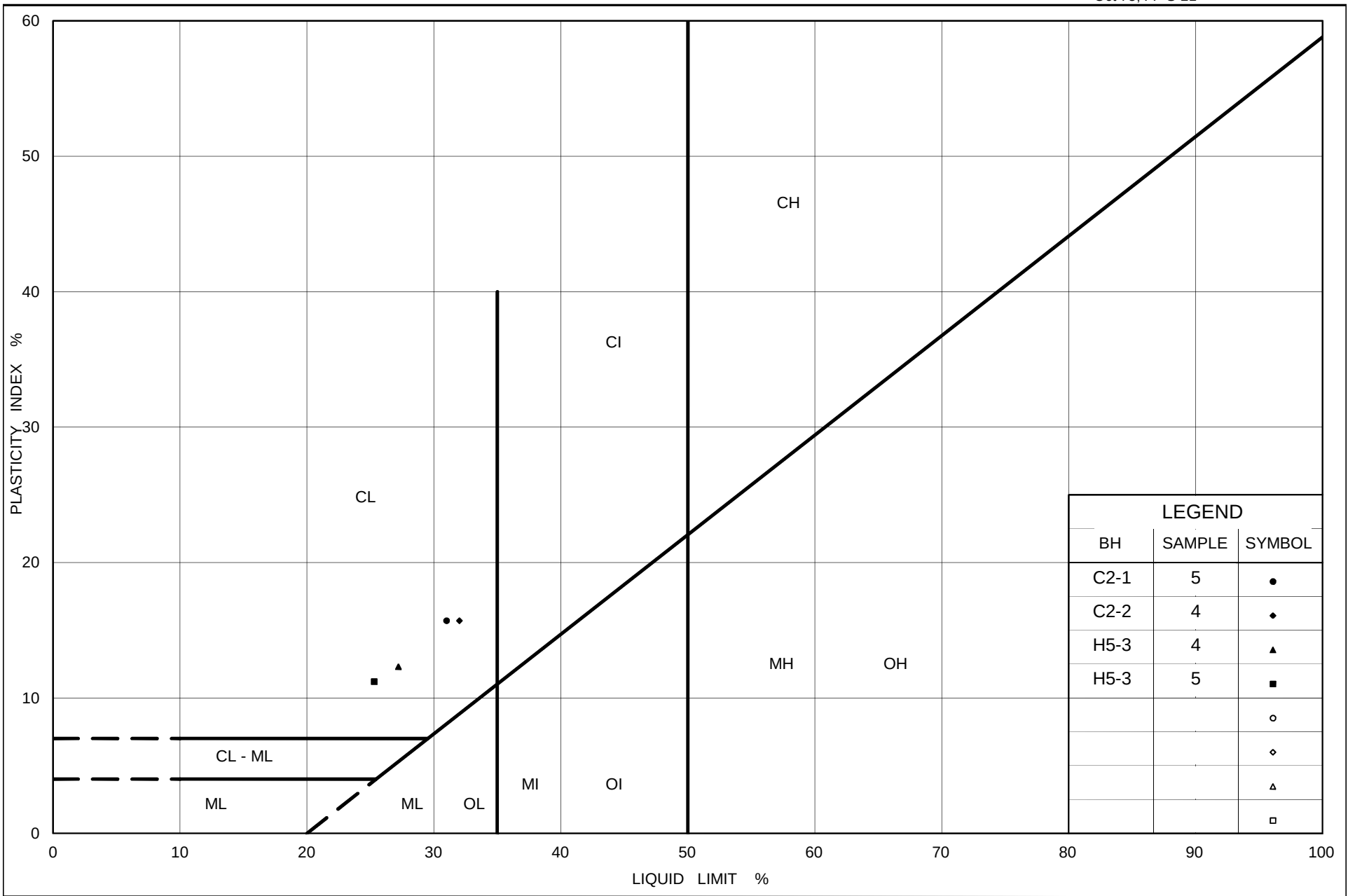
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C2-2	4	219.7
■	H5-3	4	219.6
◆	C2-1	5	218.8
▲	H5-3	5	218.8
▽	C2-2	6	217.4

Project Number: 10-1184-0016

Checked By: SMM

Golder Associates

Date: 10-Feb-15



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt (Till)

Figure No. C3

Project No. 10-1184-0016

Checked By: SMM

C2-1 : Box 1 of 1: Dry : 6.5 m to 9.6 m

C2-1 : Box 1 of 1: Wet : 6.5m to 9.6 m

Note:
1. Intervals given above represent depth below ground surface.

PROJECT

Highways 5 and 6, Hamilton
Grindstone Creek Culverts

TITLE

Bedrock Core Photographs – Borehole C2-1

Golder Associates

PROJECT No.:	10-1111-0211		FILE No.	----
DESIGN	--		SCALE	AS SHOWN
CADD	--		REV.	
CHECK	SP	JANUARY 2015	**FIGURE C4**	
REVIEW	SMM	JANUARY 2015		

UNCONFINED COMPRESSION TEST (UC)

Figure C5

ASTM D 7012-07

SAMPLE IDENTIFICATION

PROJECT NUMBER	10-1184-0016	SAMPLE NUMBER	-
BOREHOLE NUMBER	C2-1	SAMPLE DEPTH, m	7.04-7.19

TEST CONDITIONS

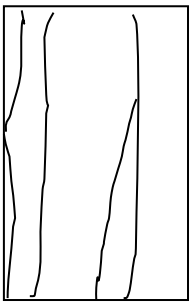
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.40

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	11.35	WATER CONTENT, (specimen) %	0.24
SAMPLE DIAMETER, cm	4.73	UNIT WEIGHT, kN/m^3	25.14
SAMPLE AREA, cm^2	17.60	DRY UNIT WT., kN/m^3	25.08
SAMPLE VOLUME, cm^3	199.78	SPECIFIC GRAVITY	-
WET WEIGHT, g	512.38	VOID RATIO	-
DRY WEIGHT, g	511.15		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	68.2

REMARKS:

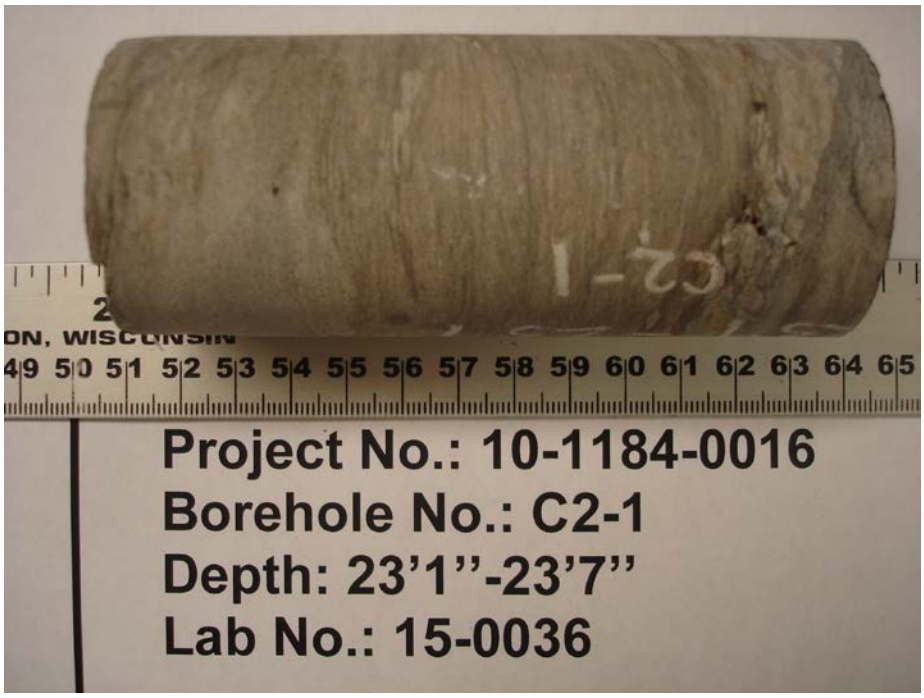
DATE: 1/15/2014

Checked By: SMM

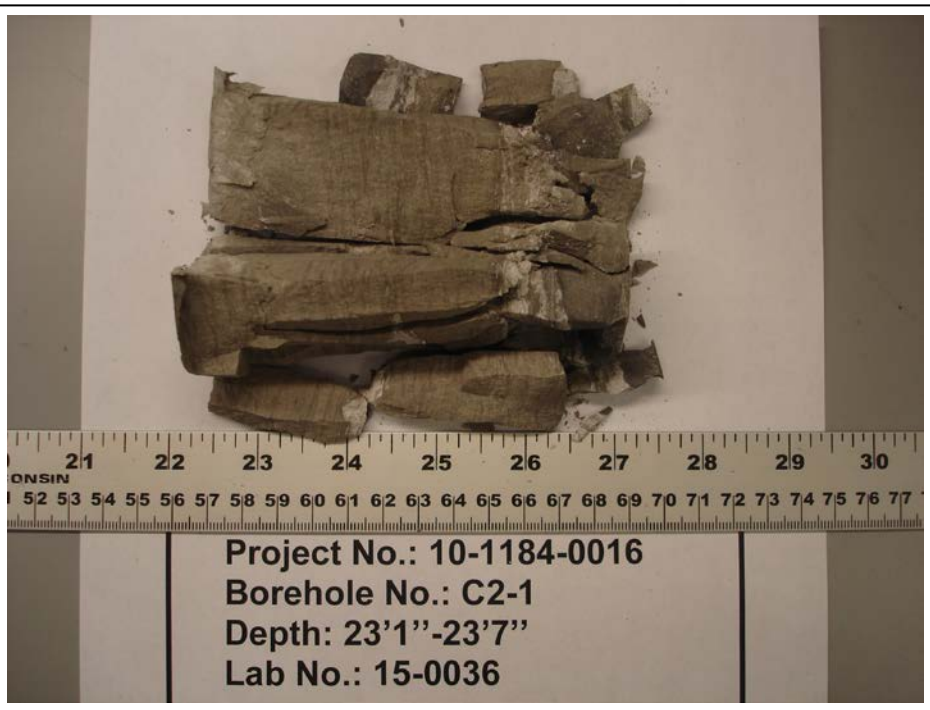
Golder Associates

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

FIGURE C5
Sheet 2 of 2



BEFORE COMPRESSION



AFTER COMPRESSION

Date Jan. 16, 2015
Project 10-1184-0016

Golder Associates

Drawn Frank
Chkd. SMM

FORM PRODUCED JUNE 1986

Form GA-D-4 (imperial)

APPENDIX D

Culvert 2A at Station 30+132 (Commercial Access Road)
Record of Boreholes, Drillholes and Laboratory Test Results

Golder Associates

RECORD OF BOREHOLE No C2A-1

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4796872.1 ;E 270897.7 ORIGINATED BY AJS

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS

DATUM Geodetic DATE October 14, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
219.7	GROUND SURFACE										
0.0	SILTY CLAY, trace gravel, containing rootlets and organics Firm Brown Moist		1	SS	5		219		○		
219.0 / 0.7	CLAYEY SILT trace sand to sandy, trace gravel, containing dolostone fragments (TILL) Very stiff Brown Moist to wet		2	SS	20						
			3	SS	23		218		⊢○⊣		2 28 52 18
			4	SS	22		217				
	Auger grinding at 3.0 m		5	SS	23				○		
215.8	Becoming grey below 3.7 m		6	SS	100/0.13		216				
3.9	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK										

NOTE:

1. Open borehole dry upon completion of drilling.

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

Golder Associates

RECORD OF BOREHOLE No C2A-2

SHEET 1 OF 1

METRIC

PROJECT 10-1184-0016

G.W.P. 2112-05-00 LOCATION N 4796845.2 ;E 270930.8 ORIGINATED BY AJS

DIST Central HWY 5 & 6 BOREHOLE TYPE 102 mm O.D. Continous Flight Solid Stem Augers COMPILED BY PKS

DATUM Geodetic DATE October 10, 2014 CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
219.1	GROUND SURFACE						219				
0.0	SILTY CLAY, containing rootlets and organics Soft Brown		1	SS	2						
218.4											
0.7	Moist CLAYEY SILT, trace to some sand, trace to some gravel, containing roots to a depth of 1.4 m (TILL) Very stiff to hard Brown Moist to wet		2	SS	17		218				1 17 50 32
			3	SS	29		217				
			4	SS	41						
	Becoming grey below 3.0 m		5	SS	24		216				
215.4			6	SS	100/0.0						
3.7	DOLOSTONE (BEDROCK) Bedrock cored from depths of 3.8 m to 6.9 m For bedrock coring details, refer to Record of Drillhole C2A-2.		1	RC	REC 98%		215				RQD = 98%
			2	RC	REC 100%		214				RQD = 95%
212.2			3	RC	REC 100%		213				RQD = 100%
6.9	END OF BOREHOLE NOTES: 1. Spoon bouncing and auger refusal at a depth of 3.7 m (Elev. 215.4 m) 2. Open borehole dry upon completion of drilling and prior to rock coring.										

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

PROJECT: 10-1184-0016

RECORD OF DRILLHOLE: C2A-2

SHEET 1 OF 1

LOCATION: N 4796845.22 ;E 270930.83

DRILLING DATE: October 10, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-55 Track

DRILLING CONTRACTOR: DBW Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER .25	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	WEATH-ERING INDEX	Diametral Point Load Index (MPa)	FEATURES	PIEZOMETER
		Continued from Record of Borehole C2A-2		215.30															
4	NQRC NW Casing / Rock Coring	Slightly weathered to fresh, thinly to medium bedded, grey, fine grained, faintly porous, strong, nodular DOLOSTONE (Lockport Formation, Goat Island Member)		3.80	1						90	JN,PL,RO					9.2	9.2	7.4 MPa 9.2 MPa UC=101 MPa
											90	BD,UN,RO							
5											90	BD,PL,RO							
					2						90	BD,PL,RO							
6		Infill with clay seam (33 mm)									90	BD,PL,SM,Cl,33 mm							
				212.20	3														
7		END OF DRILLHOLE		6.90															
8																			
9																			
10																			
11																			
12																			
13																			

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATH-ERING INDEX: W1 W2 W3 W4 W5 W6

DEPTH SCALE

1 : 50

LOGGED: SP

CHECKED: SMM

Golder Associates

GTA-RCK 046 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-MISS.GDT 7/2/15 DD

TABLE D1
SUMMARY OF UNIAXIAL COMPRESSIVE STRENGTH TEST RESULTS
GRINDSTONE CREEK NEW / REPLACEMENT CULVERTS
HIGHWAY 5 AND HIGHWAY 6, HAMILTON, ONTARIO

Borehole Number (Core Run)	Sample Depth (m)	Sample Elevation (m)	Rock Type	Core Diameter (mm)	Uniaxial Compressive Strength (MPa)
C2A-2 (1)	4.3	214.8	Dolostone	47.4	100.9

Compiled By: AJS
Reviewed By: SMM

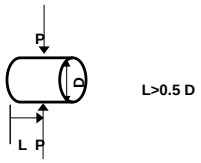
TABLE D2

POINT LOAD TEST RESULTS ON ROCK SAMPLES

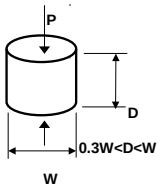
Borehole Number	Run	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Core Length (mm)	Core [(2)] Diameter (mm)	Is (50mm) (MPa)	Approx. UCS Value [(1)] (MPa)
C2A-2	1	4.1	215.1	Dolostone	Diametral	90.11	39.26	7.370	88
C2A-2	1	4.1	215.0	Dolostone	Axial	31.35	47.43	9.201	110

[(1)] Is_{50} x K, from ASTM Designation: D 5731 "Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications". A value of K = 8 has been used based on the average of two (2) Is_{50} axial tests and the average of two (2) UCS tests conducted at the culvert location.

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)

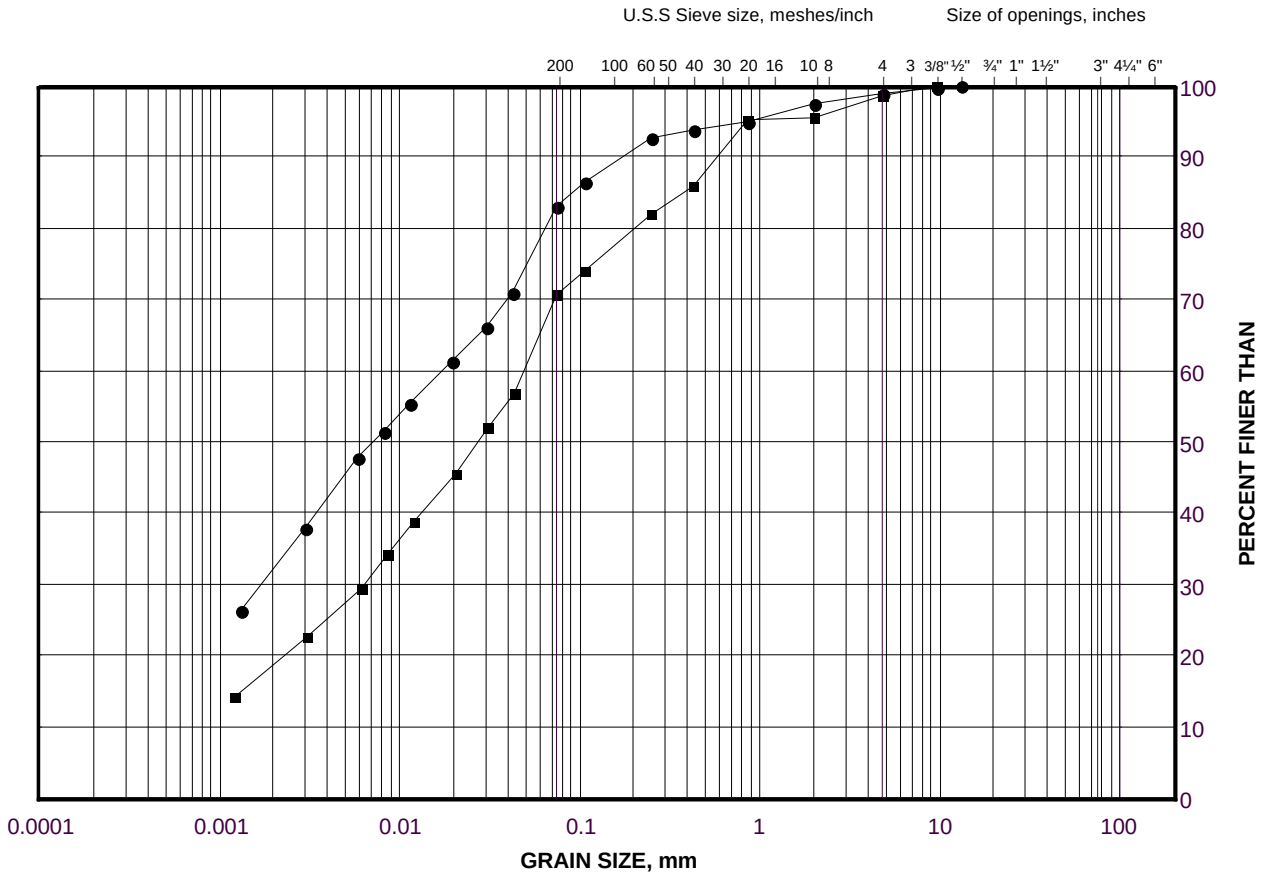


Compiled By: AJS
Checked By: SP
Reviewed By: SMM

GRAIN SIZE DISTRIBUTION

Clayey Silt (Till)

FIGURE D1



LEGEND

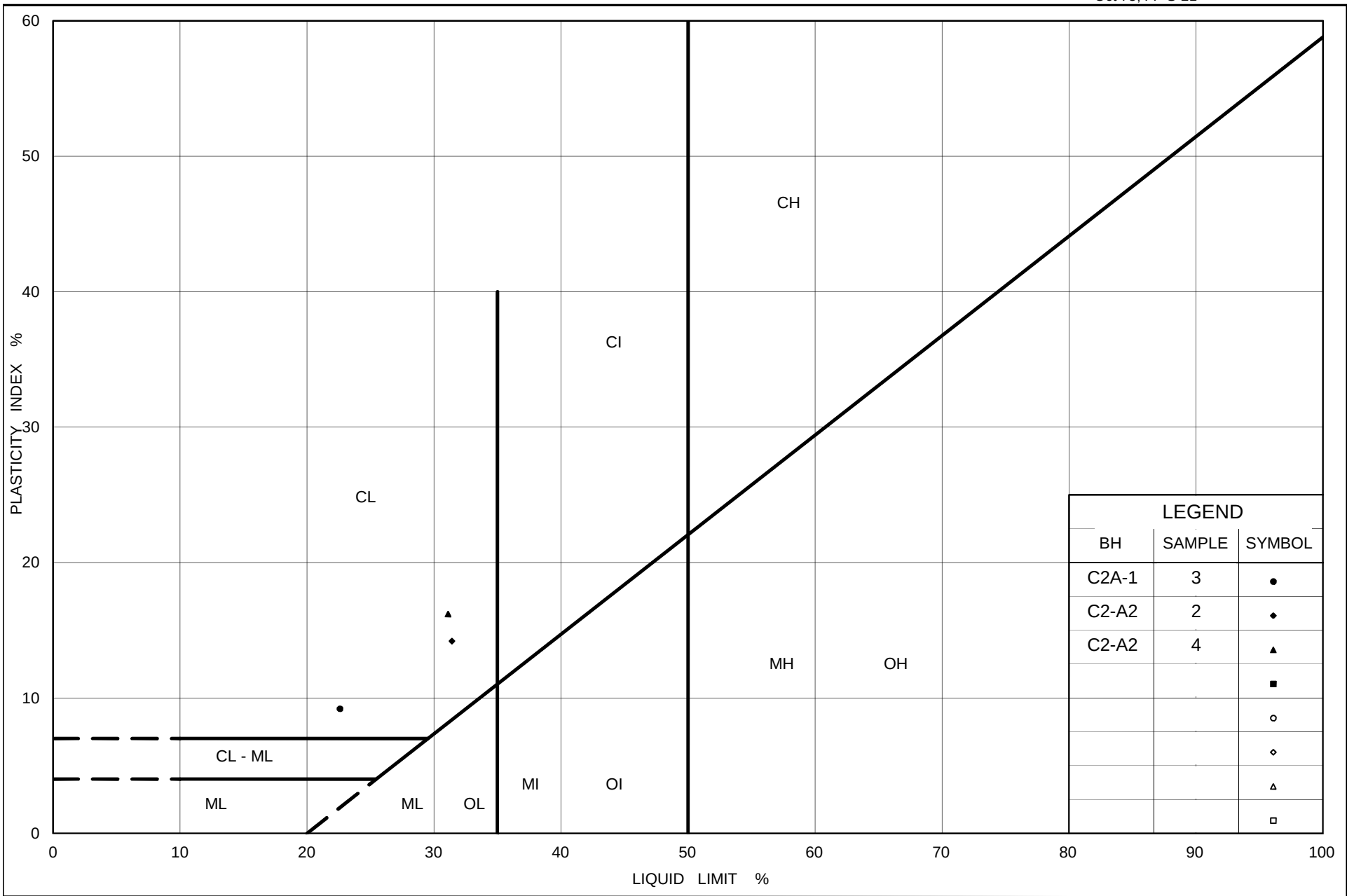
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C2A-2	2	218.1
■	C2A-1	3	217.8

Project Number: 10-1184-0016

Checked By: SMM

Golder Associates

Date: 02-Feb-15



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt (Till)

Figure No. D2

Project No. 10-1184-0016

Checked By: SMM

C2A-2 : Box 1 of 1: Dry : 3.8 m to 6.9 m

C2A-2 : Box 1 of 1: Wet : 3.8 m to 6.9 m

Note:
1. Intervals given above represent depth below ground surface.

PROJECT

Highways 5 and 6, Hamilton
Grindstone Creek Culverts

TITLE

Bedrock Core Photographs – Borehole C2A-2

Golder Associates

PROJECT No.:	10-1111-0211		FILE No.	----
DESIGN	--		SCALE	AS SHOWN REV.
CADD	--			
CHECK	SP	JANUARY 2015	**FIGURE D3**	
REVIEW	SMM	JANUARY 2015		

UNCONFINED COMPRESSION TEST (UC)

Figure D4

ASTM D 7012-07

SAMPLE IDENTIFICATION

PROJECT NUMBER	10-1184-0016	SAMPLE NUMBER	-
BOREHOLE NUMBER	C2A-2	SAMPLE DEPTH, m	4.29-4.47

TEST CONDITIONS

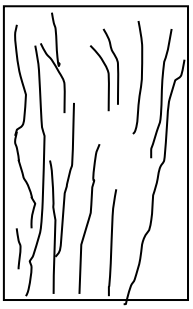
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.37

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	11.24	WATER CONTENT, (specimen) %	0.25
SAMPLE DIAMETER, cm	4.74	UNIT WEIGHT, kN/m^3	25.32
SAMPLE AREA, cm^2	17.64	DRY UNIT WT., kN/m^3	25.26
SAMPLE VOLUME, cm^3	198.22	SPECIFIC GRAVITY	-
WET WEIGHT, g	512.03	VOID RATIO	-
DRY WEIGHT, g	510.75		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	100.9

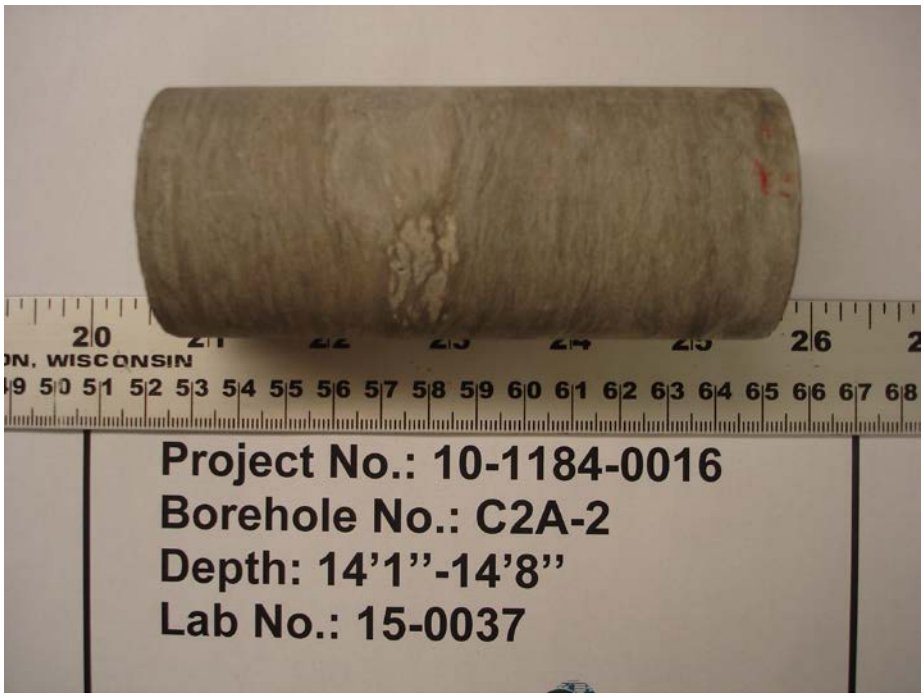
REMARKS:

DATE: 1/15/2014

Checked By: SMM

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

FIGURE D4
Sheet 2 of 2



BEFORE COMPRESSION

AFTER COMPRESSION

Date Jan. 16, 2015
Project 10-1184-0016

Golder Associates

Drawn Frank
Chkd. SMM

FORM PRODUCED JUNE 1986

Form GA-D-4 (imperial)

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